WORLD LEARNING
Science and Mathematics Education Ministerial Observational Study Tour

FINAL REPORT and SUMMARY RECOMMENDATIONS
8/8/2011 – 10/31/2011

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FINAL REPORT
Science and Mathematics Education Ministerial Observational Study Tour
Philadelphia, PA and Washington, DC
August 15 – 22, 2011

World Learning developed and implemented a program in collaboration with our partners grounded in the principles of experiential learning by providing the overall experience, an opportunity for observation and guided reflection, the space to interpret and generalize the observations and reflections to the Egyptian system and its needs, and the tools to develop an action plan for future STM school development and expansion.

The program enabled the delegation to see firsthand different models of STM schools: magnet schools, STM schools for elite students, and the application of STM principals in a broader education environment. The delegation also saw firsthand and discussed firsthand with the experts in the expansive 360^{O} degree public and private support system that has developed to help ensure the success of the programs for the students. The linkages to the greater communities including universities and private sector business were seen as critical links in the support system for the schools and in creating opportunities for the students.

The delegation was also provided insights into curriculum design, assessments, and pedagogy in STM schools. They were able to engage directly with the experts designing and researching the efficacy of these tools. The end objective was to provide the information to help the Minister and the delegation to make informed plans to establish effective processes, policies, and practices for STM schools in Egypt.

This program incorporated all the stakeholder groups in STM education including policy makers, curriculum and assessment designers, school managers, teacher educators, teachers, students, private sector alliances, and public sector alliances. The program provided the delegation insights to successful STM models, policies and practices, and focused on the needs and implications for particular groups involved in the transformation of STM thinking and education.

Links:
http://www.nap.edu/catalog.php?record_id=13158
http://www.itif.org/files/2010-refueling-innovation-economy.pdf
http://www.oecd.org/dataoecd/11/28/44417824.pdf
http://ies.ed.gov/
www.cogscied.org
www.parloproject.org
http://www.selectgreaterphiladelphia.com/index.cfm
http://www.tiesteach.org/Consultant-Team.aspx
http://ctl.sri.com/publications/displayPublication.jsp?ID=848
www.ed-msp.net

Learning and instructional design links:
http://www3.cet.edu/instep/online.html
http://www.rwnc.org/

http://www.njgreenprogramofstudy.org/
http://wvde.state.wv.us/teach21/pbl.html
http://greenschoolsforteachers.wikispaces.com/
http://pbl4teachers.wikispaces.com/

Ministerial Observational Study Tour
Program Schedule

Lower Merion School District
www.lmsd.org

- Dr. Chris McGinley, Superintendent
- Dr. Wagner Marseille, Director of Secondary Education
- Mr. Sean Hughes, Principal, Lower Merion High School
- Ms. Joey Rider Bertrand, STEM Supervisor for Secondary Education
- Mr. George Frazier, Director of Information Systems
- Mr. Steve Barbato, Director of Elementary Education
- Ms. Nancy Acconciamessa, STEM Supervisor for Elementary Education

The Lower Merion School District (LMSD), located in Philadelphia's historic Main Line suburbs, serves the 62,000 residents. Established as one of Pennsylvania's first public school districts in 1834, LMSD enjoys a rich tradition of achievement, innovation and community partnership and a longstanding reputation as one of the finest school systems in the United States. The District's six elementary schools, two middle schools and two high schools provide a challenging, multi-disciplinary academic program and dynamic, co-curricular experience to more than 6,900 students. They have one of the best STEM education programs in the State of Pennsylvania.

LMSD session focused on examining the inclusion of STEM education in a non-STEM school model of schools. This visit and meetings showed how STEM achievements are realized and managed.

University of Pennsylvania
School of Engineering and Applied Science
http://www.seas.upenn.edu/education/summer-programs.php

- Dr. Joseph Bordogna, Dean Emeritus, School of Engineering & Science
  Former Chief Operating Officer, U.S. National Science Foundation
- Dr. Jan Van der Spiegel, Associate Dean of Education
- Ms. Rebecca Stein, Associate Director, Educational Outreach & Research

More than 250 years ago, Benjamin Franklin, founder of the University of Pennsylvania, envisioned an academic institution where classical learning would be united with a sound practical education in the arts and sciences. In Ben's own words, students ought to receive everything that is practical and everything that is ornamental. Today Penn, the oldest university in the nation, is fulfilling that vision by preparing students for a technological world, a world where leadership goes to those who have learned how to combine the practical and the ornamental.

The School of Engineering and Applied Science is a world-class research institution. In the spirit of founder, Benjamin Franklin, the research mission of Penn Engineering is not only to have the highest scholarly standards within disciplines, but also to be an international leader in interdisciplinary research across fields.

Faculty of the University of Pennsylvania examined public-private partnerships to support high achieving secondary and younger STEM focused students, corporate partnerships, community engagement, and the role of higher education in the establishment and support of STEM education in K-12 education.

Science Leadership Academy Charter School &
Franklin Institute Science Museum
www.scienceleadership.org

Dr. Dennis Wint, President & CEO
The Franklin Institute (Co-sponsor of the Science Leadership Academy School)

Frederic M.N. Bertley, Ph.D.
Vice President, Science and Innovation, The Franklin Institute

The Science Leadership Academy (SLA) is a partnership high school between the School District of Philadelphia and The Franklin Institute. SLA is an inquiry-driven, project-based high school focused on 21st century learning. SLA provides a rigorous, college-preparatory curriculum with a focus on science, technology, mathematics and entrepreneurship. Students at SLA learn in a project-based environment where the core values of inquiry, research, collaboration, presentation and reflection are emphasized in all classes.

