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Maggie Beachner
University of Arkansas

Michael K. Daugherty
University of Arkansas

Vinson Carter
University of Arkansas

Lindsey Swagerty
University of Arkansas

Cathy Wissehr
University of Arkansas

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Expanding Earth Science in STEM: A Model

Maggie Beachner, Michael K. Daugherty, Vinson Carter,
Lindsey Swagerty, and Cathy Wissehr
University of Arkansas

Abstract

Despite the national call for STEM preparation, there is still a need to foster student interest in STEM at an early age. Although stakeholders have begun to develop STEM curricula at the elementary level, many of these focus on single disciplinary content and often have an emphasis on physical science. Efforts must be made to develop STEM curriculum that is truly integrated and adequately represents NGSS grade-level learning. This may require the use of interdisciplinary teams to improve integrated STEM programs. Projects like the covered wagon mini greenhouse can be used to strengthen student interest in STEM and encourage students to understand and practice the design process while engaging in earth science instruction.

Keywords: Earth science, Integration, NGSS, STEM

National Call for STEM Preparation

Despite increased national attention to the need for more K–12 curriculum and instruction centered on science, technology, engineering, and mathematics (STEM), students who graduate from high school with sufficient skills in these areas seem to be in short supply. In 2012, Uttal and Cohen stated that “there is little doubt that the United States faces a serious, and growing, challenge to develop and educate enough citizens to perform jobs that demand skill in . . . [the STEM] domains” (p. 148). Similarly, Rockland et al. (2010) noted that

> [The STEM fields] are in desperate need of more qualified workers, yet not enough students are pursuing studies in . . . [STEM] that would prepare them for technical careers. Unfortunately, many students have no interest in STEM careers . . . because they are not exposed to topics in these fields during their K-12 studies. (p. 53)

In 2010, the National Science Board reported that the American and global economies had changed substantially over the previous decade with an increased importance on science, technology, and innovation. In that same year, President Obama stated that “strengthening STEM education is vital to preparing our students to compete in the 21st century economy” (The White House, Office of the Press Secretary, 2010, para. 2). Most researchers and governmental authorities agree that adding higher numbers of STEM trained professionals to the workforce would vastly increase the global competitiveness of the United States (Tsupros, Kohler, & Hallinen, 2009, Atkinson & Mayo, 2010; National Science Board, 2010).

> The increase in professional workers in . . . [STEM] fields in the United States has seen steady growth over the past decade, but lags behind the dramatic growth of our . . . global

> competitors in developed countries (National Science Board, 2010). (DeJarnette, 2012, p. 77)

Additionally, DeJarnette (2012) reports that

> Results on the PISA [Program for International Student Assessment] and TIMSS [Trends in International Mathematics and Science Study] international studies . . . have shown that American youth fall behind other developed countries in countries in their abilities in science and math (Russell, Hancock & McCullogh, 2007; Russell, 1999). (p. 78)

The perceived need to increase the economic output of the United States and the academic performance of American students has resulted in pressure to develop STEM initiatives in public schools.

These pressures have resulted in a number of STEM curriculum and instruction programs such as Project Lead the Way (PLTW), Engineering by Design (EdB), Engineering is Elementary (EiE), and many other programs. As a result, the importance of providing earlier exposure to STEM learning for students in grades K–12 has increasingly come to light (Bagiati, Yoon, Evangelou, & Ngambeki, 2010; Bybee, & Fuchs, 2006). Most of these programs have been designed to impact students in middle and high school, "but there has been little change in the elementary curricula to support these growing trends" (DeJarnette, 2012, p. 77). Bencze (2010) suggested that "although there is considerable academic and official curricular support for promoting student-directed, open-ended science inquiry and technological design projects in schools, the reality is that they rarely occur" (p. 58). Hoachlander and Yanofsky (2011) noted that

> There are few more crucial initiatives . . . [in school reform] than increasing student proficiency in . . . [STEM]. Yet in too many schools, STEM is still mostly science and mathematics, taught separately with little or no attention to technology and engineering. Where connections do get made to technology and engineering, too often they happen through a hodgepodge of disconnected projects that lack coherence or strong grounding in content standards and student performance objectives. (p. 60–61)

Educational leaders and public and private organizations around the nation are beginning to offer STEM curriculum programs for K–12 students. These programs range from instilling increased rigor into single discipline subjects within the STEM acronym to a variety of STEM inspired activities.

