Preparing for NGSS

Dear NGSS,
Teach Engineering? What ?!?
From,
Classroom Teacher

John Heffernan
10/8/2015

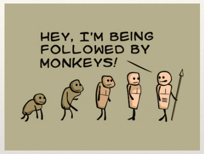
Outline

- What is NGSS? How is it organized? How is it different?
- Exercise
- Engineering and NGSS
- MA NGSS differences and timeline

Introductory Video

- http://www.nextgenscience.org/case-next-generation-science-standards

Political Stuff



- Not Common Core
- Not federal
- Not PARCC tested
- 26 lead states (11 adopted so far, 39 have expressed interest)
- Includes climate change and evolution

Organization of NGSS

- Dimension 1: Scientific and Engineering Practices
- Dimension 2: Crosscutting Concepts
- Dimension 3: Disciplinary Core Ideas—Physical Sciences
- Dimension 3: Disciplinary Core Ideas—Life Sciences
- Dimension 3: Disciplinary Core Ideas—Earth and Space Sciences
- Dimension 3: Disciplinary Core Ideas—Engineering, Technology, and Applications of Science

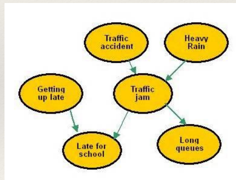
Science and Engineering Practices

- Asking questions (for science) and defining problems (for engineering)
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking
- Constructing explanations (for science) and designing solutions (for engineering)
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information

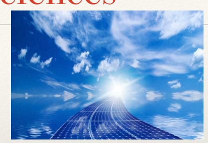
These change by grade level band.

Crosscutting Concepts

1. Patterns
2. **Cause and effect: Mechanism and explanation**
3. Scale, proportion, and quantity
4. **Systems and system models**
5. **Energy and matter: Flows, cycles, and conservation**
6. **Structure and function**
7. Stability and change



DCI - Physical Sciences

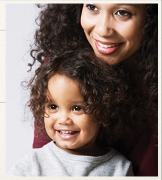


- PS1: Matter and its interactions
- PS2: Motion and stability: Forces and interactions
- PS3: Energy
- PS4: Waves and their applications in technologies for information transfer

DCI - Earth and Space Sciences

- ESS1: Earth's place in the universe
- ESS2: Earth's systems
- ESS3: Earth and human activity

DCI - Life Sciences



- LS1: From molecules to organisms: Structures and processes
- LS2: Ecosystems: Interactions, energy, and dynamics
- LS3: Heredity: Inheritance and variation of traits
- LS4: Biological evolution: Unity and diversity

DCI - Engineering, Technology, and Applications of Science

- ETS1: Engineering design

Organization of NGSS

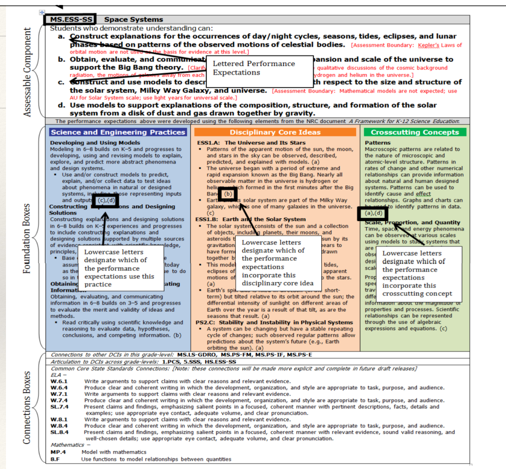
- 2 PDFs
- By DCI Arrangement
- By Topic Arrangement
- Many appendices (A-M)
- MA version(s) simpler to read

Topic Arrangement

MA STE Standards

Table of Contents

- Integrated to grade 8
- With or without foundation boxes



MS.ESS-SS **Space Systems**

Students who demonstrate understanding can:

a. **Construct explanations for the occurrences of day/night cycles, seasons, tides, eclipses, and lunar phases based on patterns of the observed motions of celestial bodies.** [Assessment Boundary: Kepler's Laws of orbital motion are not used as the basis for evidence at this level.]

b. **Obtain, evaluate, and communicat… …ansion and scale of the universe to support the Big Bang theory.** [Clarify… …qualitative discussions of the cosmic background radiation, the motions of galaxies away from each … …ydrogen and helium in the universe.]

