Professional Development Strategies for Implementing Integrated STEM Education in the Elementary Classroom

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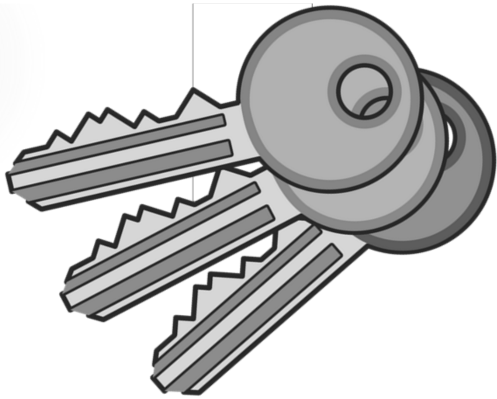
Professional Development



- ✓ Recognize the need for elementary STEM
- ✓ Cultivate a vision for elementary STEM
- ✓ Understand problem/project-based learning & assessment
- ✓ Develop STEM curriculum

Assumptions about STEM

- **K-12 STEM** = **Integrated S**cience, **T**echnology, **E**ngineering, and **M**athematics
  - **Science** – Discover and describe - A better understanding of life and the natural world (What is)
  - **Technology** – Invent and innovate – The human-made world - Improving the natural world
  - **Engineering** – Control, modification, or design of materials, processes, and systems (What could be)
  - **Mathematics** –Symbolic language for representing reality – (Making sense of the world through numbers)

- 21st century economy will be increasingly driven by contributions that come from discoveries and innovations in STEM

What We Need in Schools

- Improve the quality of STEM education and experiences;
- Promote engaged learning in STEM fields;
- Prepare teachers to deliver comprehensive STEM education;
- Encourage individuals from underrepresented groups to engage in the STEM disciplines; and,
- Increase the number of students in STEM programs and fields.

