Improving Bridge Design

STEM Road Map for Middle School

Grade 8

Edited by Carla C. Johnson,
Janet B. Walton, and Erin Peters-Burton

NSTApress
National Science Teachers Association

Improving Bridge Design

STEM Road Map for Middle School

Grade 8

Improving Bridge Design

Grade 8

STEM Road Map for Middle School

Edited by Carla C. Johnson, Janet B. Walton, and
Erin Peters-Burton

NSTA press
National Science Teachers Association
Arlington, Virginia

NSTA press®
National Science Teachers Association

Claire Reinburg, Director
Rachel Ledbetter, Managing Editor
Deborah Siegel, Associate Editor
Andrea Silen, Associate Editor
Donna Yudkin, Book Acquisitions Manager

Art and Design
Will Thomas Jr., Director, cover and interior design
Himabindu Bichali, Graphic Designer, interior design

Printing and Production
Catherine Lorrain, Director

National Science Teachers Association
David L. Evans, Executive Director

1840 Wilson Blvd., Arlington, VA 22201
www.nsta.org/store
For customer service inquiries, please call 800-277-5300.

21 20 19 18 4 3 2 1

NSTA is committed to publishing material that promotes the best in inquiry-based science education. However, conditions of actual use may vary, and the safety procedures and practices described in this book are intended to serve only as a guide. Additional precautionary measures may be required. NSTA and the authors do not warrant or represent that the procedures and practices in this book meet any safety code or standard of federal, state, or local regulations. NSTA and the authors disclaim any liability for personal injury or damage to property arising out of or relating to the use of this book, including any of the recommendations, instructions, or materials contained therein.

Library of Congress Cataloging-in-Publication Data
Names: Johnson, Carla C., 1969- editor. | Walton, Janet B., 1968- editor. | Peters-Burton, Erin E., editor.
Title: Improving bridge design, grade 8 : STEM road map for middle school / edited by Carla C. Johnson, Janet B. Walton, and Erin Peters-Burton.
Description: Arlington, VA : National Science Teachers Association, [2018] | Includes bibliographical references and index.
Identifiers: LCCN 2018012163 (print) | LCCN 2018007473 (ebook) | ISBN 9781681404158 (E-book) | ISBN 9781681404141 (print)
Subjects: LCSH: Bridges--United States--Design and construction--Study and teaching (Middle school) | Structural analysis (Engineering)--United States--Study and teaching (Middle school) | Infrastructure (Economics)--United States--Study and teaching (Middle school) | Eighth grade (Education)
Classification: LCC TG300 (print) | LCC TG300 .I45 2018 (ebook) | DDC 624.2/5--dc23
LC record available at *https://lccn.loc.gov/2018012163*

The *Next Generation Science Standards* (*"NGSS"*) were developed by twenty-six states, in collaboration with the National Research Council, the National Science Teachers Association and the American Association for the Advancement of Science in a process managed by Achieve, Inc. For more information go to *www.nextgenscience.org.*

CONTENTS

CONTENTS

ABOUT THE EDITORS AND AUTHORS

Dr. Carla C. Johnson is the associate dean for research, engagement, and global partnerships and a professor of science education at Purdue University's College of Education in West Lafayette, Indiana. Dr. Johnson serves as the director of research and evaluation for the Department of Defense–funded Army Educational Outreach Program (AEOP), a global portfolio of STEM education programs, competitions, and apprenticeships. She has been a leader in STEM education for the past decade, serving as the director of STEM Centers, editor of the *School Science and Mathematics* journal, and lead researcher for the evaluation of Tennessee's Race to the Top–funded STEM portfolio. Dr. Johnson has published over 100 articles, books, book chapters, and curriculum books focused on STEM education. She is a former science and social studies teacher and was the recipient of the 2013 Outstanding Science Teacher Educator of the Year award from the Association for Science Teacher Education (ASTE), the 2012 Award for Excellence in Integrating Science and Mathematics from the School Science and Mathematics Association (SSMA), the 2014 award for best paper on Implications of Research for Educational Practice from ASTE, and the 2006 Outstanding Early Career Scholar Award from SSMA. Her research focuses on STEM education policy implementation, effective science teaching, and integrated STEM approaches.

Dr. Janet B. Walton is a research assistant professor and the assistant director of evaluation for AEOP at Purdue University's College of Education. Formerly the STEM workforce program manager for Virginia's Region 2000 and founding director of the Future Focus Foundation, a nonprofit organization dedicated to enhancing the quality of STEM education in the region, she merges her economic development and education backgrounds to develop K–12 curricular materials that integrate real-life issues with sound cross-curricular content. Her research focuses on collaboration between schools and community stakeholders for STEM education and problem- and project-based learning pedagogies. With this research agenda, she works to forge productive relationships between K–12 schools and local business and community stakeholders to bring contextual STEM experiences into the classroom and provide students and educators with innovative resources and curricular materials.

