Data quality in automation of food production

A soil nutrient experiment

FACILITATOR GUIDE | AGRICULTURAL CYBERBIOSECURITY ACTIVITY



https://doi.org/10.21061/cyberbiosecurity

Activity overview and background information:

The overall goal of this activity is to emphasize the role of data quality to inform programming of automated systems in agriculture, while engaging participants in planning and conducting a scientific experiment on the effects of nutrient application on plant growth. This activity can be implemented using simple gardening equipment in a controlled environment. For background information on cyberbiosecurity concepts in this activity, please see the following Fact Sheets in the Cyberbiosecurity Education Resource Collection at https://doi.org/10.21061/cyberbiosecurity

- Cyberbiosecurity
- Data Literacy
- Precision Agriculture
- Sensors

Important Note: This guide is intended to provide an overarching structure for the activity, with an emphasis on situating the plant science experiment in the context of cyberbiosecurity. Facilitators unfamiliar with fertilizer application, growing plants from seed and/or experimental design are encouraged to utilize outside resources for these aspects.

You should **choose a seed variety** that best matches plants that are locally grown or can be easily grown given local laboratory conditions. The variety should be something that readily shows the effects of fertilizer application; corn, tomatoes, and pennycress (cover crop) are recommended (as appropriate for your conditions). Please consult a local gardening store or Cooperative Extension resources for guidance on 1) selecting an appropriate seed variety, fertilizer, and growing conditions and 2) plant characteristics that are sensitive to fertilizer for that variety (e.g., plant height, time to bolt).

The Driven to Discover Facilitator's Guide to Citizen Science has excellent **guidance on facilitating scientific investigations** with youth (https://conservancy.umn.edu/handle/11299/198635).

Learning objectives:

1. Determine through experimentation, observation and data collection, and data analysis the effects of nutrient application(s) on plant growth.
2. Explain the role of data quality in ensuring food safety and security in automation of food production.
3. Describe techniques for ensuring validity and reliability of data in experimental design.

Vocabulary:

1. **Independent variable**: the variable that is changed by the researcher
2. **Dependent variable**: the variable that responds to changes and is measured by the researcher
3. **Controlled variable**: a variable that is not changed (held constant) in a study
4. **Validity**: accuracy of a measure; do the results actually represent what they are supposed to?
5. **Reliability**: consistency of a measure; if you measure the same thing in the same way, do you get the same result?
6. **Precision agriculture**: A farm management technique that uses observations and measurements to optimize production.
7. **Automated**: carried out by machines or computers without needing human control.
8. **Fertilizer**: a substance added to soil to increase its fertility
9. **Cyberbiosecurity**: identification of the weak spots between biosecurity, cybersecurity, and cyber-physical security to safeguard data and systems
10. **Germinate**: to begin to grow from a seed
11. **Bolting**: when a plant grows flower stalks and produces seeds too early to produce a good harvest.
12. **Leaf**: flat green blade growing out from the stem; main site of photosynthesis
13. **Foliage**: leaves of a plant, typically a mass of leaves
14. **Micronutrients**: elements that are essential for plants that are needed in small amounts
15. **Macronutrients**: elements that are essential for plants that are needed in large amounts
16. **Nitrogen cycle**: the processes that move nitrogen through the atmosphere, soil, water, plants, animals and bacteria in a repeating cycle

SOLs and CTE competencies:

- CS 6.10: use models and simulations to formulate, refine, and test hypotheses.
- CS 7.8: discuss the correctness of a model representing a system by comparing the model's generated results with data that were observed in the system being modeled.
- Sci 6.1: demonstrate an understanding of scientific and engineering practices…
- Ag 8002: 44. Identify basic requirements for plant growth and development.
- Ag 8004: 40. Perform an agriculture/agriscience experiment.
- CTE Prof Comp: Demonstrate proficiency with technologies, tools, and machines common to a specific occupation.