c. **Construct and use models to descr… …th respect to the size and structure of the solar system, Milky Way Galaxy, and universe.** [Assessment Boundary: Mathematical models are not expected; use AU for Solar System scale; use light years for universal scale.]

d. **Use models to support explanations of the composition, structure, and formation of the solar system from a disk of dust and gas drawn together by gravity.**

The performance expectations above were developed using the following elements from the NRC document *A Framework for K-12 Science Education*:

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to explain, explore, and predict more abstract phenomena and design systems. ▪ Use and/or construct models to predict, explain, and/or collect data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs. (c),(d) **Constructing Explanations and Designing Solutions** Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence … **Obtaining, Evaluating, and Communicating Information** Obtaining, evaluating, and communicating information in 6–8 builds on 3–5 and progresses to evaluate the merit and validity of ideas and methods. ▪ Read critically using scientific knowledge and reasoning to evaluate data, hypotheses, conclusions, and competing information. (b)	**ESS1.A: The Universe and Its Stars** ▪ Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. (a) ▪ The universe began with a period of extreme and rapid expansion known as the Big Bang. Nearly all observable matter in the universe is hydrogen or helium, which formed in the first minutes after the Big Bang. (b) ▪ Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. (c) **ESS1.B: Earth and the Solar System** ▪ The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids … ▪ This model … tides, eclipses of … apparent motions of … the stars. (a) ▪ Earth's spin … but tilted relative to its orbit around the sun; the differential intensity of sunlight on different areas of Earth over the year is a result of that tilt, as are the seasons that result. (a) **PS2.C: Stability and Instability in Physical Systems** ▪ A system can be changing but have a stable repeating cycle of changes; such observed regular patterns allow predictions about the system's future (e.g., Earth orbiting the sun). (a)	**Patterns** Macroscopic patterns are related to the nature of microscopic and atomic-level structure. Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. Patterns can be used to identify cause and effect relationships. Graphs and charts can be used to identify patterns in data. (a),(d) **Scale, Proportion, and Quantity** Time, space, and energy phenomena can be observed at various scales using models to study systems that are … properties and processes. Scientific relationships can be represented through the use of algebraic expressions and equations. (c)

Connections to other DCIs in this grade-level: **MS.LS-GDRO, MS.PS-FM, MS.PS-IF, MS.PS-E**

Articulation to DCIs across grade-levels: **1.PCS, 5.SSS, HS.ESS-SS**

Common Core State Standards Connections: [Note: these connections will be made more explicit and complete in future draft releases]

ELA –

W.6.1 Write arguments to support claims with clear reasons and relevant evidence.
W.6.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
W.7.1 Write arguments to support claims with clear reasons and relevant evidence.
W.7.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
SL.7.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with pertinent descriptions, facts, details and examples; use appropriate eye contact, adequate volume, and clear pronunciation.
W.8.1 Write arguments to support claims with clear reasons and relevant evidence.
W.8.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
SL.8.4 Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.

Mathematics –

MP.4 Model with mathematics
8.F Use functions to model relationships between quantities

NGSS Exercise

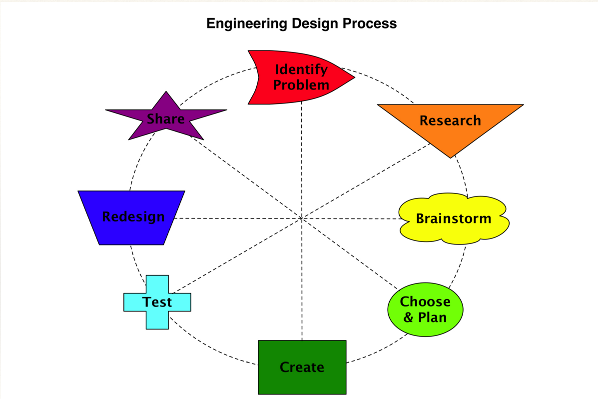
- Look at one of the three provided (MA) examples (elementary, middle school, or high school)
- How is it different, the same as the old standards?
- Questions?

What Is Engineering?

- We use the term "engineering" in a very broad sense to mean any engagement in a systematic practice of design to achieve solutions to particular human problems. (NRC 2012, p. 11-12, NGSS, Appendix I, p. 2)
- "From a teaching and learning point of view, it is the iterative cycle of design that offers the greatest potential for applying science knowledge in the classroom and engaging in engineering practices" (NRC 2012, p. 20-202).

