Agriculture from Above x Agriculture for All
Drone and GIS education for teenagers
AgFromAbove.org

SkyMappers: Agricultural Drones and GIS Mastery

AgFromAbove.org

Abstract

SkyMappers: Agricultural Drones and GIS Mastery is a 17-lesson curriculum designed for youth ages 13 to 18. Developed through the Ag from Above x Ag for All project, the curriculum introduces drones, remote sensing, and geographic information systems as tools for investigating agriculture, food systems, environmental conditions, and community issues. Youth progress from matching drone types and payloads to real-world missions, to learning responsible flight rules, equipment care, airspace awareness, crew communication, preflight routines, and supervised flight skills. They then explore how drone imagery becomes useful data through GPS, photo stitching, sensor imagery, spatial resolution, Drone2Map, ArcGIS, and careful interpretation. The curriculum culminates in youth-driven projects in which teams define a mission question, plan a safe and respectful workflow, collect or use imagery, process data, interpret results, and present findings.

The curriculum integrates experiential learning, project-based learning, positive youth development, culturally relevant pedagogy, and data ethics. Across the sequence, youth build five core competencies: place-based problem framing, responsible operations, mission design for data quality, imagery processing, and GIS-based analysis and communication. The curriculum emphasizes safety, FAA awareness, privacy, consent, cultural respect, and the importance of choosing whether drones are the right tool for a given purpose.

Authors

Steven M. Worker, 4-H Youth Development Advisor, University of California, Agriculture and Natural Resources, smworker@ucanr.edu
Sean Hogan, IGIS Academic Coordinator, University of California, Agriculture and Natural Resources
Nathaniel Caeton, 4-H Youth Development Advisor, University of California, Agriculture and Natural Resources
Matthew Rodriguez, 4-H Youth Development Advisor, University of California, Agriculture and Natural Resources
Andy Lyons, Program Coordinator, Informatics and GIS Program (IGIS), UC Berkeley
Flavie Audoin, Rangeland Management Extension Specialist, University of Arizona
Joseph Anthony Isam, 4-H Community Education Specialist, University of California, Agriculture and Natural Resources

Collaborators

Becca Fenwick, Director, CITRIS Initiative for Drone Education and Research, University of California, Santa Cruz
Lucy Diekmann, Urban Agriculture/Food System Advisor, University of California, Agriculture and Natural Resources

Expert Reviewers

From the National 4-H Geospatial Team:
- Brandon Estevez, North Carolina 4-H
- Vrishab Nooka, North Carolina 4-H
- Sudharsan Gopalakrishnan, California 4-H
- Sasirekha Nandyala, California 4-H

AI Acknowledgement

The authors thank ChatGPT (OpenAI) for providing initial brainstorming, drafting, and revision support. All AI-generated content was reviewed, revised, and edited by the authors for accuracy, relevance, safety, developmental appropriateness, and alignment with 4-H youth development and curriculum standards. All interpretations, conclusions, and any errors remain the responsibility of the authors.

Financial Acknowledgement

This work is supported by the U.S. Department of Agriculture, National Institute of Food and Agriculture, Agriculture and Food Research Initiative Competitive Grants Program, award #2024-68018-42793. The findings and conclusions in this [publication/presentation/blog] have not been formally disseminated by the U. S. Department of Agriculture and should not be construed to represent any agency determination or policy.

USDA National Institute of Food and Agriculture
U.S. DEPARTMENT OF AGRICULTURE

Suggested Citation
Worker, S. M., Hogan, S., Caeton, N., Rodriguez, M., Lyons, A., Audoin, F., & Isam, J. (2026). *SkyMappers: Agricultural drones and GIS mastery* [Curriculum]. University of California, Agriculture and Natural Resources.

Lesson List

SkyMappers includes 17 lessons with total learning time ranging from 23 to 28 hours, depending on implementation choices, group size, equipment, weather, software access, educator experience, software processing time, and the scope of the final project.

Lesson	Title	Time needed	Drone equipment required	Computer required*
01	Build Your Fleet: Drone Types, Payloads, and Purpose	1 hour	No	No
02	Drone Rules & Responsible Flight	1 ½ hours	No	No
03	Get to Know Your Gear – Equipment & Inspection (Indoor)	1 hour	Yes	No
04	Drone Startup, Calibration & Preflight Procedures (Outdoor)	1 hour	Yes	No
05	Your Flight Path: Discovering Drone-Powered Jobs	1 hour	No	No
06	Sky Rules: Reading Airspace Charts	45 minutes	No	Yes
07	Team in Flight: Crew Resource Management	1 hour	No	No
08	Nano-Mini Drone Skills Lab	1 hour	Yes	No
09	Ready to Fly: Preflight Safety Circuit	1 hour	Yes	No
10	Flight Check - TRUST Certification	30-60 minutes	No	Yes*
11	Clear Skies Ahead: Drone Flight Day	1 ½ hours	Yes	No
12	Turning Flight into Insight – Intro to Drone Data Processing	1 ½ hours	No	Yes*
13	Processing the Data with Esri ArcGIS and Drone2Map	1 ½ hours	No	Yes*
14	Data Ethics & Culturally Responsive Mapping	1 hour	No	No
15	Autonomy Begins on the Ground: Mission Planning & Safety	1 hour	No	No
16	Conducting the Autonomous Flight	2 to 3 hours	Yes	Yes*
17	Youth-Driven Drone Missions	5 to 8 ½ hours	Yes	Yes*

* ***Note:*** Computers will need Internet access as well as Esri ArcGIS Pro (or Online) and Drone2Map software installed.

Introduction to Drones and GIS in Agriculture

Young people are living in a world shaped by complex agricultural, environmental, technological, and community challenges, including climate change, water access, sustainable food systems, disaster response, biodiversity loss, and community health. The future will require youth who are scientifically literate, civically engaged, technically capable, and prepared to use emerging technologies responsibly.

