Engineer the Perfect Wheat Plant

Suggested Grade Level: 9-12

Time: Activity 1: 1 45-minute class period, Activity 2: 2 45-minute class periods. Activity 3: several months.

Subject: Science, Biology, Genetics, Engineering, English Language Arts, Informational Reading, Writing, Research, Speaking and Listening, Social Studies, Economics, Climate and Natural Resources, Agriculture

Overview: Students will take on the persona of a young Dr. Norman Borlaug and engineer a perfect wheat plant. Activity 1: Students research Norman Borlaug and the Green Revolution, reporting on his role in addressing world hunger. Activity 2: Students design a "perfect" wheat plant, considering environmental factors, pest and disease risks, harvest and storage, nutrition, and food safety. Activity 3: Students plant wheat seeds and monitor growth to learn about the Feekes scale in real time. *Note: We recommend doing this lesson at the beginning of the year and preparing as early as the beginning of August. See the note at the beginning of Activity 3 for more information.*

Objectives:

1. Describe the research conducted by Dr. Norman Borlaug.
2. Identify what inputs are needed to grow a highly productive food plant in an environmentally responsible way.
3. Assess strategies for delivering safe, nutritious food that helps alleviate world hunger, considering both scientific and ethical perspectives.
4. Design a theoretical "perfect wheat plant" that enhances yield, resilience, and nutrition.
5. Present the "perfect wheat plant" in a persuasive speech.
6. Conduct a controlled experiment to observe and record the growth stages of wheat under specific conditions.
7. Develop a formal report that summarizes experimental results.

Background Information:

Once the science of genetics became better understood, plant breeders used their knowledge of a plant's genes to select for specific desirable traits. This type of genetic modification, known as traditional plant breeding, alters the genetic composition of plants by creating crosses and selecting new, superior genotype combinations. Traditional plant breeding has been practiced for hundreds of years and remains a standard method used today. Plant breeding is a valuable tool, but it has its limitations. First, breeding can only be done between two plants that can mate (cross) with each other. This limits the new traits that can be added to those that already exist in that species. Second, when plants are crossed, many characteristics are transferred along with the trait of interest, including traits with undesirable effects on yield potential. Developing new desirable characteristics is achieved by genetic engineering. Genetic engineering physically removes the DNA from one organism and transfers the gene(s) for one or a few traits into another. It involves four steps to complete:

1. Gene Cloning: Separation of a desired gene from the DNA source and replicating the desired gene thousands of times.
2. Gene Design: Placing the desired gene into the DNA of the plant being engineered.
3. Transformation: The new gene is inserted into the nucleus of some cells, where it is then regenerated into a transgenic plant.
4. Backcross Breeding: Using traditional plant breeding methods, transgenic plants are crossed with elite breeding lines to produce a plant that expresses the trait encoded by the new transgene, with a yield potential similar to that of many hybrids.

Kansas Connections:

Kansas is nicknamed "The Wheat State" for a good reason. Nearly every year, Kansas ranks number one in wheat production nationwide. Kansas farmers regularly contribute several million bushels per year, bringing in more than a billion dollars to our economy. There are three main classes of wheat produced in Kansas: hard red winter wheat, hard white wheat, and soft red winter wheat. Hard red winter wheat is the most common by far because it is ideally suited for our climate. It accounts for almost 40 percent of the wheat grown in the whole United States and 94 percent of all of the wheat grown in Kansas. It's typically used to make high-quality breads and rolls. Aside from that, about five percent of the wheat grown in Kansas is hard white wheat. Hard white wheat is grown for tortillas, hard rolls, noodles, and bread. Soft red winter wheat makes up only about one percent of our wheat, and is usually used for cakes, crackers, flatbreads, and pastries. Wheat can be useful for more than just bread and pastries, though. The elastic nature of gluten, which is found in wheat, makes wheat useful for adhesives, packaging materials, paper, and construction materials. Wheat is also used to produce ethanol, cosmetics, and healthcare products.

Wheat, as we know it, is a modern crop. Its earliest ancestors, wild einkorn ("one-seed") and emmer, were used to make unleavened bread in Europe as early as 5,000 BC. Wheat spread globally after Christopher Columbus brought it from Europe to the West Indies in the 1400s, and Spaniards introduced it to Mexico in the 1500s before it reached the southwestern United States. The first record of wheat grown in Kansas was at the Shawnee Methodist Mission in 1839, and by 1876, production had reached one million acres. Early wheat varieties from the eastern U.S. and Europe struggled in Kansas's climate until the introduction of Turkey Red hard red winter wheat, which transformed wheat farming and remained the most popular variety in Kansas until 1939.

