INTEGRATED STEM EDUCATION: PAIRING ENGINEERING IS ELEMENTARY & LEARNING.COM

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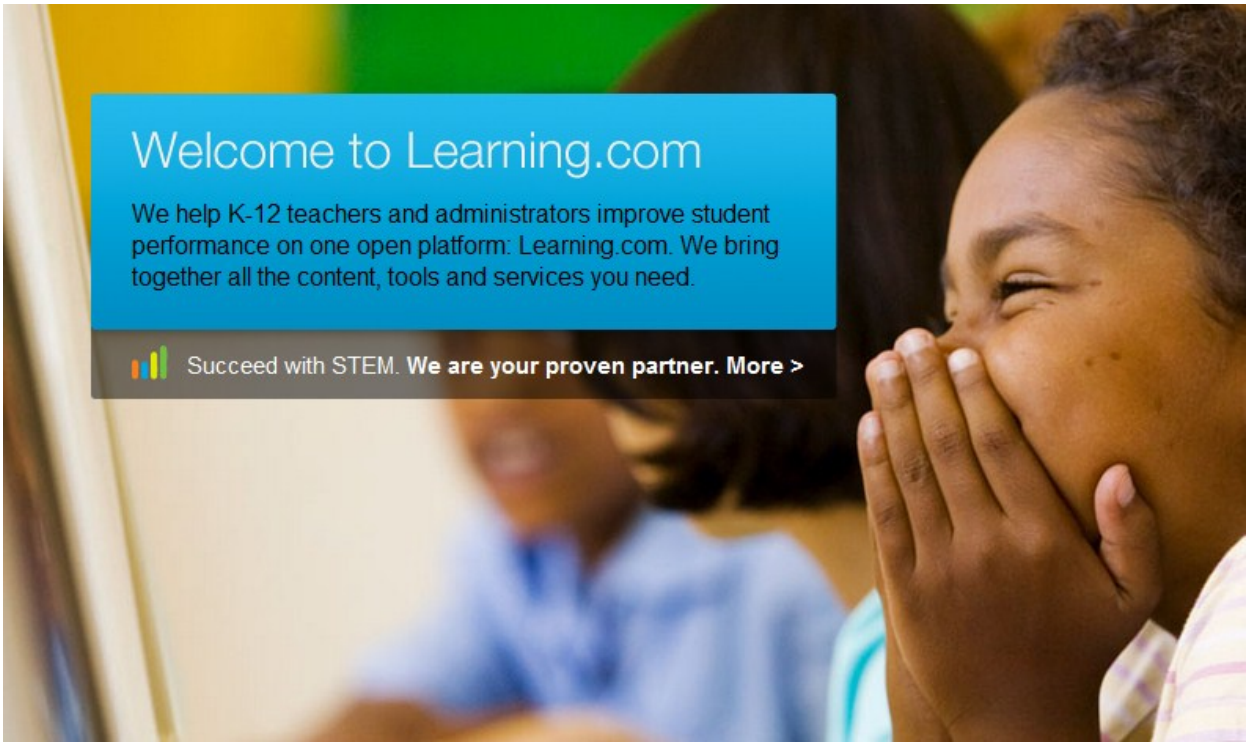

In order to succeed in our technologically advanced global community, students need to be prepared to enter a competitive world where quality science and mathematical training are becoming the most basic of requirements. The current workforce projections highlight that nine of the 10 fastest-growing occupations requiring at least a bachelor's degree will necessitate significant scientific or mathematical training[1]. In addition, jobs requiring specialized (i.e. STEM) training are growing at five times the rate of other occupations[2].

Research from engineering education and the learning sciences suggests that students need to develop a deep understanding of fundamental science, mathematics and technology principles *across* K-12 if they want to pursue a wide range of engineering and technical career opportunities[3], and this means starting early! Fortunately, many initiatives such as Engineering is Elementary (EiE) and Learning.com enable young learners to develop literacy, competency and interest in engineering thinking and technology proficiency, which are important attributes for all citizens[4, 5].