STEM in Elementary School

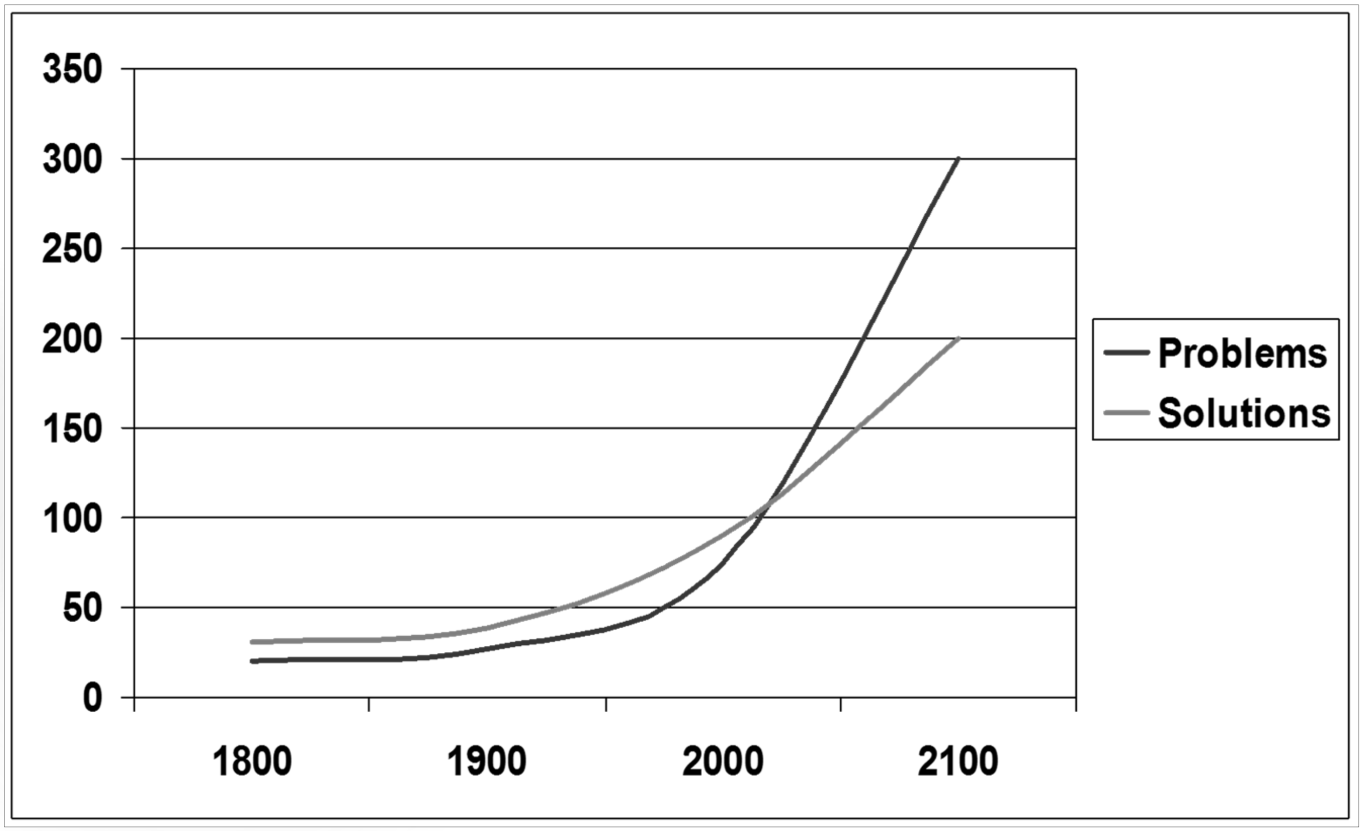
Call for Action

- Educational and political efforts are being made to improve students' overall performance, attitudes, and aspirations to learn in STEM subjects
- School districts across the nation are implementing STEM programs in their schools
  - However, STEM programs are primarily targeted at middle and high school grades
  - Students have already decided by this point whether STEM subjects will be of interest and regardless of program and are not likely to change their minds
    - In 2008 315 STEM programs were being implemented but only 3-4% included elementary grades

Why STEM in Early Grades

- It is important that special attention and efforts be given to students who are in critical grade levels (Elementary) for developing dispositional attitudes toward learning in STEM subjects
- Up to 50% of elementary students turn away from STEM disciplines by 3rd or 4th grade
- 29% of elementary teachers report teaching science two or fewer days per week.

The Ingenuity Gap



Currently, Schools Tend to:

- Emphasize solving problems correctly
- Minimize creativity
- Focus on tests, grades, college admissions
- Reward factual competence and logical thinking

What Needs to be Emphasized

- Critical thinking
- Problem solving abilities
- Leadership and teamwork
- Ethics and responsibility
- Invention, imagination, and ingenuity
- Communications

Quick challenge: ‘The Color Trader’

Cooperative Learning Activity

Teacher Summary

At the conclusion of this activity, ask the teams to share their team scores.

Typically, you will find that a number of the teams lost a significant amount of money. This loss is caused by a lack of cooperation among the teams. If all teams cooperated, each team would complete the activity with a total of $40,000.

However, most of your teams will probably not complete the activity with this total. This lack of cooperation between teams is very common. You may wish to calculate the total amount of money that could have been earned by the class if all teams had cooperated. The lesson: Cooperation between competitors is not always a negative.

Too often, we teach students that in order to win, they must defeat their competition—this is most often not true in the "real-world".

