

How Does Your Garden Grow?

Adapted from article by Bill Burton, Jessa Adler, Ana Casanova, Annie Jonas, and Lakeshia Peters • *Science & Children* • Vol. 52 • Issue 5

Time	Grade Level	Content Area [s]
Nearly four months	Grades 3–5	Life Science

Materials
<ul style="list-style-type: none"> Hydroponic System – described in Background Information for Teachers Cucumber seeds Water gel crystals (sodium polyacrylamide) Rockwool Grow Cubes Safety glasses or goggles Gloves Science journals Rulers and tape measures Small paintbrushes Pickling brine ingredients Jars for pickling Internet access for research

Objective

Students plant seeds in water gel crystals to enhance their ability to observe the growth of roots, stems, and leaves over several days. Students also explore how plants grow in a hydroponic system.

Activity Outline

Plant Science

- Using the water gel crystals, students will plant seeds and will record observations of the growth in their seed journals over multiple days. An additional investigation to help students make observations about what plants need to grow is using Rockwool Grow Cubes to plant cucumber seeds.

Note to the teacher: The hydroponics system that is described will need to be built prior to the lesson. The system is designed using standard parts available at hardware stores including PVC pipes and fittings. The larger PVC pipes are cut lengthwise to form a gutter-style growing tray. Clay growing media is used to fill these long gutters.

- 2 Once the plants sprout, ask students to transplant the seedlings to the hydroponics system in the school's greenhouse. Because hydroponic growing is new to most students at this age, allow time to explore all parts of the hydroponic system and how those parts work together to support the plants growing within. As the plants grow, students should take regular trips to the greenhouse to make observations. When the plants are still relatively small, students record plant height and leaf width with rulers. Because the plant growth is so speedy, the class will quickly graduate to using tape measures for plant height. This data will be recorded and used in math lessons.
- 3 One of the concepts that students learn through this investigation is the need for the flowers on plants to be pollinated. Through discussion of how flowers are pollinated by bees, a question is raised as to how will plants inside the greenhouse be pollinated? Equip students with small paintbrushes and visit the greenhouse periodically to pollinate the flowers by transferring pollen from one flower to another with the paintbrush.

Math Connections

- 1 Students have the opportunity to extend their understanding through inclusion of math activities using the data they collect and measurements of the plants' growth. As the lessons progress, students work cooperatively to organize the data by creating a tally mark chart of all the cucumber length measurements obtained during their visits to the greenhouse. This data is used to create a vertical bar graph on the classroom floor.
- 2 After completing the large bar graph, the class will formulate questions and draw conclusions. Using the tally mark chart from the board, students create two bar graphs individually using the first and last data sets. Using their graphs and data, students identify the median of the data sets in cooperative groups.
- 3 Through discussion about the graphed data and using their observational notes, the class can be engaged in drawing conclusions about what plants need to grow. Teachers can help guide students' understanding that while plants can be grown hydroponically without soil, they are still obtaining nutrients from the added fertilizers in the water.

Social Studies Connections

- 1 Social studies objectives and the hydroponics project are integrated through the theme of a pioneer journey. The students explore the Oregon Trail and the hardships faced by pioneers during their journey. This opportunity will lend itself to understanding actual farming, the phases of crop production, the lifestyle, and the culture that went along with being a pioneer farmer.
- 2 In addition to farming, pioneers needed to preserve their food. Science connects with social studies as students discuss methods of food preservation. Pickling is one such method. Using their crops from the hydroponics system, student 'pioneers' preserve cucumbers using a simple recipe. Have students research online to find their favorite recipe. Students discover the importance of agriculture and its contributions to our country's history, geography, economics, government, and culture.

Language Connections

Language arts are integrated throughout this unit. Students use sequencing, poetry, and illustrations to accompany written step-by-step instructions on a 'How to Make Pickles' assessment. Students are then given a scenario that a new student is joining their class. They create written direction as if they are in charge of demonstrating to this new pupil how to grow cucumbers, prepare spices, and make pickles. Students use the terms 'First,' 'Next,' 'Then,' and 'Last' to write complete sentences for each step. In four boxes, they illustrate each step.



Safety

Make sure all sources of electrical power in the green house are GFI protected. Always wash hands with soap and water after working in the hydroponic garden.

Use caution when handling sodium polyacrylamide: safety glasses or goggles, gloves, and appropriate ventilation are required.

Use caution when handling Rockwool Grow Cubes: safety glasses or goggles, gloves, and appropriate ventilation are required.

