

V-Model Approach to K-12 Learning

Wednesday, February 27, 2019



Presentation will start at 6PM PT



The Need for Systems Engineering in K12 Schools

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About Me

- 15 years in education
- Former researcher and Forensic Analyst
- Taught: Physics, AP Physics, Biology, AP Bio, Earth, Forensics, Environmental Science
- Escondido Union HS District (Escondido, Ca)

Next Generation Science Standards



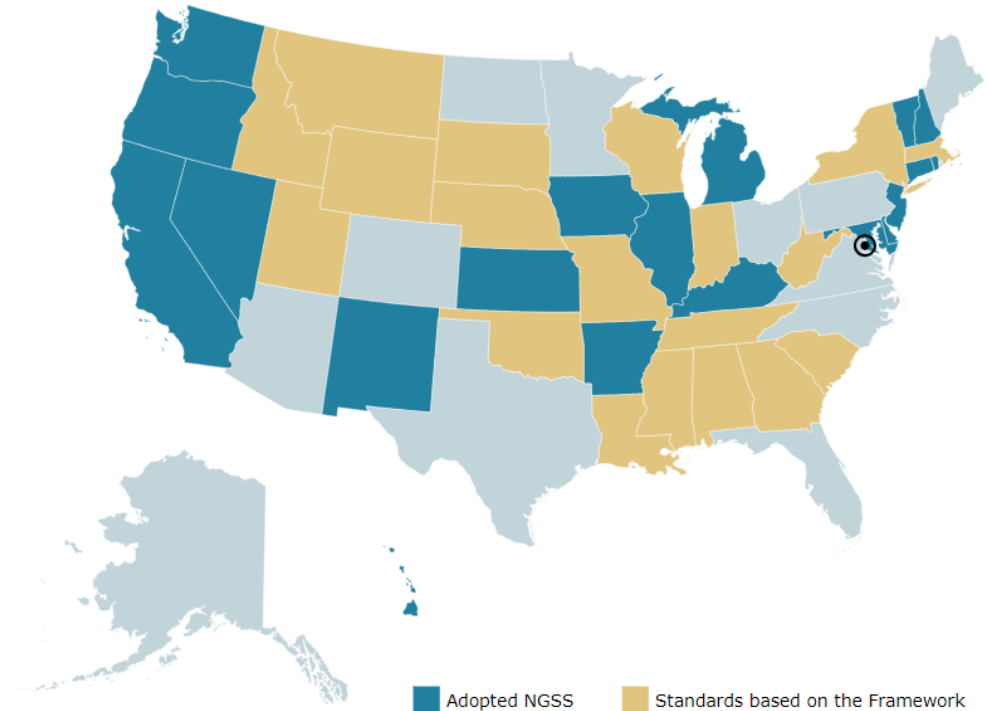
*“Next Generation Science Standards is a registered trademark of Achieve. Neither Achieve nor the lead states and partners that developed the Next Generation Science Standards were involved in the production of this product, and do not endorse it.”

NGSS

- Science AND Engineering to be taught in every grade K12
- Shift away from memorizing facts to *doing* science and engineering
- Emphasis on hands-on investigation and discovery

Next Generation Science Standards

- 19 have adopted
- 19 have adapted



*Image from NSTA, <http://ngss.nsta.org/About.aspx>

**Is ENGINEERING
different from SCIENCE?**

Engineering Standards

3-5-ETS1-3 (ETS1 Engineering Design)

Students who demonstrate understanding can:

3-5-ETS1-3: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved. [Clarification Statement: N/A] [Assessment Boundary: N/A.]

Planning 4 solutions, progressive profile	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
• Plan data collection	MS-ETS1-3 (ETS1 Engineering Design)		
• Analyze data	Students who demonstrate understanding can: MS-ETS1-3: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success. [Clarification Statement: N/A] [Assessment Boundary: N/A.]		
• Connect	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
• Connect	Analyzing and Interpreting Data	ETS1.B: Developing Possible Solutions	
• Connect	HS-ETS1-2 (ETS1 Engineering Design)		
• Connect	Students who demonstrate understanding can: HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. [Clarification Statement: N/A] [Assessment Boundary: N/A.]		
• Connect	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
• Connect	Constructing Explanations and Designing Solutions	ETS1.C: Optimizing the Design Solution	
• Connect	HS-ETS1-4 (ETS1 Engineering Design)		
• Connect	Students who demonstrate understanding can: HS-ETS1-4: Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. [Clarification Statement: N/A] [Assessment Boundary: N/A.]		
• Connect	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
• Connect	Using Mathematics and Computational Thinking	ETS1.B: Developing Possible Solutions	Systems and System Models
• Connect	Connections to California Science Framework:		
• Connect	HS Living Earth 156: Ecosystem Stability & the Response to Climate Change		
• Connect	HS Chemistry in the Earth System 152: Heat and Energy in the Earth System		
• Connect	HS Physics of the Universe 151: Forces and Motion		
• Connect	HS Physics of the Universe 153: Energy Conversion and Renewable Energy		
• Connect	HS 4-Course Chemistry 155: Energy, Conservation, Transfer, and Applications		
• Connect	HS 4-Course Physics 151: Forces and Motion		
• Connect	HS 4-Course Earth and Space Sciences 154: Water and Farming		
• Connect	HS 4-Course Earth and Space Sciences 156: Urban Geoscience		
• Connect	Connections to Environmental Principles & Concepts:		
• Connect	N/A		
• Connect	Connections to California Common Core State Standards:		
• Connect	ELA/Literacy -		
• Connect	N/A		
• Connect	Mathematics -		
• Connect	MP2 Reason abstractly and quantitatively. (HS-ETS1-4)		
• Connect	MP4 Model with mathematics. (HS-ETS1-4)		
• Connect	Evidence Statements - Observable features of the student performance by the end of the grade		
• Connect	1. Representation		
• Connect	a. Students identify the following components from a given computer simulation:		
• Connect	1. The complex real-world problem with numerous criteria and constraints;		
• Connect	2. The system that is being modeled by the computational simulation, including the boundaries of the systems;		
• Connect	3. What variables can be changed by the user to evaluate the proposed solutions, tradeoffs, or other decisions; and		

