A Handbook for Running Science Camps
in Rural Elementary Schools

Learning Together with Rural Schools



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Table of Contents

1. Foreword p.3

2. Background and Partners p.4

3. Program Overview p.6

4. Design Philosophy and Learning Goals p.7

5. A Sample Camp p.9

6. Lesson Units p.12

7. Field Experience, Results and Challenges p.26

8. Recommendations for Future Teams p.30

9. Acknowledgments and Contact p.31

Appendix A. General Safety Rules p.32

Appendix B. Pre/Post-Test Questionnaire p.33

Appendix C. Camp Document Checklist p.34

References p.34

1. Foreword

One core spirit of iGEM (the International Genetically Engineered Machine Competition) is that teams must turn what they learn in the laboratory into actions that matter to society, known as "Human Practice." For the 2026 NCKU-iGEM team, this is more than a competition requirement. It is a value we wanted to live out: to take science out of the lab and into the places that most need to be seen but are least reached by resources.

This handbook documents how we worked with STEAM from Seed (展心計畫) to run ten two-day science camps at eight rural elementary schools in Tainan during the summer of 2026. We hope it can be more than a record of events — a working toolkit that other iGEM teams, university clubs, or anyone who wants to bring science education to rural schools can pick up and use directly. It shows how we designed the lessons, prepared materials, divided the work, and dealt with the difficulties we met.

How to use it: to get started quickly, read the sample camp in Chapter 5 and then pick lesson units from Chapter 6. To understand why the lessons are designed this way, see Chapter 4. To avoid the pitfalls we ran into, read Chapters 7 and 8. The appendices contain safety rules, the pre/post-test questionnaire, and a checklist of documents.

> **About sources and labels**
> **• Lesson names, materials and steps follow the lesson slides. Where the slides are silent, we added details from the STEAM from Seed lesson preparation manual and say so in the text.**
> **• Content marked "Editor's recommendation" was added by the authors of this handbook for other readers. It was not necessarily the practice at the camps.**

2. Background and Partners

Who is STEAM from Seed?

STEAM from Seed (展心計畫) has, since July 2023, focused on science education for elementary school students in rural and "neither mountain nor city" areas. It runs camps every summer, and its volunteer team has grown from 11 people at the start to 43.



STEAM from Seed responds to common problems in rural education in the following ways:

Challenge in rural education	What STEAM from Seed does
Limited learning resources	Bring science equipment, materials and lessons into rural schools
Limited cultural stimulation and learning opportunities	Offer varied lessons such as cyanotype, DNA and genes, chemical garden, elephant toothpaste and the Da Vinci bridge
Low learning motivation	Replace one-way lectures with hands-on work, games, competitions and showcasing results
Learned helplessness and low confidence	Let children complete their own works or experiments, with encouragement from counselors
Little individual attention	Assign counselor groups who respond to difficulties immediately and communicate with parents
Limited social and cultural capital	University students and volunteers from different fields share their study and career-path experiences
Limited teaching staff	Keep training lesson leaders and counselors; the team grew from 11 to 43 people
Limited funding and resources	From self-funding at the start to winning support from companies such as TSMC and ADATA
Weak links between schools and the outside	Partner with NCKU-iGEM, companies, schools and local associations to build a resource network
Different needs at each school	Run camps at different schools and adjust lessons and facilitation on site

Challenge in rural education	What STEAM from Seed does
Lack of sustained attention	Move from one-off projects toward an association with a sustainable service model

STEAM from Seed starts at the elementary level because elementary students are already able to take part in scientific inquiry, and research has found that low-achieving students still participate actively in hands-on activities. Life-related, hands-on, team-based STEAM lessons therefore let students meet science with less constraint from academic achievement, and build early interest, problem-solving skills and confidence (Wu, 2020; Hsieh & Hong, 2004).

STEAM from Seed is supported by corporate foundations, including the TSMC Education and Culture Foundation in 2024 and the ADATA foundation in 2026. It also keeps exchanging experience on budget management and team organization with the founder's alma mater, the National Nanke International Experimental High School, and its FRC 6998 robotics team.

How did the partnership begin?

The two teams met through "Tracing Tainan" (踏溯台南), a compulsory NCKU course. NCKU-iGEM members got to know members of STEAM from Seed in class, and in conversation found that their missions overlapped closely: the iGEM team wanted to bring hard-to-grasp genetic engineering knowledge to the public, while STEAM from Seed wanted to pass on science and enthusiasm for science to elementary students. With a shared mission and goal, the two teams began exchanging ideas and preparing the camps.

What the partnership changed

Before the partnership, STEAM from Seed's lessons focused on physics, chemistry, technology and engineering, and had not considered how to show biology inside a rural classroom. With banana DNA extraction, children can actually see what DNA is and what it does in the body. In turn, iGEM members from different specialties taught STEAM from Seed's volunteers how to handle lab equipment, operate safely and dispose of waste, and STEAM from Seed regards NCKU-iGEM as one of its models to learn from.

Division of labor

- Administrative preparation (STEAM from Seed): raising funds, contacting partner schools, recruiting and grouping volunteers, writing the camp proposal, and arranging insurance for students and volunteers.
- Lesson preparation (both): STEAM from Seed volunteers propose lesson ideas, and iGEM assesses technical feasibility and safety; both teams refine them together.
- Delivery during the camps (both): volunteers from both sides teach together, and iGEM volunteers lead the DNA extraction lesson.



3. Program Overview

From July 13 to August 21, 2026, we ran ten two-day camps with STEAM from Seed at eight elementary schools in Tainan, reaching 266 student participations (a school that hosted two camps is counted per camp). Each camp was staffed by about 15 to 18 volunteers and served students in grades 1 to 6, spread evenly across grades. All camps followed a similar format: the same core lessons, with the order adjusted for each school and for the weather.