> But generally speaking, it usually includes the replacement of traditional lecture-based teaching strategies with more inquiry and project-based approaches. To some, it only becomes STEM when integrating science, technology, engineering, and math curricula that more closely parallels the work of a real-life scientist or engineer. To others, STEM is the push for graduating more students in the science, technology, engineering, and mathematics fields. (Breiner, Harkness, Johnson, & Koehler, 2012, p. 3)

For the purposes of this discussion, we will limit our foci to those programs that strive to integrate the STEM disciplines. As Moore (1903) suggested more than a century ago, students need to see the connections between different subjects, and teachers need to be intimately familiar with the relationships within and between the STEM disciplines.

In response to the push of STEM assimilation into classrooms, teachers are seeking curriculum models and lessons that can be integrated into their instruction. For many of these teachers, especially those in elementary settings, this is their first exposure to technology and engineering (Murphy & Mancini-Samuelson, 2012). This unfamiliarity can be a barrier for teachers and school administrators looking to implement STEM curricula.

Effective STEM education entails the purposeful integration of all four areas (Bybee, 2010; Roberts, 2012; Stohlmann, Moore, & Roehrig, 2012). Due to the increased attention on STEM education, proposed curricula and teaching resources are emerging to assist educators in K–12 classrooms. These curricula are often developed in the form of lesson plans, instructional resources, and student activities. A content analysis conducted by the researchers of existing STEM curricula for elementary education shows anecdotal evidence that earth science content is insufficiently represented, and the prominence of the letter *S* in STEM education is often associated with the physical sciences. Many STEM lessons include properties of matter, motion, gravity, energy, and simple machines.

STEM and the New Science Standards

Elementary teachers are sometimes challenged to find ways to include science in their curriculum, particularly during the years prior to science achievement testing. Those wishing to integrate STEM learning look for ways to combine science and engineering with other, usually tested, subject matter such as mathematics and literacy. To address the need for greater emphasis on connections between and among the STEM disciplines, science educators have recently updated the existing *National Science Education Standards* (NSES, 1996) to include a greater emphasis on engineering. Drawing from the *Standards for Technological Literacy* (STL; International Technology Education Association [ITEA], 2007); the *Next Generation Science Standards* (NGSS; NGSS Lead States, 2013) include engineering, which is intricately linked to the practice and understanding of science. NGSS advocates integrating eight distinct Science and Engineering Practices in the classroom. These include:

1. Asking questions [for science] and defining problems [for engineering]
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations [for science] and designing solutions [for engineering]
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information. (NGSS Lead States, 2013, p. xx)

In the NGSS, a Science and Engineering Practice (SEP) is combined with a Disciplinary Core Idea (DCI) and a Crosscutting Concept (CC), and the resulting standard is expressed as a Performance Expectation (PE) that demonstrates a student's level of understanding of relationships among science and engineering practices, science core content ideas, and broader connections to overarching science concepts (NGSS Lead States, 2013). Each performance expectation establishes what students will be able to do at the end of instruction and would realistically require several individual lessons that build toward the goals of the PE. Examples of performance expectations related to this project include:

3-ESS3-1. Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard. (p. 33)

This PE requires that students are Engaging in Argument from Evidence about the merit of their design (SEP) and relating Cause and Effect (CC) to reduce the impact of weather-related Natural Hazards (DCI).

> **4-PS3-4.** Apply scientific ideas to design, test, and refine a device that converts energy from one form to another. (p. 35)

This PE requires that students are Constructing Explanations and Designing Solutions (SEP) and understand Conservation of Energy and Energy Transfer (DCI) related to Energy and Matter (CC).

