

BioBee

Teacher Guide · Grade 3

Hearts Invention Lab STEM Curriculum · Reverse Engineering Series · Simple systems and forces



BioBee, a small robot bee with a clear plant-fibre body hovering by a flower

© 2026 Hearts Invention Lab. App for ages 5 and up, and grown-up inventors too. Digital-only curriculum for printing and download. Licensed to the buyer only. Not for resale or public posting.

How to use this guide

Safety rule first: BioBee has no stinger. It helps real bees but can't replace them. The snap-out core never goes in soil: it goes back to the dock or to e-waste recycling.

This guide has the Grade 3 unit. Each unit has 4 or 5 lessons. Students reverse-engineer BioBee, the robot bee: they explode it into parts, read each part's job, rebuild it and name their own version. Each unit then adds a hands-on activity using household and classroom items only.

- **Digital-only.** This curriculum is sold as printable, downloadable files. No kits or materials packs exist or are needed.
- **Facts and sources.** Every research fact carries a source tag [S#]. Parts or claims with no published source are marked "design reasoning, no source" (or "design idea, no source") so students can see the difference between evidence and design ideas.
- **Practice values.** Some maths problems in grades 9–12 use clearly labelled practice values (PV). These are made-up numbers for the exercise, not source facts.
- **Standards.** NGSS and CCSS codes are given with paraphrased descriptions. Check them against your state's standards.
- **The app.** heartsinventionlab.com/app/ (Ages 5+). Open Reverse Engineer, then BioBee. Lumet, the app's crystal guide, leads the teardown (Basic mode), the rebuild, naming your version and the material quiz (Advanced mode).
- **License.** Licensed to the buyer only. Not for resale or public posting. A Family & Classroom License covers one home or one classroom; a School Site License covers every teacher at one school building.

BioBee at a glance

BioBee is a garden-helper robot bee built mostly from plant and natural materials, designed to break down after one working season. The parts that can't safely rot live in one snap-out core that goes home to the dock to be reused. It has **no stinger**, and it helps real bees but can't replace them. Many of its materials are still lab research, so each part carries a readiness label where the sources allow. In the app it comes apart in 5 layers:

1. Outside coat and skin (timer coat, clear body shell)
2. Wings (silk wings, food-wing lesson)
3. Frame (plant-fibre frame)
4. Pads, circuits and backup power (pollen brush pads, dissolving sensor layer, backup cell)
5. Snap-out core and dock (snap-out core, quartz timing crystal, lead-free wing muscles, home dock)



1. Clear body shell



2. Plant-fibre frame



3. Silk wings



4. Food-wing lesson
(comparison only)



5. Pollen brush pads



6. Timer coat



7. Dissolving sensor layer



8. Backup cell (research
option)



9. Snap-out core



10. Home dock



11. Quartz timing crystal
(in the core)



12. Lead-free wing
muscles (in the core)

Grade-band progression

Band	Focus
K-2	Plants, pollinators and copying nature; what rots and what doesn't; taking apart and rebuilding
3-5	Life cycles and compost, structure and function, decomposers and timed breakdown
6-8	Materials from natural resources, a designed lifetime, ecosystem services
9-12	Piezoelectricity and quartz timing, transient electronics chemistry, biodegradation biology, readiness levels and e-waste

Grade 3: A Season-Long Life Cycle

4 lessons · about 135 minutes in total · © 2026 Hearts Invention Lab

Safety rule first: BioBee has no stinger. It helps real bees but can't replace them. The snap-out core never goes in soil: it goes back to the dock or to e-waste recycling.

Overview

Third graders compare a bee's life cycle with BioBee's designed 'life cycle': build, one working season, return to the dock, compost the body, reuse the core. They track a bean seed's life cycle and model BioBee's season on a timeline.

Learning objectives

Students will:

- Model the life cycle of a living thing.
- Compare a living life cycle with a designed product cycle.
- Explain BioBee's end-of-season steps.
- Record observations over time.