Dr. Erin Peters-Burton is the Donna R. and David E. Sterling endowed professor in science education at George Mason University in Fairfax, Virginia. She uses her experiences from 15 years as an engineer and secondary science, engineering, and mathematics teacher to develop research projects that directly inform classroom practice in science and engineering. Her research agenda is based on the idea that all students should build self-awareness of how they learn science and engineering. She works to help students see themselves as “science-minded” and help teachers create classrooms that support student skills to develop scientific knowledge. To accomplish this, she pursues research projects that investigate ways that students and teachers can use self-regulated learning theory in science and engineering, as well as how inclusive STEM schools can help students succeed. During her tenure as a secondary teacher, she had a National Board Certification in Early Adolescent Science and was an Albert Einstein Distinguished Educator Fellow for NASA. As a researcher, Dr. Peters-Burton has published over 100 articles, books, book chapters, and curriculum books focused on STEM education and educational psychology. She received the Outstanding Science Teacher Educator of the Year award from ASTE in 2016 and a Teacher of Distinction Award and a Scholarly Achievement Award from George Mason University in 2012, and in 2010 she was named University Science Educator of the Year by the Virginia Association of Science Teachers.

Dr. Toni A. Ivey is an associate professor of science education in the College of Education at Oklahoma State University. A former science teacher, Dr. Ivey’s research is focused on science and STEM education for students and teachers across K–20.

Dr. Tamara J. Moore is an associate professor of engineering education in the College of Engineering at Purdue University. Dr. Moore’s research focuses on defining STEM integration through the use of engineering as the connection and investigating its power for student learning.

Dr. Sue Christian Parsons is an associate professor and the Jacques Munroe Professor in Reading and Literacy Education at Oklahoma State University. A former English language arts teacher, her research focuses on teacher development and teaching and advocating for diverse learners through literature for children and young adults.

Dr. Adrienne Redmond-Sanogo is an associate professor of mathematics education in the College of Education at Oklahoma State University. Dr. Redmond-Sanogo’s research is focused on mathematics and STEM education across K–12 and preservice teacher education.

Dr. Toni A. Sondergeld is an associate professor of assessment, research, and statistics in the School of Education at Drexel University in Philadelphia. Dr. Sondergeld’s research concentrates on assessment and evaluation in education, with a focus on K–12 STEM.

Dr. Juliana Utley is a professor and the Morsani Chair in Mathematics Education in the College of Education at Oklahoma State University. A former mathematics teacher, Dr. Utley’s research is focused on mathematics and STEM education across K–20.

John Weaver is a clinical instructor in the College of Education at Oklahoma State University. A former mathematics teacher, he teaches elementary and secondary mathematics methods courses and is a master teacher for the OSUTeach program.

ACKNOWLEDGMENTS

This module was developed as a part of the STEM Road Map project (Carla C. Johnson, principal investigator). The Purdue University College of Education, General Motors, and other sources provided funding for this project.

See *www.routledge.com/products/9781138804234* for more information about *STEM Road Map: A Framework for Integrated STEM Education.*

3

IMPROVING BRIDGE DESIGN MODULE OVERVIEW

John Weaver, Toni A. Ivey, Juliana Utley, Adrienne Redmond-Sanogo, Sue Christian Parsons, Janet B. Walton, Carla C. Johnson, and Erin Peters-Burton

THEME: The Represented World

LEAD DISCIPLINE: Mathematics

MODULE SUMMARY

This module focuses on addressing the real problems of today's society through the lens of the past. The challenge for this module is led by mathematics and is focused on infrastructure decay, specifically the state of bridges in the United States. With recent bridge collapses (e.g., the Minnesota bridge in 2007), much debate has ensued about the maintenance of bridges, and designs that will prove to be more sustainable over time are now being examined. Student teams develop a decision model grounded in engineering, for the local department of transportation, on how to select bridge design aligned with appropriate span length, application, use information, and other important data. In science, students examine observable changes in rocks and fossils to interpret the past. In English language arts (ELA), students work to develop a written proposal that articulates key components of their decision model (Johnson et al., 2015, p. 116). In social studies, students learn about how infrastructure such as roads and bridges has helped move their geographic region forward. (*Note:* This module instructs teachers to show videos of collapsing bridges. Teachers should consider students' sensitivity to the videos before showing them.)