- ...criteria and constraints for solutions ...
- ...breaking it down into smaller, more manageable problems ...
- ...prioritized criteria ... range of constraints...
- ...model the impact of proposed solutions ...systems relevant to the problem.

The Difference

SCIENTIST

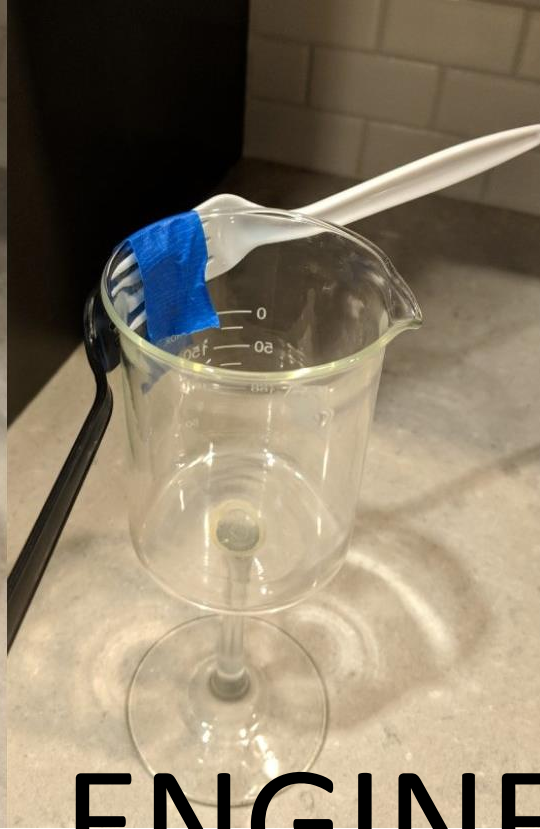
- Focus on unknown
- Create theories
- Ask questions then find answers
- Find the laws of nature
- Tell engineers what to make

ENGINEER

- Focus on known
- Implement theories
- Use the answers to make inventions
- Use the laws of nature
- Tell scientists the constraints to product ideas



SCIENCE



ENGINEERING

**HOW do I TEACH
ENGINEERING?**

Method

Scientific

- Observation
- Question
- Hypothesis
- Experiment
- Analysis/Conclusions

Engineering



Engineering Standards

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Connecting 4 Grade 4-5, Grade 5-6, Grade 5-7	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
• Analyze data	Analyzing and Interpreting Data	ETS1.B: Developing Possible Solutions	Crosscutting Concepts
• Connect 4 Grade 4-5, Grade 5-6, Grade 5-7	HS-ETS1-2 (ETS1 Engineering Design)		
• Connect 4 Grade 4-5, Grade 5-6, Grade 5-7	Students who demonstrate understanding can: HS-ETS1-2: Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. [Clarification Statement: N/A.] [Assessment Boundary: N/A.]		
Connecting 4 Grade 4-5, Grade 5-6, Grade 5-7	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
• Connect 4 Grade 4-5, Grade 5-6, Grade 5-7	Constructing Explanations and Designing Solutions	ETS1.C: Optimizing the Design Solution	Crosscutting Concepts
• Connect 4 Grade 4-5, Grade 5-6, Grade 5-7	Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses in explanations and designs that: • Criteria may be needed to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) are made. [Clarification Statement: N/A.] [Assessment Boundary: N/A.]		
Connecting 4 Grade 4-5, Grade 5-6, Grade 5-7	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
• Connect 4 Grade 4-5, Grade 5-6, Grade 5-7	Using Mathematics and Computational Thinking	ETS1.D: Developing Possible Solutions	Systems and System Models
• Connect 4 Grade 4-5, Grade 5-6, Grade 5-7	HS-ETS1-4 (ETS1 Engineering Design)		
• Connect 4 Grade 4-5, Grade 5-6, Grade 5-7	Students who demonstrate understanding can: HS-ETS1-4: Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. [Clarification Statement: N/A.] [Assessment Boundary: N/A.]		
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• Connect 4 Grade 4-5, Grade 5-6, Grade 5-7	Using Mathematics and Computational Thinking	ETS1.D: Developing Possible Solutions	Systems and System Models
• Connect 4 Grade 4-5, Grade 5-6, Grade 5-7	Using mathematics and computational thinking in 9–12 builds on K–8 experiences and progresses to using algebraic thinking and analysis, a range of linear and nonlinear functions including trigonometric functions, exponential and logarithmic, and computational tools for statistical analysis to analyze, represent, and model data. Simple computational simulations are created and used based on mathematical models of basic assumptions. • Use mathematical models and/or computer simulations to predict the effects of a design solution on systems and/or the interactions between systems. (HS-ETS1-4) • 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) • Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical, and in making a persuasive presentation to a client about how a given design will meet his or her needs. (HS-ETS1-4) • 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 of different scales. (HS-ETS1-4)		
Connecting 4 Grade 4-5, Grade 5-6, Grade 5-7	Connections to California Science Framework:		
• Connect 4 Grade 4-5, Grade 5-6, Grade 5-7	HS Living Earth 186: Ecosystem Stability & the Response to Climate Change HS Chemistry in the Earth System 152: Heat and Energy in the Earth System HS Physics of the Universe 151: Forces and Motion HS 4: Course Physics 151: Forces and Motion HS 4: Course Chemistry 155: Energy Conservation, Transfer, and Applications HS 4: Course Earth and Space Sciences 154: Water and Farming HS 4: Course Earth and Space Sciences 156: Urban Geoscience		
Connecting 4 Grade 4-5, Grade 5-6, Grade 5-7	Connections to Environmental Principles & Concepts:		
• Connect 4 Grade 4-5, Grade 5-6, Grade 5-7	N/A.		
Connecting 4 Grade 4-5, Grade 5-6, Grade 5-7	Connections to California Common Core State Standards:		
• Connect 4 Grade 4-5, Grade 5-6, Grade 5-7	ELA/Literacy - N/A Mathematics - MP2 Reason abstractly and quantitatively (HS-ETS1-4) MP4 Model with mathematics (HS-ETS1-4)		