The structure of the Science Leadership Academy reflects its core values, with longer class periods to allow for more laboratory work in science classes and performance-based learning in all classes. In addition, students in the upper grades have more flexible schedules to allow for opportunities for dual enrollment programs with area universities and career development internships in laboratory and business settings, as well as with The Franklin Institute.

This is a comprehensive high school with a focus on entrepreneurship, science, and technology, basically a research and design school. Students have an advisor teacher and they are partnered all the way through school. There are 20 advisor teachers. These teachers know students and their problems well and can help them address personal problems, academic problems, and so forth.

Students are assessed through project-based learning. And showing their commitment students are in school 1 ½ hours before it starts. To create and support the culture and allow students to be excited about learning SLA focuses on Culture, Learning, Inquiry, and Association (either in the form of the Franklin Institute, relationships with parents, connection with Board of Education, etc.)

Pennsylvania Department of Education
STEM Education Programs, Bureau of Teaching and Learning
Division of Curriculum

Delaware Valley Industrial Resource Center (DVIRC)
STEM Talent Development Division
(The regional center for STEM for the Pennsylvania Department of Education)
www.dvirc.org

- Mr. William Bertrand, Technology & Engineering Advisor, Pennsylvania Department of Education
- Mr. Anthony J. Girifalco, Executive Vice President, DVIRC
- Prof. Fred Akl, Dean, Department of Engineering
- Widener University and Former Faculty Fellow & Consultant to National Aeronautic and Space Administration (NASA)
- Mr. Robert Gorgone, Project Manager, Philadelphia Industrial Development Corporation (PIDC)

DVIRC has been working on many fronts to develop talent for the advanced manufacturing sector at the individual firm level, through focused educational programming through the Institute for World Class Manufacturing®, and through regional partnerships with schools, businesses, workforce partners, and

other non-profits. Historically, the Center has a long track record of working with secondary and post-secondary schools to support programming that stays current with the changing needs of industry. Recently, the region has established a track record of focusing on STEM Education that dates back to the Regional STEM Forums held in 2006 in partnership with many institutions and organizations.
DVIRC worked with several organizations to craft and distribute the Regional Compact for STEM Education, and co-authored the proposal which led to Pennsylvania's STEM Award from the National Governor's Association to organize the commonwealth in support of STEM education. Many others have worked directly with the state on the STEM strategy and helped to establish Pennsylvania's model and the five STEM Networks.

Pennsylvania Department of Education and DVIRC discussed in detail national policies and standards for STM education and public-private partnerships.

21st Century Center for Research and Development In Cognition & Science Instruction & 21st Century Partnership for STEM Education
www.21pstem.org

- Mr. Joseph Merlino, President, 21st Partnership for STEM Education (21PSTEM)
- Ms. Donna Cleland
- Dr. Kathleen Krier
- Mr. Neil O'Connell, 21PSTEM
- Ms. Janice Morrison, President, Teaching Institute for Excellence in STEM
- Dr Gary Cooper, Project Director, National Center for Cognition and Science Instruction
- Dr. Christine Massey, Institute for Cognitive Science Research, University of Pennsylvania
- Dr. Jennifer Cromley, Assistant Professor of Educational Psychology, Temple University
- Dr. Michael Posner, Associate Professor of Statistics, Villanova University
- Dr. Deborah Pomeroy, Professor Emerita of Science Education, Arcadia University
- Dr. Victor Donnay, Professor of Mathematics, Bryn Mawr College

The 21st Century Center for Research and Development in Cognition and Science Instruction is a five-year national grant funded by the U.S. Department of Education's Institute of Education Sciences to further the goal of fostering science literacy in young people so they are able to compete in a 21st Century global economy. The Center's work focuses on applying the lens of cognitive science to existing science curricula in an effort to improve student learning of science.

The Center's team of cognitive scientists is applying theoretical principles to systematically modify two popular middle school science programs and to prepare related teacher professional development materials. These methods for improving student learning will be evaluated through rigorously designed scientific studies.

Its partners include:

- University of Pennsylvania
- Temple University
- University of Pittsburgh

- Research for Better Schools
- The 21st Century Partnership for STEM Education (21PSTEM)

21PSTEM is a regional and national leader in data-based analysis, program planning, innovative curricula and professional development advancing science, technology, engineering, and mathematics education in K-12 and post-secondary institutions. It studies and disseminates existing research and conducts new research into the factors that most significantly promote student engagement and achievement in the areas of science and mathematics.

21PSTEM went into detail STM education program development, implementation, and assessments and the key policy and education questions facing educators and schools systems across the U.S.

Math Science and Technology (MaST) Community Charter School
www.mastcharter.org

- Mr. John Swoyer, CEO
- Ms. Tarra Gordon, Supervisor of Communications and Program Resources

This charter school within the School District of Philadelphia has 1200 students and 150 faculty for elementary and secondary education in math, science and technology.

MaST 's mission is to create a charter school that:

- Challenges their students to use their minds well
- Sets high world-class standards for student achievement
- Is a place where children and adults want to be
- Supports teachers in trying new methods and working with colleagues
- Reflects the goals of multicultural communities
- Brings teachers, students, families and community together to better educate everyone
- Creates a consistent "pathway" for student learning and development
- Creates a school that focuses on integrative and constructivist curriculum
- Establishes multiple learning sites for high school students on college campuses

George Washington Carver High School for Engineering and Science
School District of Philadelphia
www.carver.phila.K12.pa.us

Ms. Christina Murianka, Assistant Principal

Founded in 1979, this is a magnet school of the School District of Philadelphia, which focuses on engineering and the sciences. The School has 700 students with 100% graduation rate and 100%

university acceptance. It has been named a Blue Ribbon School of Excellence by the U.S. Department of Education.

