Transitioning STEM to STEAM:
Reformation of Engineering Education

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The acronym STEM was coined in 2001 by Judith A. Ramaley of the National Science Foundation. STEM now is used as a brand name to describe the integration of science, technology, engineering, and mathematics in educational curricula. Ramaley defined STEM as an educational inquiry where learning was placed in context and students solved real-world problems through creation of opportunities—a pursuit of innovation. Her concept provided an answer to the relatively poor performance of American students in standardized exams for mathematics and science as well as the need to bolster the declining enrollments in universities in the academic STEM fields. Emphasis has been placed on programs that stimulate these disciplines with half of the funding provided for K–12 educational programs and the other half for basic and advanced studies in colleges and universities.1 To make sense of the integration of these fields into the STEM initiative, the Minneapolis Public School district uses a graphical interpretation of their relationship as shown in Figure 1.2, 3, 4

The need for a strong national program for development of STEM-related disciplines was generated by a series of studies by the National Science and Technology Council, National Science Foundation, the National Science Board, and the National Academies of Science and Engineering as well as the Institute of Medicine.5 The educational programs promoted by STEM are innovative. STEM breaks the educational mold by incorporating the disciplines together in project-focused learning. For example, students may learn algebra and physics to build robots or geometry, physics, and biology to build a working greenhouse. These projects, however, tend to take a purely functional approach to the task. On occasion, however, the projects may incorporate design elements to combine function and form. This is where the necessity for considering “art” as a component of STEM occurs.

Transition From STEM to STEAM

In his 1959 Rede Lecture, Charles P. Snow identified the split of Western society into two fundamental cultures—the scientific and the humanistic. This schism is seen clearly in the early focus of STEM into a set of scientific-only disciplines.6 Some very prominent scientists have long recognized the value of art and imagination in the process of generating scientific knowledge, however. Nobel laureate Jacobus Henricus van’t Hoff said he believed true scientific imagination is correlated with and supported by creative activity outside science.7 Albert Einstein

Figure 1: Relationship Model of the STEM Initiative

- Science knowledge and skills
  - provides tools to deepen and provides context for
  - prepares us to do
  - reinforces learning of

- Engineering
  - leads to the development of

- Technology
  - provides tools to deepen and provides context for
  - prepares us to do
agreed with this viewpoint, “I am enough of an artist to draw freely upon my imagination. After a certain high level of technical skill is achieved, science and art tend to coalesce in esthetics, plasticity, and form. The greatest scientists are artists as well.”

The STEM disciplines require artistic thinking to ensure that the final design appeals to the aesthetic sense of consumers in the products created for the commercial market. The American Association for the Advancement of Science has defined engineering as “the use of creativity and logic, based in mathematics and science, utilizing technology as a linking agent to create contributions to the world.” Engineers apply a spectrum of activities in developing new products by conversion of imaginative concepts into dependable reality. These activities differ in the degree of rigor used when managing the work of the design team.

New products move from conceptual design to functional engineering, where the focus is on delivering consistent quality. The following sequential taxonomy, which recognizes the decreasing degree of coupling associated with free-form creative thinking, provides one way of characterizing these activities:

- **Creating.** This activity involves the act of producing new ideas, approaches, or actions without regard to practicality or implementation. Success is measured by the number of new ideas.
- **Inventing.** Here, the ideas that define a potentially practical, new device, composition, gadget, or process that did not exist previously are explored imaginatively. Inventions may be either derived from pre-existing works (evolutionary), or they may be conceived independently (revolutionary or radical breakthrough).
- **Innovating.** Ideas are applied in practice. This involves the process of both generating and applying creative ideas in some specific context—a new way of doing or producing something that is useful.
- **Engineering.** Designing and implementing useful features and functions at the lowest total cost (including the cost of failure) occurs during this activity.
- **Controlling.** The output of the process is managed in a way that produces consistent products, ensuring the process operates reliably and predictably throughout its life cycle.