1. Representation

a. Students identify the following components from a given computer simulation:

- The complex real-world problem with numerous criteria and constraints;
- Simulation that is being modeled by the computerized simulation; the boundaries of the system;
- What variables can be changed by the user to evaluate the proposed solutions, tradeoffs, or other decisions; and

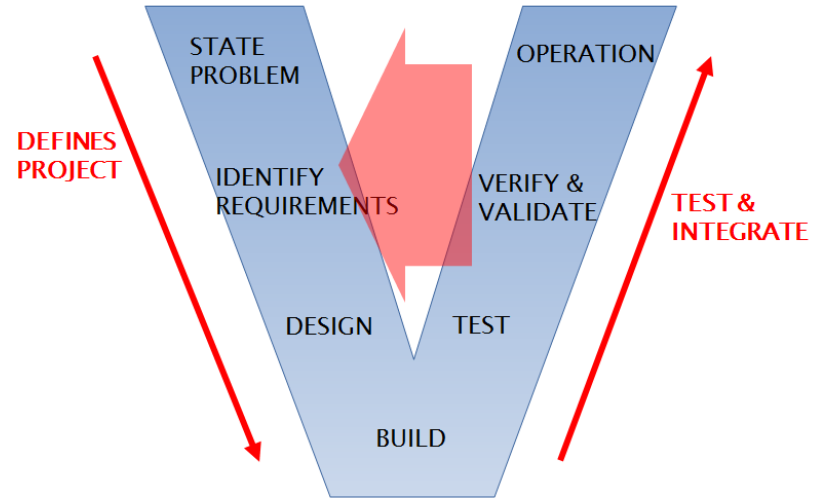
- ...criteria and constraints for solutions ...
- ...breaking it down into smaller, more manageable problems ...
- ...prioritized criteria ... range of constraints...
- ...model the impact of proposed solutions ...systems relevant to the problem.