Anne Arundel County Public Schools
Kevin Maxwell, Superintendent
Maureen McMahon, Asst. Superintendent for Advanced Studies & Programs, Annapolis, Maryland

Anne Arundel County Public Schools (AACPS) provides a challenging and rewarding educational experience for every child. Located on the magnificent Chesapeake Bay, Anne Arundel County is near the cities of Baltimore and Washington, D.C., and is home to the state capital, Annapolis, which has a rich historical past. The AACPS school system is the 5th largest in Maryland, and among the 50 largest school systems in the country with an annual operating budget of over $931 million.

AAACPS schools include: 78 elementary schools, 19 middle schools, 12 high schools, 2 charter schools, 2 applied technology centers, 3 special education centers, 1 alternative high school, 1 middle school learning center, 1 special education, 1 early education center, and 1 outdoor education center regional program. They have a staff of nearly 5,500 teachers.

The Superintendent and Assistant Superintendent reviewed teacher hiring and retention practices and how they develop strong STM curriculum. This started with the concept of giving students some school choice, hence the magnet model in high schools and middle schools. Maryland's schools are more of a choice model, which means there is only an entrance exam. An example of partnerships and community involvement was the engagement with 110 business executives to develop internships for the students.

Project based learning is a cornerstone of the curriculum. Very seldom have disciplines been traditionally integrated, but the school system is working on that now. For example, biology, chemistry, and physics are taught in an integrated manner. There is a mandate that students do a community challenge. Students are put into consulting teams and by the end need to learn and to write a white paper and a briefing paper on issues such as: engineering designs, critical area laws relating to water, and environmental issues.

Thomas Jefferson High School for Science and Technology (TJHSST)
Evan Glazer, Jefferson Tech High Principal
Heather Sondel, Jefferson Tech High Asst Principal I/II

TJHSST is a Virginia state-chartered magnet school located in Alexandria, Virginia, and is a regional high school operated by the Fairfax County Public Schools. As a publicly funded and administered high school with selective admissions, TJHSST is often compared with notable public magnet schools. Attendance at TJHSST is open to students in six local jurisdictions based on an admissions test and prior academic achievement. The selective admissions program was initiated in 1985 through the cooperation of state and county governments, as well as corporate sponsorship from the defense and technology industries. TJHSST is a founding member of the National Consortium for Specialized Secondary Schools of Mathematics, Science and Technology.

TJHSST Vice-Principal provided an in-depth presentation on their class structure, scheduling, and the delegation had an in-depth tour of the facility including labs, library and classrooms.

U.S. Department of Education

- Office of Elementary and Secondary Education, especially Mathematics and Science
- Partnerships. Institute of Education Sciences, National Center for Education Statistics
- Office of Planning, Evaluation and Policy Development

The U.S. Department of Education is the agency of the federal government that establishes policy for, administers and coordinates most federal assistance to education. It assists the president in executing his education policies for the nation and in implementing laws enacted by Congress. The Department's mission is to serve America's students—to promote student achievement and preparation for global competitiveness by fostering educational excellence and ensuring equal access.

The Department's elementary and secondary programs annually serve more than 14,000 school districts and approximately 56 million students attending some 97,000 schools and 28,000 private schools. Department programs also provide grant, loan and work-study assistance to about 11 million postsecondary students.

http://www2.ed.gov/about/overview/budget/budget12/crosscuttingissues/stemed.pdf
(Description of the FY12 budget request for STEM – cross-cutting across Education)

44 states adopted the Department of Education STEM policies. There are common core standards but the Department of Education does not publish them because Congress doesn't allow them to set curriculum, something that underscores the decentralization of the system and the diversity of systems.

A big effort now is to define what effective teachers are, and how districts can assess teachers and then reward them and pass on knowledge of effective teaching to others. A challenge to address is that States have dummied down their expectations in order to make sure they made the mark under No Child Left Behind. We're now investing to create two accountability/testing systems matched to the common core in math in reading and states can choose which of those they want to follow.

The National Science Foundation has a pipeline for NSF developed programs to continue in the the Department of Education. There is a focus on the use of technology to improve student learning by incorporating stem into early learning centers. In the US we've done a good job of taking the top performers and helping them to keep being successful, but we haven't done a good job of helping others improve. There is also the "Open Learning Initiative" at Carnegie Mellon and the Gates Foundation is also investing in this as well. The desire is that such development doesn't just start at undergraduate, but also affects high schools as well.

Many schools are pursuing the blended model: design their curriculum around project based learning. The efficacy of STEM education or schools has not been scientifically proven, although long term studies have begun. This process is in the US is new and has not been implemented for very long so there are few long term studies completed.

Ministerial Observation Study Tour

Creating the First Egyptian STEM-Focused Schools:
The US Experience, Literature Discussion, and Recommendations

