Handbook of Activity Design

Volume 2: Primary School Students

By iGEM Team JLU-CP 2025

Contents

Purpose of This Handbook

The purpose of this second volume is to **extend the structured framework of educational activity design** from kindergarten to the **primary school stage (ages 7–12)**, a period marked by significant cognitive, emotional, and social development. At this level, children begin to acquire the ability to move beyond immediate sensory experience toward **early abstract reasoning, logical thinking, and creative problem-solving**. As such, the activities collected here aim to deepen scientific understanding while maintaining the playful, engaging spirit established in Volume I.

Specifically, this handbook serves four interconnected purposes:

1. **Pedagogical Transition**
   To bridge the shift from curiosity-driven exploration to structured comprehension. Whereas kindergarten activities focused on discovery and play, primary school activities emphasize **model-building, functional reasoning, and early application of scientific concepts**.
2. **Knowledge Transfer and Continuity**
   To document our practical experiences in a format that is **replicable and scalable**, ensuring that future teams and educators can build upon, adapt, and refine proven models. By treating this handbook as part of a multi-volume series, we strengthen the **spiral curriculum** of lifelong science learning.
3. **Integration of STEAM and Design Thinking**
   To embed scientific inquiry within **creative and interdisciplinary frameworks**. Primary school students are uniquely positioned to benefit from the fusion of science, technology, engineering, art, and mathematics, particularly through design-based challenges that transform abstract biological principles into **visible, tangible, and purposeful creations**.
4. **Societal and Personal Relevance**
   To show children that science is not confined to textbooks but deeply connected to their **daily lives, health, and environment**. Activities in this volume—whether on sleep health, cell modeling, or ecological design—highlight the relevance of biology and synthetic biology to issues that matter to children personally and socially.

In summary, this handbook is both a **record of our team's educational practice** and a **blueprint for future innovation**. It is designed not only to equip children with knowledge but also to **cultivate habits of observation, reasoning, collaboration, and creativity**.

Guiding Philosophy

The guiding philosophy of this volume reflects the **developmental transition** from kindergarten to primary school learning. While young children learn best through unstructured play and sensory exploration, primary school students (ages 7–12) are ready to **move from curiosity toward comprehension, from playfulness toward structured reasoning, and from individual exploration toward collaborative design**. Our approach therefore emphasizes a balance between **imagination, structured knowledge, and applied problem-solving**.

This philosophy rests on four interrelated principles:

1. **From Curiosity to Understanding**
   At the primary level, children begin to ask not only *"What is this?"* but also *"Why does it work this way?"*. Our activities are therefore designed to go beyond surface-level exploration and guide learners toward **causal reasoning and functional explanations**. For example, sleep health lectures connect habits to biological processes, helping children see science as a tool for understanding daily life.
2. **Hands-On Modeling as a Bridge to Abstraction**
   Children in this age group are capable of forming **early abstract concepts**, but they require **physical models and metaphors** as scaffolds. Activities such as **clay cell modeling** transform the invisible into tangible, allowing learners to construct and manipulate representations of biological systems. This hands-on approach ensures that abstract terms like *nucleus* or *mitochondria* are grounded in memorable sensory experiences.
3. **Design Thinking and STEAM Integration**
   Primary school students thrive when they are **challenged to create, modify, and innovate**. By integrating principles of **design thinking** and **STEAM education**, we encourage children to move beyond replication of knowledge toward **knowledge application and creative extension**. The "My Cell" contest exemplifies this principle by asking students to redesign cells for imaginative functions, blending scientific accuracy with artistic creativity.
4. **Collaboration and Social Learning**
   At this stage, peer interaction becomes a powerful driver of learning. Group activities, such as the **Synthetic Ecology Town**, leverage collaboration to cultivate **communication, negotiation, and systems-level thinking**. By situating science within cooperative problem-solving tasks, we reinforce not only cognitive development but also socio-emotional growth—skills essential for lifelong learning.