Method

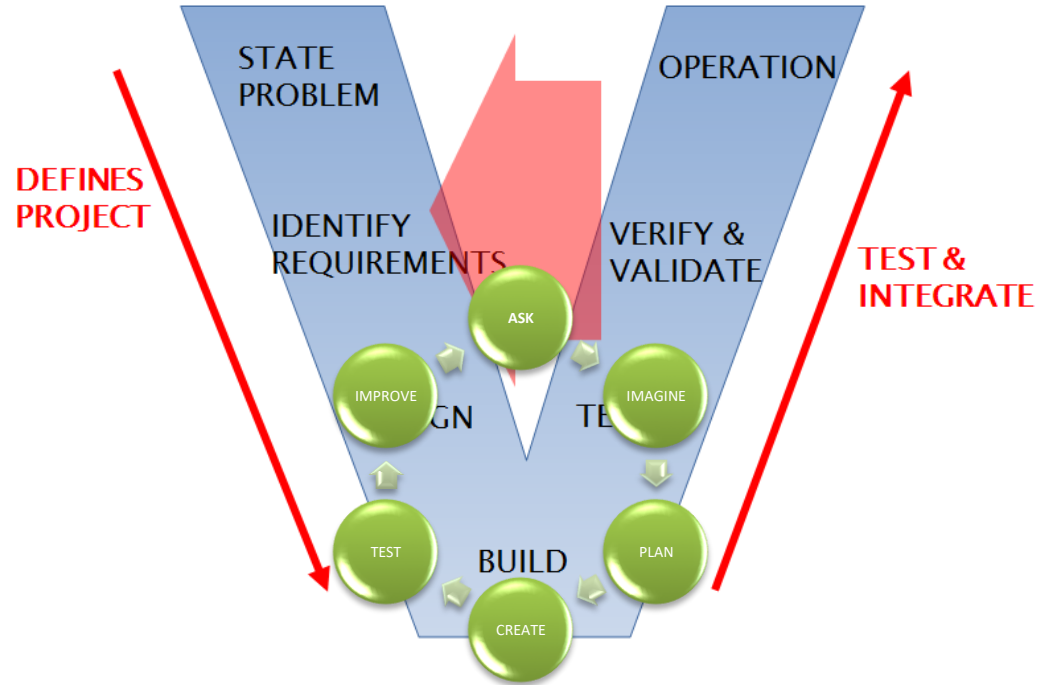
Scientific

- Observation
- Question
- Hypothesis
- Experiment
- Analysis/Conclusions

Engineering

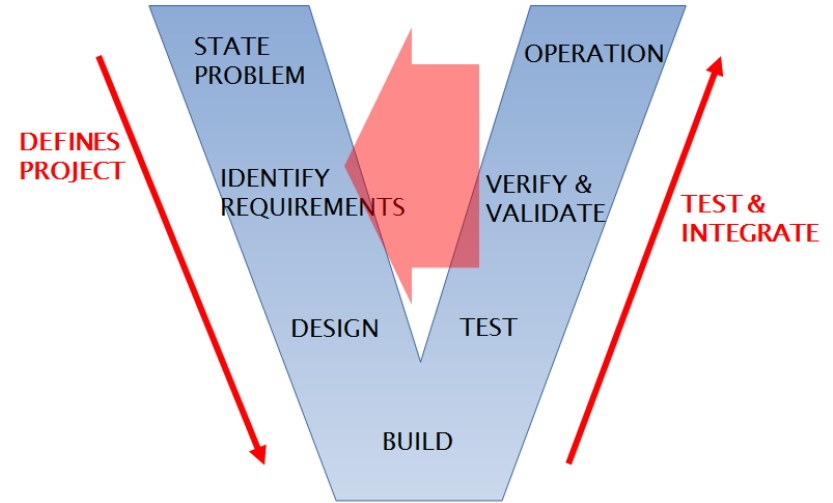


V Model of Systems Engineering



Engineering Spin on Projects

- State the problem
- Requirements
 - Physical, functional, interface, other
- Design – Build – Test
- Verify the requirements
- Validate the project





NAME of project

Date Start: _____

Date End: _____

IDENTIFY PURPOSE

What product is being made?

LIST of REQUIREMENTS

Physical Requirements

(dimensions, size, materials, etc)

Functional Requirements

(what item must be able to do, the task)

Interface Requirements

(how device/item interacts with immediate environment)

DESIGN (RESEARCH/BUILD)

Where are students going to find this research?

How long will you give them to build? What supplies will you provide for them? (paper, colored pencils, scissors, glue, tape, etc?)

TESTING

How much time will students be given to test? What equipment are you providing for them to test? Do they need to provide tables? Graphs?

VALIDATION and VERIFICATION

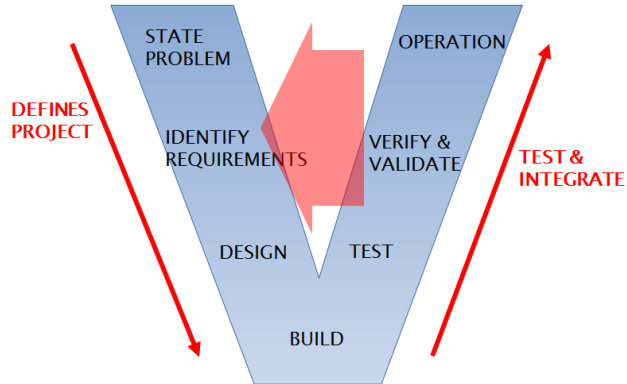
VALIDATION: How will you measure that students met their purpose?

VERIFICATION: How will you measure that students met their requirements?

ASSESSMENT

- Students verify, teacher validates

VERIFICATION →



REQUIREMENTS VERIFICATION

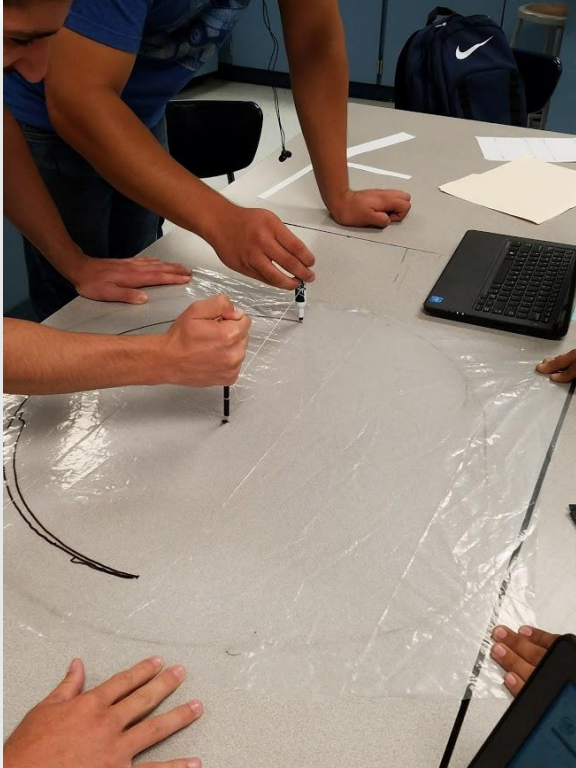
Your team must verify that the requirements were met. Circle on the verification rubric below how you met each of the stated requirements.