ESTABLISHED GOALS AND OBJECTIVES

At the conclusion of this module, students will be able to do the following:

- Use mathematical modeling to explore bridge design, structure, and function, as well as to develop a decision model to help a community make appropriate decisions that will have a positive impact on their local infrastructure. (Mathematics)

- Understand how Earth materials play an important role in all aspects of our modern lives, including the construction of roadways and bridges. (Science)
- Employ research, nonfiction writing, and multimodal composition skills to explore and communicate the significance of bridges in our cultural experiences and understandings. (ELA)
- Investigate how infrastructure such as roads and bridges affect individual and local culture. (Social Studies)
- Build mastery of relevant skills and themes of the Framework for 21st Century Learning.

CHALLENGE OR PROBLEM FOR STUDENTS TO SOLVE: BRIDGE DESIGN CHALLENGE

The teacher should explain the challenge to the students as follows: Because of the current state of bridges in the United States, we are going to spend the next few weeks researching, designing, testing, and constructing bridges. Our challenge is to help the local department of transportation make better choices that will have a positive impact on our nation's infrastructure. By making better decisions we can help ensure that future bridges are sustainable and appropriate for the community in which they are built.

As we discuss the variables involved in building a bridge, you will be working in groups to develop a decision model that can be used by the local department of transportation to determine which type of bridge is most appropriate for a given site. Once your decision model has been developed, you will be given a scenario that will allow you to apply your model and make a recommendation for the type of bridge that should be built. Each group will present its model and defend the group's recommendation to the class and members of the community.

Driving Question: How can we develop a decision model to help us make a recommendation to the local department of transportation on the type of bridge to build for a given location?

CONTENT STANDARDS ADDRESSED IN THIS STEM ROAD MAP MODULE

A full listing with descriptions of the standards this module addresses can be found in the appendix. Listings of the particular standards addressed within lessons are provided in a table for each lesson in Chapter 4.

STEM RESEARCH NOTEBOOK

Each student should maintain a STEM Research Notebook, which will serve as a place for students to organize their work throughout this module (see p. 12 for more general discussion on setup and use of this notebook). All written work in the module should be included in the notebook, including records of students' thoughts and ideas, fictional accounts based on the concepts in the module, and records of student progress through the engineering design process. The notebooks may be maintained across subject areas, giving students the opportunity to see that although their classes may be separated during the school day, the knowledge they gain is connected.

Lessons in this module include student handouts that should be kept in the STEM Research Notebooks after completion, as well as prompts to which students should respond in their notebooks. You may also wish to have students include the STEM Research Notebook Guidelines student handout on page 26 in their notebooks.

Emphasize to students the importance of organizing all information in a Research Notebook. Explain to them that scientists and other researchers maintain detailed Research Notebooks in their work. These notebooks, which are crucial to researchers' work because they contain critical information and track the researchers' progress, are often considered legal documents for scientists who are pursuing patents or wish to provide proof of their discovery process.

STUDENT HANDOUT

STEM RESEARCH NOTEBOOK GUIDELINES

STEM professionals record their ideas, inventions, experiments, questions, observations, and other work details in notebooks so that they can use these notebooks to help them think about their projects and the problems they are trying to solve. You will each keep a STEM Research Notebook during this module that is like the notebooks that STEM professionals use. In this notebook, you will include all your work and notes about ideas you have. The notebook will help you connect your daily work with the big problem or challenge you are working to solve.

It is important that you organize your notebook entries under the following headings:

1. **Chapter Topic or Title of Problem or Challenge:** You will start a new chapter in your STEM Research Notebook for each new module. This heading is the topic or title of the big problem or challenge that your team is working to solve in this module.
2. **Date and Topic of Lesson Activity for the Day:** Each day, you will begin your daily entry by writing the date and the day's lesson topic at the top of a new page. Write the page number both on the page and in the table of contents.
3. **Information Gathered From Research:** This is information you find from outside resources such as websites or books.
4. **Information Gained From Class or Discussions With Team Members:** This information includes any notes you take in class and notes about things your team discusses. You can include drawings of your ideas here, too.
5. **New Data Collected From Investigations:** This includes data gathered from experiments, investigations, and activities in class.
6. **Documents:** These are handouts and other resources you may receive in class that will help you solve your big problem or challenge. Paste or staple these documents in your STEM Research Notebook for safekeeping and easy access later.
7. **Personal Reflections:** Here, you record your own thoughts and ideas on what you are learning.
8. **Lesson Prompts:** These are questions or statements that your teacher assigns you within each lesson to help you solve your big problem or challenge. You will respond to the prompts in your notebook.
9. **Other Items:** This section includes any other items your teacher gives you or other ideas or questions you may have.