Standards alignment

Framework	Code	What students do (paraphrased)	Status
NGSS	3-LS1-1	Develop models to describe that organisms have unique and diverse life cycles (paraphrased).	Aligned
NGSS	3-LS4-3	Argue that some organisms survive well in a habitat and others don't (paraphrased).	Suggested alignment
NGSS	3-5-ETS1-1	Define a design problem with criteria and constraints (paraphrased).	Aligned
CCSS	3.MD.B.3	Draw scaled bar graphs.	Aligned
CCSS	3.MD.A.1	Measure time intervals.	Aligned
CCSS	W.3.2	Write informative texts.	Aligned

"Aligned" means the unit directly addresses the performance expectation. "Suggested alignment" means a partial or supporting fit for the teacher to confirm.

Lessons and timing

Lesson 1: Explore BioBee (40 min)

1. Safety rule. Take apart; mark parts that rot and parts in the core.

Lesson 2: Bean diary (hands-on) (15 min a day for 2 weeks)

1. See hands-on.

Lesson 3: BioBee's season (40 min)

1. Draw a circle timeline: build → work → dock → compost body → reuse core.

2. Compare with the bean.

Lesson 4: Informative writing (40 min)

1. Write 'How BioBee ends its season'.
2. Rebuild and name your version.

Materials (household and classroom items only)

- Dried beans, paper towels, zip bags or clear cups
- Ruler
- Timeline paper

Nothing in this unit needs a purchased kit.

Hands-on activity: Bean Life-Cycle Diary

1. Wrap 2 beans in a damp paper towel inside a zip bag; tape to a window.
2. Each day, measure root and shoot length and draw them.
3. Graph growth over 2 weeks.
4. Label stages: seed, sprout, seedling.
5. Link it: BioBee's 'cycle' is designed: one season, then the body is composted and the core reused (design reasoning, no source).

In-app activity (Hearts Invention Lab app, Ages 5+)

Lumet, the app's crystal guide, walks students through each step. The app is free to open at heartsinventionlab.com/app/.

1. Open Reverse Engineer, then BioBee. Read Lumet's safety rule first.
2. Explode BioBee; read every part card.
3. Basic mode: take it apart by layer and rebuild it; name your version.
4. Advanced mode: match each part to its material.

Every part: why this material, what it does, how it is built

Part (material)	Why this material was chosen	What the part does	How it is assembled in real life
Clear body shell (Cellulose nanofibre film with a thin shellac coat)	Plant nanofibres pack tight enough to look clear, and they compost. [S1]	A see-through, protective outer skin.	A cellulose film with a thin shellac coat on top. [S1]
Plant-fibre frame (Flax fibres in PLA (plant-based plastic))	Flax is stiff for its weight. [S2]	A light, stiff skeleton.	Flax fibres set in PLA, folded like origami. PLA needs hot compost to break down. [S2]
Silk wings (Silk protein (fibroin) film on plant-fibre veins)	Silk film's breakdown speed can be tuned. [S3]	Thin, bendy wing skins.	Silk film on thin plant-fibre veins. [S3]
Food-wing lesson (comparison only) (Puffed rice bonded with gelatin)	A real drone flew on puffed-rice wings. [S4]	Comparison only: too weak for BioBee.	Puffed rice bonded with gelatin; motor and electronics were normal parts. [S4]

