Introduction for Educators

The Maryland Department of Transportation State Highway Administration (MDOT SHA) has prepared the Bridging Maryland, Becoming Engineers Lesson Plan for free use to aid educators in guiding students in learning about basic bridge engineering and the Engineering Design Process through a combination of information presented about historic bridges and through hands-on problem solving. To provide an engaging and unique experience, this Lesson Plan is framed by the real-world story of the design of a specific bridge that the Maryland State Roads Commission built in 1937. The bridge was one of the first of its type built in Maryland, using a new method that combined treated wood and concrete to build a wood deck. The essential learning goal is for students to learn how a bridge's design responds to its site conditions and design constraints.

Grade Level

The target grade levels for this Lesson Plan are Grades 4-5 and 6-8, and while this Lesson Plan features Maryland bridges, it is applicable for use in other places.

Class Time

It is expected that each PowerPoint and associated activities will require class time of approximately one hour, for a total of 3 hours, spread over 3 days.

Preparation Needed

The educator leading the Lesson should schedule time to review the presentations in advance to allow time to gather the needed materials for the bridge model activity.

Materials needed for the bridge model activity include:

- Regular craft sticks (4.5" x 3/8" x 1/16")
- Jumbo craft sticks (6" x 3/4" x 1/16")
- Glue
- Paintbrushes
- Cardboard or other material to protect work surface
- Variety of materials to simulate the ground below a river within a contained area, such as sand, dirt, gravel, or other material contained within a box or pan

Standards

A matrix of Maryland STEM Standards of Practice benchmarks that are covered by this Lesson Plan, as well as a list of Next Generation Science Standards (NGSS) Science and Engineering Goals met by this Plan, are included as appendices.

Lesson Plan Components

- Pre-test Knowledge Splash exercise (3 minutes).
- Bridging Maryland, Becoming Engineers, Part 1, a PowerPoint providing a general introduction to bridge purposes, forms, and materials, as well as an introduction to the Engineering Design Process (30 minutes).
- Bridge Design Brainstorm Drawing Exercise (10 minutes).
- A Bridge Design Selection Activity for student class work or homework (10 minutes).
- Bridging Maryland, Becoming Engineers, Part 2, a PowerPoint that again presents the Engineering Design Process and provides instructions for building a prototype of a basic bridge deck unit; the students, working individually or in teams, are invited to build this prototype and design their own bridge piers (45 minutes).
- Bridging Maryland, Becoming Engineers, Part 3, a PowerPoint that guides students to test, optimize, and share their designs (45 minutes.)
- An Exit Ticket that provides students opportunity to document their design and optimization and answer the essential question (15 minutes).
- Guided notes for students to aid focus for during Part 1 and 2 PowerPoint Presentation.
- A Cheat Sheet of examples of timber piers.

Suggested Extensions

Many other Lesson Plans on bridge engineering already exist and they can provide additional information and activities for bridge engineering units. Some that we recommend include:

- Bridge Basics Educator's Resource Packet, from the National Building Museum, for grades 4-8 http://nationalbuildingmuseum.net/pdf/bridges_basics.pdf
- Bridge Building Lesson Plans from University of Minnesota Center for Transportation Studies, including a Spaghetti Bridge Building Activity for Grades 4th and up and a Wooden Bridge Building Activity for Grade 7 and up https://www.cts.umn.edu/education/k-12/lessons
- Bridge Up! Curriculum from Minnesota Department of Transportation (Lessons for all grade levels) http://www.dot.state.mn.us/stem/curriculum.html
- Bridge Unit from the TeachEngineering Digital Library from the University of Colorado (5 Lessons for Middle School Grades) https://www.teachengineering.org/curricularunits/view/cub_brid_curricularunit
- Building Model Bridges Following the Engineering Process by Joe Lewis from the Yale-New Haven Teachers Institute (Curriculum Unit for Grades 6-8) https://teachersinstitute.yale.edu/curriculum/guides/2001/5/01.05.04.x.html

Additional Maryland-related Bridge Resources in various formats include:

- Book: Historic Bridges of Maryland by Dixie Legler and Carol M. Highsmith. 2002. Available in local libraries and can be ordered from the Maryland Historical Trust: https://www.roads.maryland.gov/mdotsha/pages/Index.aspx?PageId=235 or online: https://archive.org/details/historicbridgeso0000guer

- Brochure: Maryland's Historic Highway Bridges (classroom sets may be available): https://www.roads.maryland.gov/OPPEN/MD_Historic_Highway_Bridges.pdf

- GIS: Maryland Bridges in Black and White, Maryland Department of Transportation State Highway Administration: https://roads.maryland.gov/mdotsha/pages/Index.aspx?PageId=359

- StoryMap: Maryland's Historic Highway Bridges: https://maryland.maps.arcgis.com/apps/Cascade/index.html?appid=6e47ce93010642a3a65cc9309ecd9e4a

Appendix 1. Maryland State STEM Standards of Practice	
1. Learn and Apply Rigorous Science, Technology, Engineering, and Mathematics Content	
A. Demonstrate an understanding of science, technology, engineering, and mathematics content.	X
B. Apply science, technology, engineering, or mathematics content to answer complex questions, to investigate global issues, and to develop solutions for challenges and real-world problems.	X
2. Integrate Science, Technology, Engineering, and Mathematics Content	
A. Analyze interdisciplinary connections that exist within science, technology, engineering, and mathematics disciplines and other disciplines.	X
B. Apply integrated science, technology, engineering, mathematics content, and other content as appropriate to answer complex questions, to investigate global issues, and to develop solutions for challenges and real-world problems.	X
3. Interpret and Communicate Information from Science, Technology, Engineering, and Mathematics	
A. Identify, analyze, and synthesize appropriate science, technology, engineering, and mathematics information (text, visual, audio, etc.).	X
B. Apply appropriate domain-specific vocabulary when communicating science, technology, engineering, and mathematics content.	X
C. Engage in critical reading and writing of technical information.	X
D. Evaluate and integrate multiple sources of information (e.g.: quantitative data, video and multimedia) presented in diverse formats.	
E. Develop an evidence-based opinion or argument.	
F. Communicate effectively and precisely with others.	X
4. Engage in Inquiry	
A. Ask questions to identify and define global issues, challenges, and real-world problems.	
B. Conduct research to refine questions and develop new questions.	X
5. Engage in Logical Reasoning	
A. Engage in critical thinking.	
B. Evaluate, select, and apply appropriate systematic approaches (scientific and engineering practices, engineering design process, and/or mathematical practices).	X
C. Apply science, technology, engineering, and mathematics content to construct creative and innovative ideas.	X
D. Analyze the impact of global issues and real-world problems at the local, state, national, and international levels.	X
6. Collaborate as a STEM Team	
A. Identify, analyze, and perform a STEM specific subject matter expert (SME) role.	
B. Share ideas and work effectively with a STEM focused multidisciplinary team to achieve a common goal.	X
C. Listen and be receptive to ideas of others.	X
D. Analyze career opportunities that exist in a variety of STEM fields relevant to the STEM focused multidisciplinary team's goal.	X
7. Apply Technology Strategically	
A. Identify and understand technologies needed to develop solutions to problems or construct answers to complex questions.	X
B. Analyze the limits, risks, and impacts of technology.	
C. Engage in responsible/ethical use of technology.	
D. Improve or create new technologies that extend human capability.	

Appendix 2.

The Building Bridges, Becoming Engineers Lesson Plan also meets the following Next Generation Science Standards (NGSS) Science and Engineering Practices for Grades 3-5 and 6-8:

3-5-ETS1-1 Engineering Design - 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 Engineering Design - 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 Engineering Design - 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-ETS1-1 Engineering Design - 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 Engineering Design - Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3 Engineering Design - 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 Engineering Design - 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.

Cheat Sheet

Students should use their creativity to design piers for the bridge, but here are a few examples of timber pier designs used with timber-concrete composite bridges.