LOESS INTEGRATED LEARNING SCENARIO TEMPLATE

Introduction

In LOESS, the acquisition of soil health knowledge is facilitated using integrated STEM teaching and learning, which is carried out via the Biology Science Curriculum Study (BSCS) 5E Instructional Model by Bybee and colleagues (Bybee et al. 2006) as well as the application of innovative pedagogical approaches (PBL, IBL, etc).

Keywords

Soil chemistry, soil health, chemical reactions, environmental science, sustainable practices

Title

Chemistry in the Soil: Uncovering the Secrets of Soil Health

Authors

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Summary

In this learning scenario, students explore soil chemistry by conducting hands-on experiments to investigate soil properties, such as pH, nutrient content, and its role in supporting plant growth. Through a series of activities, students connect the chemical processes in soil to broader environmental and sustainability issues. They will analyse soil samples, test for various chemical elements, and learn how soil health impacts ecosystems and agriculture. The scenario integrates chemistry, biology, and environmental science, fostering critical thinking and encouraging sustainable practices for soil management.

Subjects

Biology, Chemistry

Real-life questions

- *How do soil properties, such as pH and nutrient content, affect plant growth?*
- *Why is soil health important for the environment and food production?*
- *How do human activities, like farming or urbanization, impact soil quality and health?*
- *What role do soil organisms play in maintaining soil health and ecosystem balance?*
- *How can we use sustainable practices, like composting and crop rotation, to improve soil health?*

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Learning objectives

Students will be able to:

- *identify and describe the different layers of soil and explain their functions.*
- *explain the relationship between soil health and plant growth.*
- *analyse the impact of human activities on soil quality and suggest sustainable practices to improve soil health.*
- *use simple experiments to observe and measure soil properties such as texture, moisture, and pH.*
- *explain the role of soil organisms in maintaining soil health and ecosystem balance.*

Link to curriculum

The activities in this learning scenario are closely linked to the curriculum by addressing key science concepts such as soil composition, plant growth, and environmental impact, as outlined in the chemistry and biology standards for primary education. Through hands-on experiments and field observations, students develop essential STEM skills, including critical thinking, problem-solving, data analysis, and collaboration. The scenario also aligns with the UN Sustainable Development Goals (SDGs), particularly ***SDGI 2: Zero Hunger****, by educating students on the importance of healthy soil for sustainable agriculture, and* ***SDG 12: Responsible Consumption and Production****, by promoting sustainable soil management practices. Additionally, it connects to* ***SDG 15: Life on Land,*** *highlighting the vital role of soil ecosystems in supporting biodiversity and combating land degradation. Through these activities, students gain an understanding of both scientific concepts and their real-world application in promoting environmental sustainability.*

Age of students

11-14 years old

Time

Preparation time: 1 - 2 hours
Teaching time:

- Introductory lesson: 45 minutes
- Chemistry: 90 minutes
- Biology: 90 minutes

Teaching resources (materials & online tools)

Material for all lessons

- Computers/tablets
- Internet connection
- Soil samples (various types of soil)
- Magnifying glasses
- pH testing kits
- Containers for soil analysis

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- Soil moisture meters
- Whiteboard/markers or digital presentation tools for group work

Materials for Lesson 2

- Data sheet (for recording observations)
- Latex gloves or similar protective gloves
- Zip bags (for collecting soil samples)
- Measuring spoons or containers (for sample measurements)
- Magnifying glasses
- Digital camera or smartphones (for documenting findings)

Materials for Lesson 3

- Petri dishes or watch glasses (for measuring soil moisture)
- Laboratory scale (for weighing soil samples)
- Distilled water (for testing moisture absorption)
- Soil samples (from previous lesson)
- Tweezers (for handling small soil particles)
- Drying oven (if available) or a safe heat source for drying soil samples
- Timer or stopwatch (for measuring drying time)
- Paper towels or absorbent material (for drying and cleanup)
- Notebook or data sheets (for recording results)