Drones, remote sensing, and geographic information systems (GIS) are increasingly used in agriculture, food systems, environmental monitoring, emergency response, and community planning. These tools can help farmers and land managers monitor crop health, inspect irrigation systems, assess storm or fire damage, map habitat, understand water movement, and communicate place-based patterns. When youth learn how these tools work, they gain more than technical knowledge. They learn how to ask better questions about places, collect evidence, interpret data carefully, and communicate findings responsibly.

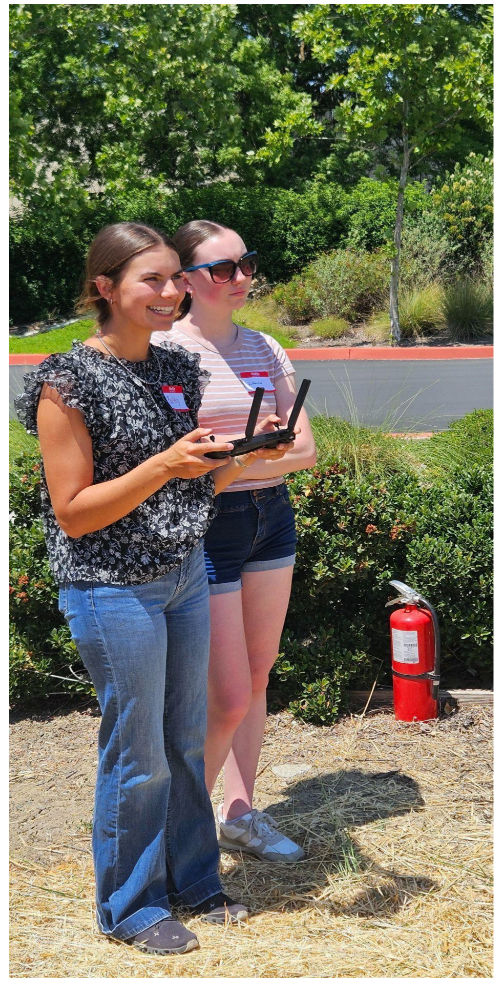
SkyMappers: Agricultural Drones and GIS Mastery is a research-informed curriculum designed to engage teenagers in learning how uncrewed aircraft systems (UAS or “drones”), remote sensing, and GIS can be used to investigate agricultural, food, environmental, and community issues. Developed as part of the Ag from Above x Ag for All (AFA2) project, the curriculum integrates experiential learning, project-based learning, positive youth development, and culturally relevant pedagogy. The curriculum is intended for educators working with youth in non-formal settings, including 4-H programs, afterschool programs, summer academies, community-based programs, and other out-of-school learning environments.

SkyMappers includes 17 lessons that scaffold from foundational drone concepts to responsible flight, equipment handling, manual flight practice, data processing, GIS mapping, data ethics, autonomous mission planning, and youth-driven capstone projects. Youth work in teams, practice defined crew roles, complete safety routines, collect and interpret data when conditions allow, and communicate findings through maps, presentations, or other shareable products.

A central goal of the curriculum is to broaden participation in drone, mapping, and agricultural technology learning. Drone and aviation fields have not been equally accessible to all youth. This curriculum intentionally uses hands-on learning, youth choice, local relevance, culturally responsive facilitation, and visible career pathways to help more young people see themselves as capable users, designers, analysts, and decision-makers in drone and GIS fields.

Intended Audience and Learning Context

This curriculum is designed for educator-facilitated group learning. It is not a self-guided manual for unsupervised drone use. The lessons are appropriate for middle school and high school youth, especially ages 13 to 17, with educator adaptations for group maturity, reading level, prior experience, available equipment, and local context.



Lessons may be used in:

- 4-H clubs and short-term programs
- afterschool and expanded learning programs
- summer academies and day camps
- community college or high school outreach programs
- youth workforce and career exploration programs
- agricultural, environmental, or GIS education programs

Recommended Implementation Options

1. **Full Curriculum**
   Educators may facilitate all 17 lessons in sequence. This model gives youth more time for flight practice, data processing, autonomous mission planning, and capstone presentations.
    a. **Day Camp or Academy Program:** Approximately 25 hours across 5 days
    b. **Multi-Week Program:** Approximately 25 to 30 hours, meeting once per week for 1 to 1 ½ hours across about 20 weeks

2. **Short Program**
   A shorter academy or workshop series may use selected lessons and educator-led demonstrations. This model works well when time is limited or equipment access is constrained. Recommended emphasis: Lessons 01, 02, 03 or 04, 07, 08, 12, 13, 14, and 17.

3. **Equipment-Limited Model**
   If drone equipment is limited, educators may use simulations, shared demonstrations, rotating flight crews, public datasets, preprocessed imagery, and backup image folders. Youth can still learn the full drone-to-map workflow without every team flying its own drone.

4. **Weather or Airspace Constraint Model**
   If outdoor flight is not safe, lawful, or feasible, educators should use backup datasets and continue with mission planning, data processing, GIS mapping, interpretation, ethics, and presentation. Choosing not to fly can be a strong example of responsible operation.

5. **Episodic or Short-Term Use**
   Some lessons can stand alone when educators want to introduce a specific concept, such as drone careers, airspace, preflight safety, data processing, autonomous planning, or data ethics.

Curriculum Learning Goals

SkyMappers is organized around five Core Knowledge Elements that recur across the full drone-to-map workflow. These elements reflect drone-based mapping as an end-to-end process that begins with a purpose and proceeds through mission preparation, flight execution, geoprocessing, product generation, analysis, interpretation, and communication.

By the end of the curriculum, youth should be able to define a mission question, plan a supervised drone operation, explain major safety and legal considerations, understand how overlapping images become map products, use GIS layers to interpret patterns, consider privacy and data ethics, and present a youth-driven drone mapping project.

Core Knowledge Elements

1. Purpose and Place-Based Problem Framing

Youth begin with a question worth answering. They identify the problem, place, audience, and information needed before choosing a drone, payload, flight path, or map product. Youth learn that strong drone work starts with questions such as: What are we trying to learn, document, or explain? Who could use this information? Why does this place matter? What information would make the map useful? Is a drone the right tool for this question?