The wheat grown in Kansas today is very different from the older varieties. Modern winter wheat varieties are still around 50 percent Turkey Red, but they've been improved through selective breeding to produce more grain, grow shorter stalks, mature earlier, and resist pests and diseases (Kansas). The bread, noodles, and other foods we eat come from wheat that has been genetically refined for quality and performance. Researchers at Kansas State University study wheat genetics and breeding to develop new varieties for specific purposes, such as drought tolerance or higher protein content. The Kansas Wheat Innovation Center in Manhattan also houses a research lab where scientists analyze wheat DNA to discover how to make future crops stronger, more nutritious, and more sustainable. Click on the links below to learn more about wheat genetic research in Kansas:

- Kansas State University Wheat Breeding: https://www.agronomy.k-state.edu/research/plant-breeding-genetics/wheat-breeding.html
- Kansas State University Wheat Genetics and Genomics: https://www.agronomy.k-state.edu/research/plant-breeding-genetics/wheat-genetics.html
- Kansas Wheat Innovation Center: https://innovation.kswheat.com/#breeding

Materials:

Activity 1: Research Norman Borlaug

- Access to a device with Internet
- Access to presentation software

Activity 2: Design the "Perfect Wheat Plant"

- Speech Scorecard (provided)
- Activity Rubric (provided)

Activity 3: Create a Living Feekes Scale

Per group:

- Clear eight oz. plastic cup
- Coffee filter
- Potting soil
- Hard Red Winter wheat kernels, obtained from a local coop or farmer
- A colored "Solo" cup
- Foil
- Thermometer
- Milk jugs
- One tray
- Popsicle Sticks
- Timer
- Fertilizer - 2 Tablespoons
- Osmocote slow-release fertilizer pellets(N (Nitrogen),15-P(Phosphorus),0-K (Potassium),12).
- General purpose fertilizer N-20; P-10; K-10

For the light stand:

- 1 10-foot-long PVC Pipe 1 inch in diameter, cut into sections: one 4ft section, two 2ft sections, four 6-inch sections. Have a hardware store cut this pipe if you do not have access to a saw
- Basic shop light
- 2 chains with s-links to adjust light height
- 2 T joints, 1-inch diameter
- 2 elbows,
- 4 end caps
- 2 shop light kits
- 2 warm bulbs
- 2 cool bulbs

Activity 1: Research Norman Borlaug

Engagement:
To introduce this lesson, read the Background Information and Kansas Connections sections aloud to the class. Then, prompt students to think critically about how breeding and altering plant genetics can influence agriculture, economies, and societies over time.

Instructional Format:
1. Review background information.
2. Complete the activity.

Procedures:
Activity
1. Explain to your students that they will research Norman Borlaug on their own and come up with a question to ask him about his work in developing the "perfect wheat plant." For example, why did he win the Nobel Peace Prize in 1970?
2. Break your students into groups and give each group a topic based on Borlaug's work.
3. To complete this activity, students will investigate Borlaug's contributions to solving food insecurity challenges. Encourage your students to use credible Internet resources. Examples:
- https://www.britannica.com/biography/Norman-Borlaug.https://www.worldfoodprize.org/index.cfm?nodeID=87664&audienceID=1, https://www.nobelprize.org/nobel_prizes/peace/laureates/1970/borlaug-facts.ht
- Acceptance speech by Norman Borlaug for Nobel Peace Prize: https://www.nobelprize.org/nobel_prizes/peace/laureates/1970/borlaug-lecture.html.
4. Guiding questions for groups:
- Who was Norman Borlaug? How did he get involved in plant breeding?
- Describe Triticale.
- What was the Green Revolution?

- What is the World Food Prize?
5. After a few minutes of research, ask each group to share what they found.
6. Conclude this activity by leading a class discussion using the questions below. Alternatively, the questions could be used for individual assessment.
- What is the significance of Norman Borlaug's work?
- How does his work affect our lives today?

Activity 2: Design the "Perfect Wheat Plant"

Instructional Format:
1. Conduct engagement.
2. Complete the activity.
3. Conduct assessment.

Engagement:
Review Activity 1. Explain to students that scientists are still researching wheat today to make stronger, more nutritious, and more efficient wheat crops. Inform students that they will be taking on the persona of Dr. Norman Borlaug and designing their own "perfect wheat plant."

