STEPS TO TRANSFORMING SCIENCE EDUCATION

A practical guide on next steps toward improvement

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Abstract

Creating a global competency in STEM (science, technology, engineering, and math) among today's students and tomorrow's skilled workers requires more than just a technology adoption in the classroom. Transformational changes require moving from the traditional approach of implementing a science experiment in the classroom to outfitting a classroom with the right technology, curriculum, and teacher guidance. The model, 5 Building Blocks for Science Education Transformation (SET), serves as a guide for anyone working to build programs and create sustainable change in education. The Fostering Transformation Assessment helps readers evaluate their position on the continuum of change and provides practical turnaround solutions that can be implemented both short- and long-term at teacher and administrator levels.

Contents

Introduction

The notion of transforming science education is not new. What is new, however, is the collective agreement on how science education can be taught more efficiently and promote deeper understanding when technology is integrated into hands-on experiences.

At its core, science education is a key driver in a knowledge economy. Pressure for nations to compete in the global marketplace requires a rapid acceleration of modernizing classrooms, especially in the science, technology, engineering, and technoogy (STEM) areas. This includes building students' information, communication, and technology (ICT) skills today in order to help unlock global opportunities for them as next generation professionals. The key to success lies in creating generations of educated citizens and skilled workers to drive economic development and thus reduce the reliance on importing talent.

This guide provides an overview of selected current issues in science education, some of which our readers may be facing. To help readers reflect on their own practices, it includes a Fostering Transformation Assessment for self-evaluation and the model, 5 Building Blocks for Science Education Transformation (SET), for guidance on next steps toward improvement.

Driving science education transformation and economic development

Now, more than ever, a scientifically literate society is critical for all nations. Its resulting value is advantageous to a country's social and economic health as well as the satisfaction of its citizens.

For students and future workers, well-developed STEM skills better prepare them to compete in the global marketplace and thus raise their standard of living (U.S. Congress Joint Economic Committee, 2012, p. 1). In France, unemployment rates for those with humanities degrees are five times higher than engineering and health care graduates (Dobbs et al., 2012, p. 48). The average STEM graduate in the U.S. earns $500,000 USD more in discounted lifetime earnings than the average non-STEM graduate. This holds true even when the STEM worker is employed in a non-STEM occupation (Dobbs et al., 2012, p. 48).

On a macro-scale, STEM expertise is an economic driver that develops knowledge economies. According to the Organisation for Economic Co-operation and Development's report of the 2012 Programme for International Student Assessment (PISA), "Nurturing excellence in mathematics, reading or science, or in all three domains, is crucial for a country's development as these students will be in the vanguard of a competitive, knowledge-based global economy" (OECD, 2013, p. 9). More specifically, it allows nations to be prepared to participate in challenges such as fresh water, clean energy, climate change, and the consequences of exploding urbanization and natural disasters (UNESCO, 2010, p. 43).

And while we recognize the value of science, math, and technology expertise, the demand for qualified STEM workers continues to grow. At the same time, the number of qualified workers is in short supply to meet the number and proportion of future STEM jobs.Global institutions, academics, and leaders are reporting:

- A worldwide shortage of STEM-focused workers by 2030 (McKinsey Global Institute in Dobbs et al., 2012).

- "The lack of qualified engineers and technicians is currently reported to be one of the principal obstacles to economic growth encountered by innovative firms in many industrialized and industrializing countries" (UNESCO, 2010, p. 71).

- From 2010 to 2020, employment in STEM occupations is expected to expand faster than employment in non-STEM occupations (Bureau of Labor Statistic, U.S. Congress Joint Economic Committee, 2012, p. 2).

- In the U.S., one solution has been to recruit qualified workers from other nations (National Science Board, 2014, p. 3-51). However, this requires a relocation of human resources away from areas of the world where they are most needed. It is realistic to think that large numbers of qualified graduates may choose to return to their home countries (U.S. Congress Joint Economic Committee, 2012, p. 4).

There is help for science education leaders who are ready to take the next step to begin the process of transforming science education to bring more students into STEM careers. The 5 Building Blocks for Science Education Transformation (SET) provide the high level requirements. The two applications for SET offer research-based, practical solutions to the transformation.