2. Responsible Operations

Youth learn that drone operations must be lawful, safe, respectful, and appropriate for the place and purpose. Responsible operations include FAA rules, site permission, airspace checks, weather awareness, equipment inspection, battery safety, privacy, communication, teamwork, and adult oversight. Youth learn that technical ability is not enough. A drone may be able to fly, but the mission may still need to be changed or canceled because of airspace, weather, people nearby, property concerns, animal welfare, privacy, cultural significance, or unsafe equipment.

3. Mission Design for Data Quality

Youth learn that how a drone mission is designed affects what the data can show. Mission design includes the area of study, altitude, ground sampling distance, overlap, flight path, sensor or payload choice, lighting, weather, timing, launch and landing area, and data collection protocol. Youth learn that mission design connects directly to claims. They should be able to explain why a flight pattern, altitude, overlap setting, or image type is appropriate for the mission question.

4. Processing Imagery into Map-Ready Products

Youth learn how raw drone images become useful map products. They explore geo-tagged data, overlapping images, photogrammetry, orthomosaics, spatial resolution, sensor imagery, data quality checks, and processing software such as Drone2Map or similar tools. Youth learn that processing is not magic. Software uses overlap, GPS information, camera position, and matching features across images to create map-like products. Poor overlap, blurry images, missing files, or weak mission design can reduce map quality.

5. GIS Analysis, Interpretation, and Ethical Communication

Youth learn that maps are evidence, not automatic answers. GIS layers, drone images, public data, field observations, and local knowledge can help youth identify patterns and ask better questions. Youth also learn to state limits and avoid overclaiming. This element includes ethical communication. Youth consider privacy, consent, data ownership, cultural respect, community benefit, and who should have a voice in collecting, interpreting, storing, and sharing data. Youth practice careful language such as “may,” “might,” “suggests,” and “needs checking.”

Core Knowledge Element Crosswalk Lesson-by-Lesson

This crosswalk shows when each lesson introduces, reinforces, or culminates in mastery of the five core knowledge elements.

I = Introduce: Youth first encounter the concept or skill.
R = Reinforce: Youth revisit and apply the concept or skill with more complexity.
M = Master: Youth transfer the concept or skill to a new problem, mission, or project.

	Lesson Title	1. Problem Framing	2. Responsible Operations	3. Mission Design	4. Processing Imagery	5. GIS Analysis
01	Build Your Fleet: Drone Types, Payloads, and Purpose	I		I		
02	Drone Rules & Responsible Flight	R	I			I
03	Get to Know Your Gear – Equipment & Inspection (Indoor)		I	R		
04	Drone Startup, Calibration & Preflight Procedures (Outdoor)		R	R		
05	Your Flight Path: Discovering Drone-Powered Jobs	R	R			R
06	Sky Rules: Reading Airspace Charts		R	R		
07	Team in Flight: Crew Resource Management		R	R		
08	Nano-Mini Drone Skills Lab		R	I		
09	Ready to Fly: Preflight Safety Circuit		R	R		
10	Flight Check - TRUST Certification		R			
11	Clear Skies Ahead: Drone Flight Day		R	R		
12	Turning Flight into Insight – Intro to Drone Data Processing	R	R	I	I	I
13	Processing the Data with Esri ArcGIS and Drone2Map			R	R	R
14	Data Ethics & Culturally Responsive Mapping	R	R	R		R
15	Autonomy Begins on the Ground: Mission Planning & Safety	R	R	R		
16	Conducting the Autonomous Flight	R	R	R	R	R
17	Youth-Driven Drone Missions	M	M	M	M	M

Core Pedagogical Elements

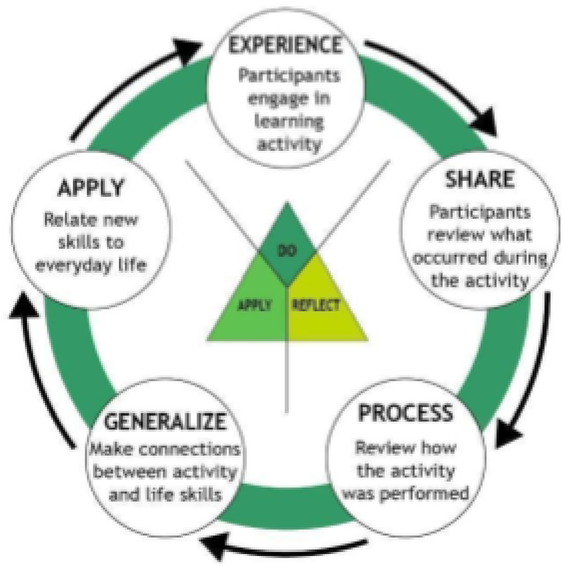
This curriculum incorporates principles of experiential learning, project-based learning, positive youth development, and culturally relevant pedagogy. These approaches help ensure that youth are not only learning technical content, but also building confidence, belonging, teamwork, judgment, and a sense of agency.

Experiential Learning

SkyMappers uses a hands-on, minds-on learning cycle. Youth are asked to experience a concept, discuss what happened, connect the experience to core ideas, and apply the learning to new situations. Each lesson follows a common structure:

1. Opening questions and prompts
2. Experiencing and procedures
3. Sharing, processing, generalizing, and applying
4. Extension ideas

This structure helps educators move beyond lecture. Youth handle equipment, examine scenarios, practice team roles, use maps, compare images, complete checklists, process data, and create shareable products.



Project-Based Learning

The curriculum builds toward youth-driven projects. Youth begin with small structured tasks, then gradually take on more complex decisions. By the final lesson, teams define a mission question, plan a workflow, collect or use imagery, process data, interpret results, and present their findings. Project-based learning is most powerful when youth have meaningful choices, a real audience, and an authentic product. In SkyMappers, final products may include Google Slides presentations, maps, orthomosaic screenshots, mission reports, StoryMaps, posters, or short videos.