Outcomes

Over the course of the project, students care for the plants, make observations, take measurements, and record data. Observations are recorded in language arts classes and data collected and used in math lessons. At harvest time, students can collect more than 50 cucumbers. They use their crop to make pickles in connection with their social studies curriculum.

Class Discussion Questions

1. Do plants really need soil to grow?
2. During a class discussion, ask the students the following:
 - What are the parts of a flower?
 - What is the purpose of flowers in helping plants grow?
 - How do plants reproduce?
 - How do flowers attract animals in order to transport pollen?

Pre-Assessment

To gauge how far along students are with their understandings in plant science, the unit begins with a discussion. Students are asked: “What do we know about plants?”

Formative Assessment

In addition to formative assessments during discussions in science classes, this project makes its way into students writings in language classes, related discussions and research in social

studies classes, and using student-gathered data in math classes. Students keep a Venn diagram in their project folders, and revisit this graphic organizer multiple times as they learn about the hydroponics system, work with the plants and discover how hydroponic farming is different from traditional farming.

Background Info for Teachers

The hydroponics system can be designed using standard parts available at hardware stores including PVC pipes and fittings. The larger PVC pipes should be cut lengthwise to form a gutter-style growing tray. Clay growing media fills these long gutters. Underneath the system support bench, bury a 32-gallon plastic trash bin in the floor to serve as a water reservoir. Water added to the reservoir should be supplemented with Canna Aqua Vega, a nutrient solution designed for hydroponic growing. Install a submersible pump connecting to a digital timer. The pump, attached to a series of drip irrigation tubes, supplies nutrient-rich water to the entire unit. Install plastic mesh above the growing trays for vining plants to grow vertically in the greenhouse.

Extension Activities

At the end of the pioneer unit, students gather around a ‘campfire’ and celebrate with the pickle recipes identified in their online research.



The Future of Farming

An integrated, multidisciplinary unit introduces second-grade students to hydroponic gardening.

By *Bill Burton, Jessa Adler, Ana Casanova, Annie Jonas, and Lakeshia Peters*

In the dawn of human civilization, nomadic hunters and gatherers transitioned to a more agrarian lifestyle. Humans began growing, controlling, and changing plants to serve the needs of society. Since then, farming has been an essential part of human existence. People rely on farming for food. But other human needs are met through farming such as textiles, fuel, building materials, medication, and more.

Products that arise from farming are not simply conveniences; they are essential. As the world population rockets past seven billion people (United States Census Bureau 2014), agricultural science needs to find new ways to meet increasing demand. Hydroponic farming is one potential solution.

During an integrated, multidisciplinary unit, the lower school science teacher teamed with second-grade teachers to explore the future of farming. This project enhanced the existing plant science unit and connected with math, language arts, and social studies curricula.

The Hydroponics System

Hydroponics systems can take many forms and use many different types of materials. In general, hydroponics is a method of growing plants using a

chemically controlled water nutrient solution and often without soil (Carlson and First 2011).

After researching the functions of hydroponics systems, the lower school science teacher custom built a system for the school's existing greenhouse space. The system was designed using standard parts available at hardware stores including PVC pipes and fittings. The larger PVC pipes were cut lengthwise to form a gutter-style growing tray. Clay growing media was used to fill these long gutters (see Internet Resources for ideas for building your own system).

Underneath the system support bench, a 32-gallon plastic trash bin was buried in the floor to serve as a water reservoir. Water added to the reservoir was supplemented with Canna Aqua Vega, a nutrient solution designed for hydroponic growing. A submersible pump connected to a digital timer was installed. Attached to a series of drip irrigation tubes, the pump supplied nutrient-rich water to the entire unit. After water circulated into the system, gravity pulled it back to the reservoir. Because of the limited horizontal space, plastic mesh was installed above the growing trays for vining plants to grow vertically in the



PHOTOS COURTESY OF THE AUTHORS

Cucumber growing in rock wool medium

greenhouse (see Figure 1). Make sure all sources of electrical power in the green house are GFI protected. Always wash hands with soap and water after working in the hydroponic garden. For additional legal safety standards and practices for students and teachers working in a greenhouse, see Roy 2009.



Project Overview

The future of farming project lasted nearly four months. It began with students exploring the characteristics of plants and growing cucumber plants from seed. Students examined the hydroponics equipment in the greenhouse and transplanted their seedlings to the system. They learned how nutrient-rich water was added to the reservoir. Over the course of the project, students cared for the plants, made observations, took measure-

ments, and recorded data. Observations were recorded in language arts classes and data were collected and used in math lessons. At harvest time, students collected more than 50 cucumbers. They used their crop to make pickles in connection with their social studies curriculum.