In essence, the guiding philosophy of this volume is to position primary school students as **emerging problem-solvers and creative designers**. They are no longer passive recipients of simplified knowledge, but active participants who can model, question, design, and imagine. By connecting science to both **personal relevance (health, daily life)** and **societal challenges (environment, sustainability)**, we ensure that their engagement with biology and synthetic biology is both **deeply meaningful and developmentally appropriate**.

Educational Rationale: Understanding Primary School Learners

Designing educational activities for primary school students requires recognition of their **unique developmental profile**. At this stage, children are undergoing rapid advances in cognition, language, social awareness, and creativity. Their learning is no longer limited to sensory exploration; they begin to **grasp rules, apply logic, and imagine alternative scenarios**. Activities must therefore be carefully tailored to bridge **concrete experiences and emerging abstract reasoning**.

1. **Cognitive Development**
   According to **Jean Piaget**, primary school students are in the **concrete operational stage (ages 7–11)**. They develop the ability to apply logic to concrete situations: classifying, sequencing, and recognizing cause-and-effect relationships. However, their reasoning still depends heavily on tangible materials and familiar contexts. For this reason, our activities use **analogies (cell as a city), models (clay cell structures), and visual storytelling** to anchor abstract biological processes in concrete representations.
2. **Social Learning and Collaborative Learning**
   Building on **Lev Vygotsky's sociocultural theory**, learning at this stage is significantly enhanced by **peer collaboration and guided scaffolding**. Primary students thrive in group discussions, team-based challenges, and role-play that require communication and negotiation. Activities such as **Synthetic Ecology Town** explicitly leverage these dynamics, allowing learners to co-construct knowledge while exercising cooperation and leadership skills.

3. Constructivist Learning

In line with **Jerome Bruner's constructivist perspective**, primary students are capable of engaging with sophisticated ideas—provided they are introduced in developmentally appropriate ways. Through the **spiral curriculum**, concepts first encountered in kindergarten (e.g., "life has rules and patterns") are revisited here with greater complexity (e.g., "cells have structures that determine function"). This staged revisiting ensures continuity and cumulative understanding, transforming fragmented facts into an integrated body of knowledge..

4. Design-Based Learning and STEAM Integration

Primary school is an ideal stage to introduce **design thinking and STEAM education**. Learners begin to see themselves as capable of creating solutions, not just absorbing information. The **"My Cell" contest** and **"Synthetic Ecology Town"** exemplify **design-based learning**, in which students define problems, generate ideas, prototype models (drawings or microbial ecosystems), and present solutions. These tasks integrate science with art, imagination with reasoning, and foster **innovation-oriented mindsets**.

5. Socio-Emotional Growth and Identity Formation

Children in this age group are also developing a sense of **personal identity and social responsibility**. They are increasingly aware of societal issues such as health, pollution, and fairness. By linking biology to real-world contexts (e.g., sleep health, environmental sustainability), activities empower children to see science as a **tool for improving both personal well-being and collective futures**. In this way, education serves not only cognitive but also **ethical and affective dimensions**.

Anticipated Outcomes and Long-Term Impact

The activities documented in this volume are designed to produce outcomes that go beyond immediate classroom enjoyment. They aim to **contribute to children's intellectual growth, family engagement, and broader educational innovation**, while also ensuring a sustainable legacy for future teams.

1. **Outcomes for Students**

- **Enhanced Conceptual Understanding**
  Students develop a tangible and structured grasp of fundamental life science concepts, such as cell structure, microbial function, and biological rhythms. Abstract terms—*nucleus, mitochondria, melatonin*—become meaningful through modeling, analogies, and storytelling.
- **Cognitive Skill Development**
  Activities cultivate spatial reasoning (e.g., clay cell models), logical inference (e.g., linking sleep habits with melatonin), and early systems thinking (e.g., designing microbial ecosystems).
- **Scientific Dispositions**
  Students begin to adopt the habits of scientific inquiry: asking "why," formulating explanations, constructing models, and communicating results. This transition from passive receivers to **active thinkers and problem-solvers** represents a critical developmental leap.
- **Creative Integration**
  By combining science with art and design (STEAM), learners practice creativity grounded in scientific logic, laying the foundation for future interdisciplinary competence.