Written and Edited by: World Learning and Dr. Ehab Abdelrahman

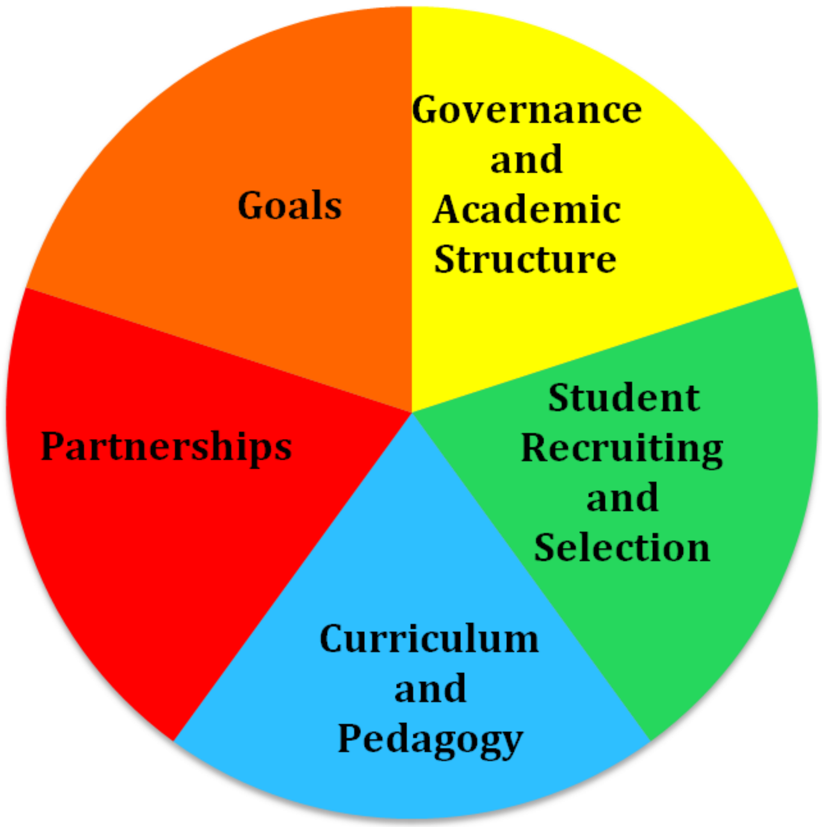
This report highlights the information gained regarding the current state of STEM education in the US as well as a review of STEM specific and broader science technology and math education recommendations and concepts that grew out of the STEM focused *Ministerial Observational Study Tour* organized by World Learning from August 15th to 22nd, 2011 in Philadelphia, PA and Washington, DC and US STEM education related data and reports. The synopsis below reviews the choices relating to recruitment, curriculum, pedagogy, partnerships, support structures, assessment practices, teacher recruitment, and professional development.

The broad objective with this observational study tour was to learn and observe the US systems for the implementation and growth of STEM Education. The assumption was that there are new and effective innovations being applied across the schools systems in the US that are applicable and adaptable for use in the Egyptian education system, with specific emphasis on the development of STEM public schools. The first such school has already been established and the model chosen was the STEM-focused high schools that only serve the highly motivated and able students, that requires an exam for admission, and the objective is to prepare them for intensive post-secondary study and STEM careers.

This is a new initiative and the first STEM school was established prior to the development of key components of STEM instruction and management. So, the areas for future planning and development would focus on: curriculum development, institutional focus on project based-learning, teacher training, focus on developing inquiry based pedagogy and creative problem solving based learning, developing assessments for students and teachers, developing linkages and partnerships with industry and universities, incorporating a school management structure that supports the STEM learning environment, and an assessment of how to scale up this model given the MOE's interest in having multiple STEM schools.

STEM School Design Dimensions:

Key elements of program design include the goals of the STEM school, the governance and academic structure, the student recruiting and selection practices, the curriculum offered and pedagogy used in the classroom, and the school or program's partnerships with other institutions.



Goals:
The first dimension is identifying goals of the STEM school/s. STEM schools and programs have different missions, ranging from providing gifted and talented students an elite STEM education experience, to bringing a broader set of students into advanced STEM studies, to providing students with STEM training for career preparation.

The National Academies provides the broadly accepted goals for K-12 U.S. STEM education:
http://www.nap.edu/catalog.php?record_id=13158

1. Expand the number of students that ultimately pursue advanced degrees and careers in STEM fields and broaden the participation of women and minorities in those fields.
2. Expand the STEM-capable workforces and broaden the participation of women and minorities in that workforce.
3. Increase STEM literacy for all students, including those who do not pursue STEM-related careers or additional study in the STEM disciplines.

There are concerns in the U.S. that it may be falling behind other countries in terms of production of an elite group of scientists, engineers, and mathematicians and there is a desire to get more talented students into the pipeline. This has stimulated the establishment of schools with the goal of feeding the *pipeline of STEM higher education elites*. In the past, the underlying assumption was that the U.S. needed to do a better job of identifying and encouraging those with STEM talent. This assumption led to a focus on early identification programs (such as the Johns Hopkins University Center for Talented Youth and Duke Talent Identification Program), competitions (Intel Science Talent Search) and special summer programs.

Many recent initiatives embrace the more ambitious goal of *broadening participation in STEM higher education.* This goal also addresses the need to produce more STEM professionals but does so by widening the pipeline, reflecting a building belief that the US can "democratize" participation in STEM professions by seeking alternative sources of talent.

At present the path of choice for the Ministry of Education is to develop a series of elite or STEM-focused schools that serve the highly motivated and able students and the objective is to prepare them for intensive post-secondary study and STEM careers, a system as described above.

Governance and Academic Structure

The second dimension in the STEM school design model is governance and academic structure, two variables that capture the school's funding and accountability and its internal organization.

Governance

Guiding the design and focus of schools, the governance system influences how a STEM school or program operates, as well as how the STEM school or program fits into the strategic objectives for secondary education. In the US this could be a district's or Charter Management Organization's (CMO). Governance arrangements in STEM educational institutions can run the full gamut found in American education, with the associated influences on school funding, administration and governing body. A next step is to define this structure.

Academic structure

This decision has been made. The MOE has decided on a residential program such as the South Carolina Governor's School of Science and Mathematics, a residential public school serving students from across the state. As this focus on STM education in Egypt expands, there are other models than can be examined closely to determine which is best in the Egyptian context.

Student Recruiting and Selection

A third dimension along which STEM schools and programs vary is how they recruit and select students. In the US *recruiting* is defined as seeking out students and encouraging them to apply, a model more compatible with the goals of inclusive STEM school, and *scouting* that involves searching for talented individual students, a model for selective institutions.