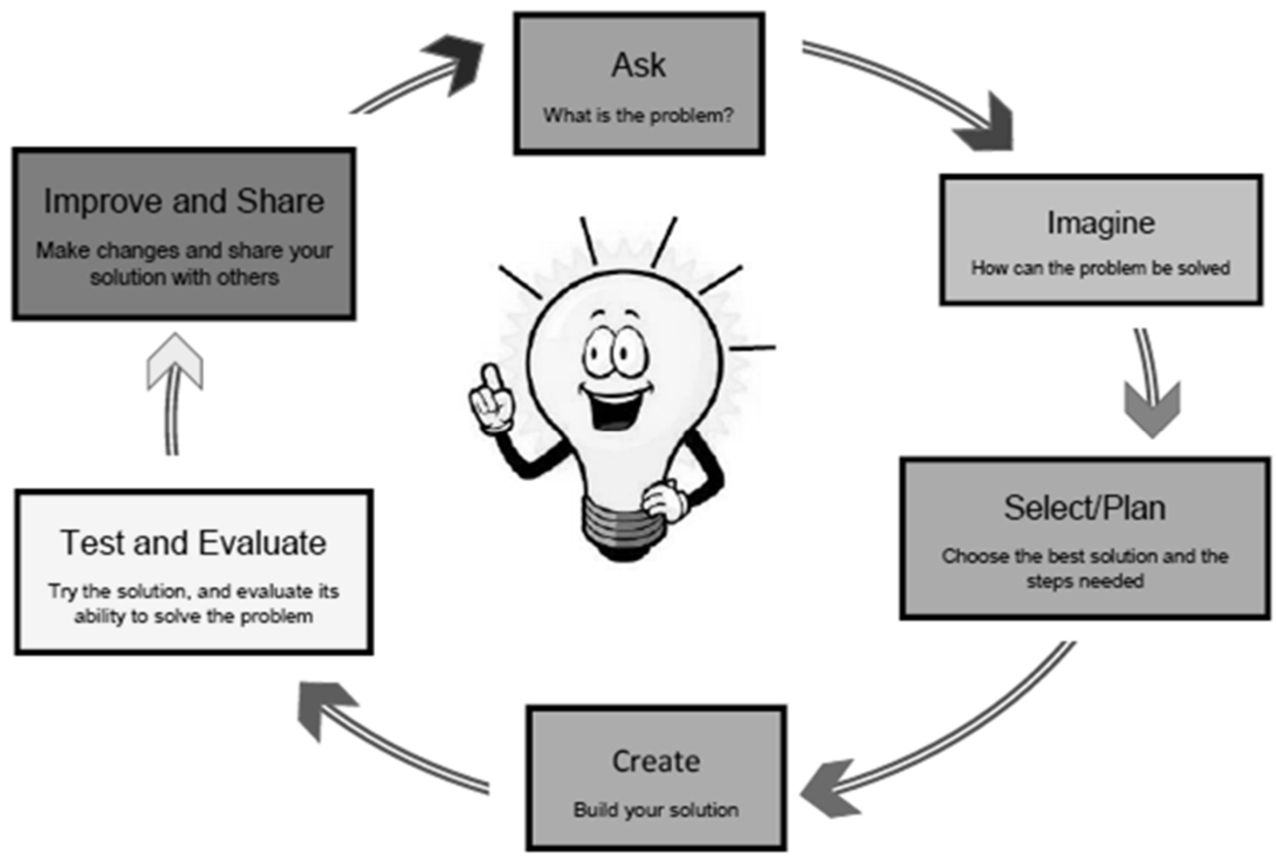
Attributes of STEM

How does STEM work?

- Technological literacy
- Creativity, problem solving and real world application
- Creating real and relatable experiences for the student
    - Shows the importance of the information being taught
- Relevant to the students' world and perspectives
- Thinking tools (heuristics)
- The ability to synthesize information
- Creating a body of content knowledge

Engineering Design Loop

- **What is the Design Loop?**
  - The Design Loop is a tool that helps make design problem solving a more effective learning tool for students
  - A structure for thinking and doing- the essence of design problem solving
  - Designing is not a linear process



Quick challenge: Spring Rockets
Repeatability and Accuracy

Questions: What items can you think of that use springs?

How many of those items are used more than once for the same purpose?

Challenge: How can you design a spring loaded rocked that can be used to hit a specific target?

Materials: 1 spring from a pen, 1 straw, 1 candy stick, masking tape, sticky-tack, and a cardboard base

Tools: writing utensils, scissors, protractors, and rulers

Is your design repeatable and accurate? Are your results consistent? What is the difference?

Strategies for STEM Problem Solving

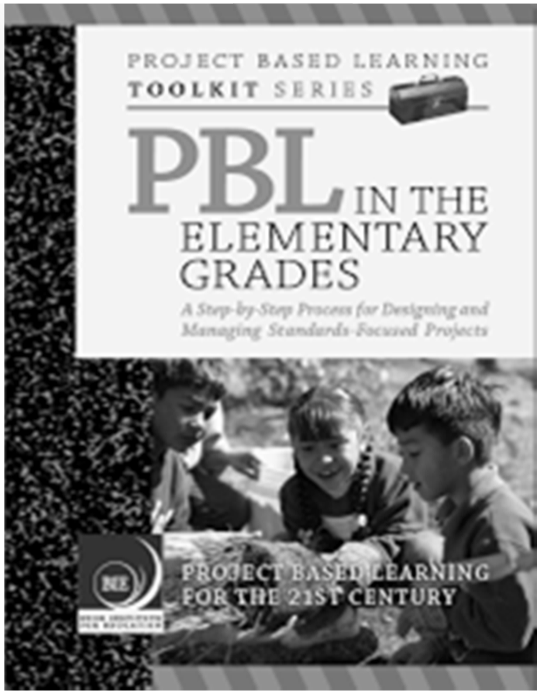
- How do your students approach a problem where the answer is unknown?
- What steps do you take to solve a problem?
- Are your students aware of heuristics used to solve complex problems?

Problem-based learning

- Students develop a solution to a problem or issue

Project-based learning

- Students develop a tangible artifact



- Project/problem-based instruction has become popular because of its impact on student learning
- It is focused on experimental learning organized around the investigation and resolution of messy, holistic, and real world problems
- Creates a learning environment that facilitates deeper understanding

Problem/Project Based Learning (PBL)

How does PBL work?

- Using ill-structured problems to increase personal responsibility for learning
- Engaging students in math, science, technology and engineering at an early age.
- Causing students to gather information, assess its validity, and provide evidence to support decisions.
- Teaching and encouraging learning transfer
- Treating teamwork as an important outcome
- Most important - teaching occurs after, not before, students attempt to perform – when students are ready to hear and grasp its value

Problem/Project Based Learning

Through PBL, students learn:

- Problem solving skills
- Self-directed learning skills
- Ability to find and use resources
- Critical thinking
- Measurable knowledge base
- Performance ability
- Social and ethical skills
- Ability to work on a team
- To become self-sufficient and self-motivated
- Facility with computer
- Leadership skills
- Communication skills
- Proactive thinking
- Congruence with workplace skills