> **5-ESS2-1.** Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. (p. 50)

This PE requires that students are Developing and Using Models (SEP) and that they understand the components of Earth Materials and Systems (DCI) and the interactions among components of Systems and System Models (CC).

Finally, performance expectations provide excellent opportunities for teachers to make numerous connections to Common Core State Standards for mathematics (CCSS-M; National Governors Association Center for Best Practices [NGA] & Council of Chief State School Officers [CCSSO], 2010b) and English language arts (CCSS-ELA; NGA & CCSSO, 2010a). Students are encouraged to use mathematics in applied situations rather than the more theoretical approach used in most K–12 classrooms. STEM integration requires students to measure, graph, and interpret results. Literacy, both oral and written, is supported through the reading and writing of informational text and through the oral communication of ideas. The NGSS-SEP, STL, and CCSS-M work in combination to allow students to understand how all STEM disciplines are related and build upon one another.

The NGSS are comprised of four core topics: earth and space science, life science, physical science, and “engineering, technology, and applications of science” (NGSS Lead States, 2013, p. xvi). Earth and space science are broken down into three progressions: Earth’s Place in the Universe, Earth’s Systems, and Earth and Human Activity. Each of these earth science progressions can provide an excellent context for STEM learning. The following design project was developed to illustrate how a STEM lesson might highlight earth science themes such as ecosystems, plants, animals, and soil properties.

The Covered Wagon Greenhouse Project

The design and construction of a greenhouse integrates all disciplines of STEM education, while emphasizing Earth science, an integral part of the NGSS for elementary students. The Covered Wagon Greenhouse project includes Earth and physical sciences, technology, engineering design concepts, and mathematics calculations. This project also allows for further extension activities, community involvement, or cocurricular collaboration. Students are guided to build their own mini greenhouse for use during the duration of the school year to grow small plants, vegetables, or flowers. Using predetermined materials, student teams design and construct a greenhouse that provides continuous learning opportunities throughout the school year. Students work collaboratively in engineering design teams to conduct ideation, problem solving, and make needed adjustments as they work to complete the project. This project promotes creativity, teamwork, troubleshooting, and exploration.

Getting Started

Similar to many lesson plans, this project can be modified to fit the needs and resources of any classroom. The following guidelines and standards are designed for third through fifth grade classrooms. There are six overall steps that are essential for students to construct their own learning and to develop a deeper understanding of STEM concepts within the project.

Step 1. Students conduct research to learn about greenhouses, how they work, their purpose, what they are made of, and other relevant goals that may situate this project in the existing classroom. There are a multitude of Internet resources and videos that can assist the students and teacher to learn more about greenhouses and how to build them. The shape and structure of a covered wagon may provide students with a starting point on the structural design of the greenhouse.

Step 2. After the teacher introduces students to the purpose of the project and the basics of greenhouses use and design, the students work in teams to make a list of materials they think would be needed to build their own greenhouse. It is essential that the teacher facilitate these discussions and help guide students' ideas to an appropriate scale and type of construction that they will use in their design. Students will undoubtedly come up with many ideas beyond those of the teacher. This may provide excellent opportunities for the teacher to foster engaging discussions about the best possible materials to use and how the materials will be used for construction. It may also provide an opportunity to bring in an expert from the construction trades. It is important that the teacher encourage students to be creative and have the freedom to explore their own ideas regarding design and construction.

Step 3. Students devise a plan for constructing the most effective mini greenhouse their group can come up with. This planning phase can be done together as a class or in small groups. Younger students may need more assistance and facilitation than older students. It is important that students understand the purpose of the greenhouse, what will be planted in it, available materials, and exactly how to engineer the best design. This is an excellent opportunity for sketching and planning for the overall dimensions of the design.

Step 4. Students create a budget for their mini greenhouse and brainstorm ideas for funding the purchase of materials and supplies. Students should use spreadsheet software to devise their own budget with possible sources of support as one component. Ideas for support include donations from local garden shops, dry cleaners (hangers), or recycling centers (plastic clothing bags). Once the students have created a materials and budget list, they can write letters to local businesses or organizations to request donations or support for their mini greenhouse projects.