Online tools

Lesson 1: Brainstorming and discussion

- **BBC Earth: Why Soil is Amazing**
  Engaging video to spark curiosity about the importance of soil, perfect for the brainstorming session.
  https://www.youtube.com/watch?v=OiLITHMVcRw
- **National Geographic – Soil Microorganisms**
  Article introducing students to the role of microorganisms in soil, ideal for connecting the discussion to scientific details.
  https://www.nationalgeographic.com/science/article/soil-microbes
- **FAO – Soil Portal**
  A reliable source of information on soil health, which students can use to deepen their understanding after the initial introduction.
  https://www.fao.org/soils-portal/en/

Lesson 2. Exploring Soil Microorganisms and Lesson 3. Exploring Soil Moisture

- **National Geographic - Soil Microorganisms:**
  This video introduces the diverse range of microorganisms in the soil and their critical role in maintaining soil health. It helps students understand how soil organisms contribute to nutrient cycling and soil structure.
  https://www.youtube.com/watch?v=7lRFObgebg8
- **USDA Soil Health - Soil Microorganisms Overview:**

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A resource from the USDA explaining how microorganisms impact soil health, including their roles in decomposition, nutrient cycling, and soil fertility. https://www.nrcs.usda.gov/conservation-basics/natural-resource-concerns/soils/soil-health

- **Soil Health and Microorganisms (FAO):**
  The FAO provides detailed information about the role of microorganisms in soil ecosystems and their impact on sustainability. Students can use this resource to gain a deeper understanding of the importance of microbial life in soil. https://www.fao.org/soils-portal/soil-biodiversity/en/
- **Soil Microorganisms Simulation:**
  This interactive online tool allows students to explore how different microorganisms contribute to soil health, offering a visual representation of soil microbial activity. https://www.youtube.com/watch?v=vihdHRvOPyQ
- **Mindmapping tools**
  Option 1: MindMeister MindMeister | Online Mind Mapping & Brainstorming Software
  Option 2: MindMup MindMup

STEM Strategy Criteria

Developing the LOESS learning scenario will help you and your school comply with the STEM School Label criteria. Please find below the STEM School Label criteria this learning scenario fulfils.

Elements and criteria	How is this criterion addressed in the learning scenario?
Instruction	
Curriculum implementation	The scenario employs inquiry-based learning methods, encouraging students to investigate soil properties and health. It addresses real-life challenges related to soil chemistry, fostering problem-solving skills.
Emphasis on STEM topics and competencies	
Interdisciplinary instruction	The scenario integrates chemistry and biology to explore soil health, promoting interdisciplinary learning. Activities are designed to connect theoretical knowledge with real-world applications, enhancing contextualized STEM teaching.
Contextualisation of STEM teaching	Contextualizing STEM education helps students make connections between their learning and the world around them, increasing engagement, problem-solving skills, and real-world application of STEM concepts. It also helps students understand how their actions can contribute to addressing global issues, such as sustainable agriculture and soil conservation.
Assessment	
Continuous assessment	The learning scenario incorporates ongoing evaluation through activities such as hands-on soil testing, group discussions, and the analysis of real-world data. Students receive regular feedback from their peers and the teacher, ensuring consistent progress tracking and immediate instructional adjustments. This fosters a deeper understanding of soil health and chemistry concepts over time.
Personalized assessment	The scenario allows students to demonstrate their knowledge in various ways, such as through group projects, written reports, or digital presentations. This caters to different learning styles and abilities, ensuring that every student can showcase their understanding in a way that aligns with their strengths.
Professionalization of staff	