Plant Science

The goal of the plant science component of the future of farming project was to explore plant structures, the basic needs of plants, and life cycles. To gauge how far along students were with their understandings in plant science, the unit began with a discussion. Students were asked, "What do we know about plants?" Because second-grade students had experienced growing plants in previous grades, many of them easily named plant parts such as leaves, roots, and stems.

One student said, "You can grow plants from seeds." That brought up a good question: What do plants need to grow? (NGSS Disciplinary Core Idea: LS2.A Interdependent Relationships in Ecosystems: Plants depend on water and light to grow).

Sunlight and water were named as two of plants' basic needs. Some students knew the word *photosynthesis* and could explain that plants make food in their leaves. When one of the students said, "Plants need soil," the conversation got interesting. We set off to explore the question "Do plants really need soil?"

Over the next few classes, we did activities to determine if plants would grow without soil. Students planted seeds in what's commonly known as water gel crystals (sodium polyacrylamide). Use caution when handling sodium polyacrylamide: safety glasses



FIGURE 1.

Setup of hydroponics system.



or goggles, gloves, and appropriate ventilation are required. Check Material Safety Data Sheet for required personal protective equipment. In “crystal” form, it is virtually clear after absorbing its fill of water. Water gel crystals are definitely not soil, but the seeds grew very well in the material. Clear plastic cups were used so students could easily observe root structures. Over several days, students recorded their observations in a seed journal. Students were introduced to rock wool, another growing medium for plants. Use caution when



handling rock wool: safety glasses or goggles, gloves, and appropriate ventilation are required. Check Material Safety Data Sheet for required personal protective equipment. Rock wool is made in a similar process to that of cotton candy. Rock is heated up to its melting point and then spun into thread-like filaments. The result is a natural rock material similar in texture to steel wool. The 1.5 in. rock wool starter plugs used in class had holes designed to accommodate seeds. Students planted cucumber seeds in the rock wool and displayed them in a shared space near their classrooms. In their journals, students recorded regular observations of seed growth.

Once the plants had sprouted, students transplanted seedlings to the hydroponics system in the school’s greenhouse. While there, students were introduced to the parts and functions of the hydroponics system. We noted that there was no soil. However, plants do need something that’s found in soil—nutrients. Students were shown the nutrient solution used to supplement the water in the reservoir. One student asked, “So plants need nutrients just like



Measuring cucumber fruit and flowers

people?” Although plants and animals have very different needs, yes, all living things need to obtain nutrients. In nature, plants get their nutrients from the soil. In hydroponics, nutrients come from water that has been supplemented with chemicals.

Because hydroponic growing was new to most students at this age, we wanted to explore all parts of the hydroponic system and how those parts worked together to support the plants growing within. Later, this knowledge would be essential when completing a graphic organizer that would help students compare a human made growing system with traditional farming. The National Research Council’s (2007) view that students’ thoughts are rather sophisticated support our decision to add some rigor to our second-grade lessons by working toward some third-grade NGSS standards, such as 3-LS4 Biological Evolution: Unit and Diversity and the Crosscutting

Concept Systems and System Models: A system can be described in terms of its components and their interactions.

As the plants grew, students took regular trips to the greenhouse to make observations. When the plants were still relatively small, students recorded plant height and leaf width with rulers. Because the plant growth was so speedy, the class quickly graduated to using tape measures for plant height. These data were recorded and used in math classes.

Until this point in the project, students had been able to witness vegetative plant growth as a major stage of its lifecycle. The first flowers signaled the beginning of the reproductive stage. During a class discussion, students explored the purpose of flowers. We used this stage of development to discuss plant reproduction, the parts of flowers, and how flowers attract animals in an effort to transport pollen (NGSS



Pollinating cucumbers with a paintbrush

Crosscutting Concept: Structure and Function). One student asked, “What about our plants? How will they get pollinated if they’re inside?” Great question! (NGSS Disciplinary Core Idea: LS2.A Interdependent Relationships in Ecosystems: Plants depend on animals for pollination or to move their seeds around).

In order for our flowers to be pollinated, we could either release bees into the greenhouse or we could pollinate the flowers ourselves. We decided against the bees, knowing students or teachers could be allergic. Equipped with small paintbrushes, students visited the greenhouse periodically and pollinated the flowers. In addition to transferring pollen, students measured and kept records of cucumber growth. These data were used during math class.

Over the course of the next several weeks, students visited the greenhouse, made observations, recorded data, and cared for their crops. Once the fruits were mature, the second

grade harvested more than 50 cucumbers.

