

## Standards Analysis

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Living and teaching in the state of New Jersey I have examined three standards documents from the New Jersey Student Learning Standards, better known as the NJSLs. They are as current as 2020. The Science NJSLs has an entire category in each grade level dedicated to engineering, technology, and the application of science. The category is titled “Science and Engineering Practices” which has nine subcategories for grades K through 8 and a separate section called “Engineering Design” for grades 9 through 12. The Mathematics NJSLs has eight standards called “Mathematical Practice”. It also provides a connection between Mathematical Practice standards and Mathematical Content standards. For technology, I found a current set of standards for New Jersey called Computer Science and Design Thinking NJSLs that are the revised and expanded version of the 2014 Technology Education NJSLs. It is split into two strands, 8.1 Computer Science and 8.2 Design Thinking.

Many, if not all, of these science, technology, and mathematical standards relate to problem solving or engineering design. In the article, “The Engineering Design Method” by Elsa Garnire she explains the Dartmouth Design Process of defining the problem, restating the problem, developing constraints and criteria, brainstorming, researching alternatives, analysis of alternatives by a trade-off matrix, identifying a potential solution, researching the potential solution, design a potential prototype, construct a prototype, evaluate the prototype, simplify if possible, and report the results. In the high school Science NJSLs I found a correlation between Planning and Carrying Out Investigations to the Dartmouth Design Process which includes:

Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. (HS-PS2-5, pg 153)

Another similar Science NJSLs, Constructing Explanations and Designing Solutions which states:

Apply scientific ideas to solve a design problem, taking into account possible unanticipated effects. (HS-PS2-3, pg154)

This standard applies to the Dartmouth Design Process of defining the problem, developing constraints and criteria, and analysis of alternative solutions by a trade-off matrix.

A third comparable Science NJSLs, Asking Questions and Defining Problems which states:

Evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. (HS-PS4-2,pg 161)

This standard applies to the Dartmouth Design Process of researching alternatives, analysis of alternatives by a trade-off matrix, and identifying a potential solution.

In the Computer Science and Design Thinking NJSLs by the end of grade 12 under standard 8.2 Design Thinking for Engineering Design the following core ideas are comparable to “The Engineering Design Method” by Elsa Garnire:

Engineering design is a complex process in which creativity, content knowledge, research, and analysis are used to address local and global problems. Decisions on trade-offs involve systematic comparisons of all costs and

benefits, and final steps that may involve redesigning for optimization. Engineering design evaluation, a process for determining how well a solution meets requirements, involves systematic comparisons between requirements, specifications, and constraints. (standard 8.2, page 41)

This can be seen under defining the problem, developing constraints and criteria, brainstorming, researching alternatives, analysis of alternatives by a trade-off matrix, identifying a potential solution, and researching the potential solution.

In the Mathematics NJSLS I can find correlations between David H. Jonassen's article, "Toward a Design Theory of Problem Solving" under Figure 1 called Problem-solving skills for Complexity under Abstractness/Situatedness, domain specific, on page 66 of the article and the Mathematical Practice standards of make sense of problems and persevere in solving them and reason abstractly and quantitatively. For standard 1 make sense of problems and persevere in solving them it is stated

Mathematically proficient students start by explaining to themselves the meaning of a problem and looking for entry points to its solution. They analyze givens, constraints, relationships, and goals. They make conjectures about the form and meaning of the solution and plan a solution pathway rather than simply jumping into a solution attempt. (Mathematical NJSLS, page 3)

This standard can and will be affected by the "complexity of the problem and can affect a learner's ability to solve problems". (Jonassen, pg 68). It includes

the number of issues, functions, or variables involved in the problem, the degree of connectivity among those properties, functional relationships, and stability among the properties of the problem over time. (Jonassen, pg 67-68)

Confidence, the seen value of the problem, and familiarity with the mathematical principles are very important to counteract the complexity of the problem.

These standards are similar to each other because the overall goal is to make sense of a problem by executing it in a systematic way. By using prior knowledge, understanding the problem statement, researching constraints and making specifications crystal clear this is the start to the engineering design process and problem solving. Communication through collaboration is a common trend here as well. The brainstorming process, researching and creating a trade-off matrix, identifying a solution, and creating a prototype all require students to communicate with each other and their teachers. This will lead students closer to or at a solution to their problem. I also noticed that student and cultural diversity is a major concern of the NJSLS. Making topics such as climate change culturally relevant to diverse learners is a goal under all STEM topics. Providing information on how a problem is culturally relevant to diverse learners is key to accelerate problem solving motivation in learners. I also noticed that algorithmic problems that are very procedural based that were discussed in Jonassen's article are seen in the mathematical standards number 7 look for and make use of structure and computer science/technology standards 8.1 Algorithms and Programming. This very rigid approach is part of the well-structured type of problem solving.

A difference that stood out to me in reviewing the mathematical, technology, and science standards is that the Science and Technology NJSLS makes reference to math, engineering, and technology standards in the actual document. The Mathematical NJSLS doesn't point out science, engineering, and technology goals specifically. It seems as if it is just all umbrellaed under the math practice and content standards. Another difference is algorithmic problems are

not mentioned directly in the science standards like they are in the mathematical and technology standards.

I feel that engineering design problem solving is truly a “unifying” concept between the engineer’s ability to have a variety of problem solving skill sets and follow well-structured all the way to ill-structured problem solving techniques to find a suitable solution that meets all specifications and constraints. In science, technology, and math class teachers are challenging students to use their problem-solving skills that they already possess to meet certain criteria. It is important to represent more ill-structured problems and increase students' knowledge of general problem solving topics such as decision-making problems, trouble-shooting problems, case-analysis problems, design problems, and dilemmas that are all mentioned in Jonassen’s article. I know that as a teacher myself I need to address more ill-structured problem solving techniques for students to have a proper experience in the engineering design problem solving process.

#### References:

NJSLS Computer Science and Design Thinking

<https://www.nj.gov/education/cccs/2020/2020%20NJSLS-CSDT.pdf>

NJSLS Mathematics

[https://www.nj.gov/education/standards/math/Docs/2016NJSLS-M\\_K-12.pdf](https://www.nj.gov/education/standards/math/Docs/2016NJSLS-M_K-12.pdf)

NJSLS Science

<https://www.nj.gov/education/cccs/2020/NJSLS-Science.pdf>

The Engineering Design Method by Elsa Garmire

Toward a Design Theory of Problem Solving by David Jonassen