Positive Youth Development

SkyMappers uses a positive youth development approach. Educators support youth sparks, belonging, developmental relationships, growth mindset, and skill-building. Drone and GIS learning can be exciting and demanding, so educators should create environments where youth can try, make mistakes, reflect, improve, and contribute. Educators should intentionally support:

- physical and emotional safety
- belonging and inclusion
- youth voice and choice
- skill progression
- teamwork and leadership
- supportive adult-youth relationships
- reflection on growth and confidence

Culturally Relevant and Locally Relevant Pedagogy

The curriculum is strongest when educators connect lessons to local places, local issues, youth experiences, and community knowledge. Youth should see that drone and GIS tools are not only for distant farms, laboratories, or professionals. They can also help youth understand places they know: campuses, parks, gardens, fields, ranches, shorelines, neighborhoods, and community spaces. Culturally relevant facilitation includes:

- using local examples that matter to youth
- honoring youth knowledge of their communities
- avoiding deficit-based maps or stories
- inviting multiple perspectives on technology use
- considering who benefits and who may be harmed
- connecting STEM learning to community well-being
- supporting youth identity and belonging in drone, GIS, and agricultural technology fields

General Facilitation Guidance

Keep Activities Active

Youth learn best in this curriculum when they are sorting, handling, testing, discussing, flying, mapping, interpreting, and presenting. Keep explanations brief and purposeful. Use demonstrations to prepare youth for action, not to replace action.

Normalize "Fix First" and "No-Go"

Youth should learn that changing, delaying, or canceling a flight can be a sign of good judgment. Avoid framing no-go decisions as failure. In aviation, agriculture, field science, and mapping, careful decisions protect people, equipment, data quality, and trust.

Use Local Examples

Whenever possible, connect lessons to local farms, ranches, gardens, parks, schools, campuses, watersheds, coastlines, wildfire areas, food access sites, or community concerns. Local relevance helps youth see why drone and GIS learning matters.

Support Multiple Ways to Participate

Not every youth will be equally excited about piloting. Some may connect more strongly to mapping, data interpretation, safety, storytelling, careers, ethics, mechanics, coding, environmental science, or community issues. Use team roles and project choices to make multiple forms of participation visible and valued.

Lesson Format

Every lesson uses the same general format so educators can prepare and facilitate consistently.

Educator Information

- **Summary:** A stand-alone overview of what youth will do and learn.
- **Drone Equipment Required and Computers Required:** A quick planning note to help educators prepare materials and space.
- **Time Needed:** Estimated time for implementation. Some lessons include shorter and longer options.
- **Learning Objectives:** Observable learning goals for the lesson.
- **Core Concepts:** A short list of key terms and ideas used in the lesson.
- **Materials:** Items needed for educators and youth.
- **Getting Ready:** Preparation tasks educators should complete before the lesson.
- **Background Information for the Educator:** Text that explains the lesson concepts, safety considerations, legal or ethical issues, facilitation tips, and connections to the broader curriculum.

Learning Activity

- **Phase 1: Opening Questions and Prompts**
  Broad, open-ended questions that activate prior knowledge, invite youth ideas, and introduce the lesson's central idea.
- **Phase 2: Experiencing / Procedures**
  Step-by-step instructions for the main hands-on activity, simulation, software task, flight practice, or project work.
- **Phase 3: Sharing, Processing, Generalizing, and Applying**
  Reflection questions that help youth make meaning, use vocabulary, connect to real-world applications, and transfer learning.
- **Extension Ideas**
  Optional activities that deepen learning, support early finishers, or extend the lesson into youth projects, community connections, or additional practice.

Appendices and Handouts

Many lessons include appendices such as role cards, mission cards, worksheets, checklists, logbooks, quick guides, posters, or presentation templates. Educators may print, laminate, reuse, or modify these materials for local conditions.

FAA, Safety, and Local Rules

Anyone flying a drone in the U.S. National Airspace System is responsible for knowing and following FAA rules. The FAA provides different guidance for recreational flyers, certificated remote pilots, educational users, and other operators. The FAA also provides information for certificated remote pilots operating under Part 107 and notes that Part 107 operations may include night operations or operations over people and moving vehicles only when the applicable rule requirements are met. Supervised flight activities should be overseen by an adult who serves as the **legal Remote Pilot in Command** when the operation is conducted under Part 107. Youth may practice crew roles, including Pilot, Visual Observer, and Mission Scribe, but the adult Pilot in Command retains final authority to pause, modify, or stop the operation. Youth complete TRUST before hands-on controller use and free flight so all participants share a baseline understanding of safe recreational drone operation. TRUST does not make youth certificated Part 107 pilots.

Adult Roles and Youth Crew Roles

SkyMappers uses defined roles to support safety, teamwork, and learning.

- **Adult Educator:** The educator facilitates learning, prepares materials, supports youth teamwork, checks understanding, and ensures that activities follow program safety procedures. In some settings, the educator may also be the adult Pilot in Command. In other settings, these roles may be held by different adults.
- **Adult Pilot in Command:** The adult Pilot in Command is the certificated adult or other qualified person who has final legal authority and responsibility for the flight operation when the operation is conducted under Part 107. The Pilot in Command may pause, modify, or stop any flight at any time.
- **Adult or Teen Co-Educator or Helper:** A co-educator or helper supports setup, supervision, group movement, equipment handling, documentation, and youth reflection. Helpers should understand the field layout, stop words, emergency procedures, and the limits of their role.
- **Youth Pilot:** The youth Pilot practices the flight-control or mission-monitoring role under adult supervision. In this curriculum, the youth Pilot is not the legal Pilot in Command unless that youth personally holds the required certification and is serving in that role under program policy.
- **Youth Visual Observer:** The Visual Observer watches the drone, sky, people, animals, vehicles, obstacles, and surrounding area. This role helps the crew maintain awareness and communicate hazards early.
- **Youth Mission Scribe:** The Mission Scribe records mission goals, settings, conditions, decisions, observations, data-quality notes, and team reflections. This role helps connect flight operations to useful evidence and later interpretation.

