CHAPTER 9

STEM Education: Where Are You Now, and Where Do You Want to Go?

#Education Reform
- Curriculum
Integration

Many discussions of STEM education begin with a question that assumes curriculum integration is an appropriate approach to reform. This may not be the best question. It may be a better approach to first consider what your system presently does and does not have relative to STEM education. An integrated curriculum may actually be the approach you finally implement. But as you saw in Chapter 8, there are several variations on the integration of STEM disciplines. So, let's begin with these questions: Where are you now? Do you have STEM 1.0? If so, here are the next questions: Where do you want to go? Can you move beyond STEM 1.0 through curriculum reform?

In this chapter, you evaluate the status of STEM education in your state, district, or school; review the different approaches to curriculum, including integration; and begin planning ways to enrich and improve STEM education.

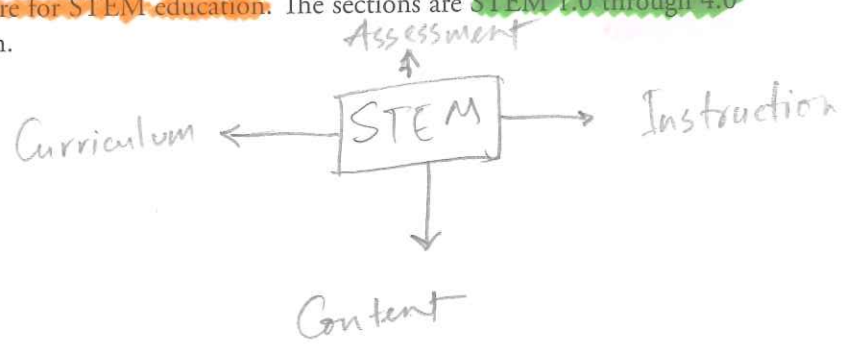
As mentioned in prior chapters, education leaders at state, district, and school levels face the challenge of figuring out what STEM means in the contexts of actual programs of curriculum, instruction, and assessment. This challenge exists at the interface of policies and their realization in terms of educational programs and classroom practices.

To be clear, this chapter does not present a model for STEM programs and practices. My approach begins with opportunities to improve students' overall understanding and achievement in science, technology, engineering, and mathematics education. In short, the aim is to achieve higher levels of STEM literacy. So, my approach here begins by having you look at STEM education as it currently exists in your state, district, or school; determine the potential for reform; and establish directions for change. To accomplish this task, I ask numerous questions designed to advance STEM education within your unique education context.

SURVEYING STEM IN YOUR EDUCATION SYSTEM

The next sections use a contemporary format for asking a question to describe your present situation and proposed future for STEM education. The sections are STEM 1.0 through 4.0 to evaluate STEM education.

Advance STEM Program (1.0- 4.0)



Do You Have STEM 1.0?

STEM 1.0 exists when an education system has standards-based K–12 programs for all students in the content areas of science, technology, engineering, and mathematics. In STEM 1.0, the disciplines may be separate. Since the No Child Left Behind (NCLB) legislation, the role of K–12 mathematics has been emphasized, so the likelihood of it not being present is very low, probably zero. But what about science? Since NCLB, the emphasis on science has been reduced in the interest of increased time for language arts and mathematics. Turning to technology and engineering—what is the status for each of these subjects? Use Table 9.1 to briefly describe the status of STEM disciplines in your system.

If you are beginning the journey of STEM education, it is always good idea to know the trip's origin. As when using MapQuest, you have to identify where you are to figure out the details of where you want to go. Table 9.1 presents the opportunity to describe where you are related to the four separate STEM disciplines. For each of the disciplines, briefly describe the current situation for the following categories:

- Curriculum (e.g., fully implemented, locally developed instructional materials)
- Instructional strategies (e.g., use of instructional model in elementary grades and varied strategies in secondary grades)
- Student achievement (e.g., average achievement on state math assessment)
- Strengths (e.g., K–6 teachers have completed a full cycle of professional development)
- Weaknesses (e.g., no engineering curriculum program in middle school and high school)
- Plans (e.g., adopt new mathematics program and professional development for teachers)
- Other comments (e.g., consider alignment with new Common Core State Standards for Mathematics)

One way to think about advancing STEM education is by improving the separate disciplines or incorporating a discipline currently not included, such as engineering. Such an approach maintains the integrity of the traditional disciplines and allows you to move forward with solid, standards-based programs for all K–12 students. Completing the questions for Table 9.1 and appropriate portions of the figures presented in the next section should contribute to this approach.

Are You Considering Curriculum Integration for STEM?

