

INSPIRE

Research Institute for Pre-College Engineering

Integrating Engineering in Science Standards and In-Service Teacher Preparation

Tamara J. Moore, Ph.D.

Associate Professor, Engineering Education

Director of STEM Integration, INSPIRE Institute

Purdue University

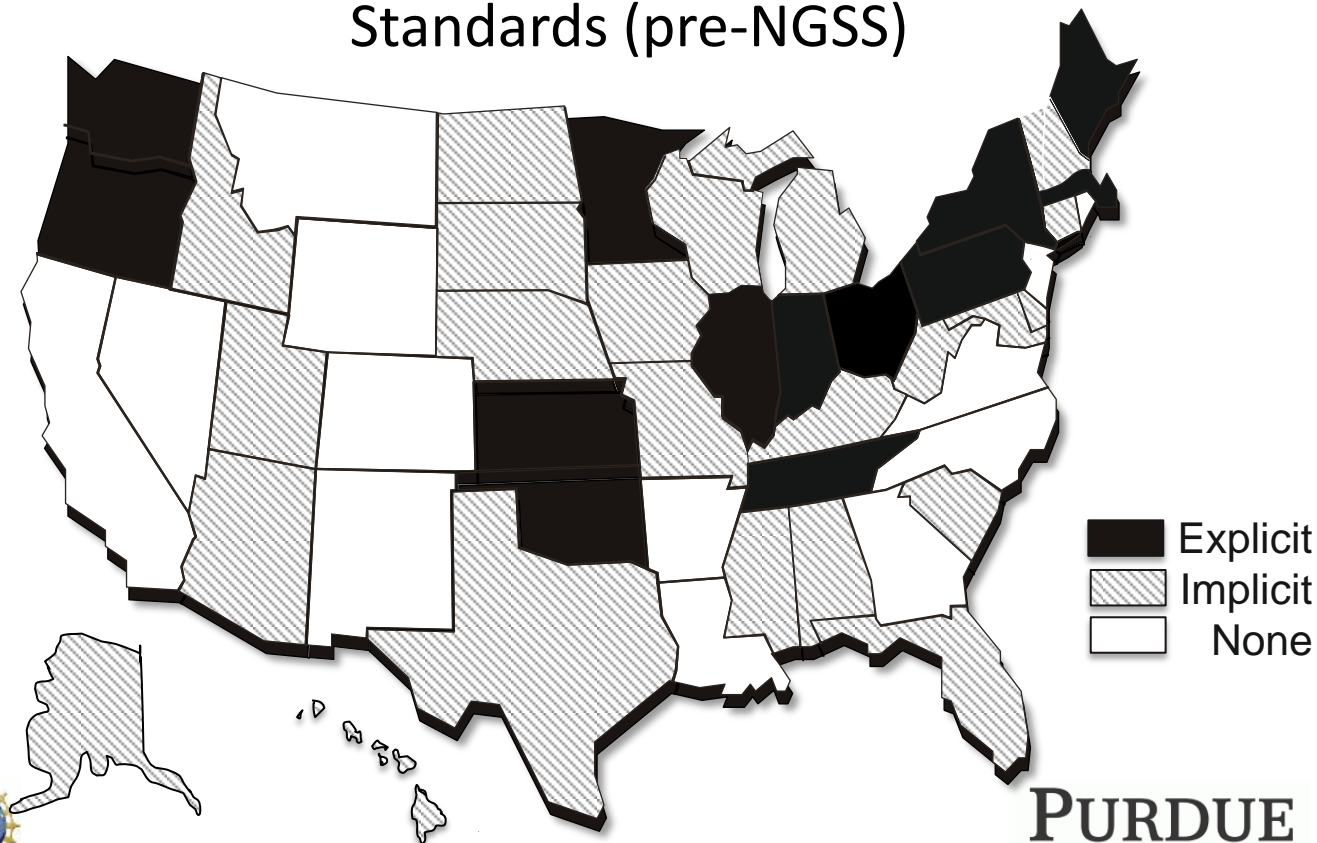


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Key Indicator		Description
Complete Processes of Design (POD)		Design processes are at the center of engineering practice. Solving engineering problems is an iterative process involving preparing, planning and evaluating the solution. Students should understand design by participating in each of the sub-indicators (POD-PB, POD-PI, POD-TE) below.
Sub-indicators of POD	Problem and Background (POD – PB)	Identification or formulation of engineering problems and research and learning activities necessary to gain background knowledge.
	Plan and Implement (POD – PI)	Brainstorming, developing multiple solutions, judging the relative importance of constraints and the creation of a prototype, model or other product.
	Test and Evaluate (POD – TE)	Generating testable hypotheses and designing experiments to gather data that should be used to evaluate the prototype or solution, and to use this feedback in redesign.