Master Materials List

Materials vary by lesson and site. The list below supports planning across the full curriculum.

Drone hardware and flight equipment

✓	Material	Quantity needed	Grouping / user
☐	Batteries, charged, spare, or extra	At least 1 fully charged battery per drone, plus spares; 1 to 2 batteries for Lesson 09 Battery Triage station	Per drone/team; station set where noted
☐	Battery chargers / charging equipment	Enough for drone inventory and battery rotation	Shared program supply
☐	Controllers / remote controllers	1 per drone	Per pair/group of 3 or flight team
☐	Drone, display or demo unit	1 optional visual hook; 1 demo drone for educator use	Educator/class use
☐	Drone, powered off with propellers removed	1	Inspection Lab station
☐	Drones, full-size / flight-capable	1 per pair/group of 3 for setup lessons; 1 per 3 youth or team for flight lessons	Per pair/group of 3 or team
☐	Landing pads or clearly marked takeoff and landing spots	1 per flight area/team, as used	Field setup
☐	LiPo-safe battery bags or approved battery containers	Enough for spare batteries	Shared flight safety supply
☐	Memory cards / SD cards	1 per drone/team, plus extras if available	Per drone/team
☐	Nano- or mini-drones with propeller guards or cages	Ideally 1 per youth, or shared as available	Individual youth or shared rotation
☐	Payloads / sensors, if used	As needed for the drone model and lesson setup	Per drone/team
☐	Spare propellers	As needed	Shared program supply
☐	Small tools, if needed	1 shared set or as needed	Shared program supply

Field safety and logistics

✓	Material	Quantity needed	Grouping / user
☐	Access to an open outdoor area with clear staging space	1 site	Whole group
☐	Battery condition cards	1 set	Battery Triage station
☐	Boundary markers, cones, flags, or markers	Enough to mark flight zones and waiting/spectator areas	Field setup
☐	Chart paper, whiteboard, or shared display	1 per room or facilitation area	Whole group
☐	Clipboard or hard writing surface (optional)	1 per youth/pair if used outdoors	Individual youth or pair
☐	Colored dots or stickers (optional)	1 set	Whole group
☐	Defect cards and green, yellow, and red tags or sticky notes	1 set	Inspection Lab station
☐	Dice	2 total	1 for Weather Go / No-Go station; 1 for Calibration Decision station
☐	Fire blanket	1 per field setup	Shared field safety supply
☐	Fire extinguisher	1 per field setup	Shared field safety supply
☐	First aid kit	1 per field setup	Shared field safety supply
☐	Highlighters or colored pencils	1 set per team or shared table supply	Teams
☐	Indoor obstacle course materials: cones, tape, floor markers, hoops, or pool noodles	Enough to create 1 indoor obstacle course	Whole group
☐	Laminated site image plus hazard and mitigation tokens	1 set	People and Property station
☐	Markers	Shared set	Whole group
☐	Poster display supplies: tape or clips	As needed	Whole group
☐	Pretend launch area / mission boundary props: cones, tape, or simple props (optional)	As needed	Whole group
☐	Station or table space	1 table/station per team or activity station	Teams/stations
☐	Sticky notes or index cards	1 set, including green/yellow/red where specified	Whole group or teams
☐	Sun protection and other site-appropriate protective items	As needed	Individual youth/adults
☐	Timer	1	Educator/facilitator use
☐	Writing utensils	1 per youth, plus extras	Individual youth

Computers, software, and data

✓	Material	Quantity needed	Grouping / user
☐	Airspace app, airspace printout, or FAA-supported drone airspace tool such as B4UFLY or LAANC-connected service	1 device/access per pair/small group, or 1 projected/shared display	Pairs/small groups or whole group
☐	ArcGIS Online accounts or class login access	1 login per youth/team as configured	Individual youth or team
☐	Backup image dataset (optional)	1 prepared dataset	Whole group or educator use
☐	Drone2Map login credentials, if required	1 login per youth/team as configured	Individual youth or team
☐	FAA-approved TRUST test administrator link	1 current link	Whole group; individual youth complete test
☐	Flight-planning app, software, simulator, or screenshots	1 shared display or 1 device per team	Whole group or teams
☐	Folder on computer for each crew's image files	1 folder per crew/team	Per crew/team
☐	Google Drive, Google Classroom, or shared folder setup (optional)	1 shared system	Whole group/teams
☐	Google Slides photo puzzle deck with real overlapping image tiles	1 shared deck	Whole group; pairs if devices allow
☐	Google Slides presentation template (optional preloaded version)	1 copy per team	Teams
☐	Headphones (optional)	1 per youth	Individual youth
☐	Internet access	Reliable classroom/field access where needed	Whole group
☐	Internet-connected computer and projector, or device per pair if available	1 shared setup or 1 device per pair	Whole group or pairs
☐	Internet-enabled device: computer, Chromebook, or tablet	1 per youth	Individual youth
☐	Internet-connected tablet, Chromebook, or computer	1 per pair or small group	Pairs/small groups
☐	Laptop or desktop computer with Drone2Map installed	1 per youth/team if processing images; 1 educator computer minimum for demonstration	Individual youth, teams, or educator
☐	Local map, aerial image, printed site map, or map with boundaries	1 shared display or 1 per team	Whole group or teams
☐	Phones or tablets with location services enabled	Ideally 1 per pair or small group	Pairs/small groups
☐	Prepared drone image dataset with photos and metadata	1 dataset	Whole group or teams
☐	Prebuilt ArcGIS map with sample layers already added (optional)	1 prepared map	Whole group or teams
☐	Processed orthomosaic backup file (optional)	1 backup file	Educator use
☐	Projector, large display, or shared screen	1	Whole group
☐	Sample screenshots from a flight planning app or software	1 set	Whole group or teams
☐	Tablet, phone, or laptop used with the drone or flight app	1 per drone/team	Pair/group of 3 or team