Starting Early Matters

In a nation that was seeded by freedom and opportunity, the roots of the United States of America are grounded by hard work, innovation, and determination. Most often through identification with a worker, ages 5 to 10 is the stage of life when the concept of working becomes ingrained in the child's conception of his or her adult life[6]. Immersed in a society that is dominated and driven by work, and vulnerable to social influences of prestige and gender bias, children as young as five years of age begin to postulate what career they will one day have[7]. Young people tend to choose professions that are familiar[8], whether traditions in their family, or professions that have been exposed to them through education and experience. Young elementary children can begin to gather information about careers and acquire the skills and competencies that will one day support success in the workplace[9]. Engineering is Elementary units are each focused on one of the various fields of engineering, such as environmental or industrial engineering, and provide a positive introduction to engineering careers and skills.

About 80% of fourth graders report positive attitudes toward mathematics and science compared to an estimated 33% of eighth graders [10], and from early adolescence, girls begin to express less interest in science or math careers than boys[11-13]. Additional studies show that students begin to lose interest in science, technology, engineering, and math by junior high school[14], so the perfect time to get students excited about STEM are the elementary years.

EiE has designed materials to engage marginalized and "at risk" populations, such as girls, minorities, youth with disabilities, and children from low socioeconomic backgrounds[15]. This commitment to diversity allows all students to understand and engage with the human-made world around them, and excite a stronger curiosity in the math and science it takes to execute engineering.

Putting the E in STEM

Engineering has strong connections to many other disciplines, particularly mathematics and science. Engineers employ scientific knowledge and mathematic principles in their work, and scientists and mathematicians benefit from the products of engineering, known as technology. Engineers exercise mathematics to describe and analyze data and to develop models for evaluating design solutions. It is imperative for engineers to be knowledgeable about the science that is relevant to the problem they are engaged in solving, and it is not uncommon for research conducted by engineers to result in new scientific discoveries [4].

K-12 engineering education should emphasize design, incorporate important and developmentally appropriate mathematics, science, and technology knowledge and skills, and should promote engineering habits of mind[16]. By emphasizing the E in STEM, engineering lessons via EiE and Learning.com's harmonizing activities can be the active catalysts needed to improve K-12 STEM education[4].

Improving the Learning Environment

There are several practices that promote an equitable learning environment for students and have a positive impact on their continuation in quantitative disciplines such as engineering. These include collaborative learning, hands-on experiences, engaging authentic activities, an emphasis on practical applications, and the teaching of science and math in a more holistic, inclusive and social context [17-21]. EiE and Learning.Com can provide the framework for this effective combination.

By highlighting broader, multidisciplinary and collaborative applications early in a curriculum, as opposed to first focusing on technical aspects, students are more likely to report more interest in a program and not quit[22].

Studies have shown that cooperative learning groups and active learning can specifically motivate young women to study mathematics and science, disciplines where females are traditionally underrepresented [23, 24].

Team-based design, as you will find with EiE, satisfies hands-on learning curriculum, integrating math and science fundamentals through creative, self-directed learning. Open ended and multidisciplinary, design provides context for theoretical foundation concepts, and forces effective teamwork skills. Designing within constraints and through iteration unleashes creativity and motivates deeper understanding[25]. For example, in one study of the National Assessment of Educational Progress (NAEP) test, mathematics scores were higher for eighth graders who participated in hands-on learning activities than for those who did not [18].

WHAT IS INTEGRATED STEM?

Integrated STEM instruction is an approach to teaching that is distinguished by its contrast to the common "silos" method of teaching. Integrated instruction uses examples, data, and information from a variety of subjects or disciplines to illustrate the key concepts, principles, generalizations, and theories in another subject area or discipline[26]. The subjects do not stand alone, like a silo, but instead interact, interface, and overlap with one another to create rich integrated units, designed for student engagement and learning. The integration of real-world interdisciplinary problems with school subject matter can support students' efforts in constructing patterns and meaningful knowledge, via the identification of math and science as relevant components of their world [27, 28].