**STEAM: More Than the Addition of Art and Design**

The foundation of STEAM can be traced to the Platonic dialogs where Socrates argued about the way beauty is related to goodness. STEAM concepts also were included in recommendations made by educator and philosopher John Dewey more than 100 years ago when he suggested integrating education across subjects and engaging students with real-world applications in order to increase their pragmatic knowledge. STEAM is a practical and holistic model that is rooted in economic need, ensuring more relevance with consumers’ experiences. Inclusion of artistic thinking in the education of scientists and engineers improves their ability to create relevant products and services. The resulting paradigm shift disrupts the structured, logical flow of the thinking processes that are encouraged by the traditional STEM disciplines. The need to extend the mental model of STEM to integrate the fields of art and design was addressed in a paper by Georgette Yakman who described STEAM as “science and technology interpreted through engineering and the arts, all based in mathematical elements.”

In the commercial world, there are many fields where the line between art and engineering has been blurred for years. For instance, both architecture and industrial design require the knowledge of an engineer but are driven by aesthetics. With the onset of digital media, the commercial publishing and advertising worlds now require engineers to have art skills and artists to have engineering skills. This blending of engineering and the arts had been adopted by companies such as Apple and Disney (where design engineers are titled “imagineers”). The term “imagineering” was popularized by Alcoa and then adopted by Disney to describe the skills required to design and build its theme parks.

In the STEAM paradigm, the arts—especially the visual arts—reinforce engineering. Although, these two fields set out to make things for different reasons, they both apply many of the same techniques, strategies, and tools. In many arts classes, the STEM disciplines already are being taught as a means to attain professionalism.
in the use of media. For instance, the physics of light, basic chemistry, and fundamentals of trigonometry are key learning areas in photography. In teaching computer graphics or game design, it is necessary to provide a foundation in mathematical thinking, geometry, and software programming. The inclusion of the arts in teaching STEM, therefore, does not minimize any aspect of the STEM disciplines; it makes them stronger, more engaging, and relevant to students.

The arts contribute to STEM education by exposing students to a different way of seeing the world. Students learn through different pedagogical modalities engaging their other interests. By applying the STEM disciplines, combined with real-world experience, students become more comfortable in both worlds. The integration of these disciplines is particularly apparent when designing new products.

Moving Forward—The Growing Need for Integrated Thinking

The recent emphasis in engineering education advocating use of the STEAM model has its foundations in the modern thinking of many prominent academics. The sidebar contains a list of recommended books to enhance understanding of the STEAM concept.

The STEM initiative was not adopted rapidly, and problems were noted with its development during governmental reviews. Its momentum seems to be increasing, however. For instance, in 2005 a technology-driven informal “do-it-yourself” community arose, driven by newly released technology such as 3-D printing. Furthermore, the self-styled Maker Movement has merged with such mainstream engineering institutions as MIT’s Design Lab, Media Lab, and Hobby Shop, as well as the Stanford D-School. Since 2008, the Rhode Island School of Design has sponsored an effort to stimulate the transition of STEM to STEAM by the addition of “Art + Design.”

Other organizations also have become involved in supporting a more cross-disciplinary approach to education improvement by embracing the STEAM concept, as shown by the examples below:

- Sesame Street is focusing its curriculum on STEAM, using creative arts to make STEM concepts more relevant to young children and fostering scientific and innovative thinking.

**Recommended Books to Enhance Understanding of STEAM**

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• A collaboration between Discovery Education and the i.am.angel Foundation recently launched an learning program, called “i.am.STEAM,” to encourage education in all of the STEAM disciplines.19

• EDUTOPIA is a foundation created by George Lucas to improve “the K–12 learning process by documenting, disseminating, and advocating innovative, replicable, and evidence-based strategies that prepare students to thrive in their future education, careers, and adult lives.”20 This organization is increasing its efforts to advance a broader concept of design.

Conclusion

The great gulf that once existed between engineering and art is becoming blurred to a thin line. Perhaps someday the distinction will become almost meaningless. To achieve this, the concept of STEAM must move from industry and higher education into the K–12 school system. Teachers must be trained in project-based learning and encouraged to collaborate across disciplines. Students need exposure to real-world problems and encouragement to apply their knowledge to explore multiple solutions. Industry needs to encourage and support these changes in schools’ curriculum. Otherwise, like so many past innovative educational programs, the STEAM emphasis may fail.

The orginal Ramaley concept for STEM education pursued innovation, but it fell short because artistic thinking was not included. STEAM doesn’t merely add art to STEM, it changes STEM’s focus from better test scores in the core STEM academic disciplines to better quality of inclusive thinking and from focus on the development of a larger, technically competent workforce to one that is also more innovative.

References