☐	USB cable, SD card reader, or other file-transfer method	1 shared set or 1 per team if available	Teams or shared program supply

Printed/digital curriculum materials

✓	Material	Quantity needed	Grouping / user
☐	Appendix 06-A: Airspace Quick Guide	1 copy	Individual youth
☐	Appendix 16-A: Autonomous Flight Checklist	1 copy	Per crew/team
☐	Appendix 16-B: Autonomous Flight Logbook	1 copy	Per crew/team
☐	Appendix 15-A: Autonomous Mission Planning Worksheet	1 copy; completed version carried forward into flight/project lessons	Per team
☐	Appendix 05-A: Career Stations Worksheet	1 copy	Individual youth
☐	Appendix 05-B: Drone Career Posters	1 copy of each poster	Station use
☐	Appendix 03-A: Drone Equipment and Startup Checklist	1 copy	Individual youth
☐	Appendix 11-A: Drone Flight Checklist	1 copy	Per team
☐	Appendix 11-B: Drone Flight Logbook	1 copy	Per team
☐	Appendix 14-A: Drone Image Ethics Posters	1 set, printed or displayed	Whole group/stations
☐	Appendix 01-C: Drone Payload Cards (cut on dotted lines)	1 set	Per pair/group of 3
☐	Appendix 01-A: Drone Type Cards (cut along lines)	1 set	Per pair/group of 3
☐	Educator (Pilot-in-Command) Role Checklist and Co-Educator / Helper Role Checklist	1 copy each	All adults
☐	Appendix 14-B: Ethics Decision Sheet	1 copy	Per team
☐	Appendix 12-A: Field GPS Notes Sheet	1 copy	Individual youth or pair
☐	Appendix 02-B: Flight Scenario Cards	1 set	Class set or per group, depending on station format
☐	Appendix 11-C: Flight Task Cards	1 set	Per team
☐	Appendix 17-C: Google Slides Presentation Template	1 copy	Per team
☐	Journals or science notebooks (optional)	1	Individual youth
☐	Large printed drone photo (optional alternative to real drone/mini drone)	1	Whole group visual hook
☐	Lesson 13 supplemental slide deck on photogrammetry and data processing, revised for youth use	1 deck	Whole group
☐	Appendix 06-B: Local Coordinates for Airspace Practice	1 copy	Per group
☐	Appendix 01-B: Mission Cards (cut along lines)	1 set	Per pair/group of 3
☐	Appendix 07-B: Mission Cards	1 set	Class set or per team, depending on rotation format
☐	Appendix 08-A: Nano-Mini Drone Skills Passport	1 copy	Individual youth
☐	Appendix 09-A: Preflight Safety Passport	1 copy	Individual youth
☐	Appendix 06-C: Printed Sectional Chart Key (optional)	1 copy or binder copy	Individual youth or participant binder

☐	Printed full-page local sectional chart excerpt (optional)	1 copy	Individual youth or participant binder
☐	Appendix 02-A: Responsible Flight Quick Guide	1 copy	Per pair/group of 3
☐	Appendix 07-A: Roles	1 role card per youth; 1 complete role set per team of 3	Individual youth / team of 3
☐	Appendix 12-B: Sensor Comparison Sheet	1 copy	Individual youth or pair
☐	Appendix 14-C: Stakeholder Lens Cards (optional)	1 card	Individual youth when used
☐	Appendix 04-A: Startup Troubleshooting Quick Guide	1 copy	Per team
☐	Appendix 09-B: Station Signs and Instructions	1 set	Station set
☐	Appendix 17-B: Team Mission Ideas	1 set, printed or displayed	Whole group / teams
☐	Appendix 17-A: Team Project Planner	1 copy	Per team
☐	Appendix 07-C: Unexpected Event Cards	1 set	Class set or facilitator use
☐	Appendix 13-A: Youth Worksheet	1 copy	Individual youth or team

Links to Educational Standards

This table summarizes the primary alignment between each revised SkyMappers lesson, the Next Generation Science Standards, and the FAA Remote Pilot (Part 107) knowledge areas. The NGSS alignment identifies the strongest high school performance expectation supported by the lesson, with most lessons emphasizing engineering design practices such as defining problems, evaluating solutions, considering trade-offs, and using data or computational tools. The FAA alignment identifies the most relevant aeronautical knowledge area for each lesson, including regulations, airspace, aircraft operations, inspection, decision-making, and mission safety.

Lesson	Revised lesson title	NGSS performance expectation	FAA Part 107 knowledge area
01	Build Your Fleet: Drone Types, Payloads, and Purpose	**HS-ETS1-1:** Analyze a major challenge to specify criteria and constraints for solutions that account for societal needs and wants.	**IV. Loading and Performance** (payload, aircraft capability, performance limitations)
02	Drone Rules & Responsible Flight	**HS-ETS1-3:** Evaluate a solution using prioritized criteria and trade-offs, including safety, reliability, and social, cultural, and environmental impacts.	**I. Regulations** (operating rules, compliance, visual line of sight, operations over people, Remote ID context)
03	Get to Know Your Gear – Equipment & Inspection (Indoor)	**HS-ETS1-2:** Design a solution to a complex real-world problem by breaking it into smaller, manageable problems.	**V. Operations** (maintenance and inspection procedures)
04	Drone Startup, Calibration & Preflight Procedures (Outdoor)	**HS-ETS1-3:** Evaluate a solution using safety, reliability, and operational trade-offs.	**V. Operations** (maintenance and inspection procedures; aeronautical decision-making)
05	Your Flight Path: Discovering Drone-Powered Jobs	**HS-ETS1-1:** Specify criteria and constraints that shape acceptable solutions in real-world technical fields.	**I. Regulations** (remote pilot certification with a small UAS rating; professional responsibilities)
06	Sky Rules: Reading Airspace Charts	**HS-ETS1-1:** Specify criteria and constraints for solutions based on location, rules, and operational context.	**II. Airspace Classification and Operating Requirements** (airspace classification, authorizations, temporary flight restrictions)
07	Team in Flight: Crew Resource Management	**HS-ETS1-3:** Evaluate decisions using safety-focused criteria and trade-offs.	**V. Operations** (aeronautical decision-making, crew resource management, communication, risk management)
08	Nano-Mini Drone Skills Lab	**HS-ETS1-2:** Break a complex real-world skill into smaller, manageable procedures that can be practiced systematically.	**V. Operations** (basic aircraft control, operational discipline, situational awareness)
09	Ready to Fly: Preflight Safety Circuit	**HS-ETS1-3:** Evaluate and refine decisions using evidence, safety, reliability, and risk trade-offs.	**V. Operations** (maintenance and inspection procedures; aeronautical decision-making)
10	Flight Check - TRUST Certification	**HS-ETS1-1:** Specify criteria and constraints that shape safe and lawful drone operation.	**I. Regulations** (operating rules and pilot responsibilities)
11	Clear Skies Ahead: Drone Flight Day	**HS-ETS1-2:** Break a complex operational task into manageable	**V. Operations** (aeronautical decision-making, emergency