Camp	Dates (2026)	School	Students
1	7/13–14	Xigang Elementary School (西港國小)	22
2	7/15–16	Dujia Elementary School (篤加國小)	21
3	7/20–21	Xigang Elementary School (西港國小)	24
4	7/22–23	Huanya Elementary School (歡雅國小)	20
5	7/30–31	Zhaigang Elementary School (宅港國小)	26
6	8/6–7	Heshun Elementary School (和順國小)	30
7	8/10–11	Anei Elementary School (岸內國小)	30

Camp	Dates (2026)	School	Students
8	8/13–14	Heshun Elementary School (和順國小)	30
9	8/17–18	Zhuqiao Elementary School (竹橋國小)	45
10	8/20–21	Sanci Elementary School (三慈國小)	18

Total: 10 camps, 8 schools, 266 student participations.

School names are romanized in Hanyu Pinyin; the schools' official English names may differ.



4. Design Philosophy and Learning Goals

Audience: elementary students in grades 1 to 6. Structure: each camp runs two days (about 07:45 to 16:00), and a single lesson lasts about 35 to 90 minutes, mostly 60 to 90. Because the same lessons must serve younger, middle and older children at once, we designed so that every child has something to do and something to take away.

Camp-level learning goals

The pre/post-test uses the following seven dimensions as indicators, and they can also be read as the overall learning goals of the camp:

- Finding science interesting
- Enjoying hands-on experiments
- Feeling less that science is too hard to understand
- Being willing to try again in a different way after failing
- Daring to raise a hand and ask when stuck
- Understanding a basic biology concept (where DNA is located)

- Knowing that experiments require following rules and procedures

Design principles

- Start from a question: most lessons open with a question close to daily life (for example "Have you ever seen elephant toothpaste?"), so children enter with curiosity instead of a lecture.
- Hands-on first: every lesson has a concrete activity, so children grasp abstract ideas by doing and take away their own work or observations.
- A shared rhythm: hook question, materials, hands-on work, an open "What did I find?" discussion, explanation of the principle, and a Kahoot review at the end. Children quickly learn how a lesson runs.
- Safety by division of labor: steps with hazardous chemicals (for example strong hydrogen peroxide in elephant toothpaste or strongly alkaline water glass in the chemical garden) are done by counselors, and children do the low-risk parts.
- Personification and analogy: explanations such as "water-molecule soldiers," "balloons = oxygen escaping," and "driving a car out of the house" make osmosis, catalysis and circuits easier to grasp.
- Layered challenges: the Da Vinci bridge has a basic level and an extension level, so children of different ages and abilities each find a suitable challenge.
- Crossing disciplines: the cyanotype lesson includes math calculations and the chemical garden teaches chemical hazard symbols (GHS). This year the sponsor also asked for more art in the lessons, so most lessons include a creative element.

A shared element in every lesson: Kahoot review

At the end of every lesson, children play Kahoot (an online quiz game) as an immediate review, going over the key points they just learned as a game. Because every lesson includes it, the lesson units in Chapter 6 do not list it again. It needs tablets (confirm with the school beforehand whether there are enough tablets for one per child): the coordinator logs in to Kahoot and opens the quiz in advance, and counselors collect and hand out the tablets and help children join and answer.



Overall, the lessons cover biology (DNA), physics (circuits, mechanics) and chemistry (photochemistry, osmosis, catalysis, acids and gases). They support SDG 4 (Quality Education) and SDG 10 (Reduced Inequalities) by giving rural students access to science education comparable to what city schools offer.

5. A Sample Camp

The following describes the schedule and on-site division of labor for one two-day camp. There were three versions of the schedule, each choosing 8 to 9 lessons in a slightly different order and adjusted for each school and for the weather. Please treat it as a reference, not a fixed template.

5.1 Two-day schedule (version 1)

Day 1

Time	Activity
07:45–08:00	Assembly, grouping and roll call
08:10–08:50	Camp introduction + field game
08:50–09:00	Pre-test questionnaire
09:00–10:00	Magician of Light and Shadow (rain plan: switch to an indoor lesson)
10:00–10:10	Break

Time	Activity
10:10–10:45	Elephant Toothpaste
10:45–11:50	Other lesson
11:50–12:00	Lunch reminders and hand washing
12:00–13:00	Lunch and rest
13:00–14:00	Chopstick arch bridge (Da Vinci Bridge)
14:00–15:30	Alcohol Cannon
15:30–15:55	Reflections and feedback
16:00	Dismissal

Day 2

Time	Activity
07:45–08:00	Assembly and roll call
08:00–08:30	Field game
08:30–10:00	Chemical Garden
10:00–10:15	Break
10:15–11:45	Light-Bulb Postcard
11:45–12:00	Lunch reminders and hand washing
12:00–13:00	Lunch and rest
13:00–14:15	The Ultimate Code of Life
14:15–15:30	Other lesson
15:30–15:35	Post-test questionnaire
15:35–15:55	Reflections, awards and group photo
16:00	Dismissal

Notes: "chopstick arch bridge" in the schedule corresponds to the Da Vinci Bridge unit in Chapter 6. "Other lesson" is outside the scope of this handbook. The cyanotype lesson needs sunlight, so a rain plan was prepared.