PHYSICAL REQUIREMENTS	4 OBJECTIVE	3 THRESHOLD	2 SUB THRESHOLD	1 DEVIATED
Materials	Only supplied materials used	Only supplied materials used, but had to get extra once	Only supplied materials used, but had to get extra twice	Built out of materials not supplied, extras three or more times
Dimensions	Largest dimension is <0.5 m in any direction	Largest dimension is 0.6 m in any direction	Largest dimension is 0.7 m in any direction	Largest dimension is > 0.7 m in any dimension

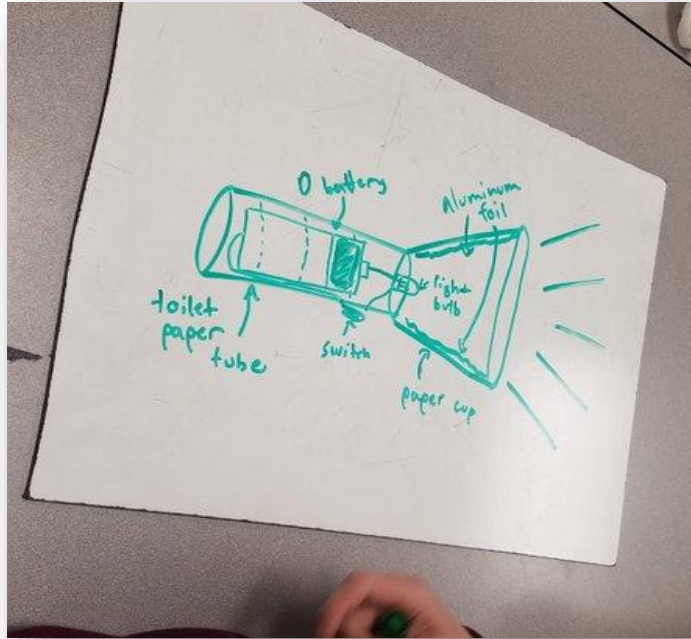
FUNCTIONAL REQUIREMENTS	4 OBJECTIVE	3 THRESHOLD	2 SUB THRESHOLD	1 DEVIATED
TIME of Flight	Time of flight >5s	Time of flight between 3-4.9 s	Time of flight between 1-2.9s	Object fell without reduced flight time.
Item Status upon Delivery	No damage	Item delivered with minimal damage (crack or small piece missing)	Damaged but not destroy (3 or more pieces broken)	Damaged beyond repair (>3 pieces broken)
Landing Zone	Package lands in 0.5 m landing zone	Package lands within the 0.6 m landing zone	Package lands in the 0.7 m landing zone	Package land in zone beyond 0.7 m

Human-Machine Interface REQUIREMENT	4 OBJECTIVE	3 THRESHOLD	2 SUB THRESHOLD	1 DEVIATED
Attachment of Package	Package easy to put on and off by stranger without damaging box	Package easy to put on and off with instructions to a stranger without damaging box	Package not easy to get on/off by stranger OR box gets damaged	Package not easy to get on/off by stranger AND box gets damaged