2. **Outcomes for Families and Communities**

- **Parental Engagement**
  Parents gain accessible frameworks for discussing science at home, such as metaphors of "cell cities" or "body clocks." This reinforces continuity of learning beyond the classroom.
- **Shared Science Culture**
  Activities foster science as a **socially shared experience** within families and schools. Discussions about healthy sleep, environmental sustainability, or creative cell design extend into everyday life.
- **Community Relevance**
  By connecting activities to real-life issues (e.g., sleep hygiene, pollution, waste management), communities recognize science as directly relevant to children's well-being and future.

3. **Outcomes for the Educational System and Future Teams**

- **Pedagogical Innovation**
  The handbook demonstrates effective models of **design-based learning** and **systems thinking** at the primary level, offering a framework that can be integrated into science curricula or extracurricular programs.
- **Continuity Across Age Groups**
  By building on kindergarten foundations (Vol. I) and preparing for more advanced abstraction in middle school (future Vol. III), this volume contributes to a **spiral curriculum of lifelong science learning**.
- **Legacy and Transferability**
  As part of a multi-volume series, this handbook ensures that experiences, challenges, and solutions are **codified for replication**. Future teams can adapt the activities across cultural contexts, scaling them from classroom workshops to public exhibitions.
- **Societal Impact**
  By positioning children as **creative designers and system-builders**, the handbook nurtures a generation that sees biology and synthetic biology not only as academic subjects but as **tools for addressing health, environmental, and social challenges**.

General Guidance for Activity Design

Before introducing specific activity blueprints, it is essential to articulate the **principles and practices** that should guide the design of science education experiences for primary school students. These guidelines are informed by our practical experience, educational research, and the unique developmental characteristics of learners aged 7–12. They function as **actionable checkpoints** to ensure that each activity is not only engaging but also conceptually rigorous, developmentally appropriate, and adaptable for diverse contexts.

1. **Safety and Accessibility**
2. **Storytelling and Narrative Framing**
3. **Multisensory Engagement**
4. **Playfulness and Agency**
5. **Structured Scaffolding**
6. **Feedback and Documentation**
7. **Adaptability and Sustainability**

Activity 1: *Health Lecture — Understanding Sleep and Melatonin*

Objective

Introduce children to the biological basis of sleep, circadian rhythm, and melatonin production through metaphors and interactive dialogue.

Target Group

Ages 7–10; suitable for whole-class sessions (20–40 students).

Materials Needed

- Projector or large display screen
- Illustrated slides and short animations (e.g., blue light disrupting melatonin)
- Story cards featuring “Melatonin Helpers”
- Simple quiz cards or tokens for interactive Q&A

Procedure

1. **Introduction (5 min):** Use the metaphor of a “body clock” to explain circadian rhythm.
2. **Demonstration (10 min):** Show an animation of how blue light delays melatonin secretion.
3. **Interactive Discussion (10 min):** Ask students to share experiences of difficulty sleeping after using devices.
4. **Science Link (10 min):** Introduce the idea that scientists can engineer bacteria to produce melatonin, connecting synthetic biology to health.
5. **Q&A and Wrap-up (5 min):** Reinforce healthy sleep habits and link them to science.

Learning Outcomes

- Understand the relationship between light, behavior, and sleep.
- Recognize melatonin as a biological regulator of circadian rhythm.
- Build awareness of the application of synthetic biology in everyday life.

Reflections & Recommendations

- Abstract concepts become more relatable when tied to daily habits.
- Consider pairing this lecture with a follow-up hands-on activity (e.g., cell modeling) to deepen understanding.

Activity 2: *Clay Cell Modeling — Cell as a City*

Objective

Introduce children to the biological basis of sleep, circadian rhythm, and melatonin production through metaphors and interactive dialogue.

Target Group

Ages 7–10; suitable for whole-class sessions (20–40 students).