Davison et al. (1995) suggests five types of science and mathematics integration that can be used in interdisciplinary curriculum development: discipline specific, content specific, process, methodological, and thematic[27]. Each of these forms of integration is described in Table 1. These methods should not be considered mutually exclusive, but instead a framework for integrating science and math.

Engineering is Elementary takes a *thematic* approach to integrated STEM instruction, and Learning.com provides *content specific* STEM instruction, complementary to EIE units. Thematic approach to integration begins with a theme which then becomes the medium with which all the disciplines interact, such as an integrated lesson on the water cycle. Content specific integration involves choosing an existing curriculum objective from math and from science, with activities that involves instruction in each. When coupled with the thematic EIE approach, students are able to explore the connections between math and science, and begin to see the relevancy of the math in science, and vice versa.

TABLE 1 SCIENCE & MATHEMATICS INTEGRATION, INTERDISCIPLINARY CURRICULUM DEVELOPMENT, DAVISON ET AL (1995)

Science and Mathematics Integration for Interdisciplinary Curriculum Development, Davison Et al (1995)	
Type of Integration	**Description**
Discipline Specific	Discipline specific integration involves an activity that includes two or more different branches of mathematics or science. For example, discipline specific integration might include activities involving algebra and geometry in mathematics and activities infusing biology, chemistry, and physics in science. Students learn that branches of math as well as the branches of science are interrelated. The connections between sciences or fields of mathematics are preeminent.
Content Specific	Content specific integration involves choosing an existing curriculum objective from mathematics and one from science. An activity is planned which will involve instruction in each of these objectives. It is content specific because it conforms to the previously developed curriculum, infusing the objectives of each curriculum. The students explore the connections between math and science and begin to see the relevancy of math in the reality of science, and vice versa.
Process Integration	Process integration involves conducting experiments, collecting data, analyzing the data, and reporting results allowing students to experience the processes of science and perform the needed mathematics. What is important is that mathematical operations are performed for a purpose: to answer questions that are of concern to the students about the problem under investigation and generally about the real world.
Methodological	Methodological integration allows students to investigate issues in both math and science using related strategies such as inquiry, discovery, and the learning cycle.
Thematic	Thematic approach to integration begins with a theme which then becomes the medium with which all the disciplines interact, such as an integrated lessons on oil spills.

Helping Teachers Teach

Education research shows that K-12 educators and students generally have a poor understanding of what engineers look like and do[15, 29]. Not only are there numerous misconceptions of engineering as a discipline, but educators tend to be very anxious to the barriers they identify between themselves and engineering. With generally no background to know how to converse with students about who designs technology and how they do it, educators can feel very strong barriers that limit their contribution to the development of future technical talent, or even teaching basic engineering principles and design activities[30].

The EiE project staff worked closely with teachers and engineers to develop a research-based, standards-driven, classroom-tested curriculum that integrates engineering and technology concepts and skills and elementary science topics and mathematics learning, as well as literacy and social studies [15]. This curriculum is comprehensive, and academically vetted, but can be still be overwhelming to teachers. Learning.com offers supplementary materials and activities to help scaffold both the teachers and the students throughout the thematic EIE units.

Conclusion

Learning.com is poised to be the perfect companion for Engineering is Elementary curricular units. When the two are coupled, students are able to better explore the connections between math and science, and begin to see the relevancy of the math *in* science, and science *in* math. EiE's and Learning.com's integration of real-world interdisciplinary problems with school subject matter can support students' efforts in constructing meaningful knowledge through the identification of math and science as relevant components of their world [27, 28]. The introduction to engineering disciplines and skills at an elementary age can positively influence student interest, college readiness and their future career trajectory.

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About the Author

Meagan Ross is an engineer turned engineering education enthusiast, and is passionate about providing awareness of engineering to K-12 educators, enabling them to actively and confidently influence students to become the next generation of world changing engineers. Meagan is a K-12 STEM consultant, curriculum developer, professional development facilitator & advocate for women in STEM.

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