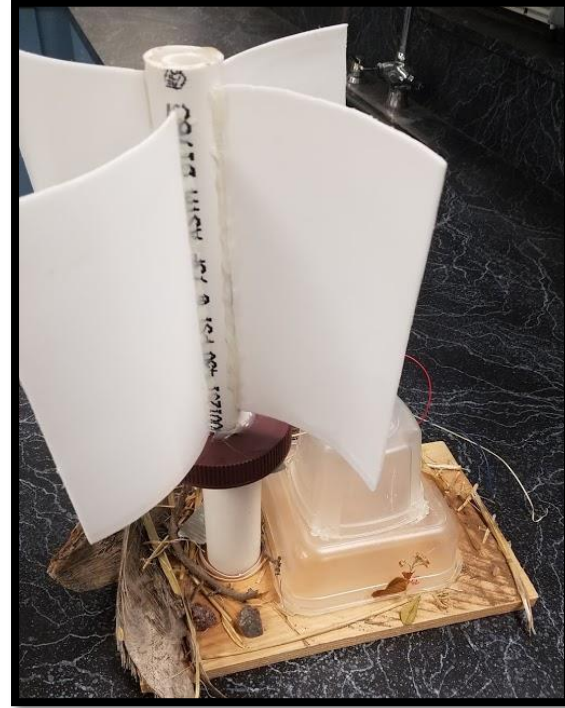
Systems Approach in the Classroom



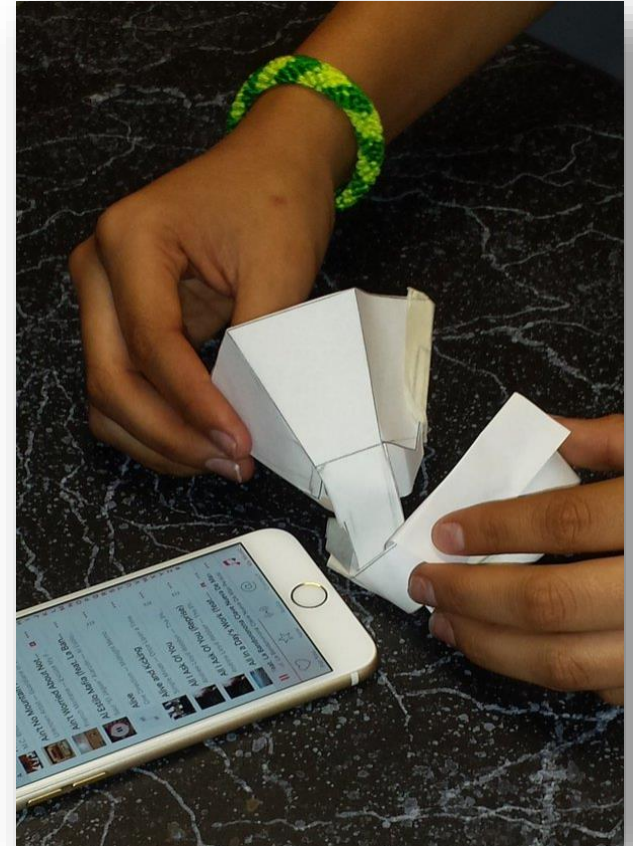
Systems Approach in the Classroom



Systems Approach in the Classroom



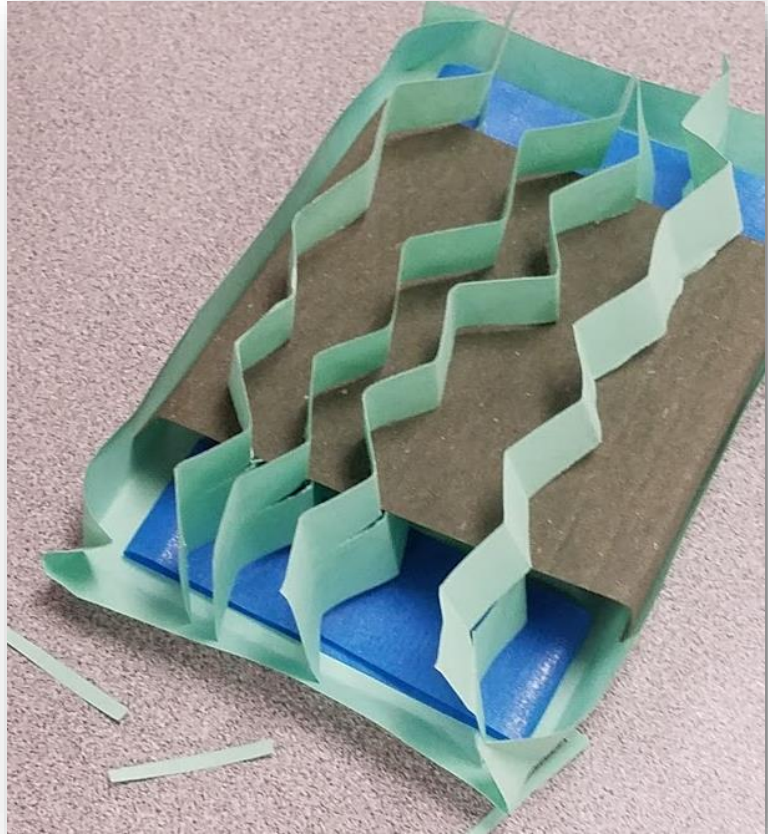
Systems Approach in the Classroom

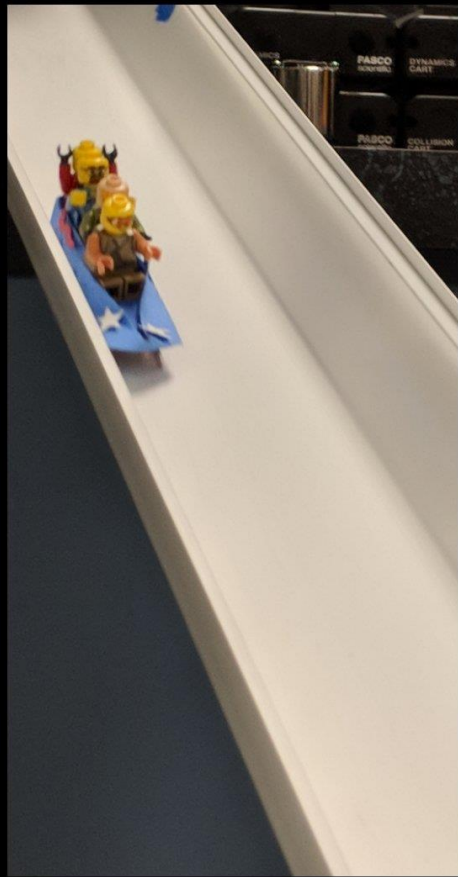
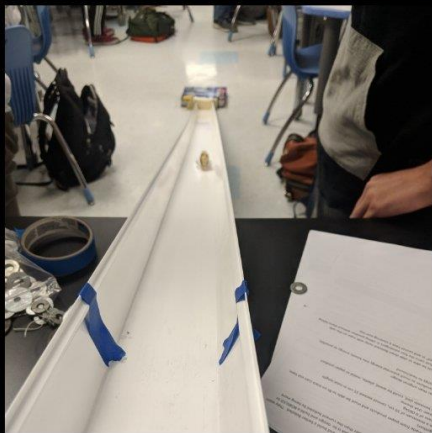
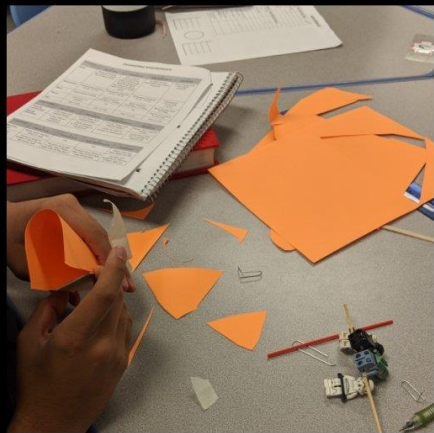
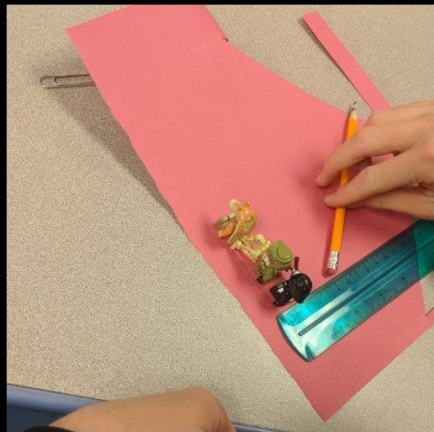