Part (material)	Why this material was chosen	What the part does	How it is assembled in real life
Pollen brush pads (Plant fibres with a light chitosan coating)	An earlier drone carried pollen on sticky gel hairs. [S5]	Pick up and drop pollen.	Plant-fibre pads with chitosan: still an open question. [S5]
Timer coat (Shellac, a natural varnish)	Shellac is a natural varnish. (design idea, no source)	Keeps rain out for one season, then wears away.	Brushed on; thickness sets the lifespan. (design idea, no source)
Dissolving sensor layer (Ultrathin magnesium and silicon on silk)	Magnesium and silicon thin dissolve in water. [S6]	Touch and bend sensors and an antenna.	Built on silk so it dissolves on a schedule. [S6]
Backup cell (research option) (Zinc battery with a chitosan gel)	A chitosan-zinc gel can rot in soil. [S7]	A reserve to guide BioBee home.	The zinc is collected, not composted. [S7]
Snap-out core (Sealed recyclable aluminium case)	Aluminium is light and recyclable. (design idea, no source)	Holds the flight battery, chip, radio, quartz and wing muscles.	One sealed, bright-coloured module with a beacon. (design idea, no source)
Home dock (Coated aluminium dock with charging contacts)	Coated aluminium with charging contacts. (design idea, no source)	Takes back and recharges the core.	Unlatches the core; an adult composts the empty body. (design idea, no source)
Quartz timing crystal (in the core) (Quartz, a natural crystal)	Quartz vibrates at a steady rate set by its cut and size. [S8]	Keeps time for the chip.	Sealed in the core and reused. [S8]
Lead-free wing muscles (in the core) (KNN (potassium sodium niobate) piezo ceramic)	KNN is a lead-free piezo ceramic. [S9]	Flaps the wings.	In the core; stacked KNN actuators are still prototypes. [S11]

Tags in brackets [S#] point to the Sources list at the end of this guide. “No source” marks a design idea from the invention file that no published source backs up yet.

Real-world assembly sequence

BioBee has not been built. Its plant and silk parts are lab experiments; its core uses parts sold today. [S1, S6, S8]

1. Seal the core: flight battery, chip and radio, quartz, wing muscles. *[design reasoning, no source]*
2. Fold the flax-in-PLA frame. [S2]
3. Attach silk wings on plant veins. [S3]
4. Add the dissolving sensor layer and backup cell. [S6, S7]
5. Fix the pollen pads. [S5]
6. Wrap the cellulose skin. [S1]
7. Brush on the shellac timer coat. *[design reasoning, no source]*
8. Snap in the core; test on the dock. *[design reasoning, no source]*

The source files do not give a build order. Building and sealing the core first, then adding the compostable body around it, is design reasoning. End of season: the core goes back to the dock, the empty body goes to a hot industrial compost, and a worn-out core goes to e-waste recycling, never into soil.

Vocabulary

Word	Meaning
Life cycle	The stages a living thing goes through.
Season	A part of the year.
Dock	BioBee's home base.
Reuse	Use something again.
Timeline	A line showing events in order.

Teacher's background (cited facts)

F12 and F11 are design reasoning; F2 adds the honest compost limit.

- Design reasoning (no source): no one has made a dissolving battery strong enough to fly or a dissolving flight computer, so those parts stay in one sealed, brightly coloured snap-out core with a locator beacon. The home dock unlatches the core for reuse; a worn-out core goes to e-waste recycling, never into soil.
- Flax is stiff for its weight. PLA (a plant-based plastic) needs a hot industrial compost (about 55-60 °C) to break down in weeks; in cool garden soil one study saw no measurable breakdown in 12 weeks. [S2]
- Design reasoning (no source): the timer coat's thickness sets the lifespan, and sun and rubbing wear it down, so the real lifetime is a range, not an exact day.

Discussion questions

1. How is BioBee's cycle like the bean's? Different?
2. Why does BioBee only work one season?
3. What happens to the core?
4. Why compost only in a hot compost bin?

Assessment

1. Name the bean's first three stages.
2. What happens to BioBee's body at season's end?
3. What happens to the core?
4. Show your growth graph.

Answer key

1. Seed, sprout, seedling.
2. It goes to a hot (industrial) compost.
3. Back to the dock to be reused, or e-waste recycling.
4. Accept labelled graph.

Rubric

Criterion	Not yet	Getting there	Got it!
Life cycle model	Missing	Some stages	All stages in order
Comparison	None	One	Likenesses and differences
Writing	Unclear	Some steps	All steps in order

Differentiation and extension

- **Support:** Provide stage picture cards.
- **Challenge:** Compare two bean varieties.
- **Extension:** Research a real bee's life cycle and cite your source.