The 5 Building Blocks for SET

Creating sustainable change is a process and can be a daunting but necessary journey. The shortage of qualified science and technology professionals is a problem that educational systems around the world must address. PASCO Scientific has done considerable work to help nations integrate technology into their science curricula and transform science education. In the course of this work, five prerequisite themes emerged. In concert, these themes serve as building blocks to help education systems guide change.

1. **Vision:** At the state and country level, there must be a vision of how education reform can lead the way in creating a knowledge-based economy. Kazakhstan redefined its educational system and established a goal of setting its people on a new path for the future by modernizing its schools, integrating technology into the teaching process, and creating a world-class education system.

A case in point is the United States. A 2012 report to the U.S. Congress's Joint Economic Committee on STEM Education cited, "Half or more of economic growth in the United States over the past fifty years is attributable to improved productivity resulting from innovation," particularly with respect to computer, information, and biomedical technologies (U.S. Congress Joint Economic Committee, 2012, p. 1).

Technological innovation improves competitive positioning in industry, drives export growth, and supports high-quality jobs. Moreover, due to the diffusion of technology across industries and occupations, demand for STEM-qualified workers has increased even in traditionally non-STEM fields (U.S. Congress Joint Economic Committee, 2012, p. 1).

In 2007, PASCO was selected as a key partner to help Kazakhstan develop a science program to propel its students into STEM success.

2. **Sustained Leadership:** If science education transformation is to be effective, the vision must be accompanied by sustained leadership. For example, the Shandong Province in China has a rich history of education and independent thinking dating back to Confucius. While the focus for student success is often placed on standardized test achievement, the Ministry of Education in the province realized that they needed to foster ingenuity by developing a student's ability to problem solve, and not just by rote learning.

Changing one's notions of science understanding from that of facts, theories, and concepts to one of a practice of inquiry can also pique students' curiosity, capture their interest, and motivate them to continue to study science. An education that focuses solely on the facts without developing an understanding of how those facts were established or that ignores the many important applications of science in the world misrepresents and marginalizes science and the importance of engineering (*Framework for K-12 Science Education,* National Research Council. pp. 42-43).

By partnering with PASCO to design such a program, teachers in Shandong Province are now building a new generation of innovators and thinkers with a passion for science.

3. **Professional Development:** Classroom support is critical for a successful transformation. With customized professional development, PASCO delivers the guidance and support teachers need to create an inquiry-based learning environment. In Arequipa, Peru, the State President was determined to reform education and create opportunities that had never been provided to local students. He relied on PASCO and its regional science partner to prepare teachers to better engage and educate students and prepare them for college. To help teachers build their confidence to deliver inquiry-based lessons in their science classes, teachers received either in-country professional development or, in a unique

format, the teachers came to PASCO headquarters accompanied by some of their students for several days of training.

4. **Customized Content:** The pedagogical transformation must also be supported with adaptable and localized content. When the city of Bergen, Norway, decided to strengthen their students' science skills to better prepare them for STEM success and the competitive global job market, they partnered with PASCO and its regional science partner to implement the project. The regional partner and PASCO worked with a local university to create electronic labs written in Norwegian and aligned to local standards to help meet their science and technology goals.

5. **Technology:** The last building block for transformation is technology. It is an essential component of modernizing an educational system, yet many countries trying to transform education find that they do not have the infrastructure to support modern classrooms. Such was the case in Kazakhstan, where many of the schools that were part of the reform project existed as single-room schoolhouses without any technology. With PASCO's help, the teachers received training as the infrastructure was being built around them. When the schoolhouse was ready, the teachers were ready to move forward in modern teaching environments. Creating support for modern classrooms is critical if we expect students to use technology and instructional contexts. Recommendations from The International Society for Technology in Education (ISTE) 2007 *National Educational Technology Standards (NETS)* include:

- "<u>Communication and collaboration</u>: Students use digital media and environments to communicate and work collaboratively, including at a distance, to support individual learning and contribute to the learning of others…

- "<u>Research and information fluency</u>: Students apply digital tools to gather, evaluate, and use information…

- "<u>Critical thinking, problem solving, and decision making</u>: Students use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources" (ISTE, 2007a).

Building Blocks for Guiding Change

1 Vision
2 Sustained Leadership
3 Professional Development
4 Customized Content
5 Technology

Two Practical Applications for SET

Given the two main drivers (the need to develop more qualified scientists, medical professionals, engineers, and technologists; and the call for students to be more scientifically literate and gain experience with the tools and practices of science), a considerable research base exists identifying components that could help transform science education. Specifically, two areas of research support the claim.