		procedures, roles, and feedback cycles.	procedures, radio/crew communication, operational limitations)
12	Turning Flight into Insight – Intro to Drone Data Processing	**HS-ETS1-4:** Use computational tools or models to examine the impact of solution choices under constraints.	**V. Operations** (mission documentation, data-quality awareness, operational planning implications)
13	Processing the Data with Esri ArcGIS and Drone2Map	**HS-ETS1-4:** Use computational tools to model impacts and compare options within systems.	**V. Operations** (post-mission documentation, data-quality review, professional workflow)
14	Data Ethics & Culturally Responsive Mapping	**HS-ETS1-3:** Evaluate a solution using trade-offs that include social, cultural, environmental, safety, and reliability impacts.	**I. Regulations** (responsibilities, compliance culture, operational accountability)
15	Autonomy Begins on the Ground: Mission Planning & Safety	**HS-ETS1-2:** Break the autonomous mission into manageable subproblems, including objective, area, altitude, overlap, hazards, and roles.	**II. Airspace Classification and Operating Requirements** (airspace constraints and authorization planning)
16	Conducting the Autonomous Flight	**HS-ETS1-3:** Evaluate and refine decisions during execution using safety, reliability, data quality, and mission-purpose trade-offs.	**V. Operations** (aeronautical decision-making, emergency procedures, maintenance/inspection procedures, operational limitations)
17	Youth-Driven Drone Missions	**HS-ETS1-4:** Use computational tools to model, compare, and communicate solution impacts within a complex real-world system.	**V. Operations** (end-to-end operational risk management and professionalism)

Informing Literature

4-H Positive Youth Development and Thriving

Arnold, M. E. (2018). From context to outcomes: A thriving model for 4-H youth development programs. *Journal of Human Sciences and Extension, 6*(1), Article 11. https://doi.org/10.54718/NBNL5438

Arnold, M. E., & Gagnon, R. J. (2019). Illuminating the process of youth development: The mediating effect of thriving on youth development program outcomes. *Journal of Human Sciences and Extension, 7*(3), Article 2. https://doi.org/10.54718/GHUP2927

Arnold, M. E., & Gagnon, R. J. (2020). Positive youth development theory in practice: An update on the 4-H Thriving Model. *Journal of Youth Development, 15*(6), 1–23. https://doi.org/10.5195/jyd.2020.954

Lerner, R. M. (2004). *Liberty: Thriving and civic engagement among America's youth*. SAGE.

Masten, A. S. (2018). Resilience theory and research on children and families: Past, present, and promise. *Journal of Family Theory & Review, 10*(1), 12–31. https://doi.org/10.1111/jftr.12255

Experiential Learning and Project-Based Learning

Barab, S. A., & Duffy, T. M. (2012). From practice fields to communities of practice. In D. H. Jonassen & S. M. Land (Eds.), *Theoretical foundations of learning environments* (2nd ed., pp. 29–65). Routledge.

Bevan, B., Gutwill, J. P., Petrich, M., & Wilkinson, K. (2015). Learning through STEM-rich tinkering: Findings from a jointly negotiated research project taken up in practice. *Science Education, 99*(1), 98–120.

Kolb, D. A. (1984). *Experiential learning: Experience as the source of learning and development*. Prentice Hall.

Marek, E. A., & Cavallo, A. M. L. (1997). *The learning cycle: Elementary school science and beyond*. Heinemann.

Penuel, W. R., Fishman, B. J., Yamaguchi, R., & Gallagher, L. P. (2007). What makes professional development effective? Strategies that foster curriculum implementation. *American Educational Research Journal, 44*(4), 921–958. https://doi.org/10.3102/0002831207308221

Roth, W.-M. (2001). Learning science through technological design. *Journal of Research in Science Teaching, 38*(7), 768–790. https://doi.org/10.1002/tea.1031

Culturally Relevant, Place-Based, and Community-Connected STEM

Erbstein, N., & Fabionar, J. (2019). Supporting Latinx youth participation in out-of-school time programs: A research synthesis. *Afterschool Matters, 29*, 17–27.

Gay, G. (2010). *Culturally responsive teaching: Theory, research, and practice* (2nd ed.). Teachers College Press.

Ginwright, S., & Cammarota, J. (2007). Youth activism in the urban community: Learning critical civic praxis within community organizations. *International Journal of Qualitative Studies in Education, 20*(6), 693–710. https://doi.org/10.1080/09518390701630833

Horton, M., & Freire, P. (1990). *We make the road by walking: Conversations on education and social change*. Temple University Press.

Ladson-Billings, G. (2014). Culturally relevant pedagogy 2.0: AKA the remix. *Harvard Educational Review, 84*(1), 74–84. https://doi.org/10.17763/haer.84.1.p2rj131485484751

Ladson-Billings, G. (2021). *Culturally relevant pedagogy: Asking a different question*. Teachers College Press.

