Standards Analysis

Problem Solving & Engineering Design as Unifying Skills in STEM

The "E" in STEM: Meaningful Content for Engineering

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Abstract

This paper explores the intersection of Science, Technology, Engineering and Math standards to reveal the unifying effect that problem solving and engineering design have across STEM disciplines. I have used a Bridge Design lesson plan that I am currently implementing in my Computer Applications class at Immaculate Heart Academy as a basis for demonstrating this intersection of standards in the STEM curriculum.

The Common Core Math Standards (National Governors Association Center for Best Practices, Council of Chief State School Officers 2010), State of New Jersey Core Curriculum Content Standards - Technology (State of New Jersey; Department of Education 2014) and the Next Generation Science Standards - Disciplinary Core Idea Arrangements. (Next Generation Science Standards 2015) were utilized for comparison.

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In order to facilitate the comparison of three standards documents, I am using a recent lesson plan entitled "Bridge Building" that I implemented with my Computer Applications class at Immaculate Heart Academy (IHA). This plan was implemented as part of our ongoing strategy to integrate engineering topics into our curriculum at IHA. The Bridge Designer 2015 software was utilized to introduce my students to the Engineering Process and to practice that process by designing a virtual truss bridge. The Bridge Designer software is downloaded via the Engineering Encounters Bridge Design Contest website (Engineering Encounters 2015) and can be utilized on either a Windows or OS X Mac platform.

In the Common Core States Standards Initiative document, High School Geometry contains a section on "Modeling with Geometry - Apply geometric concepts in modeling situations". The third "application" of this standard indicates, "Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios)." (National Governors Association Center for Best Practices, Council of Chief State School Officers 2010)

Designing a bridge is the implementation of geometry. As I introduced the components of the bridge, the students were hearing terms that are utilized in their math classes. "Chords" are the main horizontal load-carrying members of a truss bridge, "diagonals" are truss members that connect the top and bottom chords together, "transverse" floor beams support the bridge deck and transmit load from the deck to the joints of the main trusses.

Designing a bridge with the Bridge Designer software specifically charters students to create a design that will both carry the load of the bridge materials plus traffic, but also mandates the most cost effective solution. My thoughts are that this application of engineering is not only “unifying”, but necessary for the true understanding of geometric concepts. This geometry is typically taught in a “swim lane” or “silo” math class without the benefit of applying this knowledge to a real world object, such as designing a bridge. As I was mentioning the geometry terms to the class, I asked them if they recalled hearing any of these terms in Math class. Some of these terms, such as diagonal, could potentially be heard in a grammar school math class. Several students who are taking the “slash class” of Algebra/Geometry started to make “connections” to geometry class. When I drew a “chord” in a circle on the white board, they interjected the term, “line segment”. Our Computer Applications class is within the Technology Department. At IHA, we have yet to integrate our lesson plans so that the math teacher can teach the geometry and I can teach the implementation of engineering though the use of a technology platform. I can still assist my students in the construction of math skills by having them unify their learning using Bridge Builder.

The State of New Jersey Core Curriculum Content Standards - Technology document implemented in 2014, provides Content Statements by grade groupings, including 9-12. Two content statements could be justify the use of the Bridge Builder software. One standard, “8.2 Technology Education, Engineering, Design, and Computational Thinking - Programming” states, “Explain how open source technologies follow the design process.” (State of New Jersey; Department of Education 2014) The use of the verb “follow” is, in my estimation, not the best choice. Perhaps the correct verb should have been “facilitate”. The students should be able to determine if the Bridge Builder software is a realistic tool to implement the engineering design process. In the application of engineering design strand, the standard states, “Create scaled engineering drawings of products both manually and digitally with materials and measurements labeled.” (State of New Jersey; Department of Education 2014)

The Technology Standards in the State of New Jersey document provide a “broad stroke” of standards that describe a genre of tools that the educator can implement. It is up to the educator to find a software platform, such as Bridge Builder to unify the strands of content. The Math and Technology standards were similar because they mandate students to practice the engineering design process. They differ because the Math standards gave examples such as, “e.g., designing an object or structure to satisfy physical constraints or minimize cost” which suggest the intersection of science with the phrase, “physical constraints”. The Technology standard is phrased, in my estimation, to be a “swim-lane” by just mandating using technology without mentioning the math or science reason behind the design process.

The Next Generation of Science Standards website has an option which allows the selection of Grades and Disciplinary Core Ideas to refine core ideas. The resulting screen delineates Mathematics, Computational Thinking, and Constructing Explanations. The Disciplinary Core Ideas were explained the important focus of the standard stating, “When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (HS-ETS1-3).” (Next Generation Science Standards 2015) The technology standards are delineated in a “Crosscutting Concepts” block and delineated as, “Systems and System Models

Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows— within and between systems at different scales. (HS-ETS1-4).” (Next Generation Science Standards 2015)

The “scientific knowledge” mentioned in the Science and Engineering section would apply to the study of physics and chemistry to evaluate materials such as the strength of various steel to determine the material’s ability to be load-bearing within the design configuration.

The NGSS document exhibits the most unification of the content areas. The math standards provide an anemic integration of math and science, while the technology standard provided the least amount of information to support or even inspire an educator.

Conclusions and Further Study

In conclusion, after having analyzed the three versions of Engineering Design standards documents, I would return to the NGSS standards document because, in my estimation, it provides the most usable approach to unifying the Science, Math and Technology Models. The Disciplinary Core Idea Arrangements provide the educator with a clear view of overlapping content areas.

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