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Elements and criteria	How is this criterion addressed in the learning scenario?
Highly qualified professionals	Educators are provided with resources and training to effectively deliver the learning scenario, enhancing their STEM teaching capabilities. This includes understanding the integration of chemistry and biology in the context of soil health.
Professional development	This criterion is addressed in the learning scenario by encouraging teachers to continuously enhance their understanding of STEM concepts, soil health, and innovative pedagogical techniques. Teachers engage with up-to-date resources, such as online tools and external collaborations, to stay informed about the latest in soil science and teaching methods. They are also encouraged to participate in workshops or training sessions that focus on integrating STEM practices and sustainability in education, ensuring they are equipped to deliver high-quality lessons on soil health.
School leadership and culture	
School leadership	The learning scenario is part of a broader school initiative to enhance STEM education, demonstrating leadership commitment to integrating STEM across subjects. It fosters a culture that values scientific inquiry and environmental stewardship.
High level of cooperation among staff	It involves teachers from various disciplines working together to plan and deliver the lessons. For example, in your scenario, chemistry teachers could collaborate with biology or environmental science teachers to integrate concepts related to soil health. If your learning scenario involves input or coordination between teachers from different subjects, such as team teaching or sharing resources for interdisciplinary activities, it fulfils this criterion. If this collaboration isn't explicitly included in your scenario yet, you can consider adding it to further enhance the cooperative aspect among staff.
Connections	
With local communities	Collaborations with local environmental organizations and experts in soil science enrich the learning experience, providing students with real-world insights and applications.
School infrastructure	
Access to technology and equipment	The scenario utilizes online tools and resources, requiring access to computers/tablets and internet connectivity. It also involves hands-on activities with materials like soil samples and laboratory equipment, ensuring students have the necessary infrastructure for effective learning.

Description of activities

Name of activity	Procedure	Time
1st Lesson		
5E Phase	*Engage*	
Brainstorming and discussion	This first lesson is used to introduce the topic of soil health from a general perspective. The goal is to spark interest and curiosity among students about soil, its importance, and its role in the environment. Through brainstorming and open discussion, students will begin to form a foundational understanding that will be built upon in later lessons. This lesson aligns with the **Engage** phase of the BSCS 5E Instructional Model by Bybee, as it is designed to captivate students' attention and get them thinking about the topic.	10 minutes

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Name of activity	Procedure	Time
Discussion and preparation for the next lesson	Activity 1: Introduction to Soil (Brainstorming) – 15 minutes **Description**: The teacher will begin with a brief discussion to encourage students to think about soil and its relevance to them. Questions such as "What do you know about soil?" and "How do you think soil affects the world around us?" will be posed to get students thinking. Students will write their ideas on the board. **Materials:** Whiteboard, markers, sticky notes. **Outcome:** This activity will help students recall what they know about soil and set the stage for more in-depth exploration. Activity 2: Introduction to the Importance of Soil (Video or Article) – 10 minutes **Description:** After the brainstorming session, a short video or article on the importance of soil will be shown or read aloud. The video (BBC Earth: Why Soil is Amazing) or article (National Geographic – Soil Microorganisms) will introduce students to concepts like soil layers, soil composition, and how soil supports plant life and ecosystems. **Materials**: Projector, computer/tablet for video, article handouts (optional). **Outcome**: Students will gain a broad understanding of soil's role in the environment and be ready to delve deeper in future lessons. Activity 3: Set up for Next Lesson - Soil Samples Collection – 10 minutes **Description**: As part of the preparation for the next lesson, students will be asked to bring in soil samples from their surroundings (e.g., home, school yard, or park). This will be done in preparation for a hands-on activity in the following lesson where they will analyse the soil's properties. **Materials**: Containers for collecting soil samples, handouts with guidelines on how to collect and store soil samples. **Outcome:** Students will be prepared with the necessary materials to start the next lesson, where they will engage in more hands-on exploration of soil properties.	45 minutes
2nd Lesson		
5E Phase	*Engage, , Explore Phase, Explain/Elaborate*	
Subject	*Biology*	
Introduction to Soil Micro-organisms (Engage)	**Objective:** Introduce students to the diversity of microorganisms found in soil. **Description:** Begin the lesson with a brief discussion on the importance of soil microorganisms in maintaining soil health. Show a short video (such as the National Geographic video) to illustrate how microorganisms function in the soil ecosystem. Ask students: "Why do you think microorganisms are important for soil health?"	10 minutes