5.2 On-site roles

Role	Main responsibilities
Camp coordinator	Liaise with school teachers; scout and arrange classrooms; keep lessons on schedule over both days; host and link the sessions; lead the field game or teach; log in to Kahoot, Canva and the opening slides.
Lesson / station leader (top-left photo)	Prepare and teach an assigned lesson, or run a station in the field game.
Counselor group (top-right photo)	Lead a fixed group of children: roll call, name tags, order, help with experiments, hand out and collect tablets, lunch lines, and hand-over at dismissal.
Equipment team (bottom-left photo)	Prepare materials and protective gear for each lesson, move equipment, borrow the school fridge to chill alcohol, and confirm tablets and the lunch location.
Documentation team (bottom-right photo)	Photograph and record the camp, and act as a flexible helper providing on-site support as needed.



5.3 Run-of-show highlights (Day 1 at Zhuqiao Elementary School)

- Arrival and scouting: everyone collects a name tag and carries equipment upstairs; the coordinators scout the art, science and audiovisual rooms and check desk numbers, and decide where to teach on Day 2.

- First 30 minutes: the equipment team asks a teacher to chill the alcohol and confirms tablets and the lunch spot; counselors meet children with the roll sheet in the hall, attach name tags and line them up; meanwhile the room is set up, Kahoot and slides are opened, sun and drying spots for the cyanotype lesson are checked, and questionnaires are counted out.
- Opening: camp introduction, field games ("Mona Lisa" and "Support the Front Line"), the pre-test, and then the first lesson.
- Between lessons: the equipment team prepares the next lesson's materials and gear (for example five sets of elephant toothpaste materials with five pairs of goggles and gloves, starting with size M gloves); when going outside to expose or rinse prints, each counselor keeps their own group together; counselors collect and return the tablets.
- Lunch: counselors take children to wash hands; each group picks one child to help clean up; volunteers split up serving food and managing the line; bulk lunch boxes require bringing your own bowls and utensils. During the rest break, coordinators and the equipment team plan the afternoon's spaces and equipment.
- Wrap-up and dismissal: counselors guide children to write reflection notes on sticky notes and hand them to the coordinator; groups line up in the hall, and volunteers leave only after every child has been picked up by a parent.

6. Lesson Units

All eight lessons below have lesson slides or a preparation manual to draw on. Names, materials and steps follow the slides, with "Practical notes" where there are differences or additions. A quantity marked "reference quantity" comes from the preparation manual and assumes 30 students in 3 groups (6 tables). The Kahoot review at the end of every lesson is described in Chapter 4 and is not repeated in each unit.

Unit	Field	Time slot (min)	In one line
The Ultimate Code of Life	Biology	75–90	See DNA from a banana

Unit	Field	Time slot (min)	In one line
Light-Bulb Postcard	Physics / electronics	80–90	A glowing card made with copper tape
Magician of Light and Shadow	Chemistry (photochemistry)	60–75	Cyanotype prints with sunlight
Chemical Garden	Chemistry (osmosis)	80–90	"Plants" grow from metal salts in water glass
Elephant Toothpaste	Chemistry (catalysis)	35–60	A foam eruption from catalytic decomposition
Da Vinci Bridge	Physics (mechanics)	60	An arch bridge without nails
Snow Bottle	Chemistry	75–90	Baking soda, citric acid and glitter
Alcohol Cannon	Chemistry / physics	90	Alcohol vapor ignition launches a paper cup

Time slots are taken from the three schedule versions and were adjusted per school.

1. The Ultimate Code of Life: Exploring DNA and Genes

Field: biology | about 75–90 min | taught by NCKU-iGEM volunteers

Learning objectives

- Spark curiosity about why everyone looks different by observing physical traits
- Learn that DNA is the "instruction book of life" that carries genetic information, and that a gene is a "functional passage" of DNA
- See DNA with your own eyes through crude DNA extraction from a banana
- Meet applications of genetic engineering (glowing genes, engineered crops) and connect science to daily life

Materials

- Bananas (1 per table) and zip-lock bags
- Dish soap (the "bubble water") and saturated salt water
- Strainers and gauze, beakers, graduated cylinders, wash bottles (water) and chopsticks (for stirring)

- Ice-cold 95% alcohol and small glass vials (1 per child)
- Reference quantity: 600 ml ice-cold 95% alcohol, 6 bananas, 6 large bottles of saturated salt water (prepared in advance), 150 ml dish soap, 30 zip-lock bags, 30 glass vials