Apply Science, Engineering, Mathematics Knowledge (SEM)		The practice of engineering requires the application of science, mathematics, and engineering knowledge and engineering education at the K-12 level should emphasize this interdisciplinary nature.
Engineering Thinking (EThink)		Students should be independent and reflective thinkers capable of seeking out new knowledge and learning from failure when problems arise.
Conceptions of Engineers and Engineering (CEE)		K-12 students not only need to participate in an engineering process, but understand what an engineer does.
Engineering Tools, Techniques, and Processes (ETool)		Students studying engineering need to become familiar and proficient in the processes, techniques, skills, and tools engineers use in their work.
Issues, Solutions, and Impacts (ISI)		To solve complex and multidisciplinary problems, students need to be able to understand the impact of their solutions on current issues and vice versa.
Ethics (Ethics)		Students should consider ethical situations inherent in the practice of engineering.
Teamwork (Team)		In K-12 engineering education, it is important to develop students' abilities to participate as a contributing team member.
Communication Related to Engr (Comm-Engr)		Communication is the ability of a student to effectively take in information and to relay understandings to others in an engineering context.

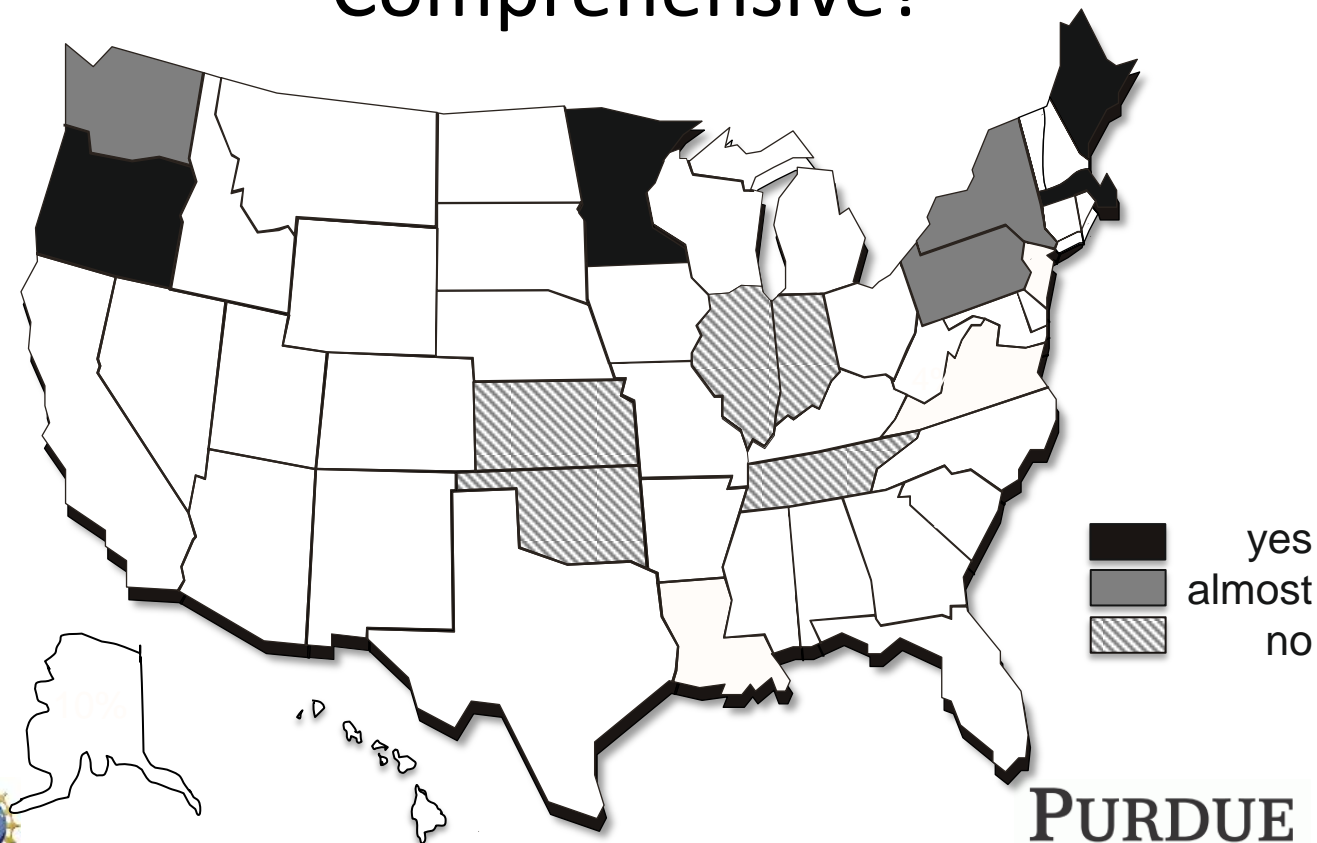
Landscape of Engineering in State Science Standards (pre-NGSS)