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Name of activity	Procedure	Time
	Materials: National Geographic Video, Whiteboard and markers	
Soil Sample observation (Explore)	**Objective:** Allow students to observe soil microorganisms in real samples and understand their role in soil health. **Description:** Students bring the soil samples they collected as preparation for the lesson. The teacher can also provide students with soil samples (prepared in advance) and magnifying glasses or microscopes. In small groups, students will examine the samples and look for signs of microorganisms, such as fungi or bacteria. Have students record their observations, noting characteristics such as colour, texture, and the presence of life (e.g., tiny movement in the sample) **Materials:** • Soil samples (different types of soil: garden, forest, sandy, etc.) • Magnifying glasses or microscopes • Petri dishes or watch glasses • Notebooks for observations	30 minutes
Group Discussion and Data Sharing (Explain)	**Objective:** Share observations and discuss the role of microorganisms in soil health. **Description:** After completing the observations, have students return to their groups to discuss what they found. Each group will share their observations with the class, focusing on any microorganisms they identified. The teacher will guide the class in understanding how these organisms contribute to soil health, such as through nutrient cycling and decomposing organic matter. **Materials:** Whiteboard and markers for note-taking	20 minutes
Reflection and Concept Mapping (Explain/Elaborate)	**Objective**: Solidify understanding of the relationship between microorganisms and soil health. **Description:** To conclude the lesson, ask students to create a concept map connecting soil microorganisms to the overall soil health and ecosystem. Students should use terms such as “decomposers,” “nutrient cycling,” and “soil structure” in their maps. Discuss how different soil types might affect the presence of microorganisms and their role in maintaining soil health. **Materials:** Concept mapping tools (paper and markers, or online tools like MindMeister, MindMup)	30 minutes
Learning products	1. Soil Observation Report: **Description**: Students will document their observations of soil samples, focusing on the microorganisms they identify, characteristics of the soil, and any significant findings related to soil health. **Assessment Focus**: Accuracy of observations, completeness of the report, clarity in describing findings. 2. Concept Map on Soil Microorganisms: **Description**: Students will create a concept map illustrating the relationships between different types of microorganisms and their role in maintaining soil health. The map will include key terms like nutrient cycling, decomposers, and soil structure.	

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Name of activity	Procedure	Time
	Assessment Focus: Organization, completeness, and understanding of connections between concepts. 3. Group Presentation on Soil Microorganisms: **Description:** In groups, students will present their findings on soil microorganisms, explaining their significance to soil health and the environment. **Assessment Focus**: Clear communication, depth of content, and engagement with the audience. 4. Reflection Journal Entry: **Description**: Students will write a reflective journal entry about the lesson, summarizing what they learned about soil microorganisms and any new questions they have. **Assessment Focus:** Depth of reflection, integration of lesson concepts, and personal insights.	
3rd Lesson		
5E Phase	*Engage:, Explore, Explain, Elaborate, Evaluate:*	
Subject 2	Chemistry	
Introduction and set-ip	• Begin the lesson by briefly discussing the importance of soil moisture for plant growth and ecosystem health. • Introduce the concept of capillarity and how soil particles interact with water.	10 minutes
Experiment – Measuring Soil Moisture	• Divide the students into small groups and assign each group a different type of soil. • Instruct students to weigh a certain amount of dry soil (e.g., 20 grams) and place it in their petri dish. • Slowly add a set amount of water to the soil and allow it to absorb for a specific amount of time (e.g., 15 minutes). • After the absorption period, students will measure the remaining moisture by weighing the soil again to calculate the amount of water retained. • Students should repeat this process with different soil samples, recording their results.	30 minutes
Data collection and analysis	• Students will analyse the moisture retention of each type of soil and calculate the percentage of water absorbed by each soil sample. • Discuss the role of soil structure in water retention, such as how smaller particles in clay retain more water compared to the larger particles in sand. • Students should be encouraged to present their findings through graphs or tables for better visualization	20 minutes
Discussion and explanation	• After completing the experiment, students will come together to discuss their results and explain the scientific concepts behind soil moisture retention. • Focus on the chemical processes that occur when water interacts with soil, such as adsorption and capillary action. • Introduce key vocabulary terms such as "hydroscopic water," "field capacity," and "permanent wilting point."	30 minutes

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Name of activity	Procedure	Time
	• Discuss real-world applications, like how soil moisture affects agricultural practices and the importance of soil health in maintaining ecosystems. • Ask students to consider how different farming techniques or climate changes might impact soil moisture retention. • This could lead into a discussion on sustainable farming practices and how chemical principles are applied to improve soil health.	
Learning products	1. Report Students will write a brief report summarizing their findings, including the calculations of moisture retention for each type of soil and their explanations for the differences. 2. Presentation: Students can also create a short presentation of their findings to share with the class, visualizing their data through graphs and tables.	