As the recruitment and selection process develops it is interesting to note that literature on specialized STEM schools a number of strategies for recruiting students from under-represented groups including targeted recruiting and bridge programs. *Targeted recruiting* involves identifying schools or other programs with large proportions of historically under-served students and concentrating recruiting activities in those locations. Targeting *Bridge Programs* helps to contact a student population that is provided additional educational support to advance in math and sciences.

In addition to recruiting students, STEM schools and programs also must *select* members of the incoming classes to fill a limited number of spaces. The most prevalent strategy is competitive selection relying on standardized or locally developed tests; other criteria include prior achievement, teacher recommendations, and demonstrated interest and motivation. Many STEM schools employ these mechanisms in various combinations. Some of the US STEM schools reviewed for this report use a nonselective lottery. This latter option has been chosen as the selection process for the first STEM school in Egypt. As the process evolves there could be increased targeted recruiting and if this the STEM focus expands into the broader primary and secondary education system Bridge Programs could be developed to increase the pool of potential students ready for the STEM school entrance exam.

Curriculum and Pedagogy

A fourth dimension on which STEM schools vary is in their curricular and pedagogical approaches.

Curriculum

One element of curriculum variation is whether the school attempts to offer a full range of science and mathematics topics or elects to concentrate on preparation in a particular subfield (such as engineering or biotechnology). Another type of curricular variation among STEM schools concerns the way in which they treat the integration of different disciplines or topic areas. Are the STEM disciplines taught as distinct fields, adding "layer cake" course sequences culminating in Advanced Placement or college level courses? Or are the STEM disciplines taught in a more integrated fashion, exploring connections between the fields? This last option would appear to be the curriculum model that will be implemented by the Ministry of Education. There would need to be significant curriculum development and training needed to implement any of these strategies given how they differ from existing curriculum strategies.

Many of the US STEM schools reviewed offer basic, intermediary, and advanced STEM courses in distinct STEM disciplines, such as Algebra and Advanced Algebra, Biology and Honors Biology, AP Computer Science, Mathematical Modeling, and Organic Chemistry. All of these schools also offer advanced courses for college credits.

In the last 20 years, an alternative strategy for sequencing STEM course work has emerged in which topics from a variety of subfields are integrated. In mathematics, this trend has led to the articulation of standards for mathematics in two forms: traditional and integrated. It is not known at this time which is the preferred model for the Egyptian context. This is an issue that requires further examination and follow-up. Some states, likewise, provide two alternative approaches for sequencing mathematics topics, and recently the State of Georgia opted to require the use of an integrated approach. Similar issues of integrated course work are found in science, especially through efforts to increase attention to cross-disciplinary topics such as engineering.

Thus, there is no widespread consensus on whether and how different STEM disciplines should be integrated. Many studies promote the idea of bringing coherence to STEM education by stressing trans-disciplinary concepts such as "systems" and "modeling" as well as student ability to transfer knowledge and skills within and between disciplines. Based on this idea, a movement to define a concept of "transdisciplinary" STEM courses is surfacing and replacing the terms "multidisciplinary" or "interdisciplinary," terms that have been challenged because they take the boundaries of the current disciplines for granted *a priori.*

STEM curricula vary also in the extent to which they take an applied orientation. Career and technical education (CTE) curricula are designed to provide training in specific technical fields (e.g., automotive technology, information technology, agricultural mechanics). These curricula are designed to train students for industry-defined positions and to equip them for advanced and continuing education in that field. A key decision to be made by the Ministry of Education is whether the STEM schools will adapt universal curriculum for all STEM schools, and perhaps universal revamped standards across all primary and secondary schools, or to have each STEM school adapt some of their curricula to the local industries and environment.

Pedagogy

Schools and programs can select from or combine traditional, teacher-led forms of instruction; project-based learning; workplace or lab-based learning; and the use of technology-supported learning tools, to name a few prominent options. By the end of this study tour and subsequent re-entry workshop it seemed that the focus would be on project-based learning and that future training would be required to implement this learning methodology. As with curriculum above, this will need to be implemented in conjunction with extensive teacher training.

In addition, many STEM schools offer internships, mentor programs and other learning experiences outside of school. Increasingly, technology is a part of the practice of STEM professions, and practitioner tools or simplified versions of them are finding their way into secondary STEM courses. Other technology-supported systems seek to apply cognitive science ideas about knowledge integration to an on-line support system combining information resources and scaffolds for student thinking with the goal of making complex ideas more accessible. The decisions in this area are tied to developing partnerships so that implementation can be expedient with quicker access to needed technologies and information.

Partnerships

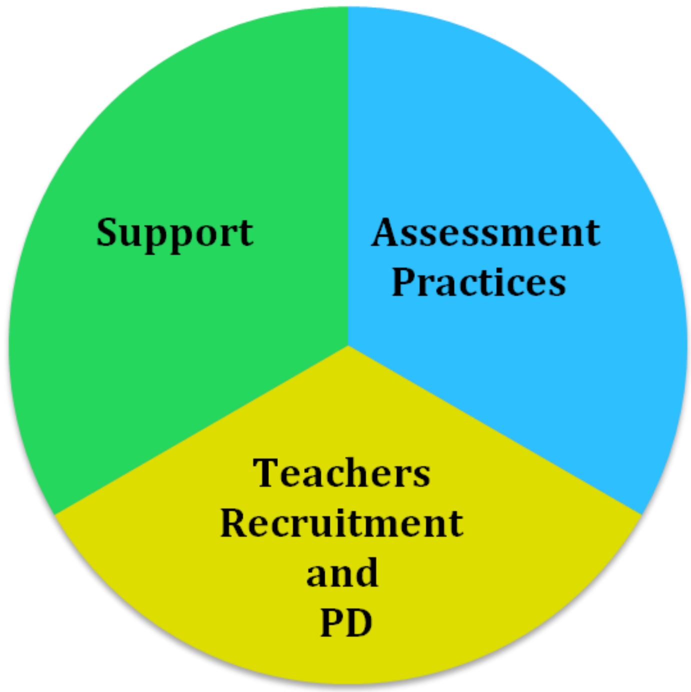
Finally, an important dimension around which STEM schools differ is the extent to which they create and integrate partnerships with outside organizations into their design and operations. Partner organizations may include corporations, institutions of higher education, and museums and other public institutions for the dissemination and promotion and science and technology. These partnerships can range from loose associations with a few joint activities to partnering on essential functions such as operations, curriculum, and securing resources. From the schools' perspective, partnerships can provide both curricular and laboratory resources and can serve as an entrée for students into a professional STEM community, helping schools offer students more creative programs, role models, support, and continuity across school years and institutions.