Procedures:
Activity
1. Students will need to learn background material about wheat production.
2. Gather props to be used for the model of the "perfect wheat plant." Give them the speech scorecard and PowerPoint rubric so they can effectively prepare their speech and presentation.
3. Create groups of students to work on designing the perfect wheat plant traits. Group work can be divided by cutting the rubric into rows and distributing tasks to each group member.
4. Assign each group of students an area in the U.S. or the world that grows wheat. They need to design their "perfect" wheat plant for that particular environment. To satisfy the requirements in the rubric, they need to choose pests they are controlling, such as diseases, insects, and weeds, by designing appropriate genetic modifications to combat these conditions.
5. Their drawings should be scanned into PowerPoint to illustrate the changes in the plant that will help it meet the environmental challenges outlined in the rubric. Each new variety of wheat should include:
- Traits that deal with a hostile environment (they decide the challenge), examples: very cold, very hot, very dry, very wet
- Traits that help with resistance to a common wheat disease of their choice
- Traits that allow a plant to produce a crop despite pressure from a common weed of their choice
- Traits that help with resistance to common wheat insect pests of their choice
- Plants that have traits that show a high yield capacity

- Plants that have traits that make it easy to capture the majority of the grain at harvest
- Plants that have traits that lend themselves to high nutrition and food safety (free from allergens or toxins)

6. *Optional:* Teams can also go into more detail on the production environment and management practices that will enhance growth and grain production in their wheat plant. They may also provide more detailed information on the infrastructure, such as roads and transportation, as well as the funding of farming, which will help increase the food supply for their local population.
7. To conclude this lesson, have students discuss what they liked about each group's new wheat plant. After discussing, collaboratively create a list describing the "perfect wheat plant" that incorporates different traits from each group.

Extension:

1. Take this activity further by writing a paper on a challenging food problem to qualify for admission to the Kansas Youth Institute, which is connected with the World Food Prize. Explore the Youth Programs sponsored by the World Food Prize and Kansas State University College of Agriculture: https://www.worldfoodprize.org/index.cfm?nodeID=87664&audienceID=1.

Activity 3 - Create a "Living Feekes" Scale

Note: The "Living Feekes Scale" activity will most likely not be fully complete within the school year. Winter wheat is planted in the fall, enters winter dormancy around November or December, and reaches maturity in June or July. Teachers may choose to extend the activity only until the wheat enters winter dormancy or the end of the school year. By the end of a typical school year, wheat plants will generally be in the flowering and grain fill phases. Begin preparing for this activity in early August for best results.

Each group of five can grow a different type of plant:

- Winter Bread Wheat - (hexaploid) 42 chromosomes
- Triticum Monococcum (Einkorn) - (diploid) 14 chromosomes
- Aegilops Tauschii (goat grass) - (diploid) 14 chromosomes
- Winter Barley - (diploid) 14 chromosomes
- Winter Rye - (diploid)14 chromosomes

Note: When working with the einkorn seeds, you will need to take an extra amount of time to peel the glume (outside hard covering) away from the seed to prepare for germinating and planting (Soaking the seeds may help loosen the outside coating.)

Instructional Format:

1. Prepare the activity materials ahead of time.
2. Conduct engagement.
3. Complete the activities.
4. Conduct assessment.

Engagement:
Before or during Week 1, read the Career Information section to your students. Ensure students understand that researchers have to be meticulous, and that they will have to be as well to complete this experiment correctly. The Career Information section includes a few videos that you can choose to watch about the Kansas Wheat Innovation Center, which is a wheat research facility in Manhattan. Provide some background information on the Feekes scale, which is used to stage wheat and determine its growth stage. This K-State Research and Extension poster shows the stages: bookstore.ksre.ksu.edu/pubs/wheat-growth-and-development-poster-20x30_MF3300.pdf.

Procedures:
Preparation:

1. Group students into groups of five. Assign each group a different type of wheat:

- Winter Bread Wheat - (hexaploid) 42 chromosomes - Bread Einkorn**
- Triticum Monococcum - (diploid) 14 chromosomes - Flat Bread
- Aegilops Tauschii (goat grass) - (diploid) 14 chromosomes
- Winter Barley - (diploid) 14 chromosomes - a member of the grass family
- Winter Rye - (diploid)14 chromosomes - member of the grass family

*Note**: When working with the einkorn seeds, you will need to take an extra amount of time to peel the glume (outside hard covering) away from the seed to prepare for germinating and planting (Soaking the seeds may help loosen the outside coating.)*

Activity Part 1
Day 1

1. Pass out the Living Feekes Scale Research Journal (provided) to each student. Explain that students will be investigating wheat as it grows to create a "Living Feekes Scale" on PowerPoint/Keynote. They will need to have lots of pictures as well as the date and any observations. Explain that they will be using their research journal to note changes in real-time.
2. Instruct students to read the first page of the research journal and flip to Day 1. Students should follow the instructions and fill out entries as a group.
3. Monitor and offer help when needed.

Day 4:

4. On Day 4, students begin to take the clear cup out of the colored cup to observe germination and early root growth. Guide students to notice the germination and roots.