NSF EEC – 1442416, IIP – 1519387, DRL – 1543175, DRL - 1238140

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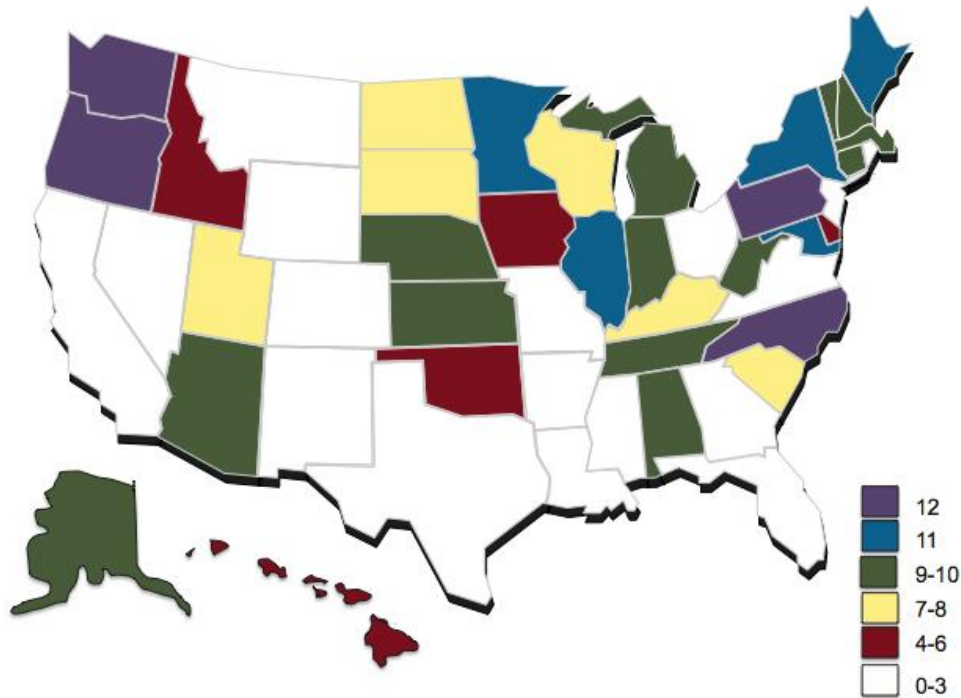
Comprehensive?