Initial assessment

1. ***Pre-lesson Quiz (Chemistry & Biology)*:**
   - *A short quiz with multiple-choice and short-answer questions about basic soil properties, types of soil, and their importance for plant growth and ecosystems.*
   - *Example questions:*
     - *What are the three main types of soil?*
     - *Which soil type retains the most water?*
     - *Why is soil important for plant growth?*
     - *How does soil structure impact water retention and drainage?*
2. ***Class Discussion*:**
   - *Engage students in a class discussion to gauge their prior experiences with soil and related outdoor activities (e.g., gardening, farming, field trips).*
   - *Questions to ask:*
     - *Have you ever worked with soil in a garden or during a school project?*
     - *What do you know about soil and its importance for plants?*
     - *Can you describe any observations about how different soils behave in nature?*
3. ***Hands-on Activity (Optional)*:**
   - *Provide a small sample of soil (or different types of soil) and ask students to describe its texture, color, and appearance.*
   - *Ask them to make hypotheses about the soil's properties (e.g., drainage ability, nutrient content) before conducting any experiments.*

This initial assessment will provide insights into the students' prior knowledge and allow the teacher to tailor the lesson to their existing understanding of soil science and chemistry.

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Formative evaluation

1. ***Group Discussions***
   - *During the lesson, engage students in small group discussions where they can share their observations, questions, and insights about soil types, moisture retention, and other related topics.*
   - *Ask targeted questions to gauge understanding:*
     - *What do you think happens when water interacts with different types of soil?*
     - *How do you think the size of soil particles affects its ability to hold moisture?*
   - *Provide real-time feedback, address misconceptions, and guide students toward deeper understanding.*
2. ***Interactive Quiz***
   - *Create an interactive quiz using online tools (e.g., Kahoot!, Google Forms) that focuses on the chemical processes, vocabulary terms, and soil types discussed so far.*
   - *Example questions:*
     - *Which soil type is best for moisture retention?*
     - *What is capillarity and how does it affect soil moisture?*
     - *Define "field capacity" in the context of soil moisture.*
     - *Why is soil pH important for plant growth?*
     - *How do microorganisms help maintain soil health?*
     - *What happens to soil if it becomes too compacted?*
     - *How can composting or crop rotation improve soil structure and fertility?*
     - *Why is soil considered a non-renewable resource?*

<u>Guidance for teachers:</u>

When designing quiz questions, teachers should:

- *Include both chemical (e.g., moisture, pH, reactions) and biological (e.g., microorganisms, decomposition) aspects of soil.*
- *Mix multiple-choice, true/false, and short answer questions.*
- *Encourage application-based thinking by connecting questions to everyday examples (e.g., gardening, farming).*
- *Adjust the number and complexity of questions according to students' age and lesson length.*
- *Use quiz results to assess whether the class is ready to move to more complex discussions or if further clarification is needed.*

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3. ***Poster or Concept Map Creation (End of Lesson 2)***
    - *At the end of the lesson, ask students to create a visual poster or concept map that connects soil properties, water retention, and their experiment findings.*
    - *Students can use paper or online tools (e.g., MindMeister, MindMup).*
    - *This will allow students to express their understanding in a creative way and give teachers a clear sense of their grasp of the topic.*
    - *Provide formative feedback on their accuracy, the depth of their connections, and the clarity of their reasoning.*
4. ***Soil Moisture Experiment***
    - *As students are conducting their experiments, walk around and observe the groups as they weigh, add water, and measure soil moisture.*
    - *Provide feedback on their methods, ensure they understand the steps, and encourage accurate data collection.*
    - *Ask guiding questions such as:*
        - *What changes do you notice when you add water to different soil types?*
        - *How can we improve our data collection process?*

Final assessment

1. **Presentation (Group Project) (Annex 1)**

Objective:

To assess students' ability to synthesize the concepts learned, collaborate effectively, and communicate their findings clearly.