Day 5-6:

5. Students should start to see three roots appear, one primary and two secondary roots.

Day 7

6. The shoots should start to grow rapidly. Encourage students to think about the beginning of the Feekes scale. Ask, “Does the Feekes scale start at germination or emergence? Have your plants reached Feekes 1?” If the plant has emerged from the soil, it has reached Feekes 1.

Activity Part 2

Day 8:

1. After about a week of germination, the plants will need a grow light. You can create a few of these yourself or have students create their own. Follow the instructions from this video. K-State Extension: Easy to Make Grow Light https://www.youtube.com/watch?v=s_XsyTOYM_M&t=124s

- Insert a two-foot section of pipe into the center of a T joint.
- On each side of the T-joint, insert a 6-inch pipe piece.
- Put an end cap on the exposed ends of the 6-inch pipes.
- Make another leg the same way.
- Put an L-joint on each end of a 4-foot section of pipe.
- Attach the legs to the L-joints.
- Attach two chains to a shop light using S-hooks.
- Hang the light on the frame and adjust by unhooking and hooking the S-hooks.

2. Position the grow light two feet above the growing plants. Set the grow lights on a timer to supply 16 hours of light a day.
3. For the next three weeks, students will need to water plants at least three times per week and record their observations each time. Instruct your students to observe the transplants and log the growth of the stems, leaves, and roots as they water.

Activity Part 3

1. After about one month, plants should start to develop several tillers and leaves. They will need to be moved to a large container (like a 2-3 gallon bucket) or an outdoor plot. Assist students in transplanting their plants.
2. If you are transplanting the plants into a large container: have students plant 3 plants per container, then add Osmocote slow-release fertilizer pellets (N-15, P-0, K-12) to the top of the soil, two tablespoons of fertilizer per container. Make sure you keep the soil watered. Water whenever your finger comes out dry when placed an inch into the soil.
3. If you are transplanting the plants into an outdoor plot: Make sure to plant wheat in October. Place plants in the soil and add Osmocote slow-release fertilizer pellets (N-15, P-0, K-12) to the top of the soil, two tablespoons of fertilizer every 3 plants.
4. Students will sacrifice one plant in each grouping every two weeks by pulling it out of the soil and documenting its appearance. Have students fill out a new copy of the Two Week Checkpoint page every two weeks.

5. At the end of the experiment, have students compile their images with dates included into a PowerPoint/Keynote presentation. Each image should link directly to a stage in the Feekes scale (aside from germination). Instruct students to include helpful information such as observations or a graph of growth rates.

Vocabulary:

- **Traditional Plant Breeding:** Modification of the genetic composition of plants by making crosses and selecting new superior genotype combinations.
- **Genetic Engineering:** The process of removing the DNA from one organism and transferring the gene(s) for one or a few traits into another. It involves four steps: gene cloning, gene design, transformation, and backcross breeding.
- **Gene Cloning:** Separation of a desired gene from the DNA source and replicating the desired gene thousands of times.
- **Gene Design:** Placing the desired gene into the DNA of the plant being engineered.
- **Transformation:** The new gene is inserted into the nucleus of some cells, where it is then regenerated into a transgenic plant.
- **Backcross Breeding:** Using traditional plant breeding methods, transgenic plants are crossed with elite breeding lines to produce a plant that expresses the trait encoded by the new transgene, with a yield potential similar to that of many hybrids.
- **Green Revolution:** An increase in the availability of food in the mid-20th century, driven by American scientist Norman Borlaug and the development of high-yield crop varieties.
- **Feekes Scale:** A system developed by Willem Feekes in 1941 that organizes the growth and development of crops, such as wheat, into distinct stages.

Kansas Standards:

Next Generation Science Standards

Ecosystems: Interactions, Energy, and Dynamics

HS-LS2-7. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Heredity: Inheritance and Variation of Traits

HS-LS3-1. Ask questions to clarify relationships about the role of DNA and chromosomes in coding the instructions for characteristic traits passed from parents to offspring.

Biological Evolution: Unity and Diversity

HS-LS4-6. Create or revise a simulation to test a solution to mitigate the adverse impacts of human activity on biodiversity.