Creating STEM Lessons

Stages in the Understanding by Design (Backward Design) Process

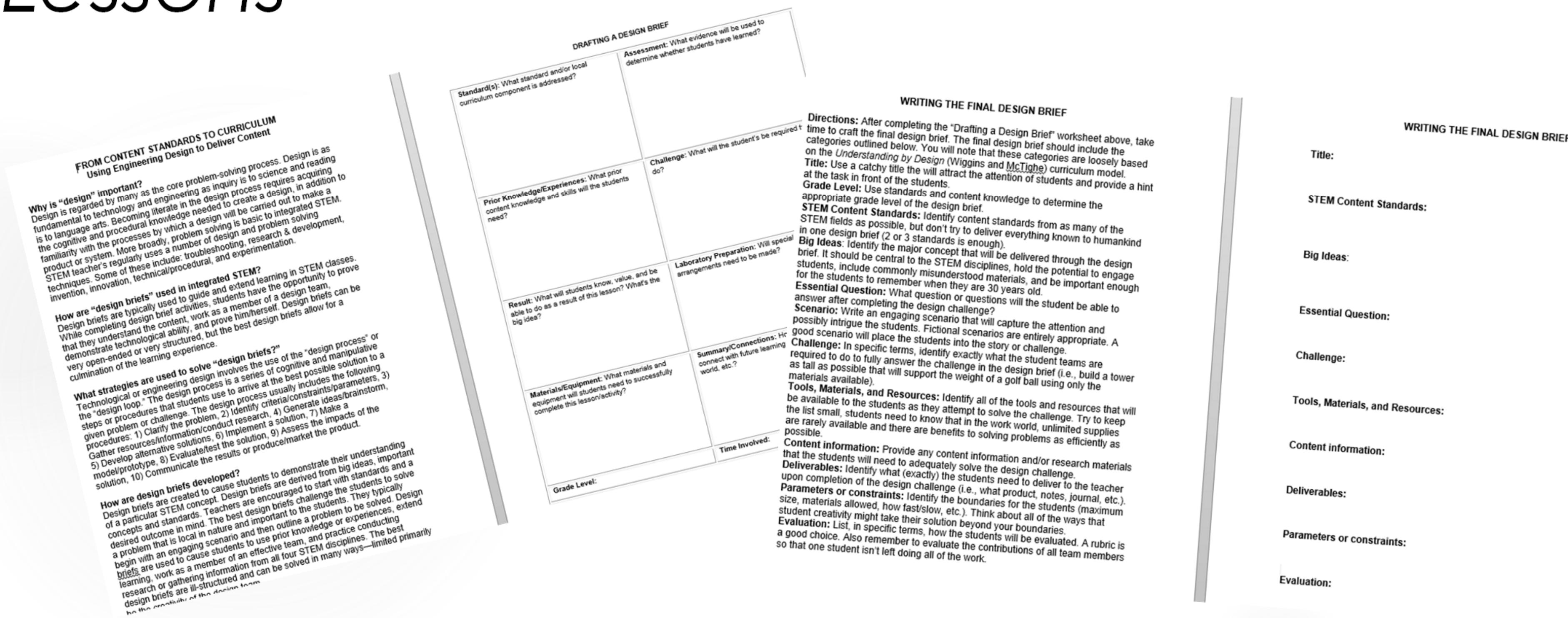
Identify desired results

Determine acceptable evidence

Plan learning experiences and instruction

From Content Standards to Curriculum

Using Engineering Design to Deliver Lessons



FROM CONTENT STANDARDS TO CURRICULUM
Using Engineering Design to Deliver Content

Why is "design" important?
Design is regarded by many as the core problem-solving process. Design is as fundamental to technology and engineering as inquiry is to science and reading is to language arts. Becoming literate in the design process requires acquiring the cognitive and procedural knowledge needed to create a design, in addition to familiarity with the processes by which a design will be carried out to make a product or system. More broadly, problem solving is basic to integrated STEM. STEM teacher's regularly uses a number of design and problem solving techniques. Some of these include: troubleshooting, research & development, invention, innovation, technical/procedural, and experimentation.

How are "design briefs" used in integrated STEM?
Design briefs are typically used to guide and extend learning in STEM classes. While completing design brief activities, students have the opportunity to prove that they understand the content, work as a member of a design team, demonstrate technological ability, and prove him/herself. Design briefs can be very open-ended or very structured, but the best design briefs allow for a culmination of the learning experience.

What strategies are used to solve "design briefs?"
Technological or engineering design involves the use of the "design process" or the "design loop." The design process is a series of cognitive and manipulative steps or procedures that students use to arrive at the best possible solution to a given problem or challenge. The design process usually includes the following procedures: 1) Clarify the problem, 2) Identify criteria/constraints/parameters, 3) Gather resources/information/conduct research, 4) Generate ideas/brainstorm, 5) Develop alternative solutions, 6) Implement a solution, 7) Make a model/prototype, 8) Evaluate/test the solution, 9) Assess the impacts of the solution, 10) Communicate the results or produce/market the product.