Step 5. Once all materials are obtained, students begin construction of their mini greenhouses according to their plan from Step 3. This is where problem solving and troubleshooting come into play. With guidance from the teacher, students should be able to follow directions according to the group or class plan of construction. The materials presented below are only suggestions. Students may discover ideas for other appropriate building materials during the design process.

Step 6. Once students have completed their greenhouse construction, it is important that they present their designs to an audience. Members of the community, parents, and students from other grades may be asked to come, providing an authentic audience to whom the students will present their findings and completed projects.

Suggested Materials (per engineering design team)

- 1 rectangular planter that is large enough for the intended purpose (additionally, students

may design and build their own planter from recycled materials, see Figures 1–3)
- 7–10 wire hangers (or other sturdy but flexible wire)
- 10 ft smaller, more flexible wire (floral wire)
- Wire cutters
- Gloves for handling wire
- Clear plastic to cover greenhouse (could use large clear plastic bags)
- Enough soil to fill planter
- Seeds

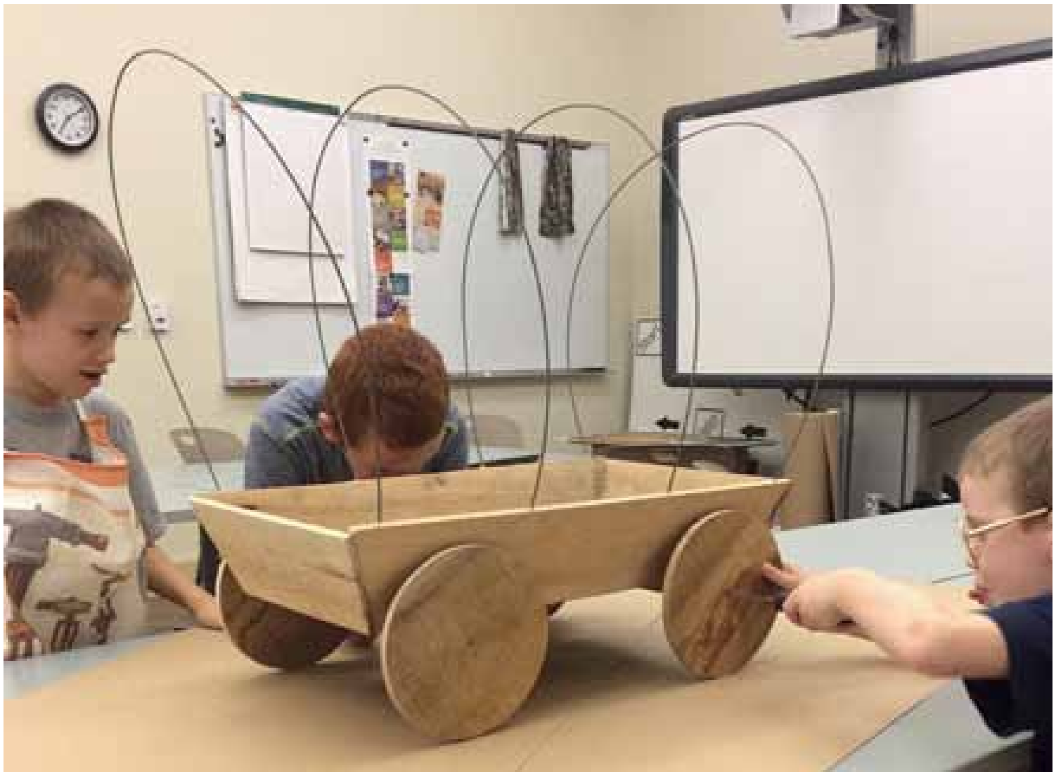

Figure 1. Elementary students assemble their own planter from recycled materials.

Project Instructions

The following steps can be used to construct the covered wagon mini greenhouse using the suggested materials list provided above.