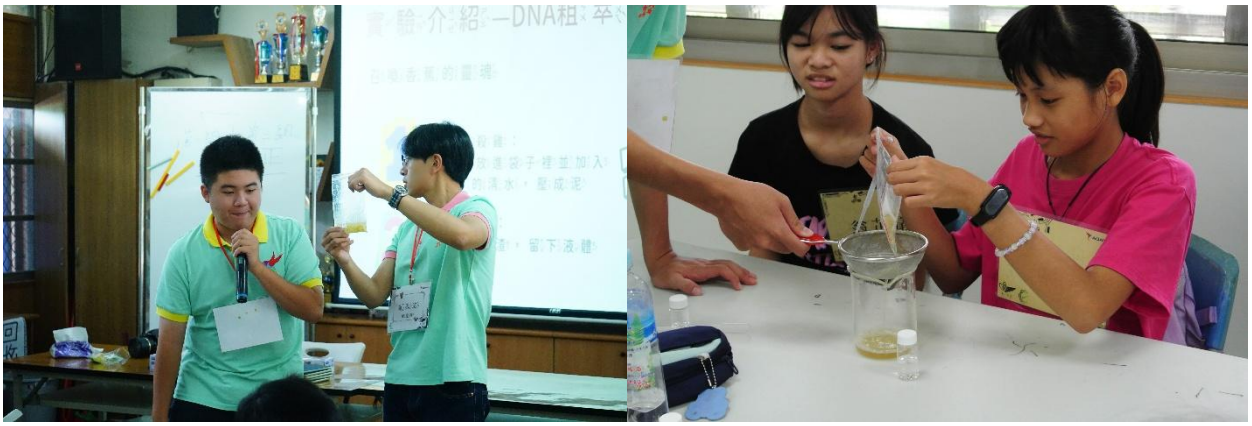
Lesson flow

1. Opening question, "Feature Survival": use picture cards of facial and body features to get children thinking about why everyone's features differ
2. "Instruction book of life" and "Meet DNA": explain DNA with analogies such as a LEGO manual, a code, or an encyclopedia
3. "Secrets inside DNA": explain that a gene is a functional passage inside DNA
4. Think-it-over time: discuss where the secrets of traits, such as a polar bear's or a jellyfish's, are stored
5. Experiment, crude DNA extraction ("summoning the soul of the banana"): (1) mash the banana in a zip-lock bag; (2) add soapy water and salt to break the cell membranes; (3) filter out the residue and keep the liquid; (4) pour in cold alcohol and watch white DNA appear
6. Extension, "If you had magic hands": introduce genetic engineering examples such as glowing plants and golden rice
7. "If you had magic scissors": ask children which animal's gene they would paste onto which organism
8. Closing: "You are the most limited-edition code in the world." Genes set the starting values, but effort and environment decide how far you go

Practical notes

- Operating details from the preparation manual: divide the banana into six portions and put each in a bag (with 20 ml water and 5 ml dish soap already inside) and mash it; snip a small hole in the bottom of the bag, pour the mixture through a strainer and gauze into a 100 ml beaker (containing 30 ml saturated salt water); stir, transfer 10 ml of the mixture to a glass vial, add 20 ml ice-cold alcohol, and wait.

- The alcohol must be chilled in advance. Ask a teacher to put it in the school fridge as soon as you arrive. Once, the alcohol was forgotten, and teammates found a workaround on the spot.



2. Light-Bulb Postcard

Field: physics / electronics | about 80–90 min

Learning objectives

- Learn the parts of a basic circuit (source, wire, switch, load)
- Understand closed circuits, open circuits and short circuits
- Learn that components have polarity (positive and negative)
- Make a glowing handmade postcard and learn basic electrical safety

Materials

- Card stock (1 per child; in practice, 4K drawing paper cut into 16 small sheets)
- Button cell batteries (1 per child) and LEDs (1 per child)
- Double-sided conductive copper foil tape, 5 mm (1 roll per group), and regular tape (1 roll per table)
- Colored markers (1 box per table) and stainless-steel scissors (1 per table)

Lesson flow

1. Discussion: when do you get or send cards, and what do they look like?
2. Discussion: why do lights and fans turn on when you press a switch? Why do LEDs have a long leg and a short leg?
3. Design a picture on the front of the card and decide where the LED goes

4. Turn the card over and lay out the circuit with copper tape (mind the polarity of the LED and battery)
5. Fold the lower-left corner over the battery (make sure the battery sits fully on the copper tape)
6. Share reflections
7. Explain the principle: four circuit elements, closed/open/short circuits, polarity, and a note on current-limiting resistors
8. Electrical safety: the fire service's "five don'ts and one must" rules

Practical notes

- Two things go wrong most often: the polarity of the LED and battery, and whether the battery sits fully on the copper tape. The lesson leader also noted that it does not always work the first time and needs several counselors to help troubleshoot.
- In a first trial run, the lesson leader found that the terms closed, short and open circuit were hard for children. The leader switched to the analogy of "driving a car out of the house" to explain the whole circuit, after several rounds of practice and adjustment.
- A suggested pace: form groups and let children design their pictures (about 10 minutes), design the circuit (about 15 to 20 minutes), then hand out batteries together and troubleshoot as a class. Once, one group's counselors handed out batteries early, which interrupted the polarity reminder the lesson leader had planned, so align on battery timing with counselors before class.
- The current-limiting resistor is introduced only as a fun fact; no resistor is on the materials list.




3. Magician of Light and Shadow: Cyanotype

Field: chemistry (photochemistry) | about 60–75 min | needs sunlight; a rain plan is needed

Learning objectives

- Connect ultraviolet (UV) light to everyday phenomena such as faded clothes and posters
- Learn the photochemical principle behind the light-sensitive solution
- Practice ratio calculations in teams, combining chemistry and math
- Create a personal cyanotype artwork

Materials

- 20% ferric ammonium citrate solution and 10% potassium ferricyanide ("red prussiate") solution
- Watercolor paper, brushes, markers, clear zip-lock bags or folders, and gloves
- Amber glass sample bottle (for leftover solution)
- Reference quantity: 70 g ferric ammonium citrate and 35 g potassium ferricyanide; also a scale, weighing paper, beakers and stainless-steel spoons (a separate spoon for each chemical)

Lesson flow

1. Hook questions: what happens to clothes left in the sun? To a poster on a window? Why does wearing a hat help prevent tanning?
2. Introduce the chemicals: ferric ammonium citrate (brown or green) and potassium ferricyanide (bright red, also called red prussiate); encourage children to use materials at hand for their designs
3. Put on gloves and prepare the two solutions by ratio, then mix them (ferric ammonium citrate : water = 1 : 5; potassium ferricyanide : water = 1 : 10)
4. Math exercise: each child needs 0.2 g ferric ammonium citrate and 0.1 g potassium ferricyanide; work out how many grams of chemicals and water the whole group needs
5. Explain storage: the solution reacts to light, so keep it out of sunlight and long exposure to fluorescent light, and store it in dark containers

6. Create: with gloves on, coat the watercolor paper with the solution, draw on the folder, expose it to sunlight and watch the color change (coated side up), then rinse off the excess solution with water
7. Share works and observations
8. Explain the principle: UV light triggers a redox photochemical reaction of the iron ions in the solution; add fun facts such as the origin of the word "ultraviolet"

Practical notes

- The preparation manual mixes ferric ammonium citrate : water at 1 : 5 (70 g in 350 g tap water) and potassium ferricyanide : water at 1 : 10 (35 g in 350 g tap water). Confirm the ratio before use.
- Exposing and rinsing the prints takes children outdoors, so each counselor must keep their group together; on site, children were also taken outside to pick leaves.
- Scout the spots for exposure and drying beforehand, and prepare a substitute lesson for rain.