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State by State Completeness: Number of Key Indicators Met (pre-NGSS)



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Next Generation Science Standards

4-PS4 Waves and their Applications in Technologies for Information Transfer

4-PS4 Waves and their Applications in Technologies for Information Transfer		
Students who demonstrate understanding can:		
4-PS4-1. Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move. [Clarification Statement: Examples of models could include diagrams, analogies, and physical models using wire to illustrate wavelength and amplitude of waves.] [Assessment Boundary: Assessment does not include interference effects, electromagnetic waves, non-periodic waves, or quantitative models of amplitude and wavelength.]		
4-PS4-2. Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen. [Assessment Boundary: Assessment does not include knowledge of specific colors reflected and seen, the cellular mechanisms of vision, or how the retina works.]		
4-PS4-3. Generate and compare multiple solutions that use patterns to transfer information.* [Clarification Statement: Examples of solutions could include drums sending coded information through sound waves, using a grid of 1's and 0's representing black and white to send information about a picture, and using Morse code to send text.]		
The performance expectations above were developed using the following elements from the NRC document <i>A Framework for K-12 Science Education</i> .		
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Developing and Using Models Modeling in 3-5 builds on K-2 experiences and progresses to building and revising simple models and using models to represent events and design solutions. <ul style="list-style-type: none"> Develop a model using an analogy, example, or abstract representation to describe a scientific principle. (4-PS4-1) Develop a model to describe phenomena. (4-PS4-2) Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 3-5 builds on K-2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems. <ul style="list-style-type: none"> Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution. (4-PS4-3) 	PS4.A: Wave Properties <ul style="list-style-type: none"> Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; there is no net motion in the direction of the wave except when the water meets a beach. (Note: This grade band endpoint was moved from K-2.) (4-PS4-1) Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). (4-PS4-1) PS4.B: Electromagnetic Radiation <ul style="list-style-type: none"> An object can be seen when light reflected from its surface enters the eyes. (4-PS4-2) PS4.C: Information Technologies and Instrumentation <ul style="list-style-type: none"> Digitized information can be transmitted over long distances without significant degradation. High-tech devices, such as computers or cell phones, can receive and decode information—convert it from digitized form to voice—and vice versa. (4-PS4-3) ETS1.C: Optimizing The Design Solution <ul style="list-style-type: none"> Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (secondary to 4-PS4-3) 	Patterns <ul style="list-style-type: none"> Similarities and differences in patterns can be used to sort and classify natural phenomena. (4-PS4-1) Similarities and differences in patterns can be used to sort and classify designed products. (4-PS4-3) Cause and Effect <ul style="list-style-type: none"> Cause and effect relationships are routinely identified. (4-PS4-2) <hr/> Connections to Engineering, Technology, and Applications of Science <hr/> Interdependence of Science, Engineering, and Technology <ul style="list-style-type: none"> Knowledge of relevant scientific concepts and research findings is important in engineering. (4-PS4-3)
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Common Core State Standards Connections: ELA/Literacy — RI.4.1 Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text. (4-PS4-3) RI.4.9 Integrate information from two texts on the same topic in order to write or speak about the subject knowledgeably. (4-PS4-3) SL.4.5 Add audio recordings and visual displays to presentations when appropriate to enhance the development of main ideas or themes. (4-PS4-1), (4-PS4-2) Mathematics — MP.4 Model with mathematics. (4-PS4-1), (4-PS4-2) 4.G.A.1 Draw points, lines, line segments, rays, angles (right, acute, obtuse), and perpendicular and parallel lines. Identify these in two-dimensional figures. (4-PS4-1), (4-PS4-2)		