- Use of technology tools for data collection, analysis, and visualization as part of hands-on, inquiry-based science instruction has been shown to deepen students' understanding of science concepts.

- Involving students in hands-on, technology- and inquiry-based science can increase their motivation and interest in science.

Sensor-based investigations provide extensive opportunities for students to develop scientific literacy and familiarity with the practices of science through hands-on experiences using tools similar to those used by scientists and engineers.

Specific scientific and engineering practices identified in the *Framework for K-12 Science Education* include:

"1. Asking questions (for science) and defining problems (for engineering)

"2. Developing and using models

"3. Planning and carrying out investigations

"4. Analyzing and interpreting data

"5. Using mathematics and computational thinking

"6. Constructing explanations (for science) and designing solutions (for engineering)

"7. Engaging in argument from evidence

"8. Obtaining, evaluating, and communicating information"

Note: For science, all of these practices are integrated into the practice of inquiry (*Framework for K-12 Science Education*, National Research Council, 2012, pp. 3 and 44-46).

Research affirms that (1) inquiry-based instruction and (2) hands-on technology-based activities (i.e., sensor-based) have been shown to deepen students' understanding of science concepts and have increased motivation and interest in science.

Inquiry-based Instruction for Understanding

A substantial body of research confirms the positive impact of inquiry-based instruction on student understanding of science (Furtak et al., 2012, p. 301, citing earlier meta-analyses and research reviews). For example, as part of a recent survey of studies about inquiry-based teaching (the Inquiry Synthesis Project), Minner et al. (2010):

"identified a subset of 42 comparative studies that contrasted inquiry-based teaching with other approaches. Of these studies, 55% found students in the condition with 'higher inquiry saturation' to outperform students in the comparison group. Overall, the authors argued that their synthesis indicates a 'clear, positive trend in favor of inquiry-based teaching' " (Furtak et al., 2012, p. 303, quoting Minner et al., 2010, pp. 483, 474).

Furtak et al.'s own meta-analysis found substantially higher science learning from inquiry-based instruction in primary and secondary classrooms, compared to other methods lacking inquiry characteristics, with a mean effect size of .502 over 37 studies from around the world published between 1996 and 2006 (Furtak et al., 2012, p. 315).

As part of their meta-analysis, Furtak and colleagues identified four "domains" of inquiry instruction: procedural, epistemic (i.e., understanding the nature of and acquisition of scientific knowledge), conceptual, and social. Each of these was further divided into subcategories. The studies were then categorized according to which inquiry domains were present in one condition but absent in the other condition. According to the researchers:

"The three studies that explicitly contrasted the epistemic domain of inquiry had the largest mean effect size on student learning [.75], followed by the six studies that contrasted the procedural, epistemic, and social domains" [.72] (p. 318).

Furtak et al. also codified studies based on the degree of guidance students received: as teacher-led traditional instruction, teacher-guided inquiry, or student-led inquiry (discovery learning). While the six studies that directly contrasted teacher-guided versus student-led inquiry were essentially the same in effect size (mean difference = .01), there was a substantial difference when each one was compared to teacher-led traditional instruction: "the ten studies that explicitly contrasted teacher-guided reform versus traditional conditions had a higher mean effect size [.65] than the five that contrasted student-led reform versus traditional [.25]" (p. 319). These findings suggest that some degree of teacher guidance is more likely than "pure" student-led discovery learning to result in improved student learning, compared to traditional instruction.

Inquiry-based Instruction for Motivation and Interest

Research supports the value of inquiry-based science instruction for its potential to motivate students and build their interest in science. According to a 2014 review of inquiry practices in primary and secondary science classrooms, "There is ample evidence that classroom-based inquiry science can be beneficial to… developing positive attitudes toward life-long science learning" (Crawford, 2014, p. 537).

More specifically, a 2006 report on high school science laboratory experiences in the United States—including experiences that use technology tools for data collection, analysis, and visualization—found evidence that such experiences can increase students' interest in science, particularly when integrated with other science learning experiences and when "students are engaged in framing research questions, making observations, designing and executing experiments, gathering and analyzing data, and constructing scientific arguments and explanations" (National Research Council, 2006, p. 4).