Safety reminder (from the preparation manual)
• Potassium ferricyanide mixed with acid releases highly toxic hydrogen cyanide gas. Containers must never hold any residue of acidic chemicals (for example citric acid or acetic acid).
• Wear gloves throughout; skin contact causes mild irritation.





4. Chemical Garden

Field: chemistry (osmosis) | about 80–90 min

Learning objectives

- Learn the hazards shown by GHS chemical symbols (flame, corrosion, exclamation mark, skull, and so on)
- Learn about semipermeable membranes and osmosis
- Watch "chemical plants" grow from metal salts in water glass through swelling, rupture and regrowth

Materials

- Sodium silicate (water glass): 50 g in 50 g water
- Ferric chloride, ferrous sulfate, copper sulfate and calcium chloride, each 20 g in 80 g water (orange-yellow, yellow-green, blue and white)
- 30 ml lidded plastic bottles (1 per child), droppers, measuring cups, beakers and gloves

Lesson flow

1. Hook questions: what comes to mind for "garden"? How does chemistry relate to a garden? What matters most in an experiment? (leading to safety)
2. Introduce GHS symbols: flammable, oxidizing, explosive/pressurized, corrosive (wear gloves), environmental hazard, irritant/sensitizer, acutely toxic and so on
3. Introduce the "flower seeds": water glass and the various salts (not table salt) and their GHS symbols
4. Preparation (by counselors): prepare each salt solution by ratio and pre-fill the small bottles with water glass
5. Children's task: choose one to three colors and use a dropper to release the chosen solutions at the bottom of the bottle, placing each new color away from the previous one
6. Observe the "chemical plants" grow
7. Explain the principle (with personification): when a metal-ion solution touches water glass it instantly forms a semipermeable membrane (an invisible city wall); water

molecules rush in like soldiers and swell the membrane; when it bursts, the solution leaks out and reacts with water glass to form a new membrane that seals the hole, and the cycle repeats to grow hollow colorful tubes

Practical notes

- The slides originally had children add the water glass themselves. The preparation manual changes this to counselors pre-filling the bottles so children never handle it, because water glass is strongly alkaline. The manual puts 15 ml of water glass in each bottle in advance.
- The manual's recipe for each salt solution: dissolve 30 g in 120 ml of water and divide it evenly among six 50 ml beakers (about 25 ml each).

> **Editor's recommendation**
> **• Do not pour waste solutions of metal salts or water glass down the sink; collect them and dispose of them according to laboratory waste rules.**
> **• If water glass touches skin, rinse immediately with plenty of water and seek medical assessment.**




5. Elephant Toothpaste

Field: chemistry (catalysis) | about 35–60 min

Learning objectives

- Build observation skills by noticing color, smell and texture during a reaction

- Learn about catalysis and gas release through analogies, without difficult chemical formulas
- Experience the predict, observe, explain cycle of scientific inquiry

Materials

- 35% hydrogen peroxide 40 ml, potassium iodide powder 1.5 g, dish soap 25 ml, food coloring and warm water
- One large and one small beaker, a tray, and plastic sheeting (to protect the surface)
- Safety goggles and gloves

Lesson flow

1. Hook questions: have you seen toothpaste for elephants? What color is it? Have you seen a volcano erupt?
2. Put on safety equipment
3. Ask about materials: what is in elephant toothpaste, and what else is needed?
4. Solution A (made by counselors): after laying out the plastic sheet and tray, pour the hydrogen peroxide and dish soap into the large beaker, and let children pick a food coloring to add
5. Solution B: stir 1.5 g potassium iodide into warm water until dissolved
6. Place the beaker of Solution A in the center of the tray, quickly pour in Solution B, and step back at once
7. Observe and discuss: what did you see, how did it feel at first, and what do the color, smell and texture remind you of?
8. Explain the principle: hydrogen peroxide breaks down with a catalyst and releases lots of oxygen; use "a balloon = the oxygen escaping" and "the dish soap catches the balloons and gathers them into elephant toothpaste"

Practical notes

- The hazardous mixing step (Solution A) is done by counselors, and children only do the low-risk parts. This division of labor is the safety core of the lesson.

- Because potassium iodide became too expensive as raw material prices rose, manganese dioxide was sometimes used as the catalyst instead. The preparation manual's version is 50 ml hydrogen peroxide solution, 25 ml dish soap, and 1.5 g manganese dioxide per table (in 30 ml of water).
- The preparation manual warns that concentrated hydrogen peroxide is a strong oxidizer and dangerous, and that the rod used to stir Solution A must not be used for Solution B.