MODULE LAUNCH

To launch the module, facilitate a class discussion about the need for bridges, including impact on a community and the types of bridges that students are familiar with. Following the discussion, the class should view a video clip related to the construction of bridges. A variety of videos can be found on the internet or on YouTube; one example is "Bridge Building Video" at *www.sciencekids.co.nz/videos/engineering/bridgebuilding.html*. After viewing the video, extend previous discussion about types of bridges, but now begin a conversation about the pros and cons of bridge types and the need to make a decision about the type of bridge each time a new bridge is planned.

Tell students that as part of their challenge in this module, they will help the local department of transportation develop a decision model to help the department decide on the best type of bridge to put in place based on the location.

PREREQUISITE SKILLS FOR THE MODULE

Students enter this module with a wide range of preexisting skills, information, and knowledge. Table 3.1 (p. 28) provides an overview of prerequisite skills and knowledge that students are expected to apply in this module, along with examples of how they apply this knowledge throughout the module. Differentiation strategies are also provided for students who may need additional support in acquiring or applying this knowledge.

Table 3.1. Prerequisite Key Knowledge and Examples of Applications and Differentiation Strategies

Prerequisite Key Knowledge	Application of Knowledge by Students	Differentiation for Students Needing Knowledge
• Apply the notion of scale factor and proportional reasoning in real-world contexts. • Graph points in the *x-y* coordinate plane and use the plot of these points to analyze data. • Generate and solve linear equations in a real-world context. • Know and be able to apply the Pythagorean theorem.	Scale Factor: • Develop a scale drawing and construct a 3-D model of a bridge in their community. Graphing: • Throughout module, collect data and display findings on a coordinate plane. Linear Equations: • From investigations, organize data and write/solve linear models to make predictions that will inform decision model. Pythagorean Theorem: • Use the Pythagorean theorem to find the length of support cables in a cable-stayed bridge.	• Do a short activation lesson for all students on scaling. • Have students work in project groups; students needing support with the concept of scaling can be grouped with students who demonstrate an understanding of the concept. • Supply students with a graphing utility.
• Have basic internet research skills. • Conduct internet research, including determining important information and reliable sources. • Have a basic understanding of figurative language, including metaphors. • Be familiar with nonfiction text structures and features and able to use them in writing.	• Use computers and the internet to research the types and uses of minerals found in your state. • Research bridges that are or have been significant in our cultural experiences as well as the various metaphorical uses of *bridge.* • Articulate the significance of *bridge* as a metaphor and use that information to understand literature.	• Provide a class guide for internet search engines. • Hold a classroom discussion about how to effectively use Boolean search terms. • Provide students the opportunity to practice assessing the credibility of various websites. • Select varied types and forms of literature and allow choice to support access for all learners. For struggling readers, reduce concept load by selecting literature that addresses familiar contexts.

POTENTIAL STEM MISCONCEPTIONS

Students enter the classroom with a wide variety of prior knowledge and ideas, so it is important to be alert to misconceptions, or inappropriate understandings of foundational knowledge. These misconceptions can be classified as one of several types: "preconceived notions," opinions based on popular beliefs or understandings; "nonscientific beliefs," knowledge students have gained about science from sources outside the scientific community; "conceptual misunderstandings," incorrect conceptual models based on incomplete understanding of concepts; "vernacular misconceptions," misunderstandings of words based on their common use versus their scientific use; and "factual misconceptions," incorrect or imprecise knowledge learned in early life that remains unchallenged (NRC 1997, p. 28). Misconceptions must be addressed and dismantled in order for students to reconstruct their knowledge, and therefore teachers should be prepared to take the following steps:

- *Identify students' misconceptions.*
- *Provide a forum for students to confront their misconceptions.*
- *Help students reconstruct and internalize their knowledge, based on scientific models. (NRC 1997, p. 29)*

Keeley and Harrington (2010) recommend using diagnostic tools such as probes and formative assessment to identify and confront student misconceptions and begin the process of reconstructing student knowledge. Keeley's *Uncovering Student Ideas in Science* series contains probes targeted toward uncovering student misconceptions in a variety of areas and may be useful resources for addressing student misconceptions in this module.

Some commonly held misconceptions specific to lesson content are provided with each lesson so that you can be alert for student misunderstanding of the science concepts presented and used during this module. The American Association for the Advancement of Science has also identified misconceptions that students frequently hold regarding various science concepts (see the links at *http://assessment.aaas.org/topics*).

SRL PROCESS COMPONENTS

Table 3.2 illustrates some of the activities in the Improving Bridge Design module and how they align to the SRL processes before, during, and after learning.