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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
<p>Developing and Using Models</p> <p>Modeling in 3-5 builds on K-2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.</p> <ul style="list-style-type: none"> Develop a model using an analogy, example, or abstract representation to describe a scientific principle. (4-PS4-1) Develop a model to describe phenomena. (4-PS4-2) <p>Constructing Explanations and Designing Solutions</p> <p>Constructing explanations and designing solutions in 3-5 builds on K-2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.</p> <ul style="list-style-type: none"> Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution. (4-PS4-3) <p>-----</p> <p>Connections to Nature of Science</p> <p>Scientific Knowledge is Based on Empirical Evidence</p> <ul style="list-style-type: none"> Science findings are based on recognizing patterns. (4-PS4-1) 	<p>PS4.A: Wave Properties</p> <ul style="list-style-type: none"> Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; there is no net motion in the direction of the wave except when the water meets a beach. (Note: This grade band endpoint was moved from K-2.) (4-PS4-1) Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). (4-PS4-1) <p>PS4.B: Electromagnetic Radiation</p> <ul style="list-style-type: none"> An object can be seen when light reflected from its surface enters the eyes. (4-PS4-2) <p>PS4.C: Information Technologies and Instrumentation</p> <ul style="list-style-type: none"> Digitized information can be transmitted over long distances without significant degradation. High-tech devices, such as computers or cell phones, can receive and decode information—convert it from digitized form to voice—and vice versa. (4-PS4-3) <p>ETS1.C: Optimizing The Design Solution</p> <ul style="list-style-type: none"> Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (secondary to 4-PS4-3) 	<p>Patterns</p> <ul style="list-style-type: none"> Similarities and differences in patterns can be used to sort and classify natural phenomena. (4-PS4-1) Similarities and differences in patterns can be used to sort and classify designed products. (4-PS4-3) <p>Cause and Effect</p> <ul style="list-style-type: none"> Cause and effect relationships are routinely identified. (4-PS4-2) <p>-----</p> <p>Connections to Engineering, Technology, and Applications of Science</p> <p>Interdependence of Science, Engineering, and Technology</p> <ul style="list-style-type: none"> Knowledge of relevant scientific concepts and research findings is important in engineering. (4-PS4-3)
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Common Core State Standards Connections: ELA/Literacy — RI.4.1 Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text. (4-PS4-3) RI.4.9 Integrate information from two texts on the same topic in order to write or speak about the subject knowledgeably. (4-PS4-3) SL.4.5 Add audio recordings and visual displays to presentations when appropriate to enhance the development of main ideas or themes. (4-PS4-1), (4-PS4-2) Mathematics — MP.4 Model with mathematics. (4-PS4-1), (4-PS4-2) G.4.A.1 Draw points, lines, line segments, rays, angles (right, acute, obtuse), and perpendicular and parallel lines. Identify these in two-dimensional figures. (4-PS4-1), (4-PS4-2)		

Next Generation Science Standards

4-PS4 Waves and their Applications in Technologies for Information Transfer

4-PS4 Waves and their Applications in Technologies for Information Transfer

Students who demonstrate understanding can:

- 4-PS4-1. Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can cause objects to move.** [Clarification Statement: Examples of models could include diagrams, analogies, and physical models using wire to illustrate wavelength and amplitude of waves.] [Assessment Boundary: Assessment does not include interference effects, electromagnetic waves, non-periodic waves, or quantitative models of amplitude and wavelength.]
- 4-PS4-2. Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.** [Assessment Boundary: Assessment does not include knowledge of specific colors reflected and seen, the cellular mechanisms of vision, or how the retina works.]
- 4-PS4-3. Generate and compare multiple solutions that use patterns to transfer information.*** [Clarification Statement: Examples of solutions could include drums sending coded information through sound waves, using a grid of 1's and 0's representing black and white to send information about a picture, and using Morse code to send text.]

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

Developing and Using Models

Modeling in 3-5 builds on K-2 experiences and progresses to building and revising simple models and using models to represent events and design solutions.

- Develop a model using an analogy, example, or abstract representation to describe a scientific principle. (4-PS4-1)
- Develop a model to describe phenomena. (4-PS4-2)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 3-5 builds on K-2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.

- Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution. (4-PS4-3)

Connections to Nature of Science

Scientific Knowledge is Based on Empirical Evidence

- Science findings are based on recognizing patterns. (4-PS4-1)

Disciplinary Core Ideas

PS4.A: Wave Properties

- Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; there is no net motion in the direction of the wave except when the water meets a beach. (Note: This grade band endpoint was moved from K-2.) (4-PS4-1)
- Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). (4-PS4-1)

PS4.B: Electromagnetic Radiation

- An object can be seen when light reflected from its surface enters the eyes. (4-PS4-2)

PS4.C: Information Technologies and Instrumentation

- Digitized information can be transmitted over long distances without significant degradation. High-tech devices, such as computers or cell phones, can receive and decode information—convert it from digitized form to voice—and vice versa. (4-PS4-3)