> **Editor's recommendation**
> **• 35% hydrogen peroxide can burn skin and eyes. Have an experienced member prepare it, wear goggles and gloves throughout, and keep children at a safe distance.**
> **• Without protective gear or experience, use a low concentration (for example about 3% from a pharmacy). The foam is smaller, but it is much safer.**





6. Da Vinci Bridge

Field: physics (mechanics) | about 60 min | also called the "chopstick arch bridge" in the schedule

Learning objectives

- Learn about Leonardo da Vinci's work across art, science and mathematics, and his bridge sketches
- Learn about gravity and friction
- Understand basic structural mechanics by building a bridge without nails
- Practice teamwork and open-ended exploration

Materials

- Popsicle sticks (a team of 3 shares 21 sticks, bundled with rubber bands in advance)
- A bottle of water (for the pass condition)

Lesson flow

1. Introduce da Vinci's life and design sketches
2. Ask: does a bridge need nails or screws? Can one stand without them?
3. Introduce the Da Vinci bridge: nine or more sticks interlock into an arch without nails; explain the story of the design shelved by a king in the 19th century
4. Ask: why doesn't the bridge fall? (leading to gravity and friction)
5. Basic level: (1) lay down two sticks; (2) lay other sticks across them; (3) lock the sticks in one after another; (4) complete the arch
6. Pass condition: the bridge must carry the weight of a bottle of water
7. Extension: how can the bridge be lengthened? (1) lift one end; (2) slide a new stick under the two existing supports; (3) insert two more sticks to extend it
8. Think it over: how can teammates work together faster and more stably? What did you find? Are there other ways to build it?
9. Explain the principle: define gravity and friction, with a playful comparison using the Earth's weight

Practical notes

- Low material cost and low risk make this a good starter lesson.
- The basic-plus-extension design gives fast teams something to challenge and lets slower teams still finish.




7. Snow Bottle

Field: chemistry | about 75–90 min | this unit has only the preparation manual, no lesson slides

Learning objectives

- Observe bubbles forming when baking soda (a base) meets citric acid, and learn that acids and bases can react to produce gas
- Watch how the glitter moves as the bubbles rise, making an invisible gas visible
- Practice following steps and ratios, and describe the changes in your own words

Materials

- Baby oil (200 ml per group) and glitter
- Baking soda (50 g per group) and water (100 ml per group)
- Food coloring (about 3 drops per group) and citric acid (10 g)
- 500 ml beaker (1 per group)

Lesson flow

1. Put 100 ml of water, 50 g baking soda, 3 drops of food coloring and a spoonful of glitter in the beaker
2. Stir
3. Slowly add 10 g of citric acid
4. Slowly add 200 ml of baby oil





8. Alcohol Cannon

Field: chemistry / physics | about 90 min | this unit has only the preparation manual, no lesson slides

Learning objectives

- Learn that alcohol is flammable, that burning needs fuel, oxygen and an ignition source, and build safe habits around flames and flammables
- Observe how burning alcohol vapor makes gas expand rapidly and push the paper cup out, showing that expanding gas can create thrust
- Practice observing and comparing the results of each launch and stating a guess about why
- Follow fire-safety rules: adults handle ignition, and never aim at people

Materials

- 75% alcohol (1 bottle per group)
- Yakult-style bottles and plastic cups (as many as available)
- Lighters (3)

Lesson flow

1. Counselors spray an appropriate amount of alcohol into the bottle
2. Counselors attach the bottle to the lighter and hand the device to the children
3. Aim at the target paper cup
4. Fire (never aim at people)

Editor's recommendation (the manual only says "do not aim at people"; the following are suggested additions)
• Adults handle the alcohol and ignition at all times; children only aim and observe.
• Keep the alcohol bottle capped and far from the ignition point, and use only small amounts each time.
• Keep the firing direction clear and away from people, curtains, paper and other flammables; tie back long hair.
• Work in a ventilated space, with a wet cloth or fire extinguisher at hand.



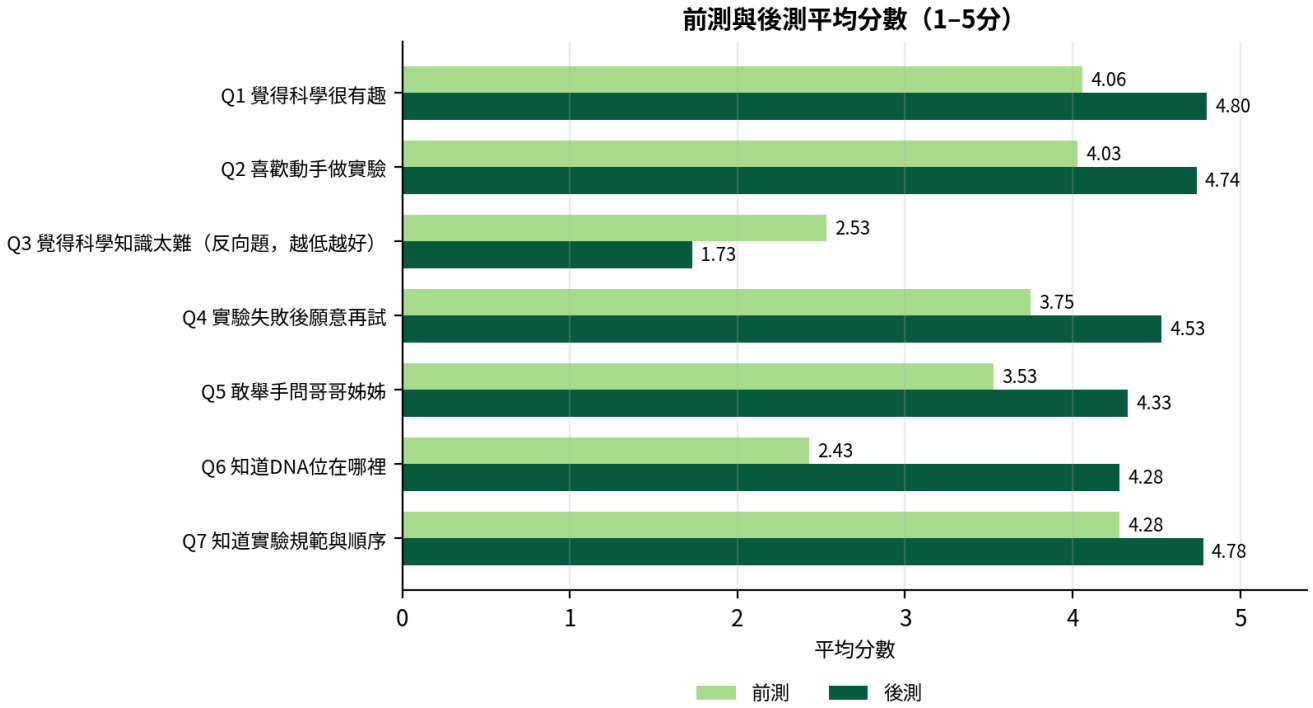
7. Field Experience, Results and Challenges