Table 3.2. SRL Process Components

Learning Process Components	Examples From Improving Bridge Design Module	Lesson Number and Learning Component
BEFORE LEARNING		
Motivates students	Students are challenged to become experts in bridge building so that they can help the community. The students are motivated by watching a bridge collapse video.	Lesson 1, Introductory Activity/Engagement
Evokes prior learning	Students tap into their prior experience with bridges by exploring bridges in their local community.	Lesson 1, Activity/ Exploration
DURING LEARNING		
Focuses on important features	Students brainstorm in small groups on what they know about bridges and what they still need to know. These thoughts are shared with the class and the entire class hones the list to the most important.	Lesson 2, Introductory Activity/Engagement
Helps students monitor their progress	While students are gathering data on the span length constraints of a beam bridge, the teacher chooses a group to display its data in graphing software to the class. Groups check their processes according to this model.	Lesson 2, Activity/ Exploration
AFTER LEARNING		
Evaluates learning	In the final challenge, students create a decision model and present it to peers, members of the local department of transportation, and other members of the community for feedback.	Lesson 6, Elaboration/ Application of Knowledge
Takes account of what worked and what did not work	In the final challenge, students reflect on the review and reactions from peers and community members for their decision model.	Lesson 6, Elaboration/ Application of Knowledge

STRATEGIES FOR DIFFERENTIATING INSTRUCTION WITHIN THIS MODULE

For the purposes of this curriculum module, differentiated instruction is conceptualized as a way to tailor instruction—including process, content, and product—to various student needs in your class. A number of differentiation strategies are integrated into lessons across the module. The problem- and project-based learning approach used in the lessons is designed to address students' multiple intelligences by providing a variety of entry points and methods to investigate the key concepts in the module (for example, investigating bridges from the perspectives of science and social issues via scientific inquiry, literature, journaling, and collaborative design). Differentiation strategies for students needing support in prerequisite knowledge can be found in Table 3.1 (p. 28). You are encouraged to use information gained about student prior knowledge during introductory activities and discussions to inform your instructional differentiation. Strategies incorporated into this lesson include flexible grouping, varied environmental learning contexts, assessments, compacting, and tiered assignments and scaffolding.

Flexible Grouping. Students work collaboratively in a variety of activities throughout this module. Grouping strategies you might employ include student-led grouping, grouping students according to ability level, grouping students randomly, grouping them so that students in each group have complementary strengths (for instance, one student might be strong in mathematics, another in art, and another in writing), or grouping students according to common interests.

Varied Environmental Learning Contexts. Students have the opportunity to learn in various contexts throughout the module, including alone, in groups, in quiet reading and research-oriented activities, and in active learning through inquiry and design activities. In addition, students learn in a variety of ways, including through doing inquiry activities, journaling, reading fiction and nonfiction texts, watching videos, participating in class discussion, and conducting web-based research.

Assessments. Students are assessed in a variety of ways throughout the module, including individual and collaborative formative and summative assessments. Students have the opportunity to produce work via written text, oral and media presentations, and modeling. You may choose to provide students with additional choices of media for their products (for example, PowerPoint presentations, posters, or student-created websites or blogs).

Compacting. Based on student prior knowledge, you may wish to adjust instructional activities for students who exhibit prior mastery of a learning objective. For instance, in Lesson 4 the teacher is prompted to provide a mini lesson on the Pythagorean theorem. The use of this theorem is needed to aid the students in their exploration of cable-stayed bridges. However, if some students exhibit mastery of the application of the Pythagorean theorem, you may wish to use this time instead to introduce ELA or social studies connections with associated activities.

Tiered Assignments and Scaffolding. Based on your awareness of student ability, understanding of concepts, and mastery of skills, you may wish to provide students with variations on activities by adding complexity to assignments or providing more or fewer learning supports for activities throughout the module. For instance, some students may need additional support in identifying key search words and phrases for web-based research or may benefit from cloze sentence handouts to enhance vocabulary understanding. Other students may benefit from expanded reading selections and additional reflective writing or from working with manipulatives and other visual representations of mathematical concepts. You may also work with your school librarian to compile a set of topical resources at a variety of reading levels.

STRATEGIES FOR ENGLISH LANGUAGE LEARNERS

Students who are developing proficiency in English language skills require additional supports to simultaneously learn academic content and the specialized language associated with specific content areas. WIDA (2012) has created a framework for providing support to these students and makes available rubrics and guidance on differentiating instructional materials for English language learners (ELLs). In particular, ELL students may benefit from additional sensory supports such as images, physical modeling, and graphic representations of module content, as well as interactive support through collaborative work. This module incorporates a variety of sensory supports and offers ongoing opportunities for ELL students to work collaboratively. The focus in this module on bridges affords opportunities to access the culturally diverse experiences of ELL students in the classroom.

