迎接新的挑战：再论 STEM 在中国

Meeting the New Challenges: Rethinking STEM in China

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Abstract: *STEM education has slowly taken its foot hold in China. While we try to reform the education system to meet the demands of the new digital and global economy, the challenges China's education system faces are vastly different from what have been extensively studied and targeted in US. In this paper, we exam the differences between the challenges US and China need to overcome, the emphases on different aspects of STEM in the two countries, the different ways to measure the success, and how to gradually phase in the STEM in current curriculums in China, especially for the early adopters, the elite schools.*

Keywords*:* STEM in US, STEM in China, STEM evaluation, STEM Curriculum Design
关键词：STEM 在美国，STEM 在中国，STEM 评估，STEM 课程设计

1. The Human Resource for Information Age and Global Economy

The world in 21st Century is destined to be more global and digital. The ways to do many things at work and at home are changing along with the wide spread of Internet and computer applications. Tasks in many areas that used to be done by humans will be handled by computers; hence more human resources will be put in use where automation is hard or even infeasible, such as science and technology, engineering and math.

Because the digitization is so ubiquitous, a different set of new skills are needed for majority of the workforce, as well as the creativity and mindset capable of dealing the ever changing world around us. As the globalization continues its course, workforces in different countries are competing in a global digital economy. The trend favors those with the right skills, knowledge and ability to perform and adapt in the fast changing environment. It is widely recognized that STEM has become the essential skills in a more and more technology oriented society.

Recently, US News and World Report issued its first national ranking of high schools in terms of STEM[1], which for sure will lead the attention of parents and students to the STEM strength of high schools nationwide.

2. Facing Different Challenges

Much research has been done over the past years on STEM education, especially on its development in US; a few research also studied STEM's future in China [2]. We believe that STEM in China faces very different challenges and we cannot simply copy what has been done in US and other countries.

US, while historically strong at producing and attracting creative elite workforce, has seen the majority of its public schools lagging behind those of most of the developed countries in terms of STEM education. Therefore, strengthening basic elements, especially the Math and Science in STEM education in majority of the public middle schools and high schools is its goal for the near future, while its elite schools continue to produce world class scientists and engineers.

On the other hand, China, known for its rigorous math programs in high schools shaped by countless quizzes and

exams with standard answers, has produced a generation of students with their imagination and creativity severely suppressed, damaged or even completely destroyed. Furthermore, exam driven school programs have pushed the students towards books and sample tests and away from hands on learning experience; in most of the middle schools and high schools, technology and engineering connected to the daily life in real world is badly lacking. The problems at hand are how to nurture students' curiosity and imagination, the ability to ask questions and think independently and critically, as well as engage in hands on learning process. In terms of STEM, its emphasis should be on T and E, and the interactive, student-centered learning experience.

Given the differences in the current states of the education systems, different metrics to gauge the effectiveness and success of the STEM are needed. In China, the metrics should measure the degree of integration of the areas in STEM, the active participation of students in project based and hands on learning experience, and students' ability to think independently. All of these are a significant deviation from the current exam driven teaching paradigm.

3. STEM in Elite Schools in China

Given the resources and motivations, a number of elite schools will be the early adopters of STEM. How they gradually develop a STEM program based on their own strength and resources and meet their own needs will have significant impact on majority of the schools.

Most of elite schools in China have very strong science (physics, chemistry and biology) and math programs and a few technology programs. For some reason, robot is a very popular technology program among the elite schools. However, until recently, the exam driven system has the following severe drawbacks:

- Some components in STEM, namely Science and Mathematics, are taught separately in a very abstract way, resulting in students lacking the knowledge and skills to use those components in an *integrated* manner; at the same time, the other components, Technology and Engineering are almost not formally covered;
- Because the whole education process is dictated by the ultimate exam, College Entrance Exam, the interactive learning experience has gradually deteriorated to memorizing the standard answers to countless quiz questions, severely limiting students' imaginations;
- It has long ignored cultivating students' creativity and critical thinking ability;
- Soft skills such as project management, team work, and communications are nonexistent.

Given this situation, we believe that STEM programs in these elite schools should focus on a number of areas as highlighted in the following table:

Table 1. STEM Education Focuses

Content	STEM Integration with Focus on *T & E*
Methods and Formats	• Interactive, Inquiry Based • Hands on • Project Based Learning
Results	• Creativity and Imagination

	• Independent Thinking • Critical Thinking
	• Communication Skills • Team Work Ability • Other Soft Skills

As we can see, the key is not only what to teach, but also how to teach and the whole learning experience as well as the skills gained during the process. Unfortunately, shortage of teachers with the skills and knowledge to teach STEM class is a major hurdle to overcome.