7.1 Student pre- and post-test

Each camp gave a pre-test before the first lesson on Day 1 and a post-test near the end of Day 2, using the same questionnaire (7 items on a five-point scale shown with emoji; items are in Appendix B). The table shows mean scores for each item.

Item	Statement	Pre	Post	Change	Cohen's d
Q1	Science is interesting	4.06	4.80	+0.74	—
Q2	Enjoy hands-on experiments	4.03	4.74	+0.71	—
Q3	Science is too difficult (reverse-scored)	2.53	1.73	−0.80	−0.79
Q4	Try again after failure	3.75	4.53	+0.78	—
Q5	Willing to ask for help	3.53	4.33	+0.80	0.74
Q6	Knows where DNA is located	2.43	4.28	+1.85	1.60
Q7	Knows lab safety procedures	4.28	4.78	+0.50	0.59

The team's analysis reports that every pre/post difference is statistically significant ($p < 0.001$). A dash means the analysis report does not list a value.



How to read it:

- The largest gain is Q6, "Knows where DNA is located" (2.43 to 4.28, d = 1.60), which matches the DNA lesson taught by NCKU-iGEM. The score for Q3, "Science is too difficult," fell (2.53 to 1.73), also in the desired direction.
- Q1, Q2 and Q7 already scored above 4 before the camp, leaving little room to rise.

Limitations
• This is a self-report scale, not a knowledge test. Q6, for example, measures a child's confidence in knowing where DNA is, not whether they answer correctly.
• There is no control group, and both tests fall within the same two-day camp, so the results show that children rated themselves higher, and cannot prove the lessons caused it.
• Children's good mood at the end of camp may also raise post-test scores.

7.2 Feedback from students and teachers

The questionnaire ends with a "secret corner" where children write what they want to tell the older students. Some responses:

- "I like every lesson. I like this kind of lesson. I hope we can keep playing."
- "I think the science the older students taught us is fun."
- "The older brothers and sisters are so thoughtful, and they taught us science experiments. It was really interesting."

Most children were delighted that older students came into their world to play and do experiments with them. For rural children who are mostly accompanied by screens after school, company from people close to their own age is a great comfort. Teachers and principals at partner schools also expressed thanks, saying the activities gave students a wider view and covered experiments that regular classes cannot. One child told a volunteer: "Thank you for being with us. It made them love science even more."

7.3 Volunteer reflections (anonymized)

The following is summarized from volunteers' written reflections, without names.

- Trial runs and taking the child's view: one volunteer found that explaining principles the textbook way lost the children's attention. After switching to everyday analogies (such as "driving a car out of the house" for circuits) and practicing repeatedly, the children could follow.
- Lesson leaders and counselors need to align beforehand: if the pace is not agreed (for example when to hand out batteries and when to remind about polarity), the planned teaching gets interrupted.
- Every school and child is different: schools differ in routines and expectations, and one volunteer described every camp as "unwrapping a surprise box"; some volunteers also felt helpless with very disengaged children and said patience and flexibility were needed.
- Suggestions on content: some volunteers felt younger children lack the background for chemistry and biology, and would be more interested in more physics activities or experiments with visible, take-home results; they also wanted less one-way, classroom-style explanation and more interaction. Some simple, playable activities were especially popular.

- Checklists and backups: someone once forgot the ice-cold alcohol and teammates rescued the situation; outdoor lessons had to adapt to Tainan's unpredictable weather, so rain plans are needed.
- The coordinator's workload: coordinators liaise with teachers, keep the two-day schedule, link sessions and lead the field game. Volunteers suggested spreading tasks across the coordination team to avoid concentrating pressure on a few people.
- Volunteers' own growth: many volunteers served for the first time as counselor, lesson leader or coordinator, and grew from nervous to comfortable speaking and interacting, learning to communicate in different ways.

7.4 Difficulties and how we responded

- Limited facilities: rural school facilities are not as generous as urban ones. One school did not run air conditioning to save money even above 30 °C, and because classes are small, classrooms lacked enough desks for a whole camp, so we borrowed spaces such as an auditorium.
- Transport: sites are remote and this year's budget did not cover hiring a coach, so volunteers rode their own vehicles or asked parents for rides.
- Every camp is a surprise box: schools manage students differently, not every school's children are used to older students running camps at school, and when the camp's rhythm clashed with the school bell some children were unhappy. We adjusted as flexibly as possible and accompanied each child with empathy.
- Unexpected situations: one camp forgot a key piece of equipment for a lesson (an air pump), so we designed a new experiment from what was at hand; potassium iodide for elephant toothpaste went over budget as prices rose, so we switched to another catalyst and the experiment still worked.
- Team management: over four years, STEAM from Seed has repeatedly gone through "unfreeze, change, refreeze" in how it manages the team, facing surprises more logically each year. This year's division of work was still uneven, and next year the lesson-leader group hopes to share work more evenly.