In differentiating instruction for ELL students, you should carefully consider the needs of these students as you introduce and use academic language in various language domains (listening, speaking, reading, and writing) throughout this module. To adequately differentiate instruction for ELL students, you should have an understanding of the proficiency level of each student. The following five overarching WIDA learning standards are relevant to this module:

- Standard 1: Social and Instructional language. Focus on social behavior in group work and class discussions.
- Standard 2: The language of Language Arts. Focus on forms of print, elements of text, picture books, comprehension strategies, main ideas and details, persuasive language, creation of informational text, and editing and revision.
- Standard 3: The language of Mathematics. Focus on numbers and operations, patterns, number sense, measurement, and strategies for problem solving.
- Standard 4: The language of Science. Focus on safety practices, scientific process, and scientific inquiry.

- Standard 5: The language of Social Studies. Focus on historical events and people, resources, geography, and environmental issues.

SAFETY CONSIDERATIONS FOR THE ACTIVITIES IN THIS MODULE

Student safety is a primary consideration in all subjects where students may interact with tools and materials with which they are unfamiliar and which may pose additional safety risks. You should ensure that your classroom set-up is in accord with your school's safety policies and that students are familiar with basic safety procedures, the location of protective equipment (e.g., safety glasses, gloves), and emergency exit procedures. For more general safety guidelines, see the Safety in STEM section in Chapter 2 (p. 18).

Internet safety is also important. You should develop an internet/blog protocol with students if guidelines are not already in place. Since students will use the internet for their research to acquire the needed data, you should monitor students' access to ensure that they are accessing only websites that you have clearly identified. Further, you should inform parents or guardians that students will create online multimedia presentations of their research and that you will closely monitor these projects. It is recommended that you not allow any website posts created by students to go public without first approving them. During this module, students will be asked to explore a bridge in their community. You should ensure that students have the appropriate parental or adult supervision when exploring their desired bridge.

DESIRED OUTCOMES AND MONITORING SUCCESS

The desired outcome for this module is outlined in Table 3.3, along with suggested ways to gather evidence to monitor student success. For more specific details on desired outcomes, see the Established Goals and Objectives section for the module (p. 23) and for the individual lessons.

Table 3.3. Desired Outcome and Evidence of Success in Achieving Identified Outcome

	Evidence of Success	
Desired Outcome	Performance Tasks	Other Measures
Students create and present a decision model that illustrates their understanding of bridge design, structure, and function.	Students are assessed on their written proposal and poster presentation of their decision model and its application to determine the appropriate bridge for a given local site(s).	Students are assessed on • how well they work together in their groups, • participation in classroom discussion, and • individual investigation activity sheets throughout module.

ASSESSMENT PLAN OVERVIEW AND MAP

Table 3.4 provides an overview of the major group and individual *products* and *deliverables*, or things that constitute the assessment for this module. See Table 3.5 for a full assessment map of formative and summative assessments in this module.

Table 3.4. Major Products and Deliverables in Lead Disciplines for Groups and Individuals

Lesson	Major Group Products and Deliverables	Major Individual Products and Deliverables
1	Short presentations about a bridge in the local community	• STEM Research Notebook entries • Individual investigation activity sheets throughout module
2	Beam bridge scale drawing and 3-D model	• STEM Research Notebook entries • Individual investigation activity sheets throughout module
3	Arch bridge scale drawing and 3-D model	• STEM Research Notebook entries • Individual investigation activity sheets throughout module
4	Suspension bridge scale drawing and 3-D model	• STEM Research Notebook entries • Individual investigation activity sheets throughout module
5	Bridge cost equation and graph	• STEM Research Notebook entries • Individual investigation activity sheets throughout module
6	Written proposal and poster presentation of decision model and its application to local sites	• STEM Research Notebook entries • Individual investigation activity sheets throughout module • Collaboration Rubric

Table 3.5. Assessment Map for Improving Bridge Design Module

Lesson	Assessment	Group/ Individual	Formative/ Summative	Lesson Objective Assessed
1	Bridge presentations	Group	Formative	• Explore the current state of infrastructure in the United States. • Explore bridge collapses in the community and describe potential causes of bridge collapses.
1	Scaling Bridges *checklist*	Group	Formative	• Using scale factor, draw and construct scale models of a bridge.
1	STEM Research Notebook *prompts*	Individual	Formative	• Research the types and uses of different minerals present in the state.
2	Beam Bridge *cluster web*	Individual	Formative	• Describe the historical impact of bridges.
2	Rock Observation *rubric*	Group	Formative	• Collect and organize data through experimentation. • Identify differences and similarities between sedimentary, igneous, and metamorphic rocks.
2	Learning activity responses (Beam Bridge Penny Challenge, Beam Bridges—Effect of Span Length, Other Beam Bridge Facts *handouts*)	Individual	Formative	• Interpret data and write a linear equation that best fits the data. • Use a linear model to solve problems in a real-world context.