Materials Needed

- Projector or large display screen
- Illustrated slides and short animations (e.g., blue light disrupting melatonin)
- Story cards featuring "Melatonin Helpers"
- Simple quiz cards or tokens for interactive Q&A

Procedure

6. **Introduction (5 min):** Use the metaphor of a "body clock" to explain circadian rhythm.
7. **Demonstration (10 min):** Show an animation of how blue light delays melatonin secretion.
8. **Interactive Discussion (10 min):** Ask students to share experiences of difficulty sleeping after using devices.
9. **Science Link (10 min):** Introduce the idea that scientists can engineer bacteria to produce melatonin, connecting synthetic biology to health.
10. **Q&A and Wrap-up (5 min):** Reinforce healthy sleep habits and link them to science.

Learning Outcomes

- Understand the relationship between light, behavior, and sleep.
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Reflections & Recommendations

- Abstract concepts become more relatable when tied to daily habits.
- Consider pairing this lecture with a follow-up hands-on activity (e.g., cell modeling) to deepen understanding.

Activity 3: *My Cell — Creative Cell Design Contest*

Objective

Encourage children to apply biological knowledge in creative design, blending scientific reasoning with artistic imagination.

Target Group

Ages 9–12; individual or small group projects.

Materials Needed

- Drawing paper or digital drawing tablets
- Colored pencils, markers, or digital art software
- Reference cards explaining organelle functions
- Display boards for exhibition

Procedure

1. **Brainstorm (10 min):** Students identify challenges (e.g., surviving in deep sea, producing light, decomposing waste).
2. **Design Phase (20 min):** Create drawings of cells adapted for chosen functions.
3. **Exhibition (10 min):** Present and explain the rationale behind designs.
4. **Peer Feedback (5 min):** Classmates comment and ask questions.

Learning Outcomes

- Understand "structure–function" relationships.
- Translate biological principles into real-world or imaginative applications.
- Strengthen communication skills through presentation.

Reflections & Recommendations

- Students often connect science to social issues (e.g., pollution, health), reflecting developing responsibility.
- Compiling designs into a booklet or online gallery enhances long-term impact.

Activity 4: Synthetic Ecology Town — Designing a Microbial Helper Community

Objective

Introduce the concept of synthetic biology and circadian rhythm regulation through narrative and metaphor.

Target Group

Ages 4–6; suitable for whole-class storytelling or small group reading corners.

Materials Needed

- Illustrated storybook (*Astronaut's Night: The Melatonin Factory*)
- Projector or large-format printed pages for group reading
- Plush toys or props representing "factory robots" (enzymes, plasmids)

Procedure

1. **Storytelling (10–15 min):** Facilitator reads aloud, dramatizing characters (bacteria as "factory," enzymes as "robots").
2. **Visualization (5 min):** Use props or toys to reinforce metaphorical roles.
3. **Interactive Q&A (10 min):** Children answer prompts such as *"Who works in the factory?"* or *"How does the astronaut sleep better?"*
4. **Creative Extension (10 min):** Children draw their own "factories" with workers and robots.

Learning Outcomes

- Children understand cells as "factories" with specialized workers.
- Builds narrative comprehension and imaginative application.
- Seeds early curiosity about synthetic biology.

Reflections & Recommendations

- Storytelling is effective in embedding abstract science into everyday imagination.
- Encourage families to continue the story at home ("What else could the cell factory make?").
- Future teams may create new sequels or thematic storybooks.

Activity 5: *Little Scientist Lab – Color-Changing Magic*

Objective

Introduce systems-level thinking by having children design ecological solutions using engineered microbes.

Target Group

Ages 10–12; group work (4–6 students per team).

Materials Needed

- Sandbox or board representing a town
- Problem scenario cards (pollution, waste, poor air quality)
- "Microbial Helper" cards (water purifier, plastic degrader, nitrogen fixer)
- Colored markers and posters for solution presentation

Procedure

1. **Introduction (5 min):** Present the "Ecology Town" facing environmental problems.
2. **Team Planning (15 min):** Groups select microbial helpers to address issues.
3. **Model Assembly (10 min):** Place microbe cards into the sandbox/board.
4. **Presentation (10 min):** Teams explain and defend their ecological designs.

Learning Outcomes

- Understand microbial roles in ecosystems.
- Practice collaborative problem-solving and reasoning.
- Develop early systems-level scientific thinking.