Math Connections

Measurement data gathered from the greenhouse were used to enhance lessons in math classes. The lesson objectives of the Second Grade Everyday Mathematics Program suggest that teachers provide experiences and connections with reading, creating, and interpreting data through bar graphs (Wright Group/McGraw Hill 2007). Children were expected to identify the range and median of a data set. The Everyday Mathematics key concepts and skills helped guide the direction of our lesson and provided the essential questions below.

- Why do we graph data?
- Can you find the median of a data set?
- What conclusions can be drawn from our graph?

As the lesson was introduced, prior knowledge was explored using six commonly-used vocabulary words: bar graph, data, mode, median, range, and conclusion. Having a foundational understanding of these words before this lesson was essential. During class discussions, student statements such as “Data is information that is gathered” demonstrated a basic understanding.

As the lesson progressed, students worked cooperatively to organize the data by creating a tally mark chart of all the cucumber length measurements obtained during our visits to the greenhouse. These data were used to create a vertical bar graph on the classroom floor. To illustrate the difference between our first and last sets of data, we used small and large cucumbers side by side in relation to one another. The small cucumbers represented the first data set while the large cucumbers represented the final data set. The large graph allowed the entire class to gather around.

After completing our large bar graph, the class formulated questions and drew conclusions. One student concluded that all the cucumbers started off at the same pace, but eventually they all grew at their own rate and the measurements were very widespread over time. Other students commented that the cucumbers were larger in the last data set.

Using the tally mark chart from the board, students created two bar graphs individually using the first and last data sets (NGSS Science and Engineering Practice: Analyzing and Interpreting Data). The individual graphs allowed teachers to assess each student’s understanding of how to create bar graphs. Using

their graphs and data, children identified the median of the data sets in cooperative groups. (Common Core Standard 2.MD.D.10 Draw a picture graph and bar graph (with a single unit scale) to represent a data set with up to four categories.)

Social Studies Connections

Social studies objectives and the hydroponics project were integrated through the theme of a pioneer journey. Second grade explored the Oregon Trail and the hardships faced by pioneers during their journey. Students were assigned “pioneer professions,” the most common being farming. This opportunity lent itself to actual farming, the phases of crop production, the lifestyle, and the culture that went along with being a pioneer farmer.

In addition to farming, pioneers needed to preserve their food. Science connected with social studies when students discussed methods of food preservation. Pickling is one such method. Using their crops from the hydroponics system, student “pioneers” preserved cucumbers using a simple recipe. Students sliced cucumbers and measured ingredients for the brine solution. Teachers heated the brine and added it to the pickling jars the students had packed.

Students learned the importance of agriculture and how its contributions to our country’s history, geography, economics, government, and culture. At the end of the pioneer unit, students gathered around the campfire (the school has built-in fireplaces) and celebrated with homemade pickles.



Measuring cucumber plant growth

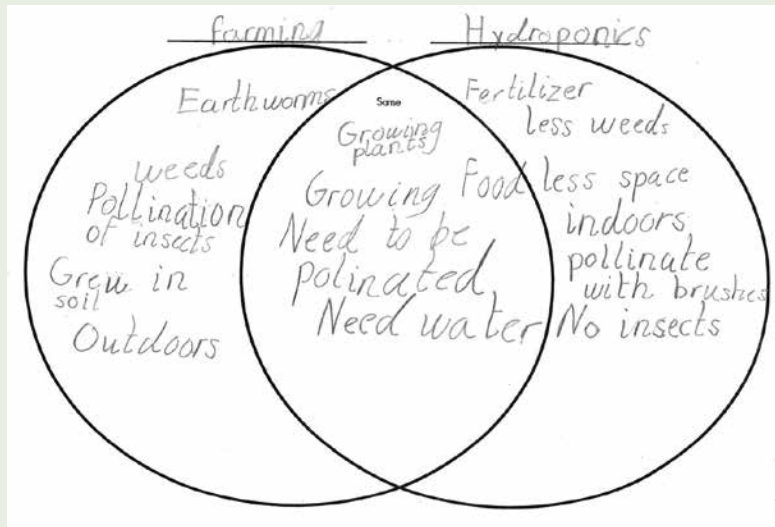
Language Connections

The second-grade students were able to further express their understanding of the hydroponic process, food preparation, and pickling through reading and writing. Students used sequencing, poetry, and illustrations to accompany written step-by-step instructions on a “How to Make Pickles” assessment (see NSTA Connection).