8. Recommendations for Future Teams

Lesson design

- Ask those with front-line experience before designing a lesson, and start from where the children's knowledge is likely to be.
- Do a trial run before teaching. When children do not understand, first look for an analogy from their daily lives.
- Choose lessons where children can make something and see results. For younger children, physics and directly hands-on activities are usually easier than abstract chemistry and biology.
- When one lesson serves several grades, layer it with a basic level plus an extension level.

On-site operations

- When children act out or respond poorly, ask where the reaction comes from. Learning about the school, family and community background makes it easier to empathize.
- Confirm desks, fridge, tablets and the lunch location with the school beforehand, and line up a backup space (such as an auditorium).
- Prepare a checklist and a backup for each lesson: have a workaround for forgotten equipment and a rain plan for outdoor lessons.
- Before class, lesson leaders should align the pace with counselors (for example when to hand out materials and which points to stress).
- Share the coordinator's tasks across the coordination team so the pressure does not fall on one person.
- At dismissal, volunteers leave only after every child has been picked up by a parent.

Safety

- Have counselors do steps with hazardous chemicals, and let children do only the low-risk parts.
- Before the camp, list the nearest medical facility at each site and give all volunteers the coordinator's contact details.

- See the safety rules in Appendix A.

Evaluation and documents

- Back up the questionnaires, and decide beforehand the sample size, pairing method and how to handle missing data.
- Obtain image release forms before photographing children.
- Keep lesson slides, preparation manuals, equipment lists and schedules together as one document set (see Appendix C) so the next cohort can pick up where you left off.

9. Acknowledgments and Contact

We thank the STEAM from Seed team and its project lead, and every volunteer who took part in the camps; the teachers and students of the eight Tainan elementary schools who provided space and support; ADATA and its foundation for their sponsorship, which gave the camps more resources; and everyone who helped make this handbook possible. This handbook was co-authored by the 2026 NCKU-iGEM team of National Cheng Kung University and STEAM from Seed.

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Appendix A. General Safety Rules

Adapted from the STEAM from Seed safety rules (July 2026).

- Always wear gloves when handling chemicals and check them for holes. Close containers promptly after use so they do not absorb moisture from the air.
- All counselors must repeatedly remind children: do not swallow chemicals, do not touch chemicals without gloves, do not spray with droppers, and do not bang glassware.
- If a chemical is spilled: put on two layers of gloves, wipe with a mop or disposable absorbent paper towels and discard them at once, then wipe and rinse the area with clean water at least three times.
- If someone is exposed: identify and record the chemical; take the child to rinse the area continuously with running water; ask others to notify the project lead and the coordinators; decide whether to go to hospital; always inform the parents and teacher and follow up.

> **Editor's recommendation: rinsing time**
> **• The team's rules do not say how long to rinse. General first aid for chemical burns is to flush with plenty of running water for at least 15 to 20 minutes (alkalis often need longer) and to follow the chemical's safety data sheet (SDS); for eye contact, rinse immediately and seek medical care. Do not try to neutralize an acid with a base or the reverse.**

Main hazards by lesson

Lesson	Main hazard	Key precautions
Elephant Toothpaste	Concentrated hydrogen peroxide (strong oxidizer)	Counselors prepare it; goggles and gloves; children keep their distance
Cyanotype	Potassium ferricyanide plus acid releases hydrogen cyanide; skin irritation	No acid residue in containers; gloves throughout; store away from light
Chemical Garden	Water glass (strongly alkaline) and metal salts	Counselors pre-fill water glass; gloves; teach GHS symbols

Lesson	Main hazard	Key precautions
Alcohol Cannon	Flammable alcohol and ignition	Adults handle ignition; never aim at people; clear the front
The Ultimate Code of Life	95% alcohol is flammable	Keep away from flames; do not ingest

Appendix B. Pre/Post-Test Questionnaire

Title: 2026 ADATA × STEAM from Seed × NCKU-iGEM Summer Science Camps in Rural Tainan Elementary Schools, pre/post-test questionnaire (the same form is used before and after).

Instruction: "Kids, here are 5 of your secret weapons (choose by looking at the pictures!)" The five-point scale is shown with emoji:

- Strongly agree (Exactly like this! Not wrong at all)
- Somewhat agree (Mostly like this)
- Not sure (Half and half)
- Somewhat disagree (Doesn't seem quite right; rarely like this)
- Strongly disagree (Definitely not like this! Not at all)

Part 1. My science day-to-day

1. I think science is very interesting.

2. I like the feeling of doing experiments with my own hands.

3. I think science knowledge is too hard and I cannot understand it at all. (reverse-scored)

4. If an experiment fails, I want to try again a different way and do not give up right away.

5. If I meet a problem I cannot solve, I dare to raise my hand and ask the older students.

Part 2. My little bit of science knowledge

6. I know where the code of life (DNA) is located.

7. I know that experiments require following rules and the order of steps.

Part 3. Secret corner

Is there anything you want to say to the older students? You can write it down or draw it!

Scoring: five points, from 5 (strongly agree) to 1 (strongly disagree); item 3 is reverse-scored, so a lower score is better.

Appendix C. Camp Document Checklist

STEAM from Seed prepared the following documents before the camps. Other teams may want to prepare a similar set:

Document	Purpose
Lesson slide collection	Teaching slides for each lesson
Lesson preparation manual	Materials and ratios, equipment and quantities, steps and safety notes for each lesson
Pre/post-test questionnaire master	Camp evaluation (Appendix B)
Image release form	Consent before photographing and using children's images
Recreation game proposal	Design of the field game and other recreation activities
In-camp checklist	Items to check during the camp
Duty schedule	Two-day schedule and staff assignments
Equipment list and inventory sheet	Equipment lists and counting before and after the trip
Reimbursement form	Expense reimbursement form for shared funds

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