How are design briefs developed?
Design briefs are created to cause students to demonstrate their understanding of a particular STEM concept. Design briefs are derived from big ideas, important concepts and standards. Teachers are encouraged to start with standards and a desired outcome in mind. The best design briefs challenge the students to solve a problem that is local in nature and important to the students. They typically begin with an engaging scenario and then outline a problem to be solved. Design briefs are used to cause students to use prior knowledge or experiences, extend learning, work as a member of an effective team, and practice conducting research or gathering information from all four STEM disciplines. The best design briefs are ill-structured and can be solved in many ways—limited primarily be the creativity of the design team.

DRAFTING A DESIGN BRIEF

Standard(s): What standard and/or local curriculum component is addressed?	**Assessment:** What evidence will be used to determine whether students have learned?
Prior Knowledge/Experiences: What prior content knowledge and skills will the students need?	**Challenge:** What will the student's be required t[o] do?
Result: What will students know, value, and be able to do as a result of this lesson? What's the big idea?	**Laboratory Preparation:** Will special arrangements need to be made?
Materials/Equipment: What materials and equipment will students need to successfully complete this lesson/activity?	**Summary/Connections:** Ho[w] connect with future learning world, etc.?
	Time Involved:
Grade Level:	

WRITING THE FINAL DESIGN BRIEF

Directions: After completing the "Drafting a Design Brief" worksheet above, take time to craft the final design brief. The final design brief should include the categories outlined below. You will note that these categories are loosely based on the *Understanding by Design* (Wiggins and McTighe) curriculum model.
Title: Use a catchy title the will attract the attention of students and provide a hint at the task in front of the students.
Grade Level: Use standards and content knowledge to determine the appropriate grade level of the design brief.
STEM Content Standards: Identify content standards from as many of the STEM fields as possible, but don't try to deliver everything known to humankind in one design brief (2 or 3 standards is enough).
Big Ideas: Identify the major concept that will be delivered through the design brief. It should be central to the STEM disciplines, hold the potential to engage students, include commonly misunderstood materials, and be important enough for the students to remember when they are 30 years old.
Essential Question: What question or questions will the student be able to answer after completing the design challenge?
Scenario: Write an engaging scenario that will capture the attention and possibly intrigue the students. Fictional scenarios are entirely appropriate. A good scenario will place the students into the story or challenge.
Challenge: In specific terms, identify exactly what the student teams are required to do to fully answer the challenge in the design brief (i.e., build a tower as tall as possible that will support the weight of a golf ball using only the materials available).
Tools, Materials, and Resources: Identify all of the tools and resources that will be available to the students as they attempt to solve the challenge. Try to keep the list small, students need to know that in the work world, unlimited supplies are rarely available and there are benefits to solving problems as efficiently as possible.
Content information: Provide any content information and/or research materials that the students will need to adequately solve the design challenge.
Deliverables: Identify what (exactly) the students need to deliver to the teacher upon completion of the design challenge (i.e., what product, notes, journal, etc.).
Parameters or constraints: Identify the boundaries for the students (maximum size, materials allowed, how fast/slow, etc.). Think about all of the ways that student creativity might take their solution beyond your boundaries.
Evaluation: List, in specific terms, how the students will be evaluated. A rubric is a good choice. Also remember to evaluate the contributions of all team members so that one student isn't left doing all of the work.

WRITING THE FINAL DESIGN BRIEF

Title:

STEM Content Standards:

Big Ideas:

Essential Question:

Challenge:

Tools, Materials, and Resources:

Content information:

Deliverables:

Parameters or constraints:

Evaluation:

7 Elements of a Good STEM Lesson/Project

1. **Purpose and Relevance:** Is it personally relevant to the students? Does it provide a certain level of intrigue? Does it cause the student to want to invest time and effort?
2. **Time:** Projects can last one class period or an entire term, but time must be provided to research, plan, build, test, debug, retest, and communicate.
3. **Complexity:** The best STEM projects include content from all disciplines in STEM and the connections between these content areas.
4. **Intensity:** Tap into that natural intensity that children exhibit when mastering a video game, reading a new book from a series, etc.
5. **Connection:** Great projects or prompts force students to connect with other students, people, and ideas (think Internet) with whom they might not naturally connect.
6. **Communication:** The big idea of PBL is the concept that the final solution must be shared and defended. This provides a great deal of motivation and a sense of satisfaction.
7. **Novelty:** Perhaps the most important consideration in STEM. Few project ideas are so profound that they can be used year after year with the same level of success with students (think egg drop activity). If the teacher is bored with the idea, students will be bored with the idea.