1. Fill planter with potting soil about one inch from the top.
2. Plant seeds in soil (this can also be done after the greenhouse is constructed).
3. Take wire hangers apart and straighten them.
4. Measure length of planter, and determine how many wire hangers will be needed for truss supports. For a 20 in planter, we recommend putting a wire hanger every 2–3 inches.
5. Measure and mark on planter where bent wire hangers will be stuck in the soil to support the plastic covering.

Figure 2. Elementary students add potting soil to planter.

6. Bend the wire hangers in the shape of a horseshoe, and poke both ends into the soil right up against the sides of the planter. This will make a rainbow-shape over the planter that resembles the top of a covered wagon.

   Note: This may require multiple students working together to hold the wires in place because they will be unstable until wired together. Depending on the height of the planter, the ends of the wire hangers may need to be secured to the sides of the planter for stability. This can be done by drilling holes in the side of the planter and wiring the truss wires to the sides of the planter.

7. Once 3–4 of the wire hangers have been placed, use thinner wire to connect them together and add support for the top. This will begin to strengthen the arc and hold the wire hangers in place. Repeat until all wires have been used and the top begins to resemble the top of a covered wagon. This will serve as the support for the plastic covering.

8. Now the two ends of the greenhouse will need to be made. The two ends will serve as doors to access the plants inside and will also allow heat to escape when necessary. Door frames and hinges will need to be constructed out of more wire. There are many ways of doing this, but the doors will need to be sturdy enough to be opened and shut frequently.
9. The door frames should be made from the thicker hanger wire, but the grid-like support on the inside could be done with floral wire. Students will need to measure and configure doors that hinge from the top and can be propped open.
10. Once the "covered wagon" top and doors are strong and stable, it is time to cover them with clear plastic. Depending on the plastic used, there may be different ways of completing this step most effectively.

Figure 3. Elementary students add plastic cover to the greenhouse in preparation for planting.

11. Students must measure and cut proportionate sizes of plastic to fit on the greenhouse cover. One solid piece would cover the main arch, but plastic on the doors must cover all cracks when the doors are shut. Students must problem solve to determine how to do that as well as keep the doors accessible. This is another way that students must be creative and come up with the best way to make sure the plastic is tightly sealed when the doors are shut. This could be done with Velcro strips on the outsides of the doors, small snaps for extra plastic to cover around the doors, or any other way of ensuring a closed container when the doors are shut. This will keep the warm air in and the cool air out.
12. The final step in the covered wagon mini greenhouse project is determining how to extend the project beyond planning and construction. Maintenance of the greenhouse and the plants inside is a crucial aspect of this project, but students and teachers should also devise a plan for extending collaboration and further learning activities using the mini greenhouse. Possible ideas include inviting garden specialists in from the community to speak about other possible garden projects, discussing what can be grown in a greenhouse year round and the importance of self-sustainment and nutrition. Other suggestions include conducting a plant life cycle lesson observing the growth of plants, studying the greenhouse effect in an atmosphere lesson, or developing a project, titled Build a Better Greenhouse, using what they learned from their first design.

Connection to Standards

This project, including extension activities, offers an eclectic array of valuable learning experiences for students at any grade level. Standards addressed by this project may vary, depending on targeted concepts or how in-depth teachers are able to develop the project. Table 1 lists the national standards in mathematics, English language arts, science, and technological literacy that could potentially be addressed by this project and further extension activities.

- **Common Core State Standards: Math, Grades 3–5 (NGA & CCSSO, 2010b)**
    - Within this project, students have the opportunity to perform tasks that align with the Common Core State Standards (CCSS) regarding measurement of volume and length, geometry concepts, and calculating formulas. Students will calculate the amount of soil needed to fill the planter, measure where the wire braces will need to be placed, calculate the plane area of plastic needed to cover the greenhouse, and measure the perimeter for accurate construction of doors for the greenhouse.
- **Common Core State Standards: English Language Arts, Grades 3–5 (NGA & CCSSO, 2010a)**
    - Additional writing could be incorporated into this project, but the existing format does align with English Language Arts CCSS in grades 3–5. Students will be making step-by-step instructions for construction of the mini greenhouse, which involves writing with a specific task and purpose in mind. Organization of thoughts and explanation are essential to this project. Students will be researching using online or print materials, reading for understanding, and using the information they find to make predictions and plans for designing and building their greenhouses.