Students were given a scenario that a new student was joining their class. In their second-grade science notebook, they created written directions as if they were in charge of demonstrating to this new pupil how to grow cucumbers, prepare spices, and make pickles. The language arts literature study familiarized students with the vocabulary used to sequence events (or parts of a story). Students used the terms “First,” “Next,” “Then,” and “Last” to write complete sentences

FIGURE 2.

Farming and hydroponics Venn diagram.



for each step. In four boxes, they illustrated each step. As they completed this task, students were able to apply new language arts skills, while completing a summative assessment of their science lesson on food preservation. This work relates to *Common Core State Standard SL.2.5* (create audio recordings of stories or poems; add drawings or other visual displays to stories or recounts of experiences when appropriate to clarify ideas, thoughts and feelings. Teachers were able to assess language arts writing and comprehension objectives such as mechanics, sequencing events, and the use of sensory details through a science exploration.

Assessments

Teachers working as a team on the future of farming project led to natu-

ral ways to assess students. In addition to formative assessments during discussions in science classes, the project made its way into student writings in language classes, related discussions and research in social studies classes, and using student-gathered data in math classes.

In addition to these methods of assessment, students kept a Venn diagram in their project folders (see Figure 2). Students revisited this graphic organizer multiple times as they learned about the hydroponics system, worked with the plants and discovered how hydroponic farming is different from traditional farming. Using a Venn diagram in this way served as a good formative assessment tool for plant science content understanding as well as understanding of the hydroponics system itself (see NSTA Connection).

Alternative Systems and Projects

While the custom system built at The Lamplighter School worked very well within the existing greenhouse facilities, many schools have limited space and funds for such systems. What's great about hydroponic growing is that it's scalable. Systems can range in size from large commercial growing spaces to simple desktop units. Systems can use natural sunlight or artificial light. Carolina Biological Supply Company offers a complete desktop hydroponics kit for less than \$100 (see Internet Resources). The system we used was designed and built for second-grade classes. However, similar systems could be used for science instruction at other grade levels as well.

Conclusion

At first glance, growing crops in a hydroponic greenhouse system with carefully controlled variables may seem too complicated of a project for second-grade students. But research shows that young children are far more capable than once thought. According to the National Research Council (2007), young children's "thinking is surprisingly sophisticated" and they "already have substantial knowledge of the natural world, which can be built on to develop their understanding of science concepts" (p. 53).

Thematic units that reach across academic disciplines often engage students on a much deeper level. While most second-grade students were excited to work with plants in the hydroponics system during science class, other students became more fully engaged when writing

about their experiences, using their data to learn new math skills, or making pickles like the pioneers did. As a collaborative, multidisciplinary unit, the future of farming project connected to multiple *Next Generation Science Standards* (NGSS Lead States 2013) and *Common Core State Standards* (NGAC and CCSSO 2010) in literacy and mathematics and Crosscutting Concepts. And most importantly, it helped connect science with student interests. ■

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Internet Resources

- Home Hydroponics Systems
www.homehydrosystems.com/
- DIY Network
www.diynetwork.com/how-to/how-to-assemble-a-homemade-hydroponic-system/index.html

Everyday Math
www.everydaymath.com

Hydroponics Supplies
www.carolina.com/hydroponics/visual-desktop-hydroponics-kit/
www.texashydroponics.com

Pickle Recipe
<http://whatscookingwithkids.com/2009/08/04/making-refrigerator-pickles-with-kids>

NSTA Connection

Visit www.nsta.org/SC1501 for templates of the Venn diagram and the “How to make Pickles” assignment.

Connecting to the Next Generation Science Standards (NGSS Lead States 2013)

2-LS2 Ecosystems: Interactions, Energy, and Dynamics

www.nextgenscience.org/2ls2-ecosystems-interactions-energy-dynamics

Science and Engineering Practices

Developing and Using Models
Analyzing and Interpreting Data

Disciplinary Core Ideas

LS2.A: Interdependent Relationships in Ecosystems

- Plants depend on water and light to grow.

Crosscutting Concept

Systems and System Models

Connecting to the Common Core State Standards (NGAC and CCSSO 2010)

CCSS.ELA-Literacy.SL.2.5 Create audio recordings of stories or poems; add drawings or other visual displays to stories or recounts of experiences when appropriate to clarify ideas, thoughts, and feelings.

CCSS.MATH.CONTENT.2.MD.D.10 Draw a picture graph and a bar graph (with single-unit scale) to represent a data set with up to four categories. Solve simple put-together, take-apart, and compare problems using information presented in a bar graph.