Creating STEM Lessons - PBL

Six essential features for Problem/Project-based task:

1. Have a clear purpose that specifies the decision that will be made resulting from the assessment.
2. Focus be on process, product, or both
3. No simple right or wrong answers; they must be assessed along some sort of continuum.
4. Focus on *degrees* (e.g., quality, proficiency, understanding, etc.).
5. Try to reduce potential subjectivity in scoring.
6. Share scoring information with students early—as a guide

Developing Design Briefs

1. Make sure it delivers something important

   (standards, big ideas, extension of a lesson or unit)

   - But remember, it's not something fun to do after the lesson—it is the lesson

2. Make sure it captures a big idea and answers an essential question (think assessment)

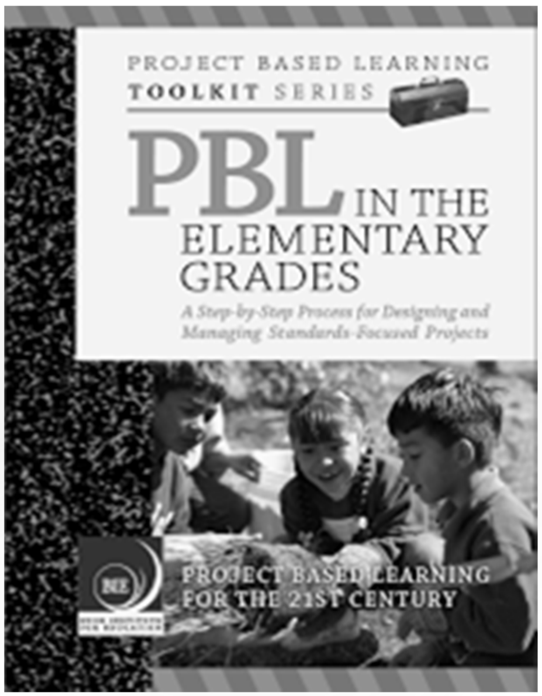
   Big idea filters

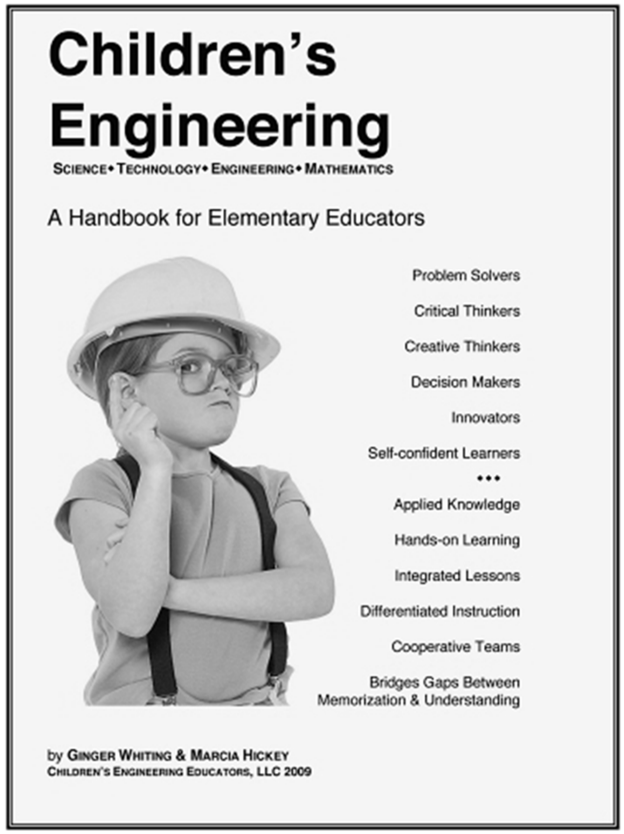
   - Is it important enough to remember when the child is 30?
   - Does it have the potential to engage to child?
   - Is it central to understanding the STEM content?

