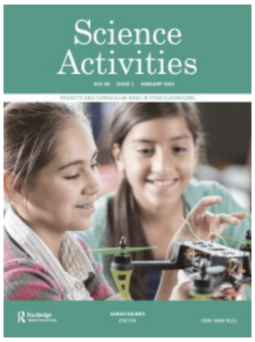

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The 3-H social and emotional learning cycle and the three sisters garden

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ABSTRACT

Social connections are crucial for today's middle and high school students. We address this social need through a 3-H Social and Emotional Learning (SEL) Cycle. Through the Three Sisters Garden activity presented here, we teach secondary school students about biodiversity and sustainability as we integrate the arts into STEM (STEAM). Students investigate the growth and development of organisms from a crosscutting lens of systems. Students initiate the sensemaking process by paralleling their own need for companionship to plants. Students end the lesson by initiating a scientific argumentation for a Three (or Four) Brothers/Others Garden. The 3-H learning cycle begins and returns to social and emotional connections, giving equal weight of importance to the heart (social and emotional), hands (problem-solving), and heads (sensemaking). The lesson presented here exemplifies school garden-based learning and students' ability to initiate sensemaking of the indigenous Three Sisters Garden intercropping method. Analyzing gardens from a systems lens allows students to make emotional and cognitive connections between their own need for social connections and plants increased growth and productivity in a polyculture. When students emotionally, socially, and cognitively participate in the process of science, they begin to see themselves as a part of the scientific process.

KEYWORDS

3-H Social and Emotional Learning Cycle; social and emotional learning (SEL); school gardens; companion planting

"All plants are our brothers and sisters. They talk to us and if we listen, we can hear them."

—Arapaho Proverb

Introduction

Social connections are crucial for today's middle and high school students (secondary, grades 6–12; ages 11–18 years), especially in the context of the COVID-19 pandemic and the related impacts of social isolation and loneliness on children's and adolescents' mental health (Loades et al. 2020). While the COVID-19 crisis recently highlighted the importance of social connections, staying closely connected with peer groups, however, dates back across generations. Imagine starry-eyed, fresh-faced adolescents… sitting around fires and exchanging glances during storytelling sessions of the early 1900s… shooting hoops or pitching baseballs during the 1940s… hanging out in groups at county fairs and amusement parks during the 1950s… and sitting on porches or tying up phone lines for hours with gossipy exchanges during the 1960s and 1970s. With the introduction of Internet-facilitated communications, teens migrated from telephone calls toward chatrooms, Instant Messages, emails, text messages, and social networks. Regardless of the method of communication, teens across the decades found ways to stay connected and hang out in physical or cyberspaces with their companions, creating their own cultures. Today's middle and high school students stay connected with their social networks while hanging out together after school or through a constant stream of texts and social media posts *via* Instagram, Snapchat or TikTok. In fact, an adolescent in the US exchanges an average of 60–70 text messages per day!

Social and emotional learning (SEL) provides a process for students to develop the knowledge, skills, and attitudes they need to manage their

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emotions so that they are able to set and attain goals, make rational decisions, feel empathy, and establish and maintain relationships (Bahnson et al. 2020; Collaborative for Academic, Social, and Emotional Learning [CASEL] 2019). Psychology researchers emphasize the importance of supportive relationships and special connections for adolescents' academic, behavioral, and emotional well-being, especially in science (Bahnson et al. 2020; Carolina 2019; Pekrun 2014; Sinatra, Broughton, and Lombardi 2014). Lessons and textbooks traditionally portray science as strictly cognitive or emotionally sterile when in fact science topics often elicit strong feelings and emotions (Brígido et al. 2010; Sinatra 2022; Zembylas 2005). Students enter our classrooms with emotions, both positive and negative, connected to science (Sinatra, Broughton, and Lombardi 2014). Young children tend to show high levels of interest in and excitement about science, and they generally hold positive attitudes about science topics (Brígido et al. 2010). Unfortunately, as students' progress through school and advance into secondary level science classes, their positive attitudes and emotions toward science decrease, and these less positive emotional perceptions persist into adulthood (Lin, Hong, and Huang 2012; Organization for Economic Co-operation and Development [OECD] 2018; Potvin and Hasni 2014). For example, in a study where science was portrayed as strictly objective, 10th grade students became disengaged (Davis and Bellocchi 2018). We are beginning to recognize the critical role emotions and emotional engagement play in science learning (Carolina 2019; Pekrun 1992; Sinatra, Broughton, and Lombardi 2014), especially for marginalized groups of students who are underrepresented in the sciences (Laursen 2019). To support effective science learning for all students, we must do more than engage students' heads and hands—we must also engage their hearts.

During the lesson we present here, students investigate the growth and development of organisms from a crosscutting lens of systems (MS-LS2 Ecosystems: Interactions, Energy, and Dynamics, [NRC] 2013). A focus on the emotional aspect of the interconnected cultural sociality of adolescence aids students in constructing explanations of the indigenous Three Sisters Garden intercropping methods. Students initiate the sensemaking process by paralleling their own need for companionship to plants. Students end the lesson by initiating a scientific argumentation for a Three/Four Brothers/Others Garden.