Description:

In small groups, students will present their findings from the soil moisture retention experiment, connecting the results with the broader concepts of soil properties, chemical processes, and real-world applications.

Groups will:

- Explain the experimental setup and the findings from their soil moisture testing.
- Discuss how soil types affect water retention, drawing on concepts like capillarity, hydroscopic water, and field capacity.
- Explain the implications of their findings for soil health, agriculture, and ecosystem sustainability.

Presentations can include visual aids such as graphs, concept maps, or posters.

Assessment Criteria:

- Clarity and accuracy of scientific explanations.
- Depth of analysis regarding soil properties and their real-world implications.
- Collaboration and organization of the group presentation.

2. **Written Test (Annex 2)**

Objective:

To assess individual students' understanding of soil properties, water retention processes, and the scientific concepts behind them.

Description:

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Students will take a written test that includes both multiple-choice and essay questions.

- Multiple-choice questions (e.g., Which soil type retains the most moisture?, What is capillarity?)
- Essay questions that require more detailed explanations, such as:
- Explain how soil moisture affects plant growth and ecosystem health.
- Describe the chemical processes involved in water retention in different soil types.

Assessment Criteria:

- Accuracy and depth of knowledge on soil properties and moisture retention.
- Ability to apply theoretical knowledge to practical scenarios.
- Correct use of scientific terminology.

3. Concept Map or Summary Report (Annex 3)

Objective:

To assess students' ability to connect and synthesize various concepts related to soil science and chemistry.

Description:

Students will create a concept map or a summary report that outlines the key concepts they have learned about soil moisture, chemical interactions, and the role of soil in ecosystems.

Assessment Criteria:

- Completeness and accuracy of the concept map or report.
- Logical connections between concepts.
- Clarity of explanations and understanding of the science involved.

Student feedback

1. Standardized Short Questionnaire (Annex 4)

- *Objective: Gather structured feedback on student learning.*
- *Description: Students will complete a short, anonymous questionnaire after the lesson, focusing on clarity, engagement, and suggestions for improvement.*
- *Duration: 5-10 minutes.*
- *Method: Paper-based or online (e.g., Google Forms).*

2. Oral Comments (Class Discussion)

- *Objective: Allow students to share thoughts in a casual, interactive manner.*
- *Description: A brief class discussion where students reflect on what they enjoyed, what was challenging, and suggestions for future lessons.*

Teacher feedback

1. Standardized Self-Assessment Table (Annex 5)

- *Objective: To evaluate how effectively the lessons were implemented and received.*

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- *Description: The teacher will complete a standardized self-assessment table after each lesson, reflecting on aspects such as student engagement, lesson clarity, and achievement of learning objectives. This table will help identify areas for improvement in future lessons.*
- *Method: Paper-based or online (e.g., Google Forms).*

2. Written Teacher Reflection

- *Objective: To provide detailed reflections on the lesson's success and challenges.*
- *Description: After the lesson, the teacher will write a brief reflection about the lesson's implementation, student engagement, and any challenges faced during the lesson. This can be used for further lesson planning.*
- *Method: Written reflection (paper or digital).*

Reflection on the development process

Add here your personal reflection on the creation of your learning scenario (max 200 words). Here below are a few questions that can help you brainstorm.