Given that the first STEM school is in its nascent stage the preferred strategy for developing partnerships and linkages has not been decided. However, there already are linkages developing between Mansour University and members of the Ministerial OST study tour have begun to make the initial linkages, setting the foundation for future partnerships.

Implementation

The second major component of the STEM school framework is implementation. This component addresses the ways in which an innovation or program unfolds in a particular setting. Implementation includes the ways in which intended program elements function within the context of the resources, setting, structures, and capacity of a particular site. Professional development is key to implementation as are the timeline and sequence in the plan for change. Classroom-based assessment practices provide information to the teacher on how his or her implementation of instruction is affecting student learning, thus playing a key role in using feedback for systemic adjustments.

This section discusses three specific implementation topics that research suggests have a major influence on successful school implementation: support structures, teacher recruitment and professional development, and assessment practices. All these areas need near term attention.



Support Structures
One category of implementation conditions concerns the academic support structures in place for students. These can include tutoring and special support classes, academic counseling and advising, and commitments of scholarships. *Tutoring* is a common support that cuts across almost all STEM schools in the US, and may be offered during school (e.g., "study block"), lunchtime, after school, on Saturdays, or during the summer. Teachers, paid tutors, and / or peers, may offer it. Some schools hire private companies (e.g., Back to Basics, Kaplan) to provide tutoring services. Additionally, some schools provide *special classes* for those who are in need of academic support.

Scholarship commitments are another key support for students within STEM secondary schools. This would require a defined partnership strategy to implement and is probably a high order item at this stage of the STEM school model.

Other student supports are not explicitly academic in nature but do foster academic success by addressing youth development needs. These may include counselors, nurses, internship coordinators, and mentors. Also in the category of non-academic programming are social-cultural activities and clubs, some of which may be directed specifically toward the interests of under-represented students.

Teacher Recruitment and Professional Development
Any STEM school needs to recruit qualified teachers with both STEM expertise and pedagogical skills, but an inclusive STEM school needs especially skilled teachers to work with a broad range of achievement levels, hold high expectations for all students, and hold a commitment to helping students advance whatever their entering knowledge and skill levels. Research on professional development in mathematics and science suggests that it is essential that teachers facing these challenges should receive ongoing professional development and support that is learner-centered as well as knowledge- centered. Professional development should also link directly to curricular

programming and include both extended interactions and follow-up activities.

Studies and past experiences stress the importance of teacher professional development and of teacher collaboration, and recommend that schools provide structures and facilities that support teacher collaboration through such measures as organizing around units of several subjects or by groups of students, rather than single-subject academic departments, and providing time for teachers to collaboratively develop instructional materials. These recommendations are not STEM-specific, but their effectiveness applies to the STEM instructional environment.

Assessment Practices at the Classroom Level

Performance-based assessment practices, especially those incorporating technology, have an authentic fit with STEM disciplines. Student projects are easily documented using portfolios or digital portfolios. In addition, technology can be used to support the administration and almost instant scoring of formative assessments—those conducted during instruction to inform additional instruction on the same concept or skill--so that teachers can use the information "in the moment".

Formative assessments help teachers shift in their purpose from topic coverage to student mastery. They can be used to obtain early and continuous feedback about how offerings are working both for students as a whole and for different subgroups within the classroom. Formative assessment data help teachers identify the ways in which intended program elements function within the context of the resources, the setting, the structures, the capacity, the professional development and the timeline, sequence and plan for change.

Minstrell's DIAGNOSER system (2000) is an example of an assessment designed for formative use. DIAGNOSER contains science assessment items carefully constructed so that each possible student response is associated with a different conception of the science concept being addressed. Students' responses to DIAGNOSER items provide teachers with information about the misconceptions that need to be corrected through further instruction. In mathematics, Ginsberg's (2004) m-Class software (Wireless Generation) supports teachers' use of diagnostic interviews with hand-held devices that collect, upload and display data on student thinking. Similar approaches based on learning trajectories are under development for rational number.

Formative and performance-based assessment practices are the exception rather than the rule in the U.S., but some education systems put more emphasis on them. Another example would be France where large- scale diagnostic assessments are given at the beginning of the year, rather than at the end, to help teachers identify what students have to learn and plan their instruction accordingly.

Summative assessments (conducted at the end of a period of instruction to assess whether learning has occurred) can also play a role in a school's continuous improvement efforts. For example, the Missouri Academy of Science, Mathematics, and Computing developed the "Core Assessment of Science and Mathematics" with help from faculty at a local university, and uses it as a pre- and post-test, with administration first in the freshman year before fall classes begin, and again in the senior year two weeks prior to graduation, to document student achievement and demonstrate accountability to the school's stakeholders. In general, however, the scarcity of good summative assessment instruments for the STEM content that schools actually teach, has impeded efforts to use summative assessment data to demonstrate progress and inform improvement efforts.

This key question regarding assessments and the assessment strategy for the Egyptian STEM schools has not been identified as yet. Further examination of this is critical particularly since the first STEM school has already begun operations.