A step beyond maintaining separate STEM disciplines requires consideration and a decision to advance STEM education by integrating the disciplines. This decision can be made at the state level, but in the approach suggested here, the decision is best made at the district or school level.

Several approaches to curriculum integration have been published. I recommend reviewing the following: *Designs for Science Literacy* (AAAS 2000), *Meeting Standards Through Integrated Curriculum* (Drake and Burns 2004), *Making Sense of Integrated Science: A Guide for High Schools* (BSCS 2000), and *Interdisciplinary Curriculum: Design and Implementation* (Jacobs 1989). / *

Advance STEM -ing → Improving the separate discipline
→ Incorporating a New discipline (i.e - engineering)

Table 9.1. STEM Disciplines

Science and technology education	Science	Technology
Curriculum: Instructional strategies: Student achievement: Strengths: Weaknesses: Plans: Other comments:		
Engineering and mathematics education	Engineering	Mathematics
Curriculum: Instructional strategies: Student achievement: Strengths: Weaknesses: Plans: Other comments:		

Recall the different perspectives of STEM education described in Chapter 8. Here are several variations to consider for the integration of STEM. The first approach maintains STEM 1.0 as a traditional discipline while integrating another STEM discipline. There are several ways this can be done:

(needed in another subject)

- *Coordinate*. Two subjects taught in separate courses are coordinated so content in one subject synchronizes with what is needed in another subject. For example, students in mathematics learn algebraic functions when they need that knowledge in an engineering class.

One subject introduce another subject

- *Complement*. While teaching the main content of one subject, the content of another subject is introduced to complement the primary subject. For example, while students are designing an energy-efficient car in a technology class, science concepts of frictional resistance (drag), loss of kinetic energy, and mass are introduced to help them improve the car's design and efficiency.

(similar themes)

- *Correlate*. Two subjects with similar themes, content, or processes are taught so students understand the similarities and differences. For example, you might teach scientific practices and engineering design in separate science and technology courses.

(connect)

- *Connections*. Use one discipline to connect other disciplines, such as using technology as the connection between science and mathematics.

(combine)

- *Combine*. This approach combines two or more STEM disciplines using projects, themes, procedures, or other organizing foci. For example, one could establish a new course on science and technology that uses student projects to show the relationship between science and technology.

Because of the dominance of the traditional disciplines in state, district, and school standards, curricula, and assessments, it likely will be important for you to provide a rationale supporting recommendations for integrating the STEM disciplines. This is especially the case when you move beyond integration through coordination, complements, correlation, or connections. Combining subjects or designing courses that transcend the separate STEM disciplines will require elaborate justifications. Following are examples of arguments against and for curricular integration of STEM.

Domains
Aims & Criteria
* rigor ( )
* Standard-based
* Domains
Inquiry
conceptual foundation

The arguments against integration rest on reasonable but not unassailable grounds. One of the first arguments is that specific domains have their own ways of knowing. For example, scientific inquiry and engineering design have different aims and criteria. Another argument is that many integrated approaches historically have lacked rigor and not been standards-based. Finally, understanding domains of inquiry requires an in-depth conceptual foundation (Bransford, Brown, and Cocking 1999; Donovan, Bransford, and Pellegrino 2000). Making connections across disciplines is not as clear and straightforward as many claim.

The arguments for curricular integration include the following. First, the situations of life and living are all integrated. The decisions citizens face are not nicely contained within disciplines such as science or mathematics. Life situations typically require the knowledge, abilities, and skills of multiple disciplines. Second, individuals learn best when the context within which they are learning has personal meaning—that is, learning is enhanced when it is related

Learning Outcome Content Process

lesson ↓ Course ↓ Program

to something people recognize or know, or in which they have a personal interest. Third, there is an efficiency that comes with combining the knowledge and skills of different disciplines, and there is limited time in school days and years. If lessons, courses, and school programs can attain learning outcomes of both content and processes of different disciplines, such as engineering and mathematics, that has benefit for teachers and students.

How can states, districts, and schools achieve an appropriate balance among the separate STEM disciplines and an integrated approach? This may be the best question. STEM education does not have to be an either/or decision. This view, by the way, is the reason I began the chapter with a discussion of STEM as separate disciplines and recommended strengthening current curricula, most likely the science and mathematics programs, while implementing technology and engineering materials if they are marginal or lacking. *

STEM Integrated Approach

Moving Beyond STEM 1.0 Through Curriculum Integration

After considering the advantages and disadvantages of integrated approaches to STEM education, it is reasonable to review the levels, subjects, and approaches you think are best for your situation. There is no single best approach to STEM education. Different approaches to STEM education have their advantages and disadvantages. What do you want to achieve? What is the best approach to achieve your goals? What is reasonable given your education system?