3-H (hearts-on, hands-on, heads-on) social and emotional learning cycle

We use a 3-H learning cycle, a three-phase ongoing process, to socially and emotionally engage our students with science phenomena (National Research Council 2013; Garner et al. 2018). We begin by connecting the concepts to students' emotions using personal experiences (Emotions, HEARTS-on), move to exploration (Problem-solving, HANDS-on), and then discuss the phenomenon the students explored (Sensemaking, HEADS-on). Affective hearts-on engagement provides an integral opportunity for teacher-planned, student-directed, implicit learning (i.e., learning that happens in an incidental manner without intention or awareness that learning is taking place), which provides students opportunities to engage emotionally or affectively with science concepts. During exploration, students begin explicit, teacher-guided, hands-on inquiry learning (i.e., active development of skills, intentional construction of knowledge or understanding, and/or problem-solving). During our teacher-directed, heads-on discussions, we help students make sense of their observations, identify patterns, and label their learning by scaffolding academic language. Scaffolding allows students to make connections between their prior knowledge and the phenomenon they explored. We scaffold academic language to help students identify, define, and explain subject-specific terminology based on their own experiences with the phenomenon. We repeat student responses and integrate academic language, prompt students to elaborate on their responses, and use their examples to build on ideas and concepts they observed (Mahan 2022). After the discussion, the students return to student-directed, emotional engagement and implicit learning where they apply what they learned to familiar and novel contexts. We assess throughout the lesson. For example, we evaluate students' prior knowledge and identify possible misconceptions they may hold during Hearts-on, and the application or development of science and engineering practices are assessed during Hands-on investigations. In this way, students are supported in making sense of the evidence and applying it to their own lives, cultures, and families now and in the future.

While we developed this balanced learning, 3-H cycle for younger children (Trundle and Smith 2017; Saçkes, Trundle, and Shaheen 2019), we have found it to also be highly effective with middle, junior, and high school students (Wheeler, Hagevik, and Trundle in press, Vela et al. 2022). When students emotionally, actively, and cognitively participate in sensemaking around science phenomena, science becomes engaging, accessible, and important to all students (National Science Teaching Association 2002; Garner et al. 2018). In the following lesson, we use the 3-H SEL Cycle to engage students with companion planting (Three Sisters Garden) *via* the phenomenon of interactions among organisms across multiple ecosystems (MS-LS2, NRC 2013).

The 3-H SEL Cycle, grounded in constructivist theory like the 5-E learning cycle, uses and builds on students' prior knowledge and experiences to support their construction of meaning (Glasson and Lalik 1993). The 5-E learning cycle, which includes five steps of (1) engagement, (2) exploration, (3) explanation, (4) elaboration, and (5) evaluation (Bybee et al. 1989), aligns well with the earlier *National Science Education Standards* (NRC 1996). In contrast, the 3-H SEL Cycle, with its focus on sensemaking based on science phenomena, better aligns with the *Next Generation Science Standards* (Bahnson et al. 2020; Carolina 2019; NRC 2013). It also incorporates recent psychology research that highlights the integral role of emotions and social and emotional connections to learning (Pekrun 2014). Researchers have found SEL to be effective across cultural and socio-economic contexts, and they reported that SEL can have long-term positive outcomes (Taylor et al. 2017). In addition to increased academic performance, SEL can improve classroom behavior, enhance students' ability to manage stress and depression, and improve students' attitudes about themselves, others, and school (Durlak et al. 2011). The 3-H learning cycle begins with and returns to social and emotional connections, giving equal weight of importance to the heart (social and emotional), hands (problem-solving), and heads (sensemaking).

3-H example: companion plants and polycultures—three sisters garden

In this article, we focus on a 3-H SEL Cycle lesson from our middle school garden (grades 6–9, ages 11–15 years) and summer day camps (grades 6–12; ages 11–18 years), which we use to teach about biodiversity and sustainability through the integration of the arts into STEM (STEAM), which researchers have found to increase students' interest in and connections to science (Garner et al. 2018). The goals of our school garden include:

1. To promote sustainable practices for soil health, water conservation, and support of biodiversity, especially native pollinators.
2. To support students' connections to nature as a place for learning, social interactions, and emotional and physical well-being.
3. To use the natural environment to develop students' creativity and problem-solving skills.
4. To make cultural connections and foster appreciation of indigenous knowledge (Merritt et al. 2021).

The school garden and companion plants

Background

As students select plants and plan their school garden at the beginning of the school year, we introduce the Three Sisters legend, which capitalizes on and connects to adolescent students' penchant for companionship. We use our middle school garden and summer day camps to introduce companion plants, intercropping, and polyculture through the Three Sisters Garden as we link to the ancient practices of Indigenous peoples (Bleir 2019). While the Haudenosaunee (Iroquois) used the term *The Three Sisters*, indigenous people across the globe applied these same practices (Pace 2015).

Different types of plants grouped together to enhance and/or protect each other, like companions, create a *polyculture*. *Intercropping*, a type of polyculture, involves two or more crops grown closely together to produce greater yields. We use a polyculture system of intercropping to help students construct an understanding of the effects of resource availability on different organisms in the system and explain patterns of interactions among different organisms in an ecosystem (MS-LS2 Ecosystems: Interactions, Energy, and Dynamics, NRC, 2013).