NGSS Core Engineering Ideas

- Defining and delimiting engineering problems
- Designing solutions to engineering problems
- Optimizing the design solution



Courtesy Dr Merridith Portsmore, Tufts CEEO

EDP Model Considerations

- Ideal model, teach but not slavishly
- Help connect math and science (Mitnik, Recabarren, Nussbaum, & Soto, 2009; Puntambekar & Kolodner, 2005)
- Students may need help with considering alternative ideas, planning, going back to the drawing board, dealing with frustration

K-2 Engineering Design

- K-2-ETS1-1 Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.
- K-2-ETS1-2 Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.
- K-2-ETS1-3 Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.

3-5 Engineering Design

- 3-5-ETS1-1 Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2 Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 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.

MS Engineering Design

- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- 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.
- MS-ETS1-4 Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

HS Engineering Design

- HS-ETS1-1 Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.
- 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.
- HS-ETS1-3 Evaluate a solution to a 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.
- 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.

Curriculum Exercise

- Using the provided MA examples (elementary, middle school, or high school), discuss how the standard could be realizing using an engineering activity

Discuss how this is different from using a textbook, ie, that application of science

MA NGSS (DESE)

NGSS	MA Adaptation
Standards include 4 dimensions (disciplinary core ideas, practices, crosscutting concepts, nature of science)	Standards include only 2 dimensions (disciplinary core ideas and practices)
Standards are broadly written, leading to inconsistent interpretation	Balances broad concepts with specificity to inform more consistent interpretation
Standards require reference to the foundation boxes to identify full range of expected learning.	Standards can stand on their own without need to reference foundation boxes.
Middle school presented as grade span	Middle school presented grade-by-grade
Engineering design as occasional application of science	**Technology/Engineering as a discipline**
No definition for college and career readiness; all high school courses expected	Defines college and career readiness for STE; maintains current MA model with high school course options

Grade 4 MA Technology/Engineering

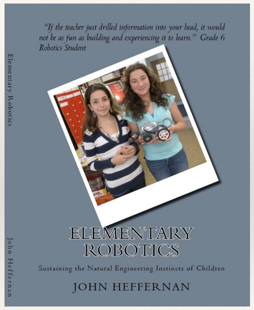
- 3-5-ETS1-3. Plan and carry out tests of one or more elements of a model or prototype in which variables are controlled and failure points are considered to identify which elements need to be improved. *Apply the results of tests to redesign a model or prototype.**
- 3-5-ETS1-5(MA). Evaluate relevant design features that must be considered in building a model or prototype of a solution to a given design problem.* [Clarification Statement: Examples of design features can include size, shape, and weight.]
- 3-5-ETS2-1(MA). Recognize that technology is any modification of the natural or designed world done to fulfill human needs or wants. These modifications can be improvements to existing technologies or the development of new technologies.*
- 3-5-ETS2-2(MA). Describe that technological products or devices are made up of parts. Use sketches or drawings to show how each part of a product or device relates to other parts in the product or device.*
- [Note: 3-5-ETS1-1, 3-5-ETS1-2, and 3-5-ETS1-4(MA) are found in Grade 3.]

MA Timeline

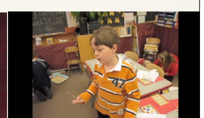
- Note: includes PK
- Draft MA NGSS standards available now
- Formal adoption starts in 2015-2016
- 2-3 year transition period to new MCAS (not PARCC)
- There are MCAS considerations until new MCAS is produced
- Crosswalk documents available