You might consider an approach that maintains the best of both a discipline-based program and some form of an integrated STEM curriculum. You might be criticized for a middle-ground initiative, but you might be recognized for implementing a reasonable and manageable perspective.

- First, maintain and improve the traditional STEM disciplines. If technology and engineering are weak or lacking, remedy the situation as best you can.
- Second, within the STEM disciplines, find places to coordinate, complement, correlate, and connect the disciplines. I discuss combining disciplines in another section.
- Third, you may find curricular integration easier at the elementary and middle school levels. If so, begin there.
- Fourth, introducing separate STEM disciplines at the high school level will help students develop more sophisticated understanding of the concepts and procedures of STEM disciplines. Proposing integrated courses that address the core ideas and practices of disciplines is an option you might review.
- Fifth, develop integrated units that can be used within the current K–12 curriculum. The units can be used for professional development and as initial steps towards integrated STEM education.

As this discussion and an evaluation of STEM progresses, I fully realize that the approach may be misused due to the fact that some content from one discipline may be found in any other discipline. Can the evaluation be misused? Yes, but it will likely be very helpful for those who want to take an honest look at what currently exists and changes that may be possible. The team of Jo Anne Vasquez, Cary Sneider, and Michael Comer have published a valuable book, *STEM Lesson Essentials: Integrating Science, Technology, Engineering, and Mathematics* (2013), for those wishing to move beyond STEM 1.0 through curriculum integration.

STEM 2.0, 3.0, OR 4.0?

In your system, are there any examples of STEM that are more than the initial STEM 1.0? This section provides a way of thinking about different levels of integration using the four STEM disciplines as organizers.

Do You Have STEM 2.0?

Table 9.2 presents a list of options for the integration of two STEM disciplines. This is only an evaluation of what may exist in your system; it is not a recommendation to have units, courses, or programs for all six possibilities. Briefly indicate the grade level and approach for the appropriate options, such as "science and math, coordinated in 9th grade"; "technology and engineering, combined as an optional course in 11th grade"; "science and technology, combined in elementary school."

Table 9.2. Two Integrated Disciplines: STEM 2.0

STEM disciplines	Coordinated	Complemented	Correlated	Connected	Other
Science and technology					
Science and engineering					
Science and math					
Technology and engineering					
Technology and math					
Engineering and math					

Do You Have STEM 3.0?

Table 9.3 represents an even more integrated approach to STEM education. Again, this is an evaluation to help with your decisions and planning. Indicate the examples of STEM 3.0 that exist in your education system. For example, we have a fully integrated math, technology, and science course for 10th grade.

Table 9.3. Three Integrated Disciplines: STEM 3.0

STEM disciplines	Examples
Science, technology, and engineering	
Science, engineering, and math	
Technology, engineering, and math	
Math, technology, and science	

Do You Have STEM 4.0?

This example represents a full integration of the four STEM disciplines. In Table 9.4, describe the units, courses, or programs for STEM 4.0 in your state, district, or school.

Table 9.4. A STEM 4.0 Program

STEM disciplines	Example
Integrated science, technology, engineering, and math program	

After completing your evaluation of STEM in your education system, you might consider these additional questions, regardless of the STEM 2.0, 3.0, or 4.0 perspectives.

- Do the STEM disciplines have representation at all grades K–12? If not, which grade (or grades) needs attention?
- Do the units, courses, or programs present the concepts and practices of the STEM disciplines with equal focus, rigor, and coherence? If not, what needs to be changed?

CONCLUSION

Most states, districts, and schools have STEM programs, but the depth and quality vary. This chapter takes a basic approach to this issue. I first ask you to clarify the status of the separate disciplines of STEM. Based on the current situation, one approach is to simply improve the separate STEM disciplines or implement new programs if they are not a part of the education system.

A second step in improving STEM education is to move toward integration by coordinating, complementing, correlating, or connecting various disciplines, concepts, processes, themes, or topics between or among STEM disciplines.

Third, there is the possibility of combining two, three, or all four STEM disciplines and implementing an integrated approach to the STEM curriculum.

Improving STEM education can take on different features, ranging from staying with and improving the four disciplines to fully integrating the disciplines. The approach taken in this book does not assume one answer or best approach. That said, there is a need to improve STEM education.

DISCUSSION QUESTIONS

1. What are the advantages and disadvantages of maintaining but improving separate STEM programs?
2. What are the reasons to integrate the STEM disciplines?
3. What are the problems of integrating, designing, and implementing an integrated approach to STEM?