The Three Sisters Garden, an example of intercropping and polyculture, includes the traditional practice of planting beans, corn, and squash together in a garden. American Indians/Alaskan Natives consider these three crops to be sustainers of life and special gifts from the Creator. The Three Sisters are *companion plants*—plants whose growth habits and attributes are mutually beneficial to each other. The Three Sister plants benefit each other in several ways. Corn stalks provide support and a cool place for climbing bean vines to grow. Bean plants, with nitrogen-fixing bacteria on their roots, convert gaseous nitrogen from the air into a usable form that the bean plant converts into proteins. As the bean plant's roots, stem, leaves, and seedpods eventually decompose, they release nitrogen into the soil for continued use by other plants. While all plants benefit from the bean plants' enrichment of the soil, the corn plants, with their high nitrogen needs, benefit the most from the companion plant relationship with bean plants. The leaves of the squash shade the soil, reduce evaporation, lower temperatures, and slow or deter weed growth. The prickly hairs on their leaves and stems discourage animal pests like raccoons. Companion planting and intercropping increase yields, enrich the soil, repress weeds, provide habitats for beneficial insects, keep pests under control, and reduce labor for gardeners.

After harvesting, gardeners often use a traditional organic gardening technique to incorporate large amounts of vegetative material back into the soil, which builds up organic matter and improves the soil structure. Due to the benefits, these plants and their fruits provide for each other plus their complimentary nutritional benefits (e.g., carbohydrates from corn, proteins from beans, vitamins and oils from squash), people have cultivated Three Sisters Gardens in North America for over 3000 years.

Safety considerations

This investigation occurs as part of the typical science instruction students receive. Students use a school garden as an outdoor laboratory, and as such, these activities and investigations follow laboratory safety protocols (e.g., long pants, ankle socks, and closed-toed shoes). Laboratory and garden safety adhere to first aid guidelines. This lesson, however, occurs in the classroom and poses no additional risk beyond that of typical classroom instruction.

Next Generation Science Standards (NGSS)

MS-LS2 Ecosystems: Interactions, Energy, and Dynamics (see Table 1) www.nextgenscience.org/dci-arrangement/ms-ls2-ecosystems-interactions-energy-and-dynamics

MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

MS-LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

Materials

Seed Cards (Appendix 1)

Three Sisters Data Sheet (Appendix 2)

Three/Four Brothers/Others Story: Data sheet, seed card template, scale drawing, graph paper, pencils with erasers, ruler, colored pencils, a device for online research, photographs of plants, story (Appendix 3).

Rubric for Brothers/Others Story (Appendix 4)

Argumentation Graphic Organizer (Appendix 5)

Rubric for Scientific Argumentation (Appendix 6)

Table 1. Next Generation Science Standards (NGSS) Connections.

Connecting to the *Next Generation Science Standards*

- This table shows one possible connection between the lesson outlined in this article and the NGSS. There are many other valid connections and space prevents us from outlining them all.
- The lesson presented in this article is but one possible step toward reaching the performance expectation listed in this table.

Standard

MS-LS2 Ecosystems: Interactions, Energy, and Dynamics

www.nextgenscience.org/dci-arrangement/ms-ls2-ecosystems-interactions-energy-and-dynamics. . .

Performance expectation

MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

MS-LS2-2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

Dimensions	Classroom connections
Science and engineering practice	
Constructing explanations and designing solutions (6–8) • Developing and using models • Analyzing and interpreting data • Construct an explanation that includes qualitative or quantitative relationships between variables that predict phenomena.	Students collect data, both quantitative and qualitative, on the mutually beneficial interactions of companion plants first in the 3 (4) Sisters Gardens [patterns], and then use this information to develop their own model brother garden. Students use data to predict, construct and explain based on criteria which brother garden should be added to their school grounds.
Disciplinary core idea	
LS2.A: Interdependent Relationships in Ecosystems • Organisms, and populations of organism, are dependent on their environmental interactions both with other living things and with nonliving factors. • Growth of organisms and population increases are limited by access to resources.	Students explore the concepts related to the interaction of organisms with both living and nonliving factors in the 3 (4) Sisters Garden and in the Brother garden to discover how organisms can benefit from each other and can change the environment to benefit themselves.
Crosscutting concept	
Patterns • Patterns can be used to identify cause and effect relationships. Cause and effect • Cause and effect relationships may be used to predict phenomena in natural or designed systems.	Students observe how each of the plants in the 3 (4) Sisters interact and benefit each other with information gathered in reading the story and history of 3 Sisters Gardens, on seed cards, in the Farmer's Almanac as well as from other sources. Students look for other companion plants with characteristics that are mutually beneficial (e.g., attracting pollinators, providing support for companion climbing plants, protecting and shading soil to retain moisture, repelling pests). Students consider how planting and growing practices add to or take away from a system.

Hearts-on: Affective, emotional connections that engage the heart

We ask students to think about the person they talk or text with most and then think about hanging out with that friend or family member: *What kinds of things do you like to do together? Think of something your friend helps you do. How do you help your friend?*

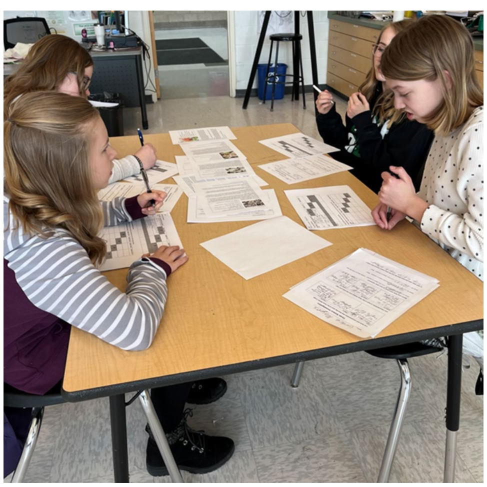
We explain that *companions* are friends who spend time together playing sports, helping with homework, talking, playing video games, or just hanging out. We help students connect with the botanical world by explaining that plants also have companions known as companion plants that help or benefit each other. *Companion plants* support each other by deterring animal pests, attracting beneficial insects, providing sun protection *via* shade, providing physical support, improving soil health and fertility, and suppressing weeds. In other words, companions work together to reduce the workload, increase the fun, and yield more productivity for everyone! Together companions create their own culture.

Hands-on: Inquiry, answering questions based on evidence, problem-solving

We transition to inquiry by sharing an example of companion plants from indigenous peoples, the Three Sisters Gardens, which include beans, corn, and squash. Many indigenous groups, including Haudenosaunee and Mayan, grew or still grow the Three Sisters.

We identify the inquiry questions for the day: *Why do people grow these plants together? How do these plants help or benefit each other?* We use these types of productive questions, questions students answer through their own observations, to initiate and facilitate inquiry and engagement with the phenomenon and support the development of scientific ways of thinking and scientific practices. We use a systems thinking approach found in the crosscutting concepts of *The Next Generation Science Standards* (NRC 2013). Systems thinking provides a framework for solving complex problems within the context of relationships with other components rather than in isolation. When considering polycultures, the interrelated needs of the plants (e.g., water, light, pollination, soil, flowering, space, nutritional and/or medicinal value, yield, cost, maturation times, hardiness, history) must be considered. If you have a Three Sisters Garden, have students make observations of the plants and how they are arranged, and discuss reasons for the planting arrangement. If not, students can make observations from photographs of corn, beans, and squash and discuss as described above (see Appendix 3). Discuss the timings of the plantings and considerations for planting the garden (e.g., lighting, shade, water, and nutrition requirements). Have students consider themselves and their friends, and ask what relationships with friends need in order to be healthy and stable.

We ask students to read the information on each seed card (Appendix 1) and work in small groups to determine how each plant or sister benefits another sister plant or plants. They complete the Three Sisters Data Sheet (Appendix 2). *How does each sister plant help the other companion plants? What does each plant gain from the companionship with the other sister plants? How do these plants work together to form a system? How do these systems relate to one another? What does the corn do for the squash?*



Students Collaborating

Heads-on: Discussion, identifying patterns, labeling learning, scaffolding language, reasoning from evidence.

Read the legend of the Three Sisters (https://www.ncpedia.org/legends-three-sisters) and ask students to identify which plant represents each sister (Wilson 2015). Ask them to explain the analogies related to the science concepts explained by the story:

- Older, strong sister (Corn): tallest, strong, stands straight, watches out for intruders and other dangers, warns sisters, provides support for sisters, wears a pale green shawl, has long sandy blond hair that blows in the wind.
- Middle, protective sister (Squash): runs off to be by herself, spends many hours reading alone, sits in the sun but sunburns easily, enjoys the wind blowing against her face, dresses in bright yellow, unbothered by pesky intruders, protects other sisters from intruders.
- Little, giving sister (Beans): young, round, can only crawl at first, dresses all in green, thin, fast, good at making food/preparing food for others, weak, needs help to stand, hugs and holds the sisters close together.

Some Southwestern Nations include Rocky Mountain Bee plant (*Cleome serrulata*) as the fourth sister, but sunflower (*Helianthus annuus*) or bee balm (bergamot, *Monarda spp.*) may also serve in this capacity. We ask students to read the seed card for bee balm and answer the following questions: *What could this plant, a fourth sister, contribute as a companion to the other three sister plants? How would you describe her personality and dress? Where would you place the fourth sister in your garden and why? What benefits might the plants receive from the fourth sister and what benefits might people receive? Students discuss medicinal uses of bergamot. Write a creative addition of the fourth sister to the legend of the Three Sisters we read in class. Use graph paper to illustrate your Three Sisters garden (see Appendix 3).*

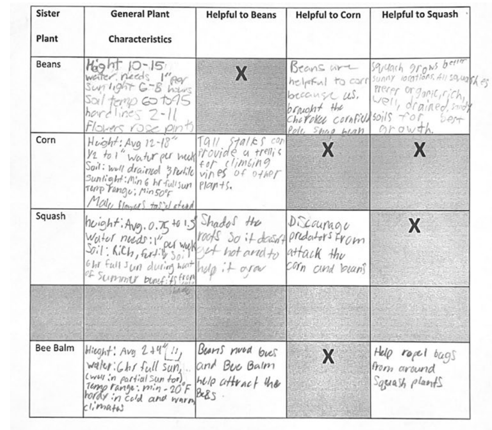
Hearts-on: Affective, emotional connections that engage the heart, application of learning to a new context.

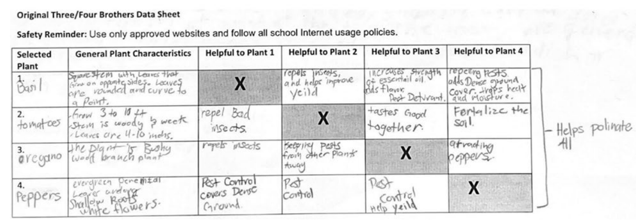
We return to the original example of a Three Sisters Garden (phenomenon) that we shared during the hands-on portion of the lesson. We assess for sensemaking by allowing students to explain their new understanding of plant polyculture now that they have identified the systems that support plant growth and productivity. After showing our example of polyculture we ask, *What advantages to plant growth are evident by this system of planting? How does polyculture increase plant productivity?* After allowing students to share their new understanding, students are prepared to apply their sensemaking of intercropping to new contexts.

Students research other companion plant relationships and describe the mutual benefits the plants share. The Farmer's Almanac (Boeckmann 2021) provides research-based information about companion plants (https://www.almanac.com/companion-planting-chart-vegetables). In groups of three to four, the students engage in a scientific argumentation lesson (see Supplemental Materials) in which they choose three or four plants (one/student) as companion plants and create their own seed cards and stories to explain the relationships between the plants and their environment. Students add another friend or friends to their Three Sisters garden. They might change the arrangements of the plants (see Appendix 3). Students use graph paper to plan and illustrate their companion gardens. We ask students to write and illustrate their own Three (or Four) Brother/Others stories with companion plants they select (Appendix 4). We ask them to justify their plant choices by explaining how their plant selections help each other. They complete the argumentation graphic organizer (Appendix 5) and use the related rubric (Appendix 6) to guide the development of their argument. Students share their polycultures, and through discourse, they select a Brother Garden to plant on the school grounds with a justification for their choice or they create an entire companion garden plan.

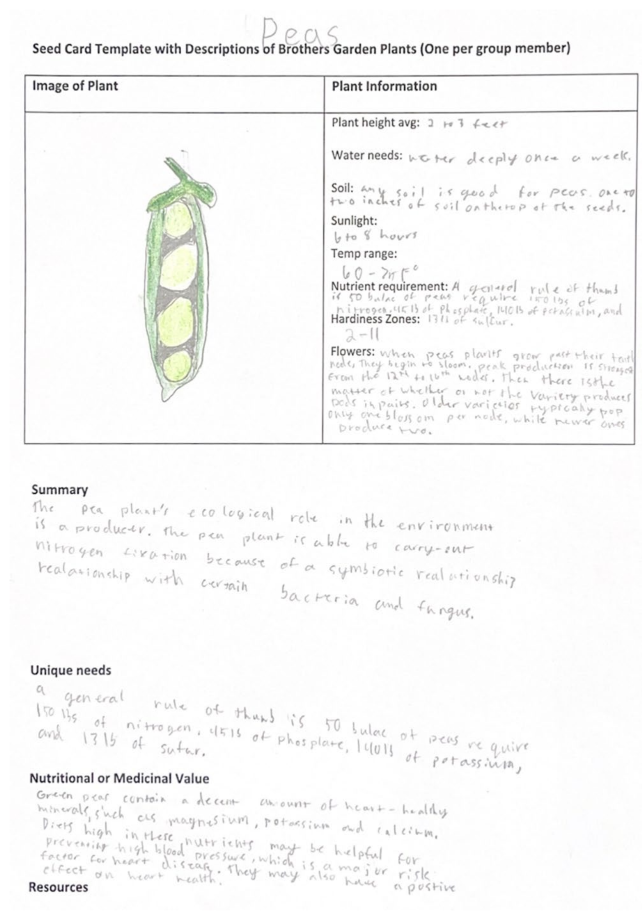
Going further: Making connections with STEAM integrated learning

To take the learning further, we ask students to compare commercial (GMO) plants to heirloom plants. For example, they compare sweet corn (Zea mays subsp. mays) to heirloom varieties of corn (Zea mays). *How are they similar and different? Why do you think people used science to modify these plants? What were the benefits? What are the environmental consequences or impacts of these modified plants compared to the heirloom varieties of similar plants? What are the histories and cultural connections of these plants?*





Student Work Samples



Students' Three Sister Garden.

In a similar way, students compare the benefits and limitations of polyculture *vs.* monoculture farming. *Why do people use monoculture farming? What are the environmental consequences or impacts? What are the benefits and limitations of polyculture farming?*

To make connections to mathematics, students research and plan optimal plant spacing and timing of the plantings (How to Grow a Three Sisters Garden; Square Foot Gardening and Companion Planting). Students may plan the layout of the whole garden area and create a scale drawing. The use of scale factors and measurement grounds the learning in a real-life context (Vela et al. 2022).

We also make connections with local art and a community garden in Salt Lake City, Wasatch Community Gardens. Students study a local artist's (Veronica Perez) painting *Milpa* and read her interpretive description. Students then create their own drawings or paintings, artistically representing the Three Sister legend.

For connections with Native American storytelling, literature and legends, cooking, and other projects, we use *Native American Gardening* (Caduto and Bruchac 1996) and *Buffalo Bird Girl* (Nelson 2015).

Conclusion

The 3-H model conceptualizes student learning through scientific phenomena as recommended by the NGSS (NRC 2013). To be most effective, we must use local phenomena that are common, familiar, real, and relevant to students' lives. This personal relevancy promotes community and culture, important components of SEL. However, we offer a word of caution—in using phenomenon-based instruction, we can risk teaching science for the sake of the phenomenon, which may or may not connect to students' interests or lives or may not be robust enough to support the instruction. In other words, we risk "phenomena mania" where we might select phenomenal phenomena that are sensationalized (e.g., volcanic explosions, tsunamis), relatively rare, and not connected to most students' daily lives (Lee 2020).

School gardens provide an excellent context for staying connected socially and emotionally with peers while engaging with relevant and familiar science phenomena, including interactions among organisms across ecosystems. Over the past 30 years, education researchers have reported overwhelmingly positive outcomes for garden-based learning (Wheeler et al. in press). While we provide one example here of how you may use gardening as a context to engage with phenomena related to companion plants and ecosystems, many other science concepts may be taught through garden-based experiences (e.g., biodiversity, sustainability, basic needs of organisms, heredity of traits, lifecycles, soils and composting [i.e., biogeochemical cycles]). The Three Sisters Garden lesson described here allows students to make connections about the importance of companions (i.e., family and friends) and the need to cultivate these relationships because of how they can benefit one another, both in their personal lives and in the garden. Gardens also provide opportunities for students to develop scientific ways of thinking and science and engineering practices. Recent research indicates that gardening can increase student motivation, facilitate community building, and encourage environmental stewardship. School gardens, including the addition of native plants to existing landscape beds, empower students to make changes in their own backyards and school grounds as they plant and cultivate a brighter future for themselves and others.

This lesson exemplifies school gardens and the ability for students to initiate sensemaking of indigenous Three Sisters Garden intercropping methods. Analyzing gardens from a systems lens allows students to make emotional and cognitive connections between their own need for cultural sociality and plants increased growth and productivity in a polyculture. Through the sensemaking process, students effectively argue for their own Three (or Four) Brothers/Others Garden based on evidence gathered from the lesson and independent research of plant polyculture. Using the 3-H model allows for the addition of SEL in the sensemaking process. When students connect their lived experiences to science, they can see themselves in and a part of the scientific process (Laursen 2019).

Disclosure statement

The authors declare that they have no conflict of interest. The authors report there are no competing interests to declare.

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Appendix 1: Seed cards

Heirloom Corn

Plant height: Avg 12–18″
Water needs: ½ to 1″ per week
Soil: Well drained and fertile
Sunlight: Min 6 h full sun
Temp range: Min 50 °F
Nutrient requirement: nitrogen and phosphorous.
Hardiness zones: 3–11
Flowers: Male flowers on tassel at end of stalk, wind pollinated

Summary
Cherokee Gourdseed Corn (*Zea mays*) (southerexposure.com—three sisters garden package), an heirloom plant, prefers full sun and fertile, well-drained soil for maximum yield. Like all corn, its lineage goes back to Mexico, with evidence from 400 to 800 AD. Indian Gourdseed varieties date back to at least 1700 and were used for roasting, animal feed, and flour. Corn will grow in all Utah soil types that are nutrient rich, well-drained, and fertile. Corn is a warm weather vegetable that requires soil and air temperatures above 60 °F for best germination and plant growth. Plant corn in blocks to ensure good pollination and ear development. Tall stalks can provide a trellis for climbing vines of other plants.

While all corn requires water, this variety is more adapted to harsh conditions, and its strong stalks resist falling over. This variety is more resistant than sweet corn to pests like European corn borers and ear worms. Days to maturity is more than 120 d and you can harvest when ears are plump, silks are dry, and kernels are fully developed. Use ears immediately for best quality. Also known as Cherokee flour, this corn can be used to make grits, tortillas or cornbread.

Unique needs
Heavy nitrogen requirements.

Nutritional value
Corn is high in fiber, potassium, folic acid, and vitamin A. One ear contains 80 calories and 20 g of carbohydrates.

Resources https://www.missouribotanicalgarden.org/plantfinder/plantfindersearch.aspx https://www.southernexposure.com/

Heirloom Beans

Plant height: Avg 10–15′ (when trellised)
Water needs: 1″ per week
Soil: Well drained. Will grow well in soil too poor for most other vegetables
Sunlight: Min 6–8 h full sun but is shade tolerant
Soil temp range: 60– 95 °F
Nutrient requirement: nitrogen and phosphorous
Hardiness zones: 2–11
Flowers: rose-pink flowers, insect pollinated

Summary
While modern North American gardens produce over 4000 different kinds of beans, beans originated in Central and South America. Cherokee peoples, on their forced 4000 mile death march out of their homeland to the Western US, brought the Cherokee Cornfield pole snap bean (*Phaseolus Vulgaris*) to other regions of the country. The drought-tolerant Cherokee Cornfield bean produces very good yields especially when grown on trellises. All beans require full sun and fertile, well-drained soil for maximum yield. Pole beans can help shade and protect other plants from the summer heat. Beans and peas form a beneficial relationship with bacteria commonly found in soil to capture nitrogen from the air, making the nitrogen available to other plants.

Requires 60–70 d from seedling to first harvest for pole beans to yield abundant clusters of thick, meaty, 7–12″ green pods. Delicious as green snap beans when fresh, cooked, or frozen, and when dried for shell beans. Water stress will reduce yields and pod quality. Harvest when pods are plump and full but before seeds develop. For dry beans delay harvest until pods are yellow and dry. Use fresh beans immediately for best quality.

Unique needs
Pole beans are climbing types that flower over long time periods thus yielding more when trellised. Trellises also make harvest easier. Wooden poles or other fencing materials make ideal supports for beans. Plants climb naturally so little additional work is required other than construction of the supports.

Nutritional value
Fresh bean pods are high in fiber, low in calories, and a good source of vitamin C. Dry bean seeds are excellent sources of protein, phosphorus, iron, vitamin B1, fiber, and have very low levels of cholesterol.

Resources https://www.missouribotanicalgarden.org/plantfinder/plantfindersearch.aspx https://www.southernexposure.com/

Heirloom Squash

Plant height: Avg 0.75–1.5′
Water needs: 1″ per week
Soil: Rich, fertile soil
Sunlight: Min 6 hr full sun. During heat of summer benefits from some shade
Soil temp range: 70 °F
Nutrient requirement: nitrogen and phosphorous
Hardiness zones: 2–11
Flowers: yellow flowers, insect pollinated

Summary
Seminole Pumpkin squash (*C. moschata*) will store up to one year at room temperature. The small fruits are sweet and have a firm deep orange flesh inside. The large vines bear 6-inch diameter fruits and are resistant to downy mildew and vine borers. It does need ample water however and room to grow. It is good as a summer squash when picked young and partially green. This winter squash was traditionally grown by the Calusa, Creek and Miccosukee peoples and named "Chassahowitza" in southwest Florida in the tropical riverbanks and swamp hammocks. The fruits can be fried, added to pasta, used in soup and in many other ways. You can eat the seed, leaves, flowers, shoot tips too! The fruit can take up to 125 d to ripen. Squash grows best in sunny locations and in fertile, well-drained soils. Incorporate organic matter and a complete fertilizer into the area before planting. Most varieties of squash do well throughout Utah. All squash prefer organic, rich, well-drained, sandy soils for best growth. Most soils in Utah will grow squash provided they are well drained. The spiky, hairy squash vines make it difficult for invading pests to reach other plants in the garden. Squash benefits from the shade provided by taller plants. Squash plants also provide dense soil coverage that helps deter weeds from popping up around other plants.

Unique needs
Squash needs space for good air circulation around plants to help ward off diseases. May trellis if horizontal space is limited.

Nutritional value
Winter squash are a good source of complex carbohydrates (sugar and starch), fiber and are rich in potassium, niacin, iron and beta carotene (Vitamin A). For example, a ½ cup serving at maturity provides at least 50% of the daily recommended allowance of vitamin A.

Resources https://www.missouribotanicalgarden.org/plantfinder/plantfindersearch.aspx https://www.southernexposure.com/

Bee balm

Plant height: Avg 2–4′

Water needs: once a week, soaking soil 6–8″ deep

Soil: moist soil, neutral pH

Sunlight: 6 h full sun, but can do well in partial sun

Temp range: min −20 °F, hardy in cold and warm climates

Nutrient requirement: nitrogen and phosphorus

Hardiness Zones: 4 – 9

Bloom Time: July to August, insect pollinated

Summary

Bee balm (*Monarda stp.*), commonly referred to as bergamot, prefers full sun but will do well in partial sun (just not blooming as fully). It needs moist, well-drained, rich humus soils and requires good air circulation so as to not develop powdery mildew on its leaves. Bee Balm is a perennial plant that will grow back each year. This plant belongs to the mint family and has bright scarlet red flowers that crowd into dense globular flowerheads. When brushed against, the leaves will emit a minty odor. Each fall the stems should be cut back to 2″ above the soil. Bee Balm is an excellent flower for attracting pollinators, such as bees, butterflies, and hummingbirds.

Unique needs

Bee Balm needs moist soil throughout the growing season and good air circulation around the plant.

Nutritional value

Bee balm plant resins can be used to soothe bee stings. The plant leaves can be used for tea or in salads. The Oswego Indians of New York State still use these leaves to make Oswego tea. The common name for bee balm is wild bergamot because it may smell like bergamot orange. The flowers and leaves are used for medicinal purposes and in supplements and herbal teas. Its main components include carvacrol, hymol, and rosmarinic acids. Bee balm is used to aid digestion, in shampoo, and in skin care products.

Resources https://www.missouribotanicalgarden.org/plantfinder/plantfindersearch.aspx https://www.southernexposure.com/

Appendix 2: Three sisters data sheet

Sister plant	General plant characteristics	Helpful to beans	Helpful to corn	Helpful to squash
Beans		X		
Corn			X	X
Squash				X
Bee Balm			X	

Appendix 3: Three/four brothers/others story

Pictures of 3 sister garden plants

Three sister garden Beans and Corn Squash

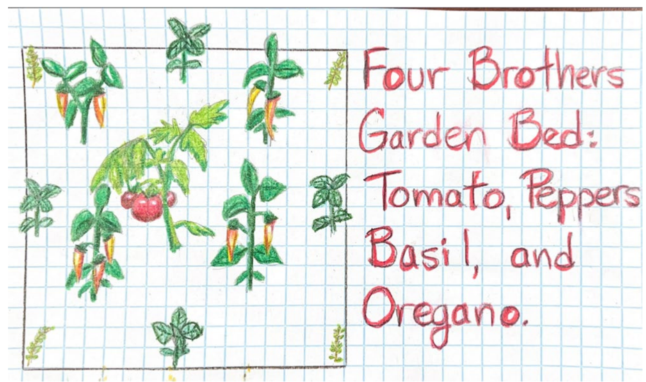
Three sister garden beans and corn squash

Student Work Samples

Three Sisters Garden

Fourth Sister Addition

Other Additions
Brothers/Others Garden



List of possible other plants to consider (remember the criteria from the seed cards as other plants are considered as well as what happens to the soil):

Other plant options: garlic, onions, basil, dill, radishes, clover, native wildflowers (tall *vs.* medium height *vs.* low to ground), other members of the squash family, other members of the legume family (peas or soybeans for example).

Original Three/Four Brothers/Others Data Sheet

Safety Reminder: Use only approved websites and follow all school Internet usage policies.

Selected plant	General plant characteristics	Helpful to Plant 1	Helpful to Plant 2	Helpful to Plant 3	Helpful to Plant 4
1.		X			
2.			X		
3.				X	
4.					X

Seed Card Template with Descriptions of Brothers/Others Garden Plants (One per group member)

Image of plant	Plant information
	Plant height avg: Water needs: Soil: Sunlight: Temp range: Nutrient requirement: Hardiness Zones: Flowers:

Summary

Unique needs

Nutritional or medicinal value

Resources

Scale Drawing of Brother/Others Garden—include a title, scale, key, authors, date, and a compass rose.

Brother/Others Story of Our Garden:

Appendix 4: Rubric for brothers/others story

	4	3	2	1	0
Purpose and background information: What is the purpose of your story? What are you describing? Include background information. Make sure you explain what you know about companion gardens. What type of Brother Garden will you describe?	Purpose and background information written in full sentences and includes the following academic language: polyculture, intercropping, biodiversity, interactions, companions, protection	Purpose and background written in full sentences, with partial use of academic language.	Purpose and background unspecific, not written in complete sentences, and little to no science terminology is referenced.	Background information is not specific, not in full incomplete sentences, and little to no terminology is discussed.	Missing purpose and background information.
Data-based: The story uses data to describe the brother garden and how all of the companions work together.	Data for each brother included in the story to describe the relationships between plants. Story is easy to follow and written in paragraph form.	Data mentioned but incomplete or unclear for each brother. Story easy to follow and in paragraph form.	Data mentioned but clear connections to Brothers unclear. Story vague but in paragraph form.	Not enough data to represent each Brother in the story.	Data about the Brothers not clearly described.
Claim: Analogy for each Brother uses data to describe a story in which all plants work as individuals and contribute to other plant(s). Includes specific description of how each plant contributes and acts as a companion to other plants.	Claim presented in full and complete sentences and answers the guiding question. Analogies for each of the brothers describes how they contribute to each other and act as companions.	Claim presented in full and complete sentences but not specific in answering the guiding question.	Claim presented but sentences are unclear and the guiding question not specifically answered.	Presents a claim but is irrelevant to the story. Guiding question not answered.	Missing a clear claim regarding the Brothers and their companionship in the story.
Data/evidence: Provides at least three pieces of evidence to back up claim. Includes information from seed cards about the Brothers.	Data provided in full sentences. Includes descriptions of the data and the Brothers' companionship. Also included are three pieces of evidence.	Data provided and relevant. Lacks support for evidence. Contains two or less pieces of evidence.	Data provided but does not support the evidence, nor does the evidence fully support the claim. Contains one piece of evidence.	Data provided but includes no description for why the information qualifies as evidence. No evidence to discuss.	Data missing or incorrect.
Conclusion/ reasoning: Explains the reasoning behind data/evidence. Discusses the importance of the Brother Garden and related evidence. Story provides examples and includes a strong ending.	Conclusion summarizes story and relates directly to the claim. Strong reasoning included. Story has an ending that relates to the claim.	Conclusion provides a summary to the story with reasoning but does not relate directly to the claim.	Conclusion does not contain strong reasoning.	Conclusion is brief, missing significant pieces (incomplete), or incorrect.	Conclusion not included.

Appendix 5: Argumentation graphic organizer

Claims-evidence-reasoning Scientific Argumentation Graphic Organizer (CER)

Investigation: Brothers/Others Garden Companion Plants	Questions: *Describe the question or problem that you are investigating, worded as a question.* How can we plant different plants together to support or improve the health and biodiversity of the ecosystem? What are the criteria we used to select the Brother Garden to be installed in our school garden? How will we organize the entire garden based on your Brother Gardens?
Claim: *(Our answers to the questions)* Evidence: *The data show…* *The evidence I use to support … is …* *Based on… I think …* Reasoning: *Based on the evidence, I conclude (restate claim) because (your analysis)…* *The most logical conclusion we can draw from this evidence is that…. because….*	

Appendix 6: Rubric for scientific argumentation

	3	2	1	0
Claim Statement that answers the original question	Makes accurate and complete claim	Makes an accurate claim	Makes an inaccurate claim	No claim
Evidence Scientific evidence appropriate and sufficient to support the claim. Evidence aligned with interpretation of the data.	Provides appropriate and sufficient evidence to support claim	Provides evidence to partially support claim	Evidence provided does not support claim	No evidence
Reasoning Explains why or how evidence supports claim. Must include scientific principles or knowledge related to the topic. Academic vocabulary included and used appropriately	Provides reasoning clearly linked to evidence using scientific principles and terminology. Explains how and why the evidence supports claim	Provides reasoning linked to evidence using scientific principles and terminology. Lacks needed details.	Provides reasoning linked to evidence. Does not include scientific principles and terminology	No reasoning
Sentence fluency and conventions Organization logical (claim, evidence, reasoning). Sentences understandable with standard (professional) grammar	Makes few errors in grammar. Errors do not hinder reader's comprehension. Sentences and overall response have logical flow	Makes some grammar errors. Some sentences are awkward or confusing	Makes many errors in grammar. Errors hinder comprehension. Several awkward or confusing sentences	Incomplete or not understandable