Materials, supplies, and activity prep:

See note in activity overview for guidance on selecting materials. For this activity, you will need:

1. Location to grow plants where each pot has relatively consistent sunlight, temperature, etc.
2. At least three seeds per participant.
3. Pots or other containers (1 per seed).
4. Soil to fill all containers.
5. Fertilizer and equipment for measurement and consistent application.
6. Water and equipment for measurement and consistent application.
7. Personal Protective Equipment
8. Youth Activity Guide for each participant
9. Precision Agriculture youth fact sheet – print or electronic access for each participant https://doi.org/10.21061/cyberbiosecurity

Safety:

Follow all relevant safety procedures as recommended for your fertilizer of choice and general laboratory safety rules, including but not limited to:

1. Proper handling of all materials
2. Personal Protective Equipment (PPE)
3. Proper disposal and storage of chemicals and materials

Time:

The timing of the activity is highly dependent on the seed variety that you are growing and the level of familiarity that participants have with basic plant science and scientific investigation concepts. The time needed for Part 1 will depend on participant prior experience with experimental design concepts, taking between 45 and 90 minutes). In general, Parts 2, 4, 5, and 6 can each be facilitated in a 45-minute session, with Part 3 (Plant Growth and Data Collection) taking a few minutes per day over several days/weeks.

Setting the stage:

Purpose: Participants become familiar with the role of automation in precision agriculture.

1. Participants review the fact sheet on Precision Agriculture to develop an understanding of what it is
    a. Extension: Facilitators could supplement this information with a video or have participants do research to find the coolest new things in precision agriculture (e.g., Farmbots, automated systems on tractors, etc.)
2. Have a group discussion on automation:
    a. What is it? *Processes being carried out by machines or computers without needing human control*
    b. How does the automated system know what to do? *Programming*
    c. How does the programmer know what to tell the computer to do? *Data from plant scientists*
3. Introduce the activity: *For this activity, you all are going to be plant scientists. We are going to focus on plant growth. We are trying to optimize the system; this requires good data to input into the automated systems to tell it what to do to maximize production and minimize cost and environmental impact. Your job is to collect the best data that you can.*
4. Review safety: Make sure to reinforce throughout activity
    a. Proper handling of all materials and PPE
    b. Proper disposal and storage of chemicals and materials
    c. General lab safety rules

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Activity facilitation steps:

There are 6 parts to this activity, as described here. Part 3 represents the growing and data collection time and is constrained by the growing process, whereas the other parts can be combined into longer sessions or facilitated as standalone lessons.

Part 1: Measurement and Experimental Design

Purpose: Introduce central ideas of measurement and experimental design and plan for the plant growth experiment.

Instructions:

1. Warm-up and context: Remind participants that they are scientists trying to get good data to give to the programmers for an automated fertilizer application system. For our experiment, we want to know the effect of amount of fertilizer on plant growth and health.
    a. Ask: What skills do we need as scientists to get good data?
2. Review/teach key concepts in measurement and experimental design in context of planning investigation on plant growth. Participants should record the design decisions in the Youth Guide. Key questions that the group should answer include:
    a. What is the independent variable? *Fertilizer application (amount, concentration, etc.)*
    b. What is(are) the dependent variable(s)? *E.g., plant growth, plant health*
    c. What are the controls? *E.g., soil, watering amount and frequency, rate of fertilizer application, size of pots, location of pots, planting procedures*
    d. What data will we collect? What do we think that it will it tell us? *E.g., plant height (measure of growth), number of leaves (measure of growth), color of leaves (measure of health), day of bolting (measure of health/stress).*
    e. What procedures will we use to ensure that we get valid and reliable data? *Participants should develop a data collection plan, including instruments that they will use, a "key" for making consistent observations (e.g., photos of bolting plant of the same variety), and procedures for plant care and fertilizer application consistent with variables and controls.*
    f. How will we ensure that we keep good records? *Participants should develop a plan for how they will record the data, including any tables that they think would help in organizing their data*
    g. How will we analyze our data? *E.g., plot bolting date versus fertilizer amount to see if there is a correlation*

Part 2: Planting

Purpose: Set up the growth experiment in the space where the plants will grow.