Curriculum Ideas

- Robotics
- Bridges
- Marble runs

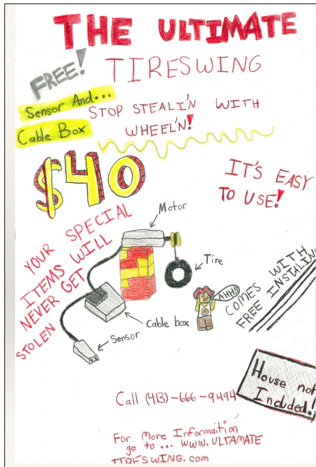


AMUSEMENT PARK RIDES - G2



AMUSEMENT PARK RIDES - G2

AIRPLANE STORIES - G3

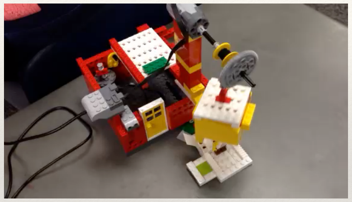


BURGLAR ALARM - G4

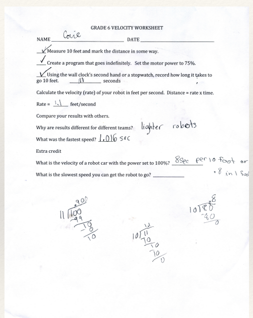
GRADE 4

GRADE 4 PLANNING

BURGLAR ALARM - G4



DRAGSTERS - G6


GRADE 6 VELOCITY WORKSHEET

NAME ______ DATE ______

___ Measure 10 feet and mark the distance in some way.

___ Create a program that goes indefinitely. Set the motor power to 75%.

___ Using the wall clock's second hand or a stopwatch, record how long it takes to go 10 feet. ______ seconds

Calculate the velocity (rate) of your robot in feet per second. Distance = rate x time.

Rate = ______ feet/second

Compare your results with others.

Why are results different for different teams?

What was the fastest speed?

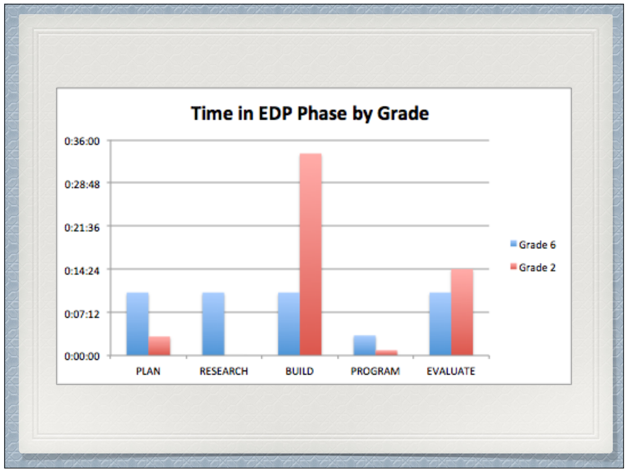
Extra credit

What is the velocity of a robot car with the power set to 100%? ______

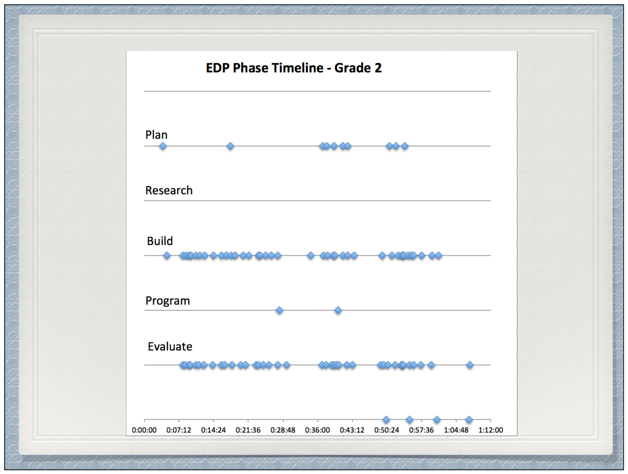
What is the slowest speed you can get the robot to go? ______

RESEARCH

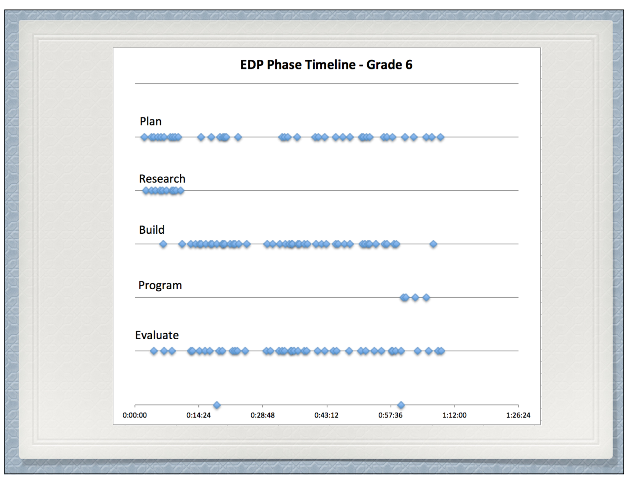
- Looking at differences between 2nd and 6th graders doing an open-ended engineering challenge
- Pilot study reveals significant differences in causal reasoning and planning