Systems Approach in the Classroom



Systems Approach in the Classroom







USA Bobsled Skeleton  @USABS · 17 Nov 2018



Replying to @TraceySchalnat @NGSSMadeMeDolt and 2 others

These look pretty fast! @eamslider24, @justinbolsen, @breinbolt, @vogtfornic, @codiebascue13... which one would you drive!?



1



2



1 more reply

Student Reflections

If there had been no requirements, how would this have changed your approach to this task?

- “The requirements sort of help us back into our thinking process...”
- “It would’ve been harder because you would’ve had many options to include...”

Which requirement do you think was most important to your customer?

- “I think the human/machine because they would have to place humans into the sled which could be difficult and affect how they like the product”
- “To have the men stay inside, upright. Safety is very important...”

Which requirement do you think was most important as the engineer?

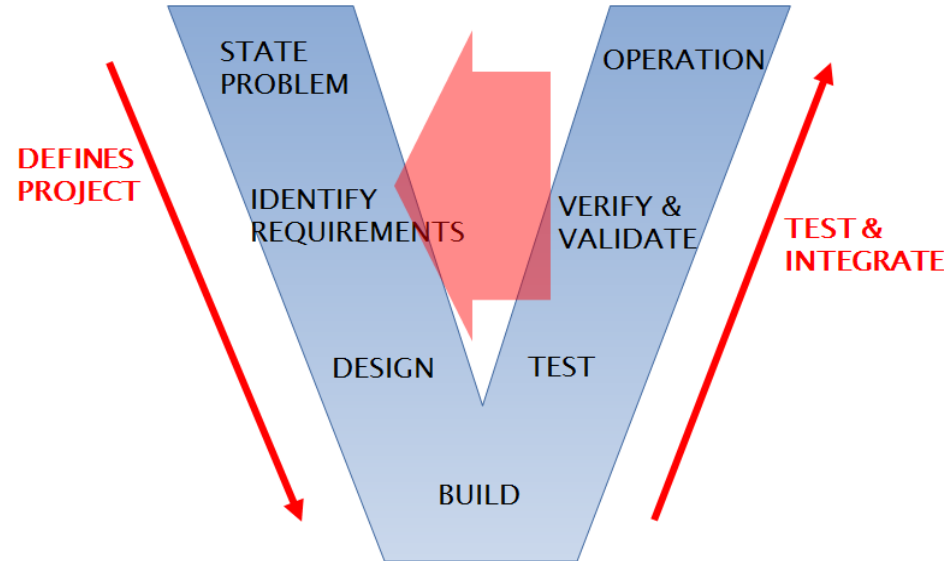
- “Time. In the sport of bobsledding your sled could not look good but still have the fastest time to get down the track.”
- “The Energy efficiency...due to it being able to affect the overall time, speed, and functionality of the bobsled”

If you got to add another requirement, what would it be?

- “A specific height...not all different type of people can fit.”
- “A time threshold would have to be met in order to be meeting the objective because the faster it goes the higher the chance there is to win.”