This report indicated that "current designs of science curricula that integrate laboratory experiences into ongoing classroom instruction have proven effective in enhancing students'… interest in science" (National Research Council, 2006, pp. 25-26). The authors concluded, "Students who participate in these units show greater interest in and more positive attitudes toward science" (p. 97).

A synthesis of research on precollege engineering education and its relationship to science learning described "evidence that by emphasizing personal, real-world connections and constructing a need to know for related science, engineering design activities can enhance student motivation to learn science" (Cunningham & Carlsen, 2014, p. 747, citing Barron et al., 1998; Kolodner et al., 2003; see also p. 754). Such activities typically involve a design process that incorporates inquiry-related practices (p. 749), and often involve hands-on student use of technology. Elements of engineering design activities with particular potential to motivate students include:

- "Giving students authority to solve problems" (p. 750)
- "Exploration of "diverse solutions" in a context of multiple competing values (p. 750)
- "The practical context of these problems" (p. 751)
- "An emphasis on the social value of the object of student learning" (p. 750)
- "Enhancing students' sense of their own competence and agency" (p. 754)

Hands-on Technology-based Activities for Understanding

Describing the value of technology to help students learn science, Krajcik and Mun (2014) identified six ways technology can support the "important learning goal" of "accessing and collecting a range of scientific data and information" by supporting students as they:

- "Use visualization, interactive, and data analysis tools similar to those used by scientists,
- "Collaborate and share… information across remote sites
- "Plan, build, and test models
- "Develop multimedia documents that illustrate student understanding…
- "Access information and data when needed
- "Use remote tools to collect and analyze data" (Krajcik & Mun, 2014, p. 338)

Along similar lines, a review

of research from the International Handbook of Information Technology in Primary and Secondary Education identified data logging (also referred to as microcomputer-based laboratories [MBL]) as one of three types of instructional technology use that "have been shown to promote science learning" in schools (Webb, 2008, p. 134). According to Webb:

"Research… over many years has produced varying results (Kulik, 2003)… Linn and Hsi (2000) found that pupils are much better at interpreting the findings of their experiments when they use real-time data collection than when they use conventional techniques for graphing their data, and that this greater understanding is carried over to topics where they have not collected the data. Russell et al. (2004) found that interactions with MBL and associated student–student interactions were supporting deep learning" (Webb, 2008, pp. 137-138).

Webb also described technology-related benefits stemming from "greater opportunities for meaningful interaction with teachers" and gave as an example, "students work[ing] in groups using data-loggers to record experimental results, [which] freed up the teachers to circulate and stimulate discussion and thinking about the results" (Webb, 2008, citing Rogers & Finlayson, 2004).

Krajcik and Mun (2014) explained the benefits of this technology as follows:

"The use of probes in the classroom… allows learners to engage with several science practices critical to supporting students in learning science. The most salient practices include designing and carrying out investigations, analyzing and interpreting data, and computational and mathematical thinking. However, the use of probes also supports students in asking and refining questions and engaging in argumentation from evidence" (p. 344).

Education experts specify further that technology—including technology tools for data collection, analysis, and visualization—is most effective in supporting student learning when it is used in an inquiry context. Krajcik and Mun (2014) report:

"Recent educational approaches emphasize the use of technology in environments in which learners engage in extended inquiry and develop knowledge and skills in the context of investigating complex and meaningful problems… Learning environments, including those that incorporate learning technologies, should engage learners in challenging and open-ended problems to provide students with opportunities to grapple with ideas and make connections. In such environments, students develop an integrated understanding of scientific core ideas by applying and using them to explain phenomena, solve problems, and make decisions" (pp. 338-339).

Similarly, America's Lab Report compared "typical" laboratory experiences (e.g., lab practicals) that are "disconnected from the flow of classroom science lessons" with laboratory experiences that are integrated with "other types of science learning activities, including lectures, reading, and discussion" and in which "students are engaged in framing research questions, making observations, designing and executing experiments, gathering and analyzing data, and constructing scientific arguments and explanations" (National Research Council, 2006, p. 4). The report found that students learned more from integrated laboratory experiences with respect to both mastery of subject matter and scientific reasoning (p. 100). This agrees with Webb's (2008) conclusion that technology "can… play a larger role when its use is fully integrated into the curriculum" (p. 143).