ETS1.C: Optimizing The Design Solution

- Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (Secondary to 4-PS4-3)

Crosscutting Concepts

Patterns

- Similarities and differences in patterns can be used to sort and classify natural phenomena. (4-PS4-1)
- Similarities and differences in patterns can be used to sort and classify designed products. (4-PS4-3)

Cause and Effect

- Cause and effect relationships are routinely identified. (4-PS4-2)

Connections to Engineering, Technology, and Applications of Science

Interdependence of Science, Engineering, and Technology

- Knowledge of relevant scientific concepts and research findings is important in engineering. (4-PS4-3)

Connections to other DCIs in fourth grade: **4.PS3.A** (4-PS4-1); **4.PS3.B** (4-PS4-1); **4.ETS1.A** (4-PS4-3)

Articulation of DCIs across grade-levels: **K.ETS1.A** (4-PS4-3); **1.PS4.B** (4-PS4-2); **1.PS4.C** (4-PS4-3); **2.ETS1.B** (4-PS4-3); **2.ETS1.C** (4-PS4-3); **3.PS2.A** (4-PS4-3); **MS.PS4.A** (4-PS4-1); **MS.PS4.B** (4-PS4-2); **MS.PS4.C** (4-PS4-3); **MS.LS1.D** (4-PS4-2); **MS.ETS1.B** (4-PS4-3)

Common Core State Standards Connections:

ELA/Literacy—

RI.4.1 Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text. (4-PS4-3)

RI.4.9 Integrate information from two texts on the same topic in order to write or speak about the subject knowledgeably. (4-PS4-3)

SL.4.5 Add audio recordings and visual displays to presentations when appropriate to enhance the development of main ideas or themes. (4-PS4-1), (4-PS4-2)

Mathematics—

MP.4 Model with mathematics. (4-PS4-1), (4-PS4-2)

4.G.A.1 Draw points, lines, line segments, rays, angles (right, acute, obtuse), and perpendicular and parallel lines. Identify these in two-dimensional figures. (4-PS4-1), (4-PS4-2)

Next Generation Science Standards

4-PS4 Waves and their Applications in Technologies for Information Transfer

4-PS4 Waves and their Applications in Technologies for Information Transfer		
Students who demonstrate understanding can:		
4-PS4-1. Develop a model of waves to describe patterns in terms of amplitude and wavelength and that waves can move objects to move. [Clarification Statement: Examples of models could include diagrams, analogies, and physical models using wire, beads, and a slinky to represent the amplitude and wavelength of waves.] [Assessment Boundary: Assessment does not include interference effects, electromagnetic waves, non-periodic waves, or quantitative models of amplitude and wavelength.]		
4-PS4-2. Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen. [Assessment Boundary: Assessment does not include knowledge of specific colors reflected and seen, the cellular mechanism of vision, or how the retina works.]		
4-PS4-3. Generate and compare multiple solutions that use patterns to transfer information.* [Clarification Statement: Examples of solutions could include drums sending coded information through sound waves, using a grid of 1's and 0's representing black and white to send information about a picture, and using Morse code to send text.]		
The performance expectations above were developed using the following elements from the NRC document <i>A Framework for K-12 Science Education</i> .		
Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 3-5 builds on K-2 experiences and progresses to building and revising simple models and using models to represent events and design solutions. <ul style="list-style-type: none"> Develop a model using an analogy, example, or abstract representation to describe a scientific principle. (4-PS4-1) Develop a model to describe phenomena. (4-PS4-2) Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 3-5 builds on K-2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems. <ul style="list-style-type: none"> Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution. (4-PS4-3) 	PS4.A: Wave Properties <ul style="list-style-type: none"> Waves, which are regular patterns of motion, can be made in water by disturbing the surface. When waves move across the surface of deep water, the water goes up and down in place; there is no net motion in the direction of the wave except when the water meets a beach. (Note: This grade band endpoint was moved from K-2.) (4-PS4-1) Waves of the same type can differ in amplitude (height of the wave) and wavelength (spacing between wave peaks). (4-PS4-1) PS4.B: Electromagnetic Radiation <ul style="list-style-type: none"> An object can be seen when light reflected from its surface enters the eyes. (4-PS4-2) PS4.C: Information Technologies and Instrumentation <ul style="list-style-type: none"> Digitized information can be transmitted over long distances without significant degradation. High-tech devices, such as computers or cell phones, can receive and decode information—convert it from digitized form to voice—and vice versa. (4-PS4-3) ETS1.C: Optimizing The Design Solution <ul style="list-style-type: none"> Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (secondary to 4-PS4-3) 	Patterns <ul style="list-style-type: none"> Similarities and differences in patterns can be used to sort and classify natural phenomena. (4-PS4-1) Similarities and differences in patterns can be used to sort and classify designed products. (4-PS4-3) Cause and Effect <ul style="list-style-type: none"> Cause and effect relationships are routinely identified. (4-PS4-2) <hr/> Connections to Engineering, Technology, and Applications of Science <hr/> Interdependence of Science, Engineering, and Technology <ul style="list-style-type: none"> Knowledge of relevant scientific concepts and research findings is important in engineering. (4-PS4-3)
Connections to Nature of Science Scientific Knowledge is Based on Empirical Evidence <ul style="list-style-type: none"> Science findings are based on recognizing patterns. (4-PS4-1) 		
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ELA/Literacy –		
RI.4.1 Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text. (4-PS4-3)		
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Mathematics –		
MP.4 Model with mathematics. (4-PS4-1), (4-PS4-2)		
4.G.A.1 Draw points, lines, line segments, rays, angles (right, acute, obtuse), and perpendicular and parallel lines. Identify these in two-dimensional figures. (4-PS4-1), (4-PS4-2)		