Observations of Success

- Failure leads to success
- Negotiations (Requirements trades and deviations)
- Backward design to identify requirements, how to test
- Self assess
- Experimentation increased
- Modeling of system

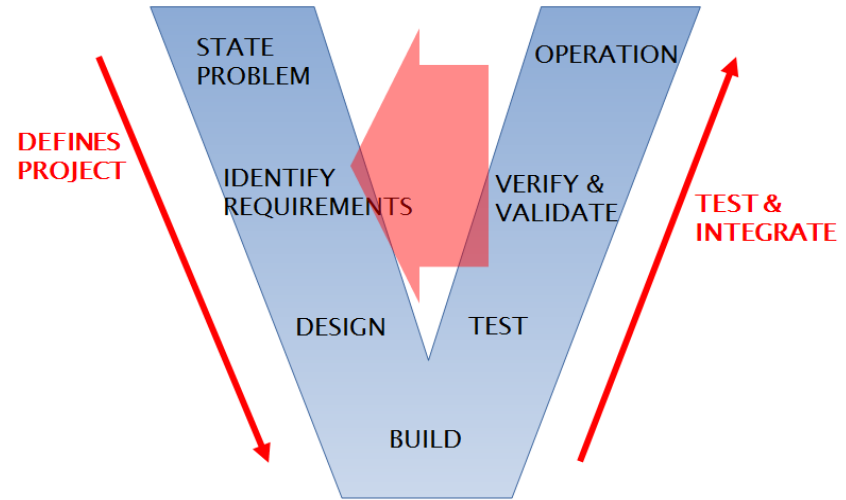


Other Applications

- Chemistry: Design a device to keep the finger cold. (thermo)
- Environmental Science: Find a property that would support off-grid living
- Biology: Microbial fuel cell grant from INCOSE
- Middle School and Elementary pilots

SUMMARY

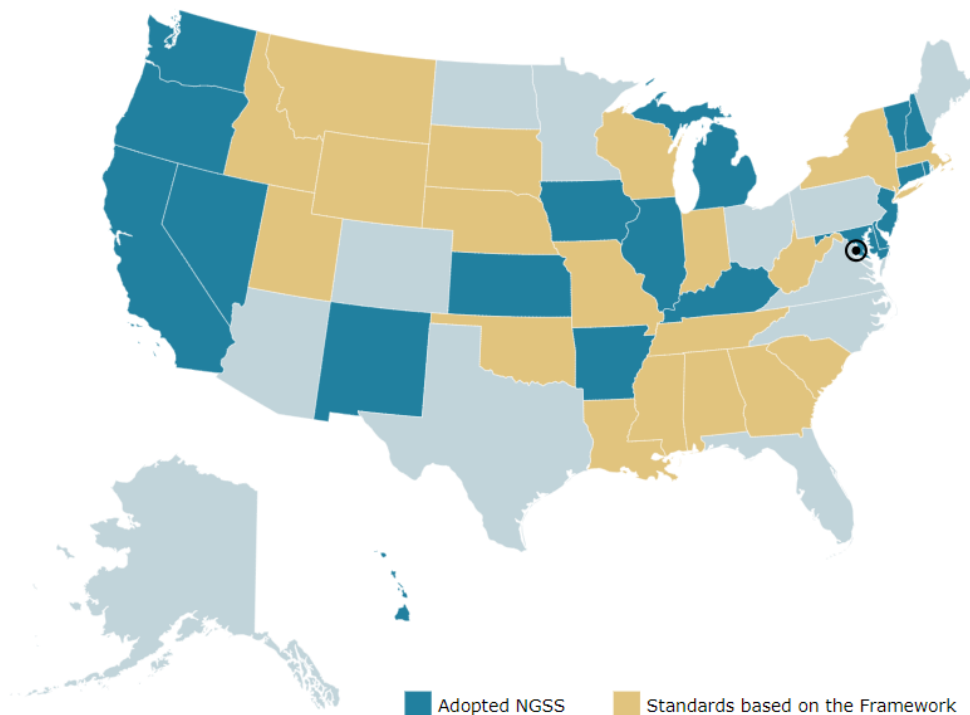
- Validated it works for
 - Students
 - Teachers
 - Across grade levels
 - Across subjects



Next Steps

- Action Items

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References

California Alliance for NGSS CA4NGSS.org

California Department of Education's webpage: <http://www.cde.ca.gov/pd/ca/sc/ngssintrod.asp>

California Science Teachers Association (CSTA)'s webpage: <http://www.casience.org/csta/ngss.asp> and monthly newsletter, "California Classroom Science": <http://www.classroomscience.org/>

Achieve's Next Generation Science Standards website: <http://www.nextgenscience.org/signup>

National Science Teachers Association (NSTA)'s NGSS@NSTA website: <http://ngss.nsta.org/>
<http://ngss.nsta.org/About.aspx>

STEM Teaching Tool <http://stemteachingtools.org/>

Engineering Standards

- Analyze a major global challenge to specific qualitative and quantitative **criteria and constraints for solutions** that account for societal needs and wants.
- Design a solution to a complex real-world problem by **breaking it down into smaller, more manageable problems** that can be solved through engineering.
- Evaluate a solution to complex real-world problem based on **prioritized criteria** and trade-offs that account for a **range of constraints**, including cost, safety, reliability, and aesthetics, as well as possible social, cultural and environmental impacts.
- Use a computer simulation to **model the impact of proposed solutions** to a complex real-world problem with numerous criteria and constraints on interactions within and between **systems relevant to the problem.**

What SKILLS do
students need?

Top 10 skills in 2020

1. Complex Problem Solving
2. Critical Thinking
3. Creativity
4. People Management
5. Coordinating with Others
6. Emotional Intelligence
7. Judgment and Decision Making
8. Service Orientation
9. Negotiation
10. Cognitive Flexibility

*Source: Future of Jobs Report, World
Economic Forum 2016*