Hands-on Technology-based Activities for Motivation and Interest

Additionally, research has found that mobile technology has specific potential to motivate students. A summary of research related to use of instructional technology in science education reported, "Evaluations by learners and teachers suggested that use of hand-held devices together with wireless networking enhanced learners' experiences and their motivation for learning science in a range of settings, including fieldwork and museum visits" (Webb, 2008, p. 140, citing Scanlon, Jones, & Waycott, 2005).

From the students' perspective, the 2007 Project Tomorrow Speak Up Survey canvassed student opinions and found that primary and secondary education students tended to value both hands-on science activities and use of technology in STEM subjects (Farris-Berg, 2008).

- Thirty-eight percent of middle school and high school students surveyed indicated that their interest in STEM careers could be improved if they had opportunities to "use advanced technology, laboratory devices, or professional tools" (p. 15). Among high school students who were "maybe" interested in STEM careers, 44% were motivated by "tech tools," rising to 66% of those who were "yes interested" in STEM careers (p. 14).

- Thirty-six percent of middle school and high school students surveyed reported that hands-on learning opportunities would increase their interest in pursuing a STEM career (p. 16). Among high school students who were "maybe" interested in STEM careers, 48% were motivated by "hands on activities," rising to 66% of those who were "yes interested" in STEM careers (p. 14).

- Asked to describe "an especially interesting or favorite learning experience in science or math," a "large portion" of primary and secondary students who had experienced "hands-on, tangible activities and group-oriented learning methods in STEM subjects" found them to be "the most interesting" (p. 8). Middle school and high school students also "frequently mentioned that their most interesting learning experiences in science and math courses involved using interactive and advanced technology tools and engaging in activities with real-world relevance" (p. 10).

Both instructional and technological applications are available for teachers to implement in their science classes, helping to deepen students' understanding of science as well as increasing interest and motivation in the pursuit of scientific knowledge. To support the transition to new applications, the following section, Fostering Transformation, provides teachers and administrators with an instrument to evaluate their current state of implementing the use of technology tools and pedagogical approaches in their science classes.

Fostering Transformation

The Fostering Transformation Assessment provides a starting point for self-evaluation of current implementations. While transformational change is a continuous process, it will help to identify strengths and areas for growth and development. Among the criteria are some that provide practical turnaround solutions for implementation in both the short- and long-term plans at teacher and administrator levels.

Fostering Transformation Assessment[1]

On a scale of 1–5 with 5 representing excellent, score your program success at the student, teacher, and graduate level.

	On a scale of 1-5, rate how well your students...	Score
1	are afforded real-life experiences in hands-on environments.	
2	apply scientific practices to their investigations.	
3	are engaged in and understand critical issues in science such as energy, water, environmental, or health issues impacting their community.	
4	engage in activities where they act and think like scientists rather than follow a set of prescribed lab procedures.	
5	represent a greater diversity engaged in science.	
6	are afforded opportunities and tools for sharing data within a classroom or a community of remote learners.	
7	develop analysis skills.	
8	have developed a curiosity, sense of exploration, or discovery of their world.	
	On a scale of 1-5, rate how well your educators...	**Score**
9	focus on data analysis and not data collection.	
10	model industry in real-life settings for students.	
11	blend sensors and data analysis technology into content and assessment.	
12	provide engaging and interactive learning environments.	
13	have seen a decrease in behavioral and truancy issues.	
14	represent a diverse population.	
15	are comfortable and confident using technology in the classroom.	
16	apply principles of inquiry-based pedagogy in their teaching.	
	On a scale of 1-5, rate how well your graduates...	**Score**
17	represent a diversified workforce.	
18	demonstrate an increased comfort with technology.	
19	are engaged in and understand science issues such as climate change, population growth, or energy resources.	
20	are workforce-ready and can apply problem-solving and higher-order thinking skills.	
21	represent careers in STEM.	
22	work for organizations where they contribute to innovative products, services, or ideas.	

[1] Note that the Fostering Transformation Assessment tool should be used only as a guideline for evaluating progress on the transformation continuum. It does not purport to be an accurate indicator of states along the continuum

Scores for the entire grid can range from 22 to 110 with 66 as the midpoint. If the midpoint is considered average progress along the transformation continuum, then scores below 66 can be considered as evidence that some effort will be required to help in the growth and development along the continuum. Scores above 66 would indicate that progress is being made, but may also require improvement, especially for scores that are closer to the mid-range.