Continued

Table 3.5. (*continued*)

Lesson	Assessment	Group/ Individual	Formative/ Summative	Lesson Objective Assessed
2	STEM Research Notebook *prompts*	Individual	Formative	• Identify differences and similarities between sedimentary, igneous, and metamorphic rocks.
3	Game for elementary students	Group	Formative	• Develop a game that accurately teaches the rock cycle to elementary-age children in the grade 3–5 range.
3	Arches in History Poster *checklist*	Group	Formative	• Understand the role that arches have played in the development of infrastructure across time and culture.
3	Learning activity responses (Arch Bridge Weight Test, Arch Bridge Basics, Arch Bridge—Span Length *handouts*)	Individual	Formative	• Interpret data and write a linear equation that best fits the data. • Use a linear model to solve problems in a real-world context.
3	STEM Research Notebook *prompts*	Group	Formative	• Understand the role that arches have played in the development of infrastructure across time and culture.
4	Bridges: Compare and Contrast Matrix *handout*	Individual	Summative	• Compare and contrast various bridge types.

Continued

Table 3.5. (*continued*)

Lesson	Assessment	Group/ Individual	Formative/ Summative	Lesson Objective Assessed
4	Learning activity responses (Suspension Bridge Weight Test, Suspension Bridge Basics, Cable-Stayed Bridge Basics, Cable-Stayed Bridge Investigation *handouts*)	Individual	Formative	• Interpret data and write a linear equation that best fits the data. • Use a linear model to solve problems in a real-world context. • Use the Pythagorean theorem to solve real-world problems. • Understand the strengths and limitations of suspension and cable-stayed bridges.
4	STEM Research Notebook *prompts*	Individual	Formative	• Understand the strengths and limitations of suspension and cable-stayed bridges.
5	Cost of Bridges Investigation *handouts*	Group/ Individual	Formative	• Write an equation for total cost given initial cost and cost of yearly maintenance. • Graph cost equation on a coordinate plane and describe what the *y*-intercept and slope mean. • Compare cost functions to determine which is the cheapest for a given time period.
5	STEM Research Notebook *prompts*	Individual	Formative	• Understand the importance of geology to roads and bridges.

Continued

Table 3.5. (*continued*)

Lesson	Assessment	Group/ Individual	Formative/ Summative	Lesson Objective Assessed
6	Proposal, poster, presentation (Written Proposal and Poster and Presentation *rubrics*)	Group	Summative	• Develop a decision model. • Use a decision model to select a bridge design for a given scenario.
6	Works Progress Administration (WPA) debate (Social Studies Debate *rubric*)	Group	Summative	• Defend a position on whether another WPA should be established.

MODULE TIMELINE

Tables 3.6–3.10 (pp. 39–40) provide lesson timelines for each week of the module. These timelines are provided for general guidance only and are based on class times of approximately 45 minutes.

Table 3.6. STEM Road Map Module Schedule for Week One

Day 1	Day 2	Day 3	Day 4	Day 5
Lesson 1 *Bridges in the Community* • Launch the module by introducing the challenge and showing the bridge-building video. • Following this, show the bridge collapse video and explore bridge infrastructure in the United States.	*Lesson 1* *Bridges in the Community* • Explore bridges in the local community. • Conduct bridge scavenger hunt and research. • Students work on researching their local bridges (e.g., age, size, folklore).	*Lesson 1* *Bridges in the Community* • Students present research on their bridges to the class.	*Lesson 1* *Bridges in the Community* • Students work on scale drawing and constructing a scale model of one bridge from their presentation.	*Lesson 1* *Bridges in the Community* • Students finish and present scale drawing and model of one bridge from their presentation.

Table 3.7. STEM Road Map Module Schedule for Week Two

Day 6	Day 7	Day 8	Day 9	Day 10
Lesson 2 *Beam Bridges* • Explore the design, structure, and function of beam bridges.	*Lesson 2* *Beam Bridges* • Continue to explore the design, structure, and function of beam bridges.	*Lesson 2* *Beam Bridges* • Explore effect span length has on a beam bridge.	*Lesson 3* *Arch Bridges* • Explore the strength of arch bridges.	*Lesson 3* *Arch Bridges* • Finish and discuss exploration of the strength of arch bridges; discuss forces involved with arch bridges.

