

Standards Analysis
The E in STEM
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Standards Examined:

International Technology Education Association: *Standards for Technical Literacy*

National Council for Teachers of Mathematics: *Principals and Standards for School Mathematics*

Next Generation Science Standards

The Relationship between Science, Technology, Engineering Design, and Mathematics

The relationship between technology and other fields of study is explained in the ITEA Standard 3, where the important connection between science, technology, and mathematics is described.

According to the ITEA,

Science and technology are like conjoined twins. While they have separate identities,

they must remain inextricably connected in order to survive. Science provides knowledge about the natural world that underlies most technological products today.

In return, technology provides science with tools needed to explore the world.

Mathematics offers a language with which to express relationships in science and technology and provides useful analytical tools for scientists and engineers.(ITEA p.44)

The ITEA Standards for Technological Literacy effectively mesh with the eight NGSS Science and Engineering Practices and Disciplinary Core Ideas in Engineering Design. ITEA Standards 8-13 address the pertinent engineering design concepts that are also highlighted in the NGSS Engineering Design Standards, ETS1.A, ETS1.B, and ETS1.C.

Key concepts and vocabulary are represented in each set of standards. For instance, the NGSS Engineering Design Standard, NGSS 3-5-ETS1-1 states:

Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). (NGSS)

Likewise, the ITEA Standard 8 states, “Students will develop an understanding of the attributes of design.”

Here, the ITEA describes the requirements for a design as criteria, and the limitations of a design as constraints. (ITEA p.91)

Links to Mathematics

The process of engineering design involves critical thinking and problem solving skills that are closely related to the skills and thinking necessary to learning and applying mathematical knowledge. The NCTM identifies *Process Standards* as a means of, “acquiring and applying content knowledge.” (NCTM) These include *Problem Solving, Reasoning and Proof, Communication, Connections, and Representations*.

According to the NCTM, *Problem Solving* is where students are, “encouraged to reflect on their thinking during the problem solving process.”(NCTM) This relates to the meta-cognitive process necessary for problem solving in engineering design. The ITEA

standards 10 and 11, respectively, describe different approaches to problem solving situations, as well as the problem solving strategies inherent in the design process.

The NCTM Process Standard, *Reasoning and Proof*, promotes analytical thinking and reasoning in mathematics. Students in grades 3-5 must apply these same skills when engaged in the design process. According to the *NGSS Science and Engineering Practices*, students must, “evaluate appropriate methods, make predictions, test, and provide evidence to support their explanations or design solutions.”(NGSS)

In mathematics, communication is crucial when “sharing ideas and clarifying understanding,” (NCTM). It’s also a principal component when collaborating as a team member in engineering design problem solving, as stated in the *NGSS Science and Engineering Practices, Obtaining, Evaluating and Communicating Information for Grades 3-5*. Students are expected to, “Communicate scientific and/or technical information orally and/or in written format.” (NGSS)

Furthermore, ETS1.B., states that, “Communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs.” (NGSS)

Students who are able to make connections, recognize that mathematics is an “integrated field of study”(NCTM) and is a useful tool that can be applied in other contexts.

In *Using Mathematics and Computational Thinking for Grades 3-5*, one of the eight *NGSS Science and Engineering Practices*, students use mathematics to,

Organize data sets to reveal patterns that suggest relationships, describe, measure, estimate, graph quantities, and use simple algorithms to compare alternative solutions to an engineering problem.”(NGSS).

Standard 9 of the ITEA states that students in Grades 3-5 should learn that, “Models are used to communicate and test design ideas and processes.” (ITEA p.102) Similarly, the NCTM Process Standard, *Representations*, provides a variety of means for representing mathematical relationships, such as pictures, concrete materials, tables, graphs, number and letter symbols, and spreadsheet displays (NCTM).

Fundamental Differences

The ITEA, NCTM and NGSS each have relevance to each other. The relevance, however, is not entirely ubiquitous. For instance, the NGSS is an all-encompassing set of standards for science as it pertains to the study of Earth and Space Science, Life Science, and Physical Science, as well as Engineering Design. Neither the ITEA nor the NCTM address specific standards related to the learning of all other science areas, although the ITEA does explore the impact of technology on the environment, how technology has influenced the way we learn about our planet, and how we use its resources.

Math is an essential component in the fields of science and technology. Without it, measurements could not be made, and data could not be collected. Mathematics provides a means to communicate numerical relationships between concepts. While mathematics learning is greatly enhanced through the use of technology, it is not necessarily dependent upon it. Mathematics is often taught as a stand-alone subject,

and its standards may be reached without incorporating specific science concepts, although integration does promote deeper understanding.

Engineering Design Problem Solving as a Unifying Concept

The principals of the design problem solving process are applicable to all subject areas. The design problem solving process calls on students to use “meta-cognition,” and higher order thinking skills when seeking a solution to a problem. Thinking about their thinking helps students analyze their thought processes and work through the stages of problem solving while providing a clear rationale for why they decided to do something. Often, students are unable to articulate how they came to a conclusion, or how they solved a problem. Teaching students to use the design problem solving process requires them to think deeply and ask questions. Identifying problems, collaborating and communicating, planning, evaluating, and rethinking are crucial strategies that can be applied to any learning situation. All creative endeavors, whether it’s creating a model to demonstrate a concept, crafting a piece of writing, composing music, or creating a work of art, require a similar process in order to refine and perfect the end product.

Citations Below:

https://www.nctm.org/uploadedFiles/Standards_and_Positions/PSSM_ExecutiveSummary.pdf

<https://www.iteea.org/File.aspx?id=67767>

<http://nextgenscience.org/dci-arrangement/3-5-ets1-engineering-design>

Willard, T.(Ed.).(2015). *The NSTA Quick-Reference Guide to the NGSS K-12*. Arlington,Va: NSTAPress.