How does NGSS fare?

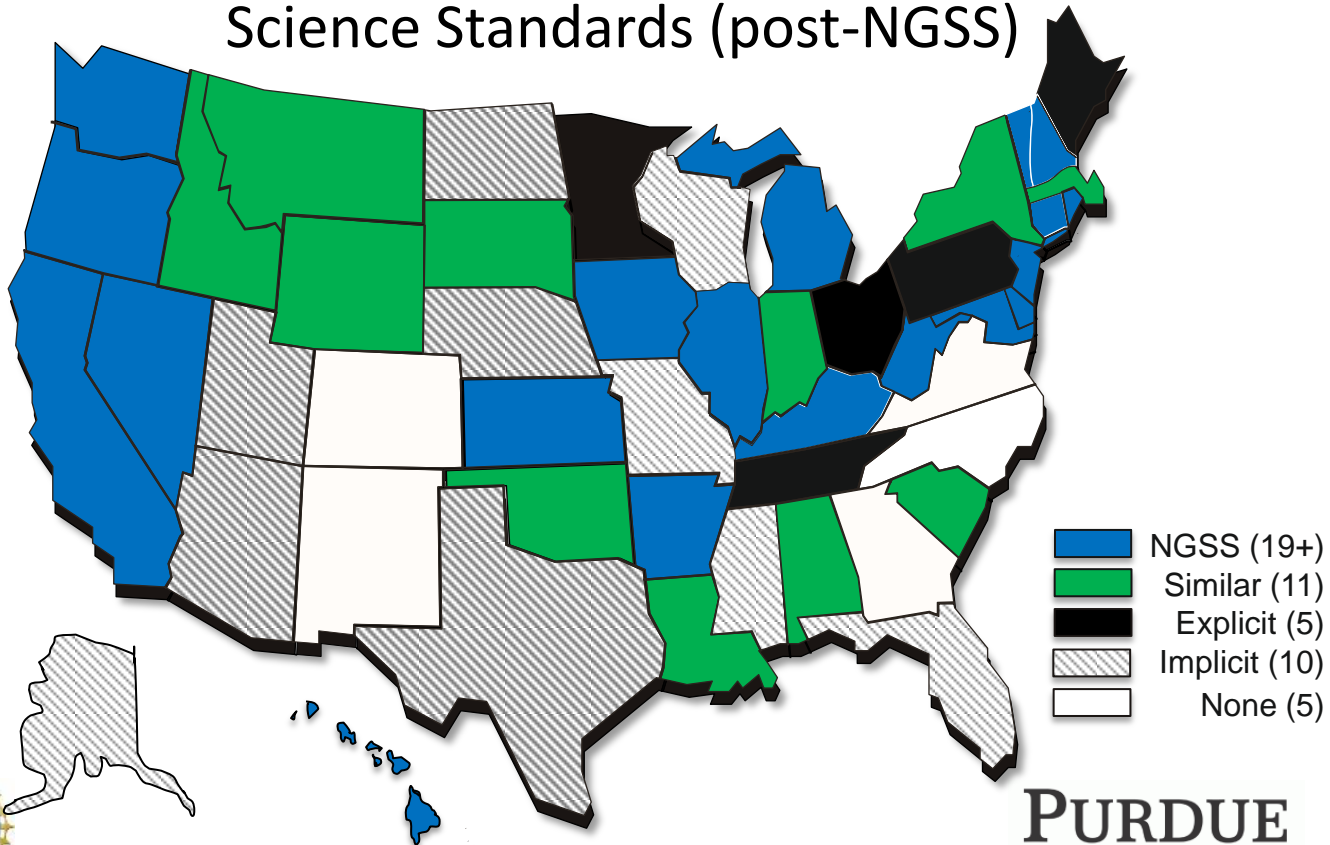
Examination of the Type of Engineering Included in the NGSS as Measured by the Key Indicators