Table 3.8. STEM Road Map Module Schedule for Week Three

Day 11	Day 12	Day 13	Day 14	Day 15
Lesson 3 *Arch Bridges* • Explore the effect span length has on an arch bridge.	*Lesson 4* *Suspension and Cable-Stayed Bridges* • Explore the design, structure, and function of suspension bridges.	*Lesson 4* *Suspension and Cable-Stayed Bridges* • Continue to explore the design, structure, and function of suspension bridges.	*Lesson 4* *Suspension and Cable-Stayed Bridges* • Explore the design, structure, and function of cable-stayed bridges.	*Lesson 5* *Economics and Bridges* • Identify the costs related to constructing and maintaining a bridge.

Table 3.9. STEM Road Map Module Schedule for Week Four

Day 16	Day 17	Day 18	Day 19	Day 20
Lesson 5 *Economics and Bridges* • Continue exploring the economics of bridges.	*Lesson 6* *Putting It All Together—Decision Models* • Review the module challenge. • Begin research on what type of bridge is the appropriate choice for a given site.	*Lesson 6* *Putting It All Together—Decision Models* • Students research the four types of bridges and begin to think about what makes them the appropriate choice for a given site.	*Lesson 6* *Putting It All Together—Decision Models* • Students complete research on appropriate bridge for a given location.	*Lesson 6* *Putting It All Together—Decision Models* • Have a speaker from the local department of transportation.

Table 3.10. STEM Road Map Module Schedule for Week Five

Day 21	Day 22	Day 23	Day 24	Day 25
Lesson 6 *Putting It All Together—Decision Models* • Students finalize bridge decision model and apply it to their local sites.	*Lesson 6* *Putting It All Together—Decision Models* • Students prepare presentations.	*Lesson 6* *Putting It All Together—Decision Models* • Students prepare presentations.	*Lesson 6* *Putting It All Together—Decision Models* • Students present decision models.	*Lesson 6* *Putting It All Together—Decision Models* • Students present decision models.

RESOURCES

Teachers have the option to coteach portions of this module and may want to combine classes for activities such as mathematical modeling, geometric investigations, discussing social influences, or conducting research. The media specialist can help teachers locate resources for students to view and read about bridges and related engineering content. Special educators and reading specialists can help find supplemental sources for students needing extra support in reading and writing. Additional resources may be found online. Community resources for this module may include civil engineers or department of transportation representatives.

REFERENCES

Johnson, C. C., T. J. Moore, J. Utley, J. Breiner, S. R. Burton, E. E. Peter-Burton, J. Walton, and C. L. Parton. 2015. The STEM road map for grades 6–8. In *STEM road map: A framework for integrated STEM education,* ed. C. C. Johnson, E. E. Peters-Burton, & T. J. Moore, 96–123. New York: Routledge. *www.routledge.com/products/9781138804234.*

Keeley, P., and R. Harrington. 2010. *Uncovering student ideas in physical science, volume 1: 45 new force and motion assessment probes.* Arlington, VA: NSTA Press.

National Research Council (NRC). 1997. *Science teaching reconsidered: A handbook.* Washington, DC: National Academies Press.

WIDA. 2012. 2012 amplification of the English language development standards: Kindergarten–grade 12. *www.wida.us/standards/eld.aspx.*

INDEX

Page numbers printed in **boldface type** indicate tables, figures, or handouts.

T

Grade 8

STEM Road Map for Middle School

Improving Bridge Design

What if you could challenge your eighth graders to help strengthen the nation's infrastructure by designing bridges that last longer? With this volume in the *STEM Road Map Curriculum Series*, you can!

Improving Bridge Design outlines a journey that will steer your students toward authentic problem solving while grounding them in integrated STEM disciplines. As are the other volumes in the series, this book is designed to meet the growing need to infuse real-world learning into K–12 classrooms.

The book is an interdisciplinary module that uses project- and problem-based learning. Students will draw on mathematics, science, English language arts, and social studies to do the following:

- Explore the current state of infrastructure in the United States and in their community, with a special focus on bridges.
- Construct scale models of bridges using scale factor, and explore types and parts of bridges using linear equations and models.
- Research and compare minerals and rocks involved in bridge building.
- Investigate the costs of building and maintaining bridges and of designs that could be more sustainable over time.
- Develop a decision model to help their local department of transportation select future bridge designs.
- Debate whether the U.S. government should establish another Works Progress Administration to improve the country's infrastructure.

The *STEM Road Map Curriculum Series* is anchored in the *Next Generation Science Standards*, the *Common Core State Standards*, and the Framework for 21st Century Learning. In-depth and flexible, *Improving Bridge Design* can be used as a whole unit or in part to meet the needs of districts, schools, and teachers who are charting a course toward an integrated STEM approach.

PB425X7
ISBN 978-1-68140-414-1

Grade 8

NSTApress
National Science Teachers Association