Reflections & Recommendations

- Students often link microbes to familiar daily-life problems, strengthening science–society relevance.
- Future teams may digitize this into an online game for broader reach.

Activity 6: *Microbe Detective — Exploring the Invisible World*

Objective

Introduce the diversity of microbes and their roles (beneficial vs. harmful) through an investigative game.

Target Group

Ages 8–11; classroom or science fair setting.

Materials Needed

- “Microbe Cards” with illustrations (e.g., yogurt bacteria, E. coli, penicillin mold)
- Magnifying glasses or microscope images
- Detective notebooks for children to record findings

Procedure

1. **Introduction (5 min):** Explain that not all microbes are harmful; some are “helpers.”
2. **Investigation (15 min):** Children examine cards or images, classify microbes into categories (food, medicine, environment).
3. **Detective Challenge (10 min):** Solve “mystery cases” (e.g., “Which microbe helps make bread rise?”).
4. **Sharing (5 min):** Groups present findings.

Learning Outcomes

- Distinguish between beneficial and harmful microbes.
- Understand the role of microbes in food, health, and environment.
- Build early scientific literacy about microbiology.

Reflections & Recommendations

- Works well as a prelude to synthetic biology topics.
- Can be expanded into an interactive card game for repeated play.

Reflection and Evolution

This volume reflects our collective effort to **translate abstract biological concepts into tangible and creative experiences** for primary school students. Through activities ranging from health education to ecological system design, we witnessed children's remarkable ability to **move beyond curiosity into structured comprehension, logical reasoning, and creative application**.

Our reflections highlight several key insights:

1. **Bridging abstraction with models**
   Children at this stage respond strongly to **hands-on modeling and analogical frameworks**. Clay cell models and the "cell city" metaphor successfully grounded invisible biological processes in concrete forms, making complex content both memorable and meaningful.
2. **Design and creativity as drivers of engagement**
   Activities such as the *My Cell* design contest demonstrated that students are capable not only of replicating knowledge but also of **reimagining it through innovation**. Their imaginative proposals—cells that clean oceans, heal wounds, or produce light—revealed a capacity to connect science with social concerns and futuristic thinking.
3. **Systems thinking as an emerging competence**
   The *Synthetic Ecology Town* activity showed that primary school learners can already begin to think in terms of **interconnected systems**, analyzing community-level problems and proposing collective microbial solutions. This represents a significant step toward higher-order reasoning that prepares them for later project-based learning in middle school and beyond.
4. **The power of relevance and narrative**
   By linking biology to **personal health (sleep, circadian rhythms)** and **societal challenges (pollution, waste, sustainability)**, children came to see science as something that directly impacts their daily lives and communities. This contextual framing deepened their motivation and reinforced the value of science as a tool for problem-solving.

Looking ahead, this handbook should not be viewed as a static compilation but as a **living framework for iterative innovation**. Future teams are encouraged to:

- **Expand interdisciplinary integration**: Combine biology with mathematics, art, and technology through STEAM approaches, reinforcing both creativity and analytical rigor.
- **Introduce digital and hybrid tools**: Augment hands-on activities with interactive simulations, AR/VR experiences, or online design platforms that can expand accessibility and engagement.
- **Strengthen assessment and evaluation**: Develop simple rubrics or observation tools to measure not only knowledge retention but also skills such as collaboration, reasoning, and creativity.
- **Foster longitudinal connections**: Link outputs from this volume to activities in subsequent handbooks (Vol. III and beyond), ensuring that the seeds of curiosity planted here evolve into sustained scientific literacy and problem-solving capacity.
- **Encourage student agency**: Provide opportunities for children to co-create future activities, thereby transforming them from learners into **co-designers of science education**.

Ultimately, the evolution of this handbook mirrors the learning journey of the children themselves: **iterative, cumulative, and expansive**. By grounding science in play, modeling, creativity, and social relevance, we have laid a foundation for learners who will carry forward not only factual knowledge but also the **confidence, imagination, and responsibility** to use science in shaping a better future.