It is important to look at the scores for each category: student, educator, and graduate. Scores for the student and educator can range from 8 to 40, and scores for the graduate can range from 6 to 30. Using the midpoint for each, 24 for student and educator and 18 for graduate, scores above and below the midpoints can indicate progress along the transformation continuum and whether efforts should be made to improve progress. In assessing scores and reflecting on progress in each of the categories, consider the following:

- What areas need to improve?
- How do students' overall scores compare with that of teachers'?
- Are they about the same or is there one group that needs more attention?
- What is contributing to the difference?
- What changes can be made in the short-term to help transform science education?
- What changes can be made in the long-term if given the resources?

Implementation Solutions

Although not a complete list, some suggestions for implementing short- and long-term solutions follow. Each suggestion should be considered for its social and cultural appropriateness and fit.

Implementation Solutions

Short-term

Teacher

- Ask all science teachers to take responsibility to identify gaps and work toward continuous improvement.
- Change pedagogical approach from "stand and deliver" to an inquiry-based format, allowing students to drive the experiment, make predictions, and collect and analyze data.
- Build collaborative networks with the STEM community.
- Promote community outreach to foster mentoring programs for students.
- Extend learning activities outside regular school hours.
- Visit neighboring schools to share successes and learn what strategies work well.
- Leverage free or inexpensive STEM apps.

Administrator

- Embrace change as the highest priority and pledge support to achieve this goal.
- Start with the 5 Building Blocks for SET and build a clear vision. Define the "problem" and point to a solution using it as a guide. Take action in the areas that need to be built out.
- Establish a team of school and community partners that will support the vision and leverage the 5 Building Blocks for SET.

Long-term

Teacher

- Provide teachers with professional development opportunities where they can build confidence and develop technical, pedagogical, and content knowledge and understand the relationship between these components.
- Move beyond initial labs to integrate technology that further develops ICT skills such as Maker's Faires[2] or Engineering Days.
- Partner with organizations to design programs that encourage students to become involved in STEM.
- Create teacher leaders capable of effectively training and mentoring teachers and carrying out the vision.
- Develop a mentor teacher program to foster relationships between teachers to leverage each other's strengths.

Administrator

- Continue to evaluate progress as it is tied to the first building block: vision
- Use the Fostering Transformation Assessment with teachers to evaluate progress and hone in on areas to target for improvement.
- Collaborate with other administrators to define a unified vision that encompasses leadership and direction.

[2] Maker's Faires are "an all-ages gathering of tech enthusiasts, crafters, educators, tinkerers, hobbyists, engineers, science clubs, authors, artists, students, and commercial exhibitors. All of these 'makers' come to Maker Faire to show what they have made and to share what they have learned." Source: www.makerfaire.com

Conclusion

Nations around the world uniformly face a shortage of citizens in STEM careers and concomitantly, a shortage of students who choose to study science, technology, engineering, and math. Moreover, all students benefit from a basic understanding of scientific concepts, processes, and ways of thinking. "An understanding of science and technology is central to a young person's preparedness for life in modern society" (OECD, 2014, p. 216). Nations must ensure that their citizens possess this understanding to prepare for economic, social, environmental, and technological challenges we all face. The need to improve this situation is paramount.

The 5 Building Blocks for SET (vision, sustained leadership, professional development, customized content, and technology) offer the overarching components required to help a nation, state, or district to begin the process of science education transformation. To help in the process, two practical applications, hands-on technology-based activities and inquiry-based instruction can be used to provide the first steps in achieving a transformation in science education. Implementation of both applications will have a positive impact on science understanding and motivation and interest in science—with the ultimate goal of having more students studying science and more students entering STEM careers.

The Fostering Transformation Assessment is an instrument for evaluating position and progress along the SET continuum. The tool serves as a guideline to identify position on the continuum from three perspectives: students, educators, and graduates. The value of the tool stems not from the ability to pinpoint a specific location on the continuum, but to offer some information on the strengths and weaknesses of the current state of SET and where improvements can be made.

As leaders around the world embark on their initiatives to transform science education programs, knowledge and understanding of requirements for success are important. Suggestions offered in this paper can serve as a guide in mapping out a direction and taking steps to action.




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