Number of Key Indicators of Engineering Included	NGSS Category
11	Learning Goals (LGs)
10	Performance Expectations (PEs)

Distribution of Engineering-related Performance Expectations and Learning Goals Across Grade Bands

Grades	K-12	K-2	3-5	6-8	9-12
Number of Engineering-related Performance Expectations	49	13	9	13	14
Number of Engineering-related Learning Goals	76	19	15	22	20
Total	125	32	24	35	34

Updated Landscape of Engineering in State Science Standards (post-NGSS)



NSF EEC – 1442416, IIP – 1519387, DRL – 1543175, DRL - 1238140



PURDUE
UNIVERSITY

INSPIRE Research Institute for Pre-College Engineering

MODELS OF INSERVICE TEACHER PREPARATION TO INTEGRATE ENGINEERING IN THE SCIENCE CLASSROOM



NSF EEC – 1442416, IIP – 1519387, DRL – 1543175, DRL - 1238140



Region 11 MSTP Math and Science Teacher Partnership 2008-2015



A Minnesota state-wide K-12 Professional Development Initiative

- 2819 teachers
- 401 schools
- 42 districts
- 187,457 students

www.region11mathandscience.org

MN: Nature of Science and Engineering PD

- 5 days across AY
- Teachers must come in teams
- PLC between each day
- Administrators required to participate in one day concurrent PD

2011-2012 NSE (Gr. 3-6)

Day 1	Engineering and Engineering Design
Day 2	Design and Redesign
Day 3	Nature of Science and Scientific Inquiry
Day 4	Connecting Science and Engineering
Day 5	Modeling and Celebration

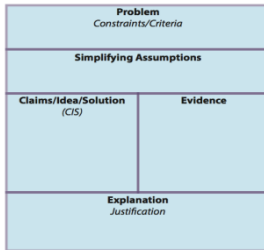


Region 11 MSTP

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Engineering as the Pedagogy of STEM Integration

Evidence-Based Reasoning



Have a personally meaningful, motivating, and engaging **CONTEXT**

Have learners participate in an **ENGINEERING DESIGN** task for a compelling purpose that involves problem-solving skills and ties to context

Allow learners to **LEARN FROM FAILURE** and then have the opportunity to **RE-DESIGN**

Include appropriate, standards-based science and/or mathematics **CONTENT**

Teach content with **STUDENT-CENTERED** pedagogies

Promote **COMMUNICATION** skills and **TEAMWORK**

Thread the **ENGINEERING** and **CONTEXT** THROUGHOUT the experience, not just at the beginning and end.

Engage students in **EVIDENCE-BASED REASONING** to integrate the subjects.

Engineering Design Process *A way to improve*