Table 1

National Standards Addressed by the Covered Wagon Greenhouse Project

National Standards	Grade Level	Individual Standards/Performance Expectations Addressed
Next Generation Science Standards (Performance Expectations) (NGSS Lead States, 2013)	**3**	**3-ESS2-2.** Obtain and combine information to describe climates in different regions of the world. **3-ESS3-1.** Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard.
	4	**4-LS1-1.** Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction. **4-PS3-4.** Apply scientific ideas to design, test, and refine a device that converts energy from one form to another. **4-PS3-2.** Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.
	5	**5-ESS2-1.** Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.
Standards for Technological Literacy (ITEA, 2007)	**3–5**	**Standard 5.** Students will develop an understanding of the effects of technology on the environment. **Standard 8.** Students will develop an understanding of the attributes of design. **Standard 9.** Students will develop an understanding of engineering design. **Standard 10.** Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving. **Standard 11.** Students will develop the abilities to apply the design process. **Standard 12.** Students will develop the abilities to use and maintain technological products and systems. **Standard 15.** Students will develop an understanding of and be able to select and use agricultural and related biotechnologies. **Standard 17.** Students will develop an understanding of and be able to select and use information and communication technologies.
Common Core State Standards: Math (NGA & CCSSO, 2010b)	**3**	**CCSS.Math.Content.3.MD.A.2** Measure and estimate liquid volumes and masses of objects using standard units of grams (g), kilograms (kg), and liters (l).1 Add, subtract, multiply, or divide to solve one-step word problems involving masses or volumes that are given in the same units, e.g., by using drawings (such as a beaker with a measurement scale) to represent the problem. **CCSS.Math.Content.3.MD.B.4** Generate measurement data by measuring lengths using rulers marked with halves and fourths of an inch. Show the data by making a line plot, where the horizontal scale is marked off in appropriate units— whole numbers, halves, or quarters. **CCSS.Math.Content.3.MD.C.5** Recognize area as an attribute of plane figures and understand concepts of area measurement.
	4	**CCSS.Math.Content.4.MD.A.1** Know relative sizes of measurement units within one system of units including km, m, cm; kg, g; lb, oz.; l, ml; hr, min, sec. Within a single system of measurement, express measurements in a larger unit in terms of a smaller unit. Record measurement equivalents in a two-column table. **CCSS.Math.Content.4.MD.A.3** Apply the area and perimeter formulas for rectangles in real world and mathematical problems. **CCSS.Math.Content.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.
	5	**CCSS.Math.Content.5.MD.C.5b** Apply the formulas $V = l \times w \times h$ and $V = b \times h$ for rectangular prisms to find volumes of right rectangular prisms with whole-number edge lengths in the context of solving real world and mathematical problems.
Common Core State Standards: English Language Arts (NGA & CCSSO, 2010a)	**3**	**CCSS.ELA-Literacy.W.3.4** With guidance and support from adults, produce writing in which the development and organization are appropriate to task and purpose. **CCSS.ELA-Literacy.RI.3.5** Use text features and search tools (e.g., key words, sidebars, hyperlinks) to locate information relevant to a given topic efficiently. **CCSS.ELA-Literacy.RI.3.7** Use information gained from illustrations (e.g., maps, photographs) and the words in a text to demonstrate understanding of the text (e.g., where, when, why, and how key events occur).
	4	**CCSS.ELA-Literacy.W.4.8** Recall relevant information from experiences or gather relevant information from print and digital sources; take notes and categorize information, and provide a list of sources. **CCSS.ELA-Literacy.W.4.5** With guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, and editing. **CCSS.ELA-Literacy.RI.4.7** Interpret information presented visually, orally, or quantitatively (e.g., in charts, graphs, diagrams, time lines, animations, or interactive elements on Web pages) and explain how the information contributes to an understanding of the text in which it appears.
	5	**CCSS.ELA-Literacy.W.5.4** Produce clear and coherent writing in which the development and organization are appropriate to task, purpose, and audience. **CCSS.ELA-Literacy.RI.5.7** Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently. **CCSS.ELA-Literacy.RI.5.9** Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably.