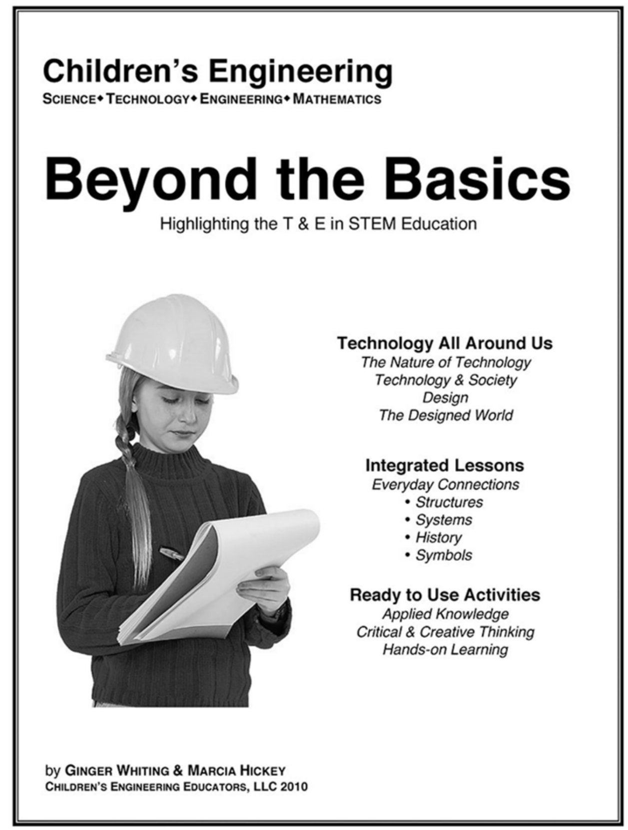
Developing Design Briefs

3. Develop a problem scenario
   - Craft an engaging scenario that both captures the attention of the child and engages them in solving an authentic problem
4. Develop content information.
   - Using the standards and big ideas for the problem, develop content information that promotes learning in science, technology, engineering, and mathematics.
5. Develop boundaries for the problem (materials/resources, parameters, deliverables)
6. Develop an authentic, performance-based assessment
7. Force students to use the Design Loop

Recommended Reading







STEM Assessment

Common concerns

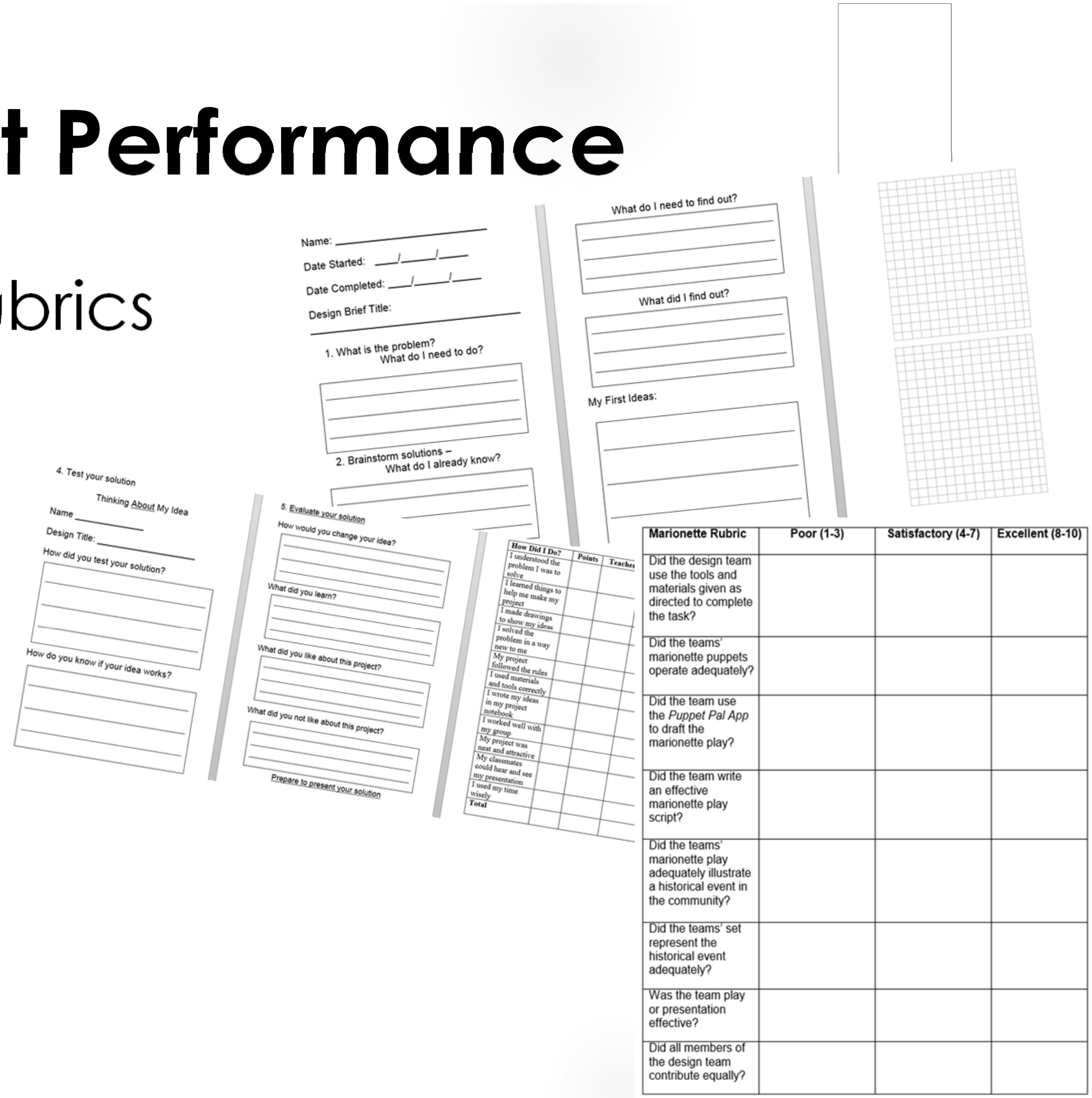
- Grading
  - Group projects
- Content Expert
- Meeting the Standards
  - Standardized testing
- Parental Questions/Concerns