As more and more schools launch various STEM programs, how to gauge the effectiveness of those programs is critical. We believe STEM is fundamental change to our current education system and its adoption will be gradual, and a set of metrics should be developed based on the above three areas to measure the efficiency of a STEM program. Previous work on STEM evaluation focused mainly on STEM education in US [3][4][5]and are not suitable for the early stage of STEM in China.

In the following table we present our design of such metrics used as a self evaluation tool:

Table 2. STEM Program Evaluation Metrics

Category	Focus	Details	Weight
Teachers	Training of the STEM teachers	• Designated STEM teachers • Average # of hours STEM teachers are trained on STEM	20%
Content	STEM Integration with Focus on *T & E*	• T & E centered curriculums • Curriculums integrating S & M teaching	20%
Methods and Formats	• Project Based Learning • Interactive, Inquiry Based • Hands on	• % of STEM classes are project based • % of Classroom time spent on discussion • % of time spent on hands on activities	30%
Results	• Creativity and Imagination • Independent Thinking • Critical Thinking	• Think out of the box; new ideas • Forming own conclusion and opinion • Challenging the authority with reasoning	20%
	• Communication Skills • Team Work Ability • Other Soft Skills	• Presentations, defending, criticizing • Consensus building, team member feedback, coordination • confrontation handling, crisis handling,	10%

4. STEM and General Technology Lab

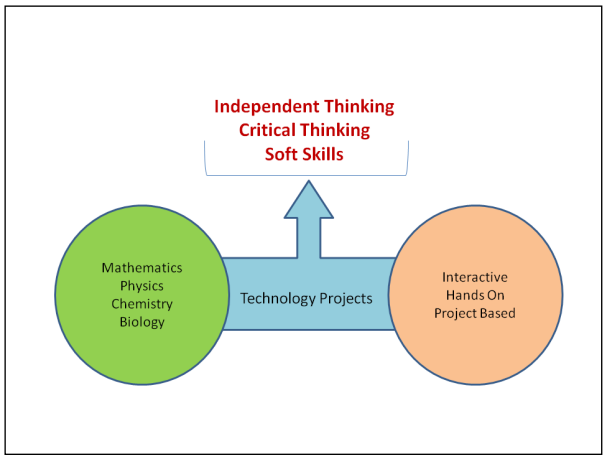
It is not feasible to completely get rid of current curriculum and start a new one with full blown STEM; though in US there are newly formed STEM schools. A more practical and natural starting point is the General Technology Lab which does have some STEM flavor.

In last few years, a number of elite schools have built a General Technology Lab, and use it to teach General Technology Class. It has been widely used to teach some engineering contents not covered in regular class, such as design process, and the students get more opportunities to do things more or less based on their own ideas (not rigorously following a standard user lab manual). However, a number of things are often lacking which highlights the difference between the general technology lab and the real STEM education. An ideal technology lab project should be designed in such a way that it:

- Blend key science concepts, theory and methods in a meaningful and realistic manner;
- Follow the real world engineering assumptions, principles and procedures;
- Provide opportunities for students to inquire, search, and draw their own conclusions;
- Encourage everyone to actively participate and take some responsibility;
- Provide opportunities for students to discuss, evaluate and defend other's and their own solutions.

Ultimately, a technology lab project should integrate science and math in a realistic scenario with carefully designed process encouraging interactions and participations to achieve the goals of enhancing students' ability to think independently and critically and developing the soft skills needed in real world, as illustrated in the following figure:

Figure 1: Technology Project Design



Many schools have built their general technology lab with state of art equipments; however, what are more important are not the fancy equipments, but how equipments are used to teach STEM classes. We should try to avoid using hardware to compensate the lack of good STEM curriculums.

5. Conclusion

Given the current state of the middle school and high school education in China and how everything is dictated by College Entrance Exam, we need to set realistic goals for new STEM programs and design an evaluation system to gauge their progress and effectiveness.

We presented some of our preliminary thoughts on how to develop a set of metrics to evaluate a STEM program, and some idea on how to use the current General Technology Lab curriculum to start a pilot STEM program.

We are launching a STEM pilot program in September, 2012 and will have more to report at the time of the conference.

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