Factors in Establishing and Growing STEM Schools

The following are factors and issues to examine in the process of establishing Egypt's STEM Schools. Some factors address the broader education system and the interrelations between the system and the growth and success of the STEM schools particularly relating to teacher quality, student success, teacher and student recruitment, and assessments. The discussion of matters relating to the broader education system augment and give some content specific suggestions to the discussions had during the OST in the US and the follow-up workshop.

1- Assessment:

In the US, at the federal level, government appeals for having national standards for STEM education and representatives have stated that the US would profit from common standards in STEM subjects in K-12 to prepare students to compete in a global economy, although there is not universal agreement on this. Egypt will require high-quality assessments that truly reflect what students need to learn and are learning, as these will further progress in STEM education and allow educators to improve their approaches and materials. Standards are key to supporting the broad establishment of Egypt's STEM schools. It would likely be that Egypt implements nationwide standards to enhance STEM education throughout all STEM high schools and the entire education system as this focus on science, technology and math expands.

In the US the federal government does not define the curricula, standards, or assessment used in public schools in the US. This is the responsibility of state and local authorities in each State. The movement toward common standards is an effort originating from and led by the states. The federal government's role is to support these state-led efforts. The state-led efforts in the US have looked at developing common core standards in mathematics – and there is an ongoing effort to develop new standards in science that could be adopted or aligned to by all states.

Shared standards create the need and opportunity to provide better materials and professional development for teachers and to lay the groundwork for fair and valid assessments that measure what students have learned and benchmark Egypt performance against that of other countries.

It is generally agreed that standards and assessments should reflect what students truly need to know. Standards should be aimed not at memorizing facts but at achieving a combination of factual knowledge, conceptual understanding, procedural skills, and habits of thought. Assessments should measure the extent to which students have mastered this full range of learning. Assessments must be fair, valid and measure important knowledge and skills in ways that provide valuable feedback to students and teachers while also providing data that are useful for school accountability.

At it relates to broader science, technology and math education across the primary and secondary education system over the last decade, studies have led to a deeper understanding of how people learn and have offered influential visions into the learning of mathematics and science from the beginner to professional levels. Important lessons emerged from initial efforts to create shared standards that have shaped a new approach. Past standards lacked a sense of prioritization of what was most important for students to learn and for educators to teach, which made them difficult to put into practice. New efforts on the part of NRC and other organizations have taken into account this history and have responded to it.

In 2011, NRC panel identified the key strands for effective mathematics education. Those strands balance the need for skills to carry out mathematical procedures with the need for conceptual understanding and complex reasoning. The idea is to expose students and teach them skills they need to apply concepts, enabling them to see the utility and relevance of mathematics. Those strands are:

1. Conceptual understanding – comprehension of mathematical concepts, operations, and relations
2. Procedural fluency – skill in carrying out procedures flexibly, accurately, and appropriately
3. Strategic competence – ability to formulate, represent, and solve mathematical problems
4. Adaptive reasoning – capacity for logical thought, reflection, explanation, and justification
5. Productive disposition – habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one's own efficacy.

In 2007 an NRC panel published a parallel set of strands for science education. These strands transcend the emphasis on low-level factual recall found in many science classes today to include the skills needed to solve complex problems, work in teams, and interpret and communicate scientific information. Those strands are:

1. Know, use, and interpret scientific explanations of the natural world. Students acquire facts and conceptual structures that incorporate those structures and use them to understand many phenomena in the natural world.
2. Generate and evaluate scientific evidence and explanations. Students have the knowledge and skills to build and refine models based on evidence, including designing and analyzing empirical investigations and using empirical evidence to construct and defend arguments.
3. Understand the nature and development of scientific knowledge. Students recognize that science is a particular kind of knowledge with its own sources, justifications, and uncertainties, and that predictions or explanations can be revised on the basis of new evidence or a new conceptual model.
4. Participate productively in scientific practices and discourses. Students understand the norms of the practice of science and how to participate in scientific debates or adopt a critical stance, and they are willing to ask questions.

There are also current efforts to support and advance assessments of technological learning and to integrate features and examples of technology and engineering (and design principles) both in mathematics standards and in the framework for science standards.

In the US there is a realization for the pressing demand for well-designed courses in technology and engineering, with high-quality instructional materials, especially in high schools. Experts believe that Computer-related courses must target not just for technological literacy, which includes such utilitarian skills as keyboarding and the use of commercial software packages and the Internet, but for a deeper understanding of the fundamental concepts, methods and wide-ranging applications of computer science. They believe that students should gain hands-on exposure to the process of algorithmic thinking and its realization in the form of a computer program, to the use of computational techniques for real-world problem solving, and to such pervasive computational themes as modeling and abstraction, modularity and reusability, computational efficiency, testing and debugging, and the management of complexity. Where feasible, active learning, higher-level thinking, and creative design should be encouraged by situating new concepts and techniques within the context of applications of particular interest to a given student or project team.

Over the past few years, a number of organizations have begun to formulate guidelines, principles, and proposed standards for the incorporation of technology-related subject matter within the K-12 curriculum. The Association for Computing Machinery (ACM) has developed a model K-12 computer science curriculum that presents a framework within which school districts and state departments of education can revise their curricula and standards to include key elements of computer science and computational thinking. In 2005, the Computer Science Teachers Association (which evolved from the ACM's K-12 Task Force) produced a report that proposed a set of principles and guidelines aimed at improving high school computer science education. In a project sponsored by NSF's Directorate for Computer and Information Science and Engineering (CISE), the College Board is developing a new Advanced Placement course designed to introduce students to the central ideas of computing, computer science, and computational thinking. Although each of these efforts has had a somewhat different focus, they are generally reflective of a shared perspective on many of the most important aspects of K-12 education in IT-related areas.