Engineering Design

HS-ETS1-1. Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Language Arts
9th-10th Grade
Informational Reading
Range of Reading and Text Complexity
RI.9-10.13 Read and comprehend high-quality informational text of appropriate quantitative and qualitative complexity for grades 9-10.
Writing
Text Types and Purposes
W.9-10.1 Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.
Production and Distribution of Writing
W.9-10.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
W.9-10.6 Use technology, including the internet, to produce, publish, and update individual or shared writing products, taking advantage of technology's capacity to link to other information and to display information flexibly and dynamically.
Research to Build and Present Knowledge
W.9-10.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate, synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
W.9-10.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism, and following a standard format for citation.
W.9-10.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.
Range of Writing
W.9-10.12 Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes, and audiences.
Speaking and Listening
Comprehension and Collaboration
SL.9-10.1 Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 9-10 topics, texts, and issues, building on others' ideas and expressing their own clearly and persuasively.
SL.9-10.2 Integrate multiple sources of information presented in diverse media or formats, evaluating the credibility and accuracy of each source.
Presentation of Knowledge and Ideas
SL.9-10.4 Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.
SL.9-10.5 Make strategic use of digital media in presentations to enhance understanding of findings, reasoning, and evidence, and to add interest.

11th-12th Grade
Informational Reading
Range of Reading and Text Complexity
RI.11-12.13 Read and comprehend high-quality informational text of appropriate quantitative and qualitative complexity for grades 11-12.
Writing
Text Types and Purposes
W.11-12.1 Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence.

Production and Distribution of Writing
W.11-12.4 Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.
W.11-12.6 Use technology, including the Internet, to produce, publish, and update individual or shared writing products in response to ongoing feedback, including new arguments or information.
Research to Build and Present Knowledge
W.11-12.7 Conduct short as well as more sustained research projects to answer a question (including self-generated questions) or solve a problem; narrow or broaden the inquiry when appropriate, synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation.
W.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source, and following a standard format for citation.
W.11-12.9 Draw evidence from literary or informational texts to support analysis, reflection, and research.
Range of Writing
W.11-12.12 Write routinely over extended time frames (time for research, reflection, and revision) and shorter time frames (a single sitting or a day or two) for a range of tasks, purposes.
Speaking and Listening
Comprehension and Collaboration
SL.11-12.1 Initiate and participate effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grades 11-12 topics, texts
and issues, building on others' ideas and expressing their own clearly and persuasively.
SL.11-12.2 Integrate multiple sources of information presented in diverse formats and media in order to make informed decisions and solve problems, evaluating the credibility and accuracy of each source and noting any discrepancies among the data.
Presentation of Knowledge and Ideas
SL.11-12.5 Make strategic use of digital media in presentations to enhance understanding of findings, reasoning, and evidence, and to add interest.

History, Government, and Social Studies
Standard 1: Choices have consequences.
1.1 The student will recognize and evaluate significant choices and consequences that have impacted our lives and futures.
1.4 The student will use their understanding of choices and consequences to make a claim or advance a thesis using evidence and argument.
Standard 3: Societies are shaped by the identities, beliefs, and practices of individuals and groups.
3.2 The student will analyze context and draw conclusions of how societies are shaped by the identities, beliefs, and practices of individuals and groups.
3.3 The student will investigate and connect how societies are shaped by the identities, beliefs, and practices of individuals and groups with contemporary issues.
3.4 The student will use their understanding of how societies are shaped by the identities, beliefs, and practices of individuals and groups to make a claim or advance a thesis using evidence and argument.
Standard 4: Societies experience continuity and change over time.
4.3 The student will investigate and connect continuity and change to a contemporary issue.
4.4 The student will use their understanding of continuity and change to make a claim or advance a thesis using evidence and argument.

National Agricultural Literacy Standards:
Plants and Animals for Food, Fiber, and Energy
- Discuss reasons for the government's involvement in agricultural production, processing, and distribution (T.2 9-12 c.)

Science, Technology, Engineering, and Mathematics

- Correlate historical events, discoveries in science, and technological innovations in agriculture with day-to-day life in various time periods (T.5 9-12 a.)
- Describe how agricultural practices have contributed to changes in societies and environments over time (T.5 9-12 b.)
- Discuss population growth and the benefits and concerns related to science and technologies applied in agriculture to increase yields and maintain sustainability (T.5 9-12 c.)
- Evaluate the benefits and concerns related to the application of technology to agricultural systems (e.g., biotechnology) (T.5 9-12 d.)

Culture, Society, Economy, and Geography

- Communicate how the global agricultural economy and population influence the sustainability of communities and societies (T.5 9-12 a.)
- Discuss how agricultural practices have increased agricultural productivity and have impacted (pro and con) the development of the global economy, population, and sustainability (T.5 9-12 e.)
- Discuss the relationship between geography (climate and land), politics, and global economies in the distribution of food (T.5 9-12 f.)
- Evaluate and discuss the impact of major agricultural events and agricultural inventions that influenced world and U.S. history (T.5 9-12 g.)