National Standards	Grade Level	Individual Standards Addressed
Next Generation Science Standards (NGSS Lead States, 2013)	3	**3-ESS2-2.** Obtain and combine information to describe climates in different regions of the world. **3-ESS3-1.** Make a claim about the merit of a design solution that reduces the impacts of a weather-related hazard.
	4	**4-LS1-1.** Construct an argument that plants and animals have internal and external structures that function to support survival, growth, behavior, and reproduction. **4-ESS2-1.** Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation.
	5	**5-ESS2-1.** Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. **5-ESS1-1.** Support an argument that the apparent brightness of the sun and stars is due to their relative distances from Earth.
Standards for Technological Literacy (ITEA, 2007)	3–5	**Standard 5.** Students will develop an understanding of the effects of technology on the environment. **Standard 8.** Students will develop an understanding of the attributes of design. **Standard 9.** Students will develop an understanding of engineering design. **Standard 10.** Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving. **Standard 11.** Students will develop the abilities to apply the design process. **Standard 12.** Students will develop the abilities to use and maintain technological products and systems. **Standard 15.** Students will develop an understanding of and be able to select and use agricultural and related biotechnologies. **Standard 17.** Students will develop an understanding of and be able to select and use information and communication technologies.
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	4	**CCSS.Math.Content.4.MD.A.1** Know relative sizes of measurement units within one system of units including km, m, cm; kg, g; lb, oz.; l, ml; hr, min, sec. Within a single system of measurement, express measurements in a larger unit in terms of a smaller unit. Record measurement equivalents in a two-column table. **CCSS.Math.Content.4.MD.A.3** Apply the area and perimeter formulas for rectangles in real world and mathematical problems. **CCSS.Math.Content.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.
	5	**CCSS.Math.Content.5.MD.C.5b** Apply the formulas $V = l \times w \times h$ and $V = b \times h$ for rectangular prisms to find volumes of right rectangular prisms with whole-number edge lengths in the context of solving real world and mathematical problems.
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	4	**CCSS.ELA-Literacy.W.4.8** Recall relevant information from experiences or gather relevant information from print and digital sources; take notes and categorize information, and provide a list of sources. **CCSS.ELA-Literacy.W.4.5** With guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, and editing. **CCSS.ELA-Literacy.RI.4.7** Interpret information presented visually, orally, or quantitatively (e.g., in charts, graphs, diagrams, time lines, animations, or interactive elements on Web pages) and explain how the information contributes to an understanding of the text in which it appears.
	5	**CCSS.ELA-Literacy.W.5.4** Produce clear and coherent writing in which the development and organization are appropriate to task, purpose, and audience. **CCSS.ELA-Literacy.RI.5.7** Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently. **CCSS.ELA-Literacy.RI.5.9** Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably.

- **Next Generation Science Standards, Grades 3–5 (NGSS Lead States, 2013)**
  - Multiple science content areas are covered in this project with an emphasis on earth science. Students will learn about and explore the impact that different climates can have on plants and learn about plant structures that support survival. In building up to this project and from researching the purpose of a greenhouse, students will also apply their knowledge of the effects of weather and atmospheric conditions. Students will engage in discussion about why there are changes of season and the need for greenhouses in the colder months. Teachers can facilitate deeper understanding of this content throughout the project as needed.
- **ITEA Standards for Technological Literacy, Grades 3–5 (ITEA, 2007)**
  - Students will be exposed to several aspects of technology and engineering in this project, including the design and engineering process. Students will be problem solving and troubleshooting within their groups or as a class and will be connecting concepts of technology to earth science and the environment. At the beginning of the project, students will be using technological devices to research about the project and to acquire material that will inform the rest of the process of design and implementation.