Lessons Learned in Assessment:
It is crucial to adopt clear standards in both mathematics and science. It is also important to disseminate these standards among all stakeholders of the school. Final decisions on the development of assessments will require a focused examination of current policies and procedures, however below are strong areas for consideration:

1. Support for Standards – Rigorous high- quality professional development of standards that are tightly aligned with the needs of teachers to implement curricula that meet the developed standards has proven to be a central requirement. Funding to universities and to nonprofit and for-profit organizations that provide technical assistance for professional development is one way to support this effort. The MOE could also provide support for the development of high-quality online resources for professional development.

2. New Assessments – The MOE could expand its support to consortia of stakeholders to finance the cost of development, evaluation, administration, and ongoing improvement of assessments tightly aligned to the standards. These assessments should foster active, inquiry-based learning together with mastery of critical concepts and facts. The process could include both periodic cumulative assessments and end-of-course assessments for selected courses in the new STEM School and maybe other Experimental Schools in Egypt. This initiative could be expanded to cover all Egyptian schools.

3. Ongoing Research – The Minister of Higher Education and Research and other foundations and organizations should support research on the transition to shared standards, evaluating their success, the challenges faced, and ways to improve them over time.

4. Benchmarking – The STEM school could participate in international assessments in order to monitor progress relative to national and international benchmarks and continue its support for PISA and TIMSS.

2- Teachers:
Teachers are the distinct prime vital factor in the education structure. They are fundamental to the strategy of preparing and motivating students in STEM schools. Great STEM teachers have at least two characteristics: deep content knowledge in their subjects, and strong pedagogical skills for teaching their students. These two characteristics enable great teachers to help students accomplish profound understandings of STEM. These characteristics empower teachers to stimulate students about the vibrant nature of STEM fields. The Ministry of Education could help

recruit, prepare, and support new STEM teachers with these characteristics. It also could support the professional development of teachers to help them achieve deep STEM content knowledge and mastery of STEM pedagogy.

To attract and retain great STEM teachers, excellence in STEM teaching should be significantly and visibly rewarded, importance of the profession should be signaled, and the level of STEM teachers should be elevated by setting a new high bar for excellence. Addressing this issue as a national concern requires recognizing a substantial number of STEM teachers nationwide and creating a network among them that can drive progress and aspiration in the profession.

Recommendation for the Teachers Based on Best Practices:
As STEM education grows the Ministry of Education could set a goal of ensuring the recruitment, preparation, and induction support of new STEM teachers from programs that are:

(i) designed to produce teachers who have strong majors in STEM fields and strong content-specific pedagogical preparation – including teachers from nontraditional backgrounds who help diversify the STEM teaching force
(ii) capable of measuring both the student achievement and the retention of the teachers they produce

In addition, the Ministry of Education could support research to identify and develop high-quality, cost- effective STEM teacher professional development programs and invest in the dissemination of those programs. Lastly, STEM teachers could be provided with opportunities to interact with each other and to have a voice in education policy at the school.

3- Educational Technology:
Technology has the potential to transform K-12 education, just as it has many other sectors of the economy and society (as witnessed in the January 25, 2011 revolution). A new mission-driven approach to the development of technology platforms could dramatically improve the STEM preparation and motivation of all students and if broadly applied bring innovation to K-12 education and prepare and inspire students in new ways.

Technology supports innovation in three fundamental ways:

1) **Continuous evaluation and improvement based on data**
2) **Rapid and inexpensive dissemination of successful solutions**
3) **Mass customization**

It is very important to realize three crucial points:

1) **Technology cannot replace the need for great teachers**. The goal of technology is not to replace teachers, but to support them. Properly used, technology can extend the reach of teachers by giving them access to the best instructional and professional development materials, to tools that can create customized learning environments and assessments for students, and to data that capture rich information about individual performance.

2) **Ensuring that schools and students have adequate technology infrastructure will require considerable attention and resources**.

3) **Technology-based solutions will need to be rigorously and continually evaluated to**

assess whether they are increasing student preparation and inspiration.

4- Students:
Success in STEM education relies on a school's ability to inspire and encourage students. This includes generating enthusing prospects for students to have individual or team-oriented experiences with the ideas, discoveries, and emerging knowledge in STEM fields. Two key avenues can provide students with experiences that allow them to explore and challenge themselves with STEM. The first is out-of-class and extended day activities that include contests, laboratory experiments, field trips, and more. The second is advanced courses that press students to set ambitious goals and achieve at higher levels. The new STEM school could launch a coordinated initiative for out-of-class and extended day programs in STEM. Existing after-school programs should be reoriented toward STEM experiences, and support for contests and programs in STEM should be increased. In addition, the school should take steps to ensure that many more students take and succeed in advanced classes in STEM subjects that go beyond the standard curriculum.

There are a variety of approaches to STEM-focused activities:

After-school programs. The assumption is that any existing programs have a connection to the STEM program.

STEM contests. Out-of-class STEM contests that reward creativity and problem solving can be particularly powerful experiences for students. Teachers who elect to engage and support these students often need training, materials, and may require supplemental pay.

Designing and building. Out-of-class and advanced day activities also provide excellent opportunities for extended projects based on inquiry, construction, and discovery. These projects can combine digital and physical resources in ways that interest all students, not just those with a pre-existing interest in STEM. These opportunities spark interest in STEM while also providing students with the skills, thinking capabilities, and background knowledge they need to excel in STEM subjects.

Summer programs. Many of today's US STEM professionals were inspired to choose careers in STEM by programs sponsored by the federal government. Egypt's STEM schools, Egyptian Universities and NGOs, may inspire Egyptian students to pursue STEM careers.