Supporting Resources:
Exploring Plants Kansas Crops Educator's Guide
https://ksagclassroom.org/education-center/educators-guide/

Kansas Wheat Alliance: K-State Wheat Breeder Guorong Zhang and variety KS Bill Snyder (KS19H10) https://www.youtube.com/watch?v=av70cvKKCe8.

K-State Extension Webpage
https://www.agronomy.k-state.edu/extension/crop-production/wheat/index.html.

The Man Who Tried to Feed the World Documentary
https://tv.apple.com/us/movie/the-man-who-tried-to-feed-the-world/umc.cmc.2oomzwlmja48lhz56249b3w45 (52 minutes)

Wheat Germ DNA Extraction Lesson
https://ksagclassroom.org/education-center/lesson-plans/wheat-germ-dna-extraction/

Wheat Growth Stages
https://ksagclassroom.org/education-center/resources/wheat-growth-stages/

Wheat Plant Part Labeling
https://ksagclassroom.org/education-center/resources/wheat-labeling-plant-parts-chart-key/

Career Information: Research Technician
A research technician works in a laboratory setting (which includes field or farm work) to assist a research scientist. Research technicians commonly operate and maintain laboratory equipment, record and input laboratory data, assist in seeding and harvesting crops, identify damage caused by pests and diseases, and provide crop treatments.

Research technicians typically require a bachelor's degree in agronomy, horticulture, animal science, poultry science, aquaculture, or laboratory technology. They often work at universities or for seed, animal health, or pharmaceutical companies.

Assessment: Students could be assessed based on their Activity 2 and Activity 3 presentations.

Author: Amy Benz, retired middle school technology teacher from St. Marys, KS, KFAC Advisory Council, and edited by Marissa Cook, Secondary Education Major at KSU, KFAC intern.

References:

Kansas Foundation for Agriculture in the Classroom. (n.d.). *Unit 4: Kansas Crops* (pp. 58–62). Retrieved June 26, 2026, from https://cdn.agclassroom.org/ks/resource/guides/naturalresources/04crops.pdf

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Speech Scorecard

Items to Consider	Possible Points	Earned Points	Teacher Comments
Subject Matter Covered in max time length Information is accurate Information is complete Sources are recognized	**40**		
Appearance Professional Good Posture	**10**		
Organization Introduction • Catches attention • States purpose Body • States main point • Develops main idea Summary/Conclusion • Reviews main points • Summarizes entire speech • Wraps up speech with comment, challenge, interesting fact, or quote	**25**		
Delivery Voice is loud and clear Talks at natural speed Uses vocabulary that is easy to understand Was at ease Was pleasant Was enthusiastic	**25**		

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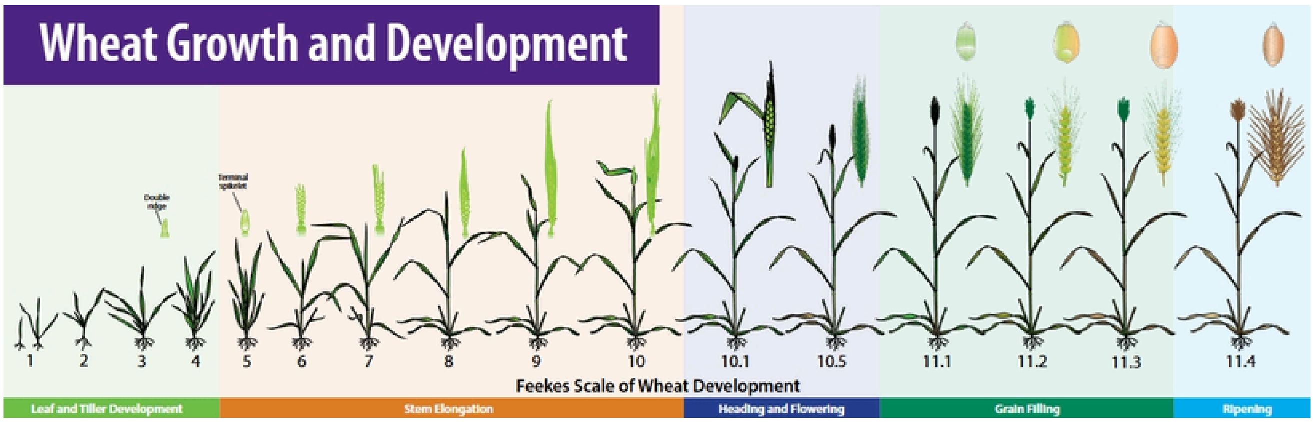
PowerPoint Rubric