For the Students

Providing learning guides such as the planning sheet below will help students successfully navigate through this project. Predetermined note sheets and lesson guides will offer some structure and concrete approaches to the more abstract portions of this project comprising the design process. For example, the project planning sheet (see Figure 4) represents a guide that students may use for brainstorming, listing materials, sketching, and performing calculations. It may be important that students see examples of existing greenhouses (and covered wagons).

<table>
<tr><td colspan="6">Project Planning
Name:________________________________ Date: ____________________</td></tr>
<tr><td>What did I learn from my research?</td><td colspan="5"></td></tr>
<tr><td>What materials will we need?</td><td colspan="5"></td></tr>
<tr><td rowspan="3">Where can we get materials?</td><td>Item</td><td colspan="2">Business/Organization</td><td colspan="2">Contact Information</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>What steps will it take to build our greenhouse?</td><td><u>Step 1</u></td><td><u>Step 2</u></td><td><u>Step 3</u></td><td><u>Step 4</u></td><td><u>Step 5</u></td></tr>
<tr><td>What will our greenhouse look like when we are done?</td><td colspan="5"></td></tr>
</table>

Figure 4. Project Planning Sheet

Considerations for Teachers

The researchers assisted students in the development of the pilot version of this project. During the pilot, students designed and used previously gathered materials. Students could create their own covered wagon greenhouse in 4 to 6 hours, depending on age and skill level; however, this is just the beginning because students learn how to use the greenhouse and modify it for its intended purposes. One important facet of a STEM project is that students guide their own learning. Students must uncover each step of the project from the ground up, including researching, brainstorming, planning, budgeting, and executing. It is common for teachers to order a commercially available kit for building a greenhouse; however, using a kit does not allow students to fully engage in the design process. Students should begin with researching the purpose of greenhouses, how and why they work, materials, and the structural elements of covered wagons. The role of the teacher is essential in facilitating each step of the design process during the project. Some steps in the project may need to be performed by the teacher for safety reasons, depending on the age level of students.

There can be many variations of this greenhouse project that offer the same quality of learning experiences for students. Depending on resources, budget, number of students, grade level, and other factors, variations may be critical for completion of this project. Teachers may prefer to give students a few guidelines and let them be the explorers and designers. It is crucial that teachers be creative and resourceful and that they encourage the students to do the same. Ultimately, students should understand the entire purpose and process of building a greenhouse at the conclusion of the project.

Summary and Call to Action

Furthering efforts to engage K–12 students in integrated STEM education are necessary to the future of our nation and the sustained strength and growth of our nation's labor force. Although the need to expose students to and get them interested in STEM content and careers at an early age has been noted by professionals, unfortunately, many students do not have the opportunity to study STEM subjects until they reach secondary schools. Additionally, many of the initiatives to develop and implement STEM into schools are focused on single disciplinary content. It is important that students are exposed to STEM learning through an interdisciplinary approach that makes connections to the real-world use and application of STEM content knowledge.

Stakeholders have responded by developing programs that focus primarily on physical science. Efforts must be made to develop STEM curriculum that is truly integrated and adequately represents NGSS grade-level learning. This may require the use of interdisciplinary teams to improve integrated STEM programs. Projects like the covered wagon mini greenhouse can be used to strengthen student interest in STEM and to encourage students to understand and practice the design process while engaging in earth science instruction.

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Authors

Maggie Beachner
Clinical Assistant Professor
Department of Curriculum and Instruction
University of Arkansas
Email: mmcgrif@uark.edu

Michael K. Daugherty
Department Head, Professor of Technology & Engineering Education
Department of Curriculum and Instruction
University of Arkansas
Email: mkd03@uark.edu

Vinson Carter
Assistant Professor of Integrated STEM Education
Department of Curriculum and Instruction
University of Arkansas
Email: vcarter@uark.edu

Lindsey Swagerty
Ph.D. Candidate in Integrated STEM Education
Department of Curriculum and Instruction
University of Arkansas
Email: lmswager@uark.edu

Cathy Wissehr
Assistant Professor of Elementary Science Education
Department of Curriculum and Instruction
University of Arkansas
Email: cwissehr@uark.edu