Need to be able to access:

- Problem-solving
- Quality of work
- Creativity
  - Creative use of materials
- Efficiency
- Collaboration
- Learning

Assessing Student Performance

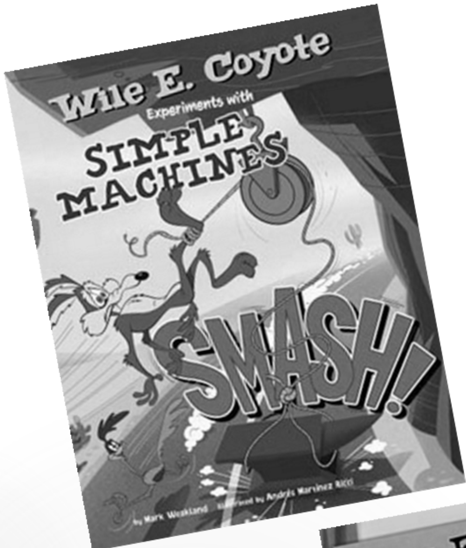
- Team performance rubrics
- Journals and logs
    - Engineering journals
        - Digital or paper
    - Analytical writing
- Checklist
- Models / Prototypes
- Cooperative learning
- Presentations

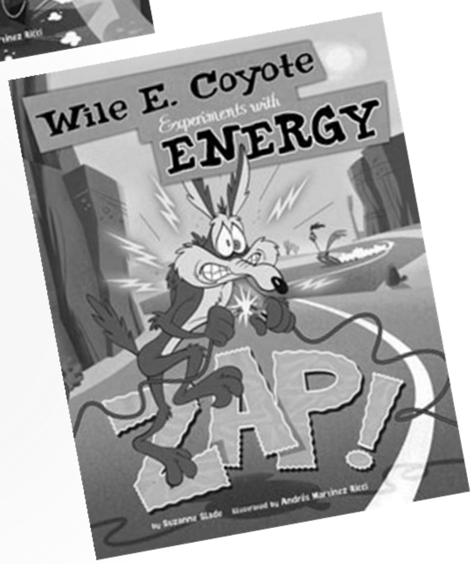


Marionette Rubric	Poor (1-3)	Satisfactory (4-7)	Excellent (8-10)
Did the design team use the tools and materials given as directed to complete the task?			
Did the teams' marionette puppets operate adequately?			
Did the team use the *Puppet Pal App* to draft the marionette play?			
Did the team write an effective marionette play script?			
Did the teams' marionette play adequately illustrate a historical event in the community?			
Did the teams' set represent the historical event adequately?			
Was the team play or presentation effective?			
Did all members of the design team contribute equally?			

Performance-based Assessments

- Based in the "real world" = *authentic assessment*
- Must be linked to instructional objectives/standards
- Assessments, by themselves, are meaningful learning activities
- Specific behaviors/capabilities should be observed
- Measure complex capabilities/skills that can't be measured with pencil-and-paper tests
- Must focus on teachable processes
- Can specifically target procedures used by students to solve problems
- Results in tangible outcome or product





Spring Into Action

Grade: 3

Unit: STEM - Force and Motion

STEM Content Standards:

Science
Next Generation Science Standards: PS2.A and PS2.B, The effect of unbalanced forces on an object results in a change of motion. Patterns of motion can be used to predict future motion. Some forces act through contact, some forces act even when the objects are not in contact. The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.

Technology
Standards for Technological Literacy: Standard 2, Students will develop an understanding of the core concepts of technology.

- B. Systems have parts or components that work together to accomplish a goal.

Engineering
Standards for Technological Literacy: Standard 9, Students will develop an understanding of engineering design.

- A. The engineering design process includes identifying a problem, looking for ideas, developing solutions, and sharing solutions with others.

Next Generation Science Standards: ETS 1-1, 1-2, 1-3, Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost; 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; 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.

Math
Common Core State Standards: Standard 2.MD.1, Measure the length of an object by selecting and using appropriate tools such as rulers, yardsticks, meter sticks, and measuring tapes.
Common Core State Standards: Standard 2.MD.10, Draw a picture graph and a bar graph (with single- unit scale) to represent a data set with up to four categories. Solve simple put- together, take- apart, and compare problems using information presented in a bar graph.

English Language Arts
Common Core State Curriculum Framework: SL1 CCR Anchor Standard: Prepare for and participate effectively in a range of conversations and collaborations with diverse partners, building on others' ideas and expressing their own clearly and persuasively.
Common Core State Curriculum Framework: SL4 CCR Anchor Standard: Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.

http://www.uastem.com/downloads/

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