Safety note

Wash hands after handling beans; beans are not for eating.

Sources

All facts in this guide come from the Hearts Invention Lab BioBee invention file and app data. Each source below was fetched or its DOI title matched on 2026-10-20 (several publisher sites block automated fetches; their DOIs were matched instead):

- **[S1]** Andrew, Lizundia & MacLachlan, “Designing for Degradation: Transient Devices Enabled by (Nano)Cellulose,” *Advanced Materials*, 2024. <https://doi.org/10.1002/adma.202401560>
- **[S2]** Borelbach et al., “Degradation Behavior of Biodegradable Man-Made Fibers in Natural Soil and in Compost,” *Polymers* 15(13):2959, 2023. <https://doi.org/10.3390/polym15132959>
- **[S3]** Tufts Now, “Smooth as Silk ‘Transient Electronics’ Dissolve in Body or Environment,” 2012. <https://now.tufts.edu/2012/09/27/smooth-silk-transient-electronics-dissolve-body-or-environment>
- **[S4]** Kwak et al., “Towards edible drones for rescue missions,” *IROS 2022 (arXiv)*. <https://arxiv.org/abs/2211.04149>
- **[S5]** Chechetka et al., “Materially Engineered Artificial Pollinators,” *Chem*, 2017. <https://doi.org/10.1016/j.chempr.2017.01.008>
- **[S6]** Hwang et al., “A Physically Transient Form of Silicon Electronics,” *Science* 337:1640, 2012. <https://doi.org/10.1126/science.1226325>
- **[S7]** Wu et al., “A sustainable chitosan-zinc electrolyte for high-rate zinc-metal batteries,” *Matter*, 2022. <https://doi.org/10.1016/j.matt.2022.07.015>
- **[S8]** NIST, “Time and Frequency from A to Z: Quartz Oscillator”. <https://www.nist.gov/pml/time-and-frequency-division/popular-links/time-frequency-z/time-and-frequency-z-q-ra>
- **[S9]** CTS, lead-free piezoceramics brochure (KNN formulations for sensors, hydrophones, imaging, ultrasound). <https://www.ctscorp.com/Files/Product-Marketing-Documents/Piezoelectric/CTS-Piezoelectric-Bulk-Piezoceramics-Lead-Free-Materials-Brochure.pdf>
- **[S10]** PI Ceramic, power ultrasonic transducers (KNN notes). <https://www.piceramic.com/en/products/ultrasonic-transducers/power-ultrasonic-transducers>
- **[S11]** Multilayer KNN actuators (research prototypes), *Frontiers in Materials*, 2020. <https://doi.org/10.3389/fmats.2020.00087>
- **[S12]** Liu et al., silk fibroin biodegradable force sensor, *Nano Energy*, 2022. <https://doi.org/10.1016/j.nanoen.2022.107787>
- **[S13]** Kim et al., “Biodegradable, electro-active chitin nanofiber films for flexible piezoelectric transducers,” *Nano Energy*, 2018. <https://doi.org/10.1016/j.nanoen.2018.03.056>
- **[S15]** NIST, “Timekeeping and Clocks FAQs” (page text checked). <https://www.nist.gov/pml/time-and-frequency-division/timekeeping-and-clocks-faqs>
- **[S16]** Ollerton, Winfree & Tarrant, “How many flowering plants are pollinated by animals?” *Oikos* 120(3):321-326, 2011. <https://doi.org/10.1111/j.1600-0706.2010.18644.x>
- **[S14]** Li et al., “Green and sustainable cellulose-derived humidity sensors: A review,” *Carbohydrate Polymers*, 2021. <https://doi.org/10.1016/j.carbpol.2021.118385>

© 2026 Hearts Invention Lab. All rights reserved. Original curriculum content. Real research appears only as cited facts. Licensed to the buyer only. Not for resale or public posting. Use is covered by the purchaser’s license (Family & Classroom License or School Site License).