1. *Describe where your initial ideas for the LS came from. What inspired you to choose the particular focus you have chosen?*
2. *Summarise the research you have conducted and resources you have found to inform your plan. How did those influence your thinking and creation process?*
3. *What did you learn about your own planning and development process?*

Creating the LOESS learning scenario was an exciting and enriching experience, as it allowed me to combine my passion for chemistry and biology with practical, hands-on learning. My initial inspiration came from my desire to explore the intricate relationship between soil, microorganisms, and plant growth—an essential topic for students to understand the environmental and chemical processes affecting ecosystems. I was also motivated by the increasing need to integrate STEM principles into education, and this topic provided a perfect opportunity to make chemistry and biology more tangible and connected to the real world. The research process was crucial in shaping my approach. I explored a wide variety of resources, from scientific journals and environmental studies to educational websites, to ensure the accuracy of my content. I also found numerous online tools and interactive materials that would engage students and reinforce their learning. These resources influenced the decision to use experiments, discussions, and real-world connections in the lessons. Through this planning process, I learned the importance of balancing content delivery with engaging activities. I realized the value of flexible lesson structures that can adapt to students' needs while encouraging critical thinking and collaboration. This experience reinforced my belief in the power of hands-on, project-based learning in STEM education.

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Appendix 1 Example rubric for final group presentation

Criteria	***Excellent (4 points)***	***Good (3 points)***	***Satisfactory (2 points)***	***Needs improvement (1 point)***
Clarity and accuracy of scientific explanations	*Explanations are clear, accurate, and show a deep understanding of soil chemistry and biology concepts.*	*Mostly accurate explanations with minor errors or omissions.*	*Some key concepts are unclear or contain factual errors.*	*Explanations are incomplete or inaccurate.*
Depth of analysis regarding soil properties and real-world implications	*Shows strong understanding of how soil properties affect ecosystems, agriculture, and sustainability.*	*Demonstrates understanding of key ideas but with limited real-world connections.*	*Basic understanding; few connections to real-world issues.*	*Minimal or no understanding of soil–environment relationships.*
Collaboration and organization	*Team collaborates effectively; presentation is well organized and engaging.*	*Collaboration evident; presentation mostly organized.*	*Limited teamwork; presentation lacks clear structure.*	*Poor collaboration; presentation disorganized or incomplete.*
Visual aids and communication	*Visuals are clear, relevant, and enhance understanding; presenters speak confidently and clearly.*	*Visuals are relevant but may lack clarity or detail; communication mostly clear.*	*Visuals used minimally; uneven participation in speaking.*	*Visuals missing or ineffective; unclear or incomplete communication.*
Creativity and engagement	*Presentation is original, engaging, and demonstrates innovative thinking.*	*Presentation is interesting with some creative elements.*	*Limited creativity; standard format.*	*Presentation lacks engagement or originality.*

Scoring:

- *18–20 points: Excellent*
- *14–17 points: Good*
- *10–13 points: Satisfactory*
- *Below 10 points: Needs improvement*

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Appendix 2: Example rubric for written test

Criteria	Excellent (4 points)	Good (3 points)	Satisfactory (2 points)	Needs improvement (1 point)
Accuracy and depth of knowledge on soil properties and moisture retention	*Demonstrates a thorough understanding of soil properties, moisture processes, and chemical/biological interactions; all answers accurate and detailed.*	*Demonstrates good understanding with minor inaccuracies or incomplete explanations.*	*Shows partial understanding with several inaccuracies or missing details.*	*Shows limited or incorrect understanding of soil concepts.*
Ability to apply theoretical knowledge to practical scenarios	*Successfully connects theory to real-world applications (e.g., agriculture, sustainability); provides clear examples and reasoning.*	*Connects theory to practice but lacks depth or consistency in explanations.*	*Attempts to apply theory but examples are vague or incorrect.*	*Fails to connect theoretical knowledge to practical applications.*
Use of scientific terminology	*Uses scientific terms precisely and appropriately throughout responses.*	*Mostly uses scientific terms correctly, with minor errors.*	*Uses some scientific terms, but with frequent errors or omissions.*	*Rarely or incorrectly uses scientific terminology.*
Structure and clarity of written answers	*Answers are well-structured, logically organized, and clearly expressed.*	*Answers are mostly clear with minor organizational issues.*	*Some lack of structure or clarity; ideas not fully developed.*	*Answers are disorganized, unclear, or incomplete.*
Critical thinking and reasoning	*Provides thoughtful, well-reasoned responses showing analytical thinking and problem-solving.*	*Shows some reasoning ability and insight but lacks depth.*	*Basic recall-level responses with little reasoning or explanation.*	*Minimal effort or incomplete reasoning.*