Time in EDP Phase by Grade
0:36:00
0:28:48
0:21:36
0:14:24
0:07:12
0:00:00
PLAN
RESEARCH
BUILD
PROGRAM
EVALUATE
Grade 6
Grade 2



EDP Phase Timeline - Grade 2
Plan
Research
Build
Program
Evaluate
0:00:00
0:07:12
0:14:24
0:21:36
0:28:48
0:36:00
0:43:12
0:50:24
0:57:36
1:04:48
1:12:00



EDP Phase Timeline - Grade 6
Plan
Research
Build
Program
Evaluate
0:00:00
0:14:24
0:28:48
0:43:12
0:57:36
1:12:00
1:26:24

Causal Reasoning Data

Code	Grade 2	Grade 6
Persist in non-optimal design	21	0
Correct Projection	15	44
Unanticipated consequences	8	0

MA STE vs NGSS ED Standards

- MA much more comprehensive
- Broken out by grade
- 4 Types
  - ETS1 = Engineering Design
  - ETS2 = Materials, Tools and Manufacturing
  - ETS3 = Technological Systems
  - ETS4 = Energy and Power Technologies
- See EXCEL spreadsheet

ENGINEERING PRACTICES RUBRIC

NGSS ENGINEERING PRACTICES RUBRIC

STUDENT(S): ____________________ DATE: __________

Engineering Practice (NGSS)	Goals	Beginning	Progressing	Proficient	Advanced
Defining problems	Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.	We understood the design problem.	We understood the design problem. We attended to some of the constraints of the problem. We used some science knowledge to limit possible solutions.	We had a good understanding of the design problem. We attended to multiple criterion and constraints. We used science knowledge to limit possible solutions.	We had an exceptional understanding of the design problem and could clearly articulate it. We attended to multiple criterion and constraints and understood the relationships between them. We used science knowledge and could clearly articulate the science behind our design.
Developing and using models	Develop or modify a model— based on evidence – to match what happens if a variable or component of a system is changed.	We noticed the direction of change when we changed one building or programming variable of the prototype. For example, we saw that if we increased the motor power, the prototype went faster.	We noticed the direction of change when we changed more than one building or programming variable of the prototype.	We created a mental model of our prototype's behavior. We understood and could name the all inputs and outputs of the prototype and we understood the direction of each building or programming variable.	We used a mental model of the prototype to understand the relationships between inputs and outputs in the prototype and we could write the formula of each relationship between each input and output.
Planning and carrying out investigations	Collect data about the performance of a proposed object, tool, process or system under a range of conditions. Evaluate the accuracy of various methods for collecting data.	We collected data on the performance of our prototype under at least one condition.	We collected data on the performance of their prototype under more than one condition.	We collected data on the performance of our prototype under a range of conditions. We evaluated the accuracy of our data collection method(s).	We collected significant amounts of data under a wide range of conditions. We improved the accuracy of our data collection methods
Analyzing and interpreting	Analyze data to define an optimal operational range	We collected some performance data of our	We collected performance data on our	We collected performance data of our prototype using	We collected some performance data of our

OVERALL IMPACT

MA Digital Literacy and CS Standards

- Under development
- Combined computer science and digital literacy
- Will not be tested

Resources

NGSS website http://www.nextgenscience.org

NGSS Introductory Video http://www.nextgenscience.org/case-next-generation-science-standards

MA NGSS website http://www.doe.mass.edu/stem/review.html

MA NGSS Comparison http://www.doe.mass.edu/stem/standards/NGSS-MAAComparison.html

MA NGSS FAQ http://www.doe.mass.edu/stem/standards/faq.html

Kids Engineer http://kidsengineer.com

Tufts Center for Engineering Education and Outreach http://ceeo.tufts.edu

Elementary Robotics: Sustaining the Natural Engineering Instincts of Children - available at Amazon.com

johnheffernan@verizon.net or jheffernan@hr-k12.org