Rudolph, J. L., & Horibe, S. (2016). What do we mean by science education for civic engagement? *Journal of Research in Science Teaching, 53*(6), 805–820. https://doi.org/10.1002/tea.21303

Worker, S. M., Neas, S., Espinoza, D., Kok, C. M., & Smith, M. (2023). Youth science learning as/for community participation: Examples from youth participatory action research. *Journal of Youth Development, 18*(1), Article 3. https://doi.org/10.34068/JYD.18.01.03

NGSS Science and Engineering Practices

National Research Council. (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press. https://doi.org/10.17226/13165

NGSS Lead States. (2013). *Next generation science standards: For states, by states*. National Academies Press. https://doi.org/10.17226/18290

Drone, GIS, Remote Sensing, and Agricultural Technology Education

Chen, X. (2013). *STEM attrition: College students' paths into and out of STEM fields* (NCES 2014-001). National Center for Education Statistics, Institute of Education Sciences, U.S. Department of Education.

De Clercq, M., Vats, A., & Biel, A. (2018). *Agriculture 4.0: The future of farming technology*. World Government Summit. https://www.bollettinoadapt.it/wp-content/uploads/2019/12/OliverWyman-Report_English-LOW.pdf

Jeziorska, J. (2014). Unmanned aerial vehicle (UAV) (a tool for acquiring spatial data for research and commercial purposes): New course in the geography and cartography curriculum in higher education. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XL-6*, 37–42. https://doi.org/10.5194/isprsarchives-XL-6-37-2014

Mathews, A. J., Singh, K. K., Cummings, A. R., & Rogers, S. R. (2023). Fundamental practices for drone remote sensing research across disciplines. *Drone Systems and Applications, 11*, 1–22. https://doi.org/10.1139/dsa-2023-0021

Moon, S., & Ock, J. (2023). Developing the framework of drone curriculum to educate the drone beginners in the Korean construction industry. *Drones, 7*(6), Article 356. https://doi.org/10.3390/drones7060356

National Academy of Sciences. (2010). *Rising above the gathering storm, revisited: Rapidly approaching category 5*. National Academies Press. https://doi.org/10.17226/12999

Data Ethics, Privacy, Equity, and Responsible Mapping

First Nations Information Governance Centre. (2020). *The First Nations principles of OCAP*. https://fnigc.ca/ocap-training/

Nelson, T. A., Goodchild, M. F., & Wright, D. J. (2022). Accelerating ethics, empathy, and equity in geographic information science. *Proceedings of the National Academy of Sciences of the United States of America, 119*(19), Article e2119967119. https://doi.org/10.1073/pnas.2119967119

Nissenbaum, H. (2004). Privacy as contextual integrity. *Washington Law Review, 79*(1), 119–158. https://digitalcommons.law.uw.edu/wlr/vol79/iss1/10/

Olson, P., & Labuski, C. (2018). There's always a [white] man in the loop: The gendered and racialized politics of civilian drones. *Social Studies of Science, 48*(4), 540–563. https://doi.org/10.1177/0306312718792619

United Nations Global Pulse. (2021). *Privacy and data protection principles for UAV data*.

UNIVERSITY OF CALIFORNIA DIVISION OF AGRICULTURE AND NATURAL RESOURCES (UC ANR) NONDISCRIMINATION STATEMENT

In accordance with Federal law and U.S. Department of Agriculture (USDA) civil rights regulations and policies, the University of California, Division of Agriculture and Natural Resources (UC ANR) is prohibited from discriminating on the basis of race, color, national origin, religion, sex, gender, gender expression, gender identity, pregnancy (which includes pregnancy, childbirth, and medical conditions related to pregnancy or childbirth), physical or mental disability, medical condition (cancer-related or genetic characteristics), genetic information (including family medical history), ancestry, marital status, family/parental status, income derived from a public assistance program, political beliefs, age, sexual orientation, citizenship, or status as a U.S. veteran, or reprisal or retaliation for prior civil rights activity.

Program information may be made available in languages other than English. Persons with disabilities who require alternative means of communication to obtain program information (e.g., Braille, large print, audiotape, American Sign Language) should contact the UC ANR ADA Coordinator, phone: 530-750-1317, email: daritz@ucanr.edu or USDA's TARGET Center at (202) 720- 2600 (voice and TTY) or contact USDA through the Federal Relay Service at (800) 877-8339.

To file a program discrimination complaint with the USDA, a complainant should complete a Form AD-3027, USDA Program Discrimination Complaint Form, which can be obtained online at https://www.ocio.usda.gov/document/ad-3027, from any USDA office, by calling (866) 632- 9992, or by writing a letter addressed to USDA. The letter must contain the complainant's name, address, telephone number, and a written description of the alleged discriminatory action in sufficient detail to inform the Assistant Secretary for Civil Rights (ASCR) about the nature and date of an alleged civil rights violation. The completed AD-3027 form or letter must be submitted to USDA by: (1) Mail: U.S. Department of Agriculture Office of the Assistant Secretary for Civil Rights 1400 Independence Avenue, SW Washington, D.C. 20250- 9410; or (2) Fax: (833) 256-1665 or (202) 690-7442; or (3) Email: program.intake@usda.gov .

The University of California, Division of Agriculture and Natural Resources (UC ANR) is an equal opportunity provider.

Alternatively, a program discrimination complaint may be filed with the UC Harassment & Discrimination Assistance and Prevention Program (HDAPP) by email hdapp@ucdavis.edu or phone: 530-304-3864; or contact the UC ANR Title IX Coordinator at (530) 752-9466.

University policy is intended to be consistent with the provisions of applicable State and Federal laws.

Inquiries regarding the University's nondiscrimination policies may be directed to: UC ANR, Interim Affirmative Action Compliance Officer, University of California, Agriculture and Natural Resources, 2801 Second Street, Davis, CA 95618, (530) 750-1280. Email: tljordan@ucanr.edu.
Website: http://ucanr.edu/sites/anrstaff/Diversity/Affirmative_Action/.