Criteria	5: Mastery	4: Proficient	3: Competent	2: Developing	1: Needs Improvement
Problem & Solution	Problem is real and well-identified, solution is realistic and well-explained.	Problem is real and identified, solution is mostly realistic and well-explained.	Problem is identified, solution fits but lacks depth.	Problem is real but vague, solution is unrealistic or unclear.	Problem and/or solution missing or unclear.
Scientific Accuracy	Strong scientific accuratcy and connection to the problem.	Mostly scientifically accurate, connection is clear.	Some scientific accuracy, some connection to the problem.	Design is scientifically weak, connection to the problem is vague.	Scientific connection missing or inaccurate.
Slide Quality	Clean, organized slides with helpful visuals; easy to follow.	Clear slides; visuals support content.	Slides are readable but inconsistent/cluttered.	Hard to follow; poor organization.	Presentation is confusing or incomplete.
Delivery	Confident, clear, well-coordinated; strong explanations.	Clear delivery, mostly coordinated and well-explained.	Understandable, some uneven coordination.	Disorganized and/or uneven participation.	Unprepared and/or little understanding and explanation.
Points					

Name: ______________________________ Group: ______________________________

Living Feekes Scale

Research Journal



From "Wheat Growth and Development" poster by Romulo Lollato, K-State Research and Extension, Kansas Wheat. bookstore.ksre.ksu.edu/pubs/wheat-growth-and-development-poster-20x30_MF3300.pdf

The Feekes scale, invented by the Dutchman W.W. Feekes in 1941, is a system used by scientists and farmers to describe the growth stages of cereal crops such as wheat. The Feekes scale is made up of standardized stages. Stages 1-4 make up the first process, Leaf and Tiller Development. During this time, wheat plants emerge from the ground and grow leaves and tillers (side shoots). Stages 5-10 make up the Stem Elongation process, where stems become stronger, nodes become visible, and the last leaf (the "flag leaf") develops. Head Emergence and Flowering occurs during stages 10.1-10.5. Stages 11.1, 11.2, and 11.3 mark the Grain Filling process, where wheat berries go from soft and watery to hard dough. At stage 11.4, wheat kernels are hard and ready for harvest.

For the next few months, you will be investigating wheat as it grows to create a "Living Feekes Scale." Use the information above to help you as you go.

PART 1: Seeding & Germination

You will need:

- Clear eight ounce plastic cup
- Sharp knife or scissors
- Potting soil
- Wheat seeds
- Colored eight ounce plastic cup
- Paper towel or coffee filter
- Pencil or popsicle stick
- Aluminum foil

Day 1

Date: ___/___/____

1. Write your name on both a clear and a colored plastic cup.
2. Use a sharp knife or scissors to make several drainage holes in the bottom of the cups.
3. Moisten a paper towel or ½ of a coffee filter and form it around the inside of a clear plastic cup.
4. Add potting soil to the cup to hold the paper towel or filter in place.
5. Using a pencil or popsicle stick, place kernels of wheat between the towel and the cup wall (so you can still see the seeds). Plant at least 10 seeds per group.
6. Place the clear cup into the plastic cup.
7. Form foil around the colored cup to block all sunlight from reaching the roots.
8. What do you think will happen to the seeds after 3 days? Record your hypothesis below.

____

____

Day 4

Date: ___/___/____

1. Take the clear cup out and observe. What do you notice about the roots? Was your hypothesis correct? Take a picture and record your observations below.

____

____

2. Place the clear cup back into the colored cup.

PART 1: Seeding & Germination

Day 5

Date: ___/___/_____

1. Observe the roots again. What do you notice? Has anything changed?

____

____

Day 6

Date: ___/___/_____

1. By Day 6, you should be able to see 3 roots: one primary and two secondary. Take a picture of the plant and record any changes below.

____

____

Day 7

Date: ___/___/_____

1. Observe the whole plant. Do you notice any changes aside from root growth?

____

____

2. At the end of Day 7, there should be three roots and beginning shoots. Has the wheat plant reached Feekes stage one? Why or why not?

____

____

____

____

PART 2: Transplant 1

You will need:

- 1 10-foot-long PVC pipe, 1 inch in diameter
- 2 elbows
- 2 warm bulbs
- Timer
- Scissors
- Fertilizer - 2 Tablespoons
- General purpose fertilizer N-20; P-10; K-10
- 2 T-joints, 1-inch diameter
- 4 end caps
- 2 shop light kits
- 2 cool bulbs
- One gallon milk jug
- Potting soil
- Osmocote slow-release fertilizer pellets

Day 8

Date: ___/___/____

1. After about a week of germination, you will need to create a light stand.
2. Insert a two-foot section of pipe into the center of a T joint.
3. On each side of the T-joint, insert a 6-inch pipe piece.
4. Put an end cap on the exposed ends of the 6-inch pipes.
5. Make another leg the same way.
6. Put an L-joint on each end of a 4-foot section of pipe.
7. Attach the legs to the L-joints.
8. Attach two chains to a shop light using S-hooks.
9. Hang the light on the frame and adjust by unhooking and hooking the S-hooks.
10. Position the grow light two feet above the growing plants. Set the grow lights on a timer to supply 16 hours of light a day.
11. Transplant seedlings into larger containers.
12. Document the growth of roots and leaves:

____

____

PART 2: Transplant 1

Day 8 - Continued

13. Cut off the tops of one-gallon milk jugs so that the jug is about 6″ tall.
14. Cut drainage holes into the bottoms of the jugs.
15. Fill a jug with potting soil, making sure to leave 2-3″ from the top.
16. Transplant 3-4 of the sprouted seedlings into a small 2″ wide x 4″ deep milk jug.
17. Put one transplant in each corner of the pot. Plant roots 1 inch deep.
18. Label the jug with your group and type of wheat using a marker and a Popsicle stick.
19. Add water to the jug so that the soil is moist, not wet.
20. Place labeled water jugs onto a tray.
21. Wheat likes cooler temperatures. Place the plants in a cooler area of the room, using your new light stand, or consider placing them outside. Keep the temperature around 40 degrees.
22. Dissolve 2 tablespoons of N-20, P10, K-10 fertilizer in 1 quart of water. Use this fertilizer water when you water the plants every other day (three times a week).
23. Each time you water the plants, take a picture.
24. What do you predict will happen to the plants after three weeks?

PART 2: Checkpoints

Checkpoint 1

Date: ___/___/____

1. How tall is the plant in inches? __________
2. Do you notice any changes in the stem, leaves, and roots?

____

____

Checkpoint 2

Date: ___/___/____

1. How tall is the plant in inches? __________
2. Do you notice any changes in the stem, leaves, and roots?

____

____

Checkpoint 2

Date: ___/___/____

1. How tall is the plant in inches? __________
2. Do you notice any changes in the stem, leaves, and roots?

____

____

PART 2: Checkpoints

Checkpoint 4

Date: ___/___/____

1. How tall is the plant in inches? __________
2. Do you notice any changes in the stem, leaves, and roots?

Checkpoint 5

Date: ___/___/____

1. How tall is the plant in inches? __________
2. Do you notice any changes in the stem, leaves, and roots?

Checkpoint 6

Date: ___/___/____

1. How tall is the plant in inches? __________
2. Do you notice any changes in the stem, leaves, and roots?

PART 2: Checkpoints

Checkpoint 7

Date: ___/___/____

1. How tall is the plant in inches? __________
2. Do you notice any changes in the stem, leaves, and roots?

Checkpoint 8

Date: ___/___/____

1. How tall is the plant in inches? __________
2. Do you notice any changes in the stem, leaves, and roots?

Checkpoint 9

Date: ___/___/____

1. How tall is the plant in inches? __________
2. Do you notice any changes in the stem, leaves, and roots?

PART 3: Transplant 2

You will need:

- 2-3 gallon bucket OR outdoor plot
- Osmocote slow-release fertilizer pellets (N-15, P-0, K-12)

When the plants have several tillers and leaves (most likely at the end of a month), they will need to be transplanted again. You can either transplant them in a large container or an outdoor plot.

If you are transplanting the wheat into a large container:

1. Transplant the wheat plants into a larger container such as a 2-3 gallon bucket. There should be around 3 plants per container.
2. Add Osmocote slow-release fertilizer pellets (N-15, P-0, K-12) to the top of the soil in the container, two tablespoons of fertilizer per container.
3. Water the soil. Water whenever your finger comes out dry when placed an inch into the soil.

If you are transplanting the wheat into an outdoor plot:

1. Make sure to transplant the wheat in early October.
2. Place plants in the soil. Roots should be deep in the soil.
3. Add Osmocote slow-release fertilizer pellets (N-15, P-0, K-12) to the top of the soil, two tablespoons of fertilizer per 3 plants.

After three to eight weeks of temperatures below 50 degrees Fahrenheit, the plants will enter a stage called winter dormancy. This process allows the wheat to survive the cold temperatures and harsh conditions of winter. In what Feekes stage does winter dormancy occur?

____

PART 3: Checkpoints

Two Week Checkpoint

1. How tall is the plant in inches? ________
2. Describe the stem. ____

____

____

3. Describe the shoots. ____

____

____

4. Describe the leaves. ____

____

____

5. Describe the head. ____

____

____

6. Describe the grain (if any). _______________________________________

____

____

7. Look at the Feekes scale. What stage do you think your wheat plant is at?

____

____

Add your picture to a PowerPoint/Keynote presentation with the Feekes stage.