Instructions:

1. Warm-up and context: Remind participants that they need to follow the plan that they developed for running the growth experiment and collecting good data. Before we can collect data, first we need to set up our growth experiment.
2. Plant: Work with the participants to plant seeds according to the recommendations for the variety you are using and ensuring that the controls are addressed (e.g., same soil for each pot). Pots should be labeled with the experimental conditions (e.g., "No fertilizer").
3. Record: Planting procedures should be recorded in the Youth Guide.

Part 3: Plant Growth and Data Collection

Purpose: Conduct the experiment and ensure careful data collection.

Instructions:

1. Warm-up: Remind participants that they need to follow the plan that they developed for running the growth experiment and collecting good data.
2. Plant care/fertilizer application: Participants will follow the procedures outlined in their plan throughout the growing period, taking care to record what they did each time.
3. Data collection: Participants will follow their data collection/ record keeping plan.

Part 4: Data Analysis and Draw Conclusions

Purpose: Analyze data and draw conclusions.

Instructions:

1. Warm-up: Why have we been collecting data on our plants over the past several weeks? What were we trying to learn?
2. Data analysis: Participants will follow the data analysis procedures that they developed, including making any plots and carrying out any calculations that they need to.
3. Draw conclusions: Participants will use their data to develop statements about the outcomes of their growth experiment. This component is in their Youth Activity Guide.

Part 5: Recommendations for Automated System

Purpose: Use findings to make recommendations for an automated system.

Instructions:

1. Warm-up: Have a group discussion on automation (review from setting the stage):
   a. What is it? *Processes being carried out by machines or computers without needing human control*
   b. How does the automated system know what to do? *Programming*
   c. How does the programmer know what to tell the computer to do? *Data from plant scientists*
2. Reminder of scenario: *For this activity, you all are going to be plant scientists. We are going to focus on plant growth. We are trying to optimize the system; this requires good data to input into the automated systems to tell it what to do to maximize production and minimize cost and environmental impact. Your job is to collect the best data that you can.*
3. Recommendations: Participants will make recommendations for an automated system based on their dataset. They will need to defend their recommendations using their data and discuss data quality control measures that they used. This exercise is in the Youth Activity Guide.

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Part 6: Connections to Cyberbiosecurity

Purpose: Identify cyberbiosecurity implications concerns in automated production systems.

Instructions:

4. Warm-up: What is cyberbiosecurity? What ideas do you have for cyberbiosecurity concerns in automated systems?
5. Discussion on security of automated systems (small group, whole group, or think-pair-share):
   a. If we were to build an automated system to grow the same plants that we did, what would you look for to know that the system is working? *E.g., healthy plants, meeting growth targets, right leaf color, etc.*
   b. How would you know if the system was "hacked" (i.e., controls were tampered with)? *For the fertilizer application system, you would expect to start seeing signs of nutrient deficiencies or excesses.*
   c. If you were in charge of making sure an automated system was operating properly, how would you monitor the system? What safeguards would you put in place? *E.g., routine drone surveillance, etc.*

Processing questions

Share

1. What are the benefits and drawbacks to precision farming?
2. What are some career opportunities that might exist in precision farming now and in the future?

Generalize

1. Why is measurement important in optimizing plant growth and minimizing environmental impact?
2. Why is the scientific method important for data quality?

Apply

1. What are some other types of agricultural production that could benefit from automation?

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About this project

Cyberbiosecurity is an emerging field that focuses on creating security measures for digital aspects of our food and agriculture systems, creating a structure and opportunity for a safe food system that can meet the large needs of a growing population and world. This educational resource was developed as part of a project to support formal and non-formal agricultural educators in integrating cyberbiosecurity topics and research-based strategies for engaging middle-school-aged girls in STEM into their educational programs.

The entire resource collection can be accessed here: https://doi.org/10.21061/cyberbiosecurity

The project is an outreach effort of the Virginia Tech Center for Advanced Innovation in Agriculture.

COLLEGE OF AGRICULTURE AND LIFE SCIENCES
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This definition of OER is provided by The William and Flora Hewlett Foundation.

How to access these templates

The main landing page for these resources is https://doi.org/10.21061/cyberbiosecurity.

This page includes a downloadable and editable Word document for the:

- Student fact sheet
- Student activity sheet
- Faculty guide

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