Using Integrated STEM to Cultivate High School Students' Critical Thinking: Whose Farm Manages Carbon Better

Rudan Wang
Graduate Student, Purdue University
Department of Curriculum and Instruction
915 West State Street, LILY 4 Floor ASEC office, West Lafayette, IN 47907
Phone: (765)7670972
Email: wang6475@purdue.edu

Hui-Hui Wang
Associate Professor | Purdue University
Department of Agricultural Sciences Education & Communication
Department of Curriculum and Instruction
915 West State Street, LILY 3-101A, West Lafayette, IN 47907
Phone: (765) 494-6897
Fax: (765) 496-1152
Email: huiwang@purdue.edu

Neil A Knobloch
Professor, Purdue University
Department of Agricultural Sciences Education & Communication
915 West State Street, LILY 3-232, West Lafayette, IN 47907
Phone: 765-494-8439
Fax: 765-496-1152
E-mail: nknobloc@purdue.edu

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1. Introduction & Need for Strategy

The carbon cycle is a crucial concept in high school biology, particularly for understanding environmental issues (NGSS Lead States, 2013). Studies have shown that students often struggle to comprehend global carbon cycling (Zangori et al., 2017). Most students think farms contribute to increasing carbon dioxide emissions, while overlooking that farms can absorb carbon dioxide (Pitaratae et al., 2017; Tubiello et al., 2022). Compounding this difficulty is the widespread perception that agriculture only contributes to greenhouse gas emissions. However, agricultural systems can be designed to minimize emissions and enhance carbon sequestration, which is crucial for pursuing environmentally sustainable farming practices. For instance, Genstwa and Zmyślona (2024) emphasized the importance of identifying areas, like enteric fermentation, agricultural soils, and liming, where agricultural changes can lead to emissions reductions.

To address students' misconceptions and deepen their understanding, this mini-unit used Learner-centered teaching (LCT), like Inquiry-Based Learning (IBL) and Problem-Based Learning (PBL) to help develop high school students' knowledge of farms from being solely carbon emitters to recognizing them as potential carbon managers, thereby raising awareness and deepening their understanding of agricultural sustainability. LCT is an educational approach that prioritizes the needs, experiences, and active participation of students in the learning process, encourages students to take an active role in their learning, fostering autonomy, critical thinking, and collaborative skills (Harpe & Phipps, 2008; Kerkhoff & Makubuya, 2022). IBL is a learner-centered pedagogy that emphasizes the role of student inquiry in the learning process. This approach invites students to engage actively with content by exploring questions, problems, and scenarios that encourage them to think critically and creatively. Learners build knowledge through exploration and experience, focusing on real-world applications, and allowing students to tackle authentic problems with IBL (Prince & Felder, 2006; Spronken-Smith et al., 2008). PBL is also a learner-centered pedagogy that emphasizes active learning through real-world problem-solving and encourages learners to engage with complex, ill-structured problems that demand critical thinking, collaboration, and self-directed learning (Klegeris & Hurren, 2011).

2. Connection to Literature

This study used the Situated Learning Theory, which indicates learning in authentic and contextual environments (Lave & Wenger, 1991). This principle explains how educators act as influential figures to create meaningful learning experiences by embedding knowledge in actual scenarios. In this mini-unit, students learned the carbon cycle by hands-on activity, calculated Mitchell Plain's carbon emissions authentically, compared carbon management on different farms, and designed the most carbon-sustainable farm.

3.How it Works & Implementation of Strategy

Participant

We implemented the third lesson (out of four lessons) in an environmental science class at a public high school in West Lafayette, Indiana. A total of six students attended this environmental science class.

Lesson Design

This mini-unit aligns with the Indiana Academic Standards and Agriculture, Food, and Natural Resources Content Standards (AFNR Standards) guided by integrated STEM through AFNR Rubric (Wang & Knobloch, 2022). The mini-unit consisted of four interconnected lessons designed to integrate STEM disciplines and addressed the environmental challenges posed by carbon emissions and absorption in agriculture.

Lesson 1 - Exploring the Carbon Cycle and Agricultural Activity on Carbon Emissions

Students engaged in a variety of hands-on activities to explore the carbon cycle and understand the impact of agricultural practices on carbon emissions. They participated in a dice-rolling activity to simulate the journey of a carbon atom, played a Kahoot! game to assess their understanding, and used a sticker book to create visual models of the carbon cycle. The lesson concluded with a class discussion on how different agricultural practices can either increase or reduce carbon emissions.

Lesson 2 - Measure Carbon Emissions in Special Terrain

Students applied problem-based learning to calculate the carbon emission within the irregular area of Mitchell Plain in Indiana using mathematical modeling techniques. This real-world application helped them connect mathematical concepts to environmental issues. As a culminating activity, students presented their final carbon emission calculations, demonstrating their understanding of both the mathematical process and its implications for carbon management.

Lesson 3 - Assist in Making a Decision

In this lesson, students assumed the role of environmental journalists, using inquiry-based learning to investigate carbon emissions and absorption related to agricultural activities. Utilizing an online carbon calculator, they analyzed how different farming practices contributed to or mitigated carbon emissions, discovering that agriculture can play a vital role in managing carbon levels. The lesson emphasized critical thinking, systems analysis, and real-world problem-solving.

Lesson 4 - Design Their Own Suitability Farm

In this lesson, students applied the engineering design process to create a model farm using a sticker book. The design included cows, and students had the option to purchase additional animals, fertilizers, and plants to enhance carbon absorption. The objective was to design a farm that either minimizes carbon emissions or maximizes carbon sequestration. This activity encouraged systems thinking by requiring students to consider the environmental impact of each design choice.

Assessment

All four lessons included either formative or summative evaluations to assess students' outcomes related to carbon emissions, absorption, footprint, and management.

4. Results to Date/Implications/Impact

This study implements lesson 3 in a local school environmental science class for six students. After we practiced Lesson 3 with these high school students, it showed that all students could propose questions about carbon emissions, but they overlooked carbon absorption. Two students(journalists) collected the correct data from the website