Scoring:

- *18–20 points: Excellent*
- *14–17 points: Good*
- *10–13 points: Satisfactory*
- *Below 10 points: Needs improvement*

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Appendix 3: Example rubric for concept map or summary report

Criteria	Excellent (4 points)	Good (3 points)	Satisfactory (2 points)	Needs improvement (1 point)
Completeness and accuracy of the concept map or report	*All key concepts related to soil chemistry, biology, and sustainability are included and accurately represented.*	*Most relevant concepts are included; minor inaccuracies present.*	*Several important concepts missing or partially correct.*	*Many key ideas missing or incorrect; incomplete work.*
Logical connections between concepts	*Connections are clear, logical, and scientifically accurate; demonstrates deep understanding of relationships.*	*Connections are generally clear, with few weak links.*	*Some connections unclear or illogical; limited understanding of relationships.*	*Few or no logical connections; shows minimal understanding.*
Clarity of explanations and understanding of the science involved	*Explanations are detailed, scientifically accurate, and clearly presented.*	*Explanations mostly clear and correct, with minor errors.*	*Basic explanations with limited clarity or depth.*	*Explanations unclear, incorrect, or missing.*
Organization and presentation	*Concept map/report is well-organized, easy to follow, and visually clear.*	*Mostly organized with minor layout issues.*	*Some disorganization; difficult to follow in parts.*	*Disorganized, unclear, or incomplete presentation.*
Creativity and personal reflection	*Demonstrates originality and thoughtful reflection on learning.*	*Shows some creativity or reflection.*	*Minimal creativity; reflection superficial.*	*Lacks creativity or personal input.*

Scoring:

- *18–20 points: Excellent*
- *14–17 points: Good*
- *10–13 points: Satisfactory*
- *Below 10 points: Needs improvement*

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Appendix 4: Example standardized student feedback short questionnaire

Student Feedback on Lesson

Instructions: Please answer the following questions honestly. Your responses are anonymous.

1. *How clear was the lesson content?*
    - *Very clear*
    - *Clear*
    - *Somewhat clear*
    - *Not clear*
2. *How engaging was the lesson?*
    - *Very engaging*
    - *Engaging*
    - *Somewhat engaging*
    - *Not engaging*
3. *Which activity or part of the lesson did you find most interesting?*

    Open-ended: _____
4. *Which part of the lesson was most difficult to understand?*

    Open-ended: _____
5. *Do you have any suggestions to improve this lesson?*

    Open-ended: _____
6. *Overall, how would you rate this lesson?*
    - *Excellent*
    - *Good*
    - *Satisfactory*
    - *Needs improvement*

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Appendix 5: Example standardized teacher self-assessment table

Criteria	***Description / Reflection***	***Rating (1–4)***	***Comments / Notes***
Lesson clarity	*Were the learning objectives clearly presented? Was the content understandable?*	*1 = Needs improvement 2 = Satisfactory 3 = Good 4 = Excellent*	
Student engagement	*Were students actively participating and interested?*	*1 = Low engagement 2 = Moderate 3 = High 4 = Very high*	
Achievement of learning objectives	*Did students meet the intended learning outcomes?*	*1 = Not achieved 2 = Partially achieved 3 = Mostly achieved 4 = Fully achieved*	
Lesson pacing	*Was the timing appropriate for activities and discussions?*	*1 = Poor 2 = Fair 3 = Good 4 = Excellent*	
Use of resources/ICT	*Were teaching materials and technology effectively used?*	*1 = Ineffective 2 = Somewhat effective 3 = Effective 4 = Very effective*	
Student understanding	*How well did students demonstrate understanding during or after the lesson?*	*1 = Poor 2 = Limited 3 = Good 4 = Excellent*	
Teacher reflection	*What went well, and what could be improved for future lessons?*	*—*	*Open-ended notes*

Instructions:

- *Complete this table immediately after each lesson.*
- *Use the rating scale to evaluate each criterion.*

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- *Provide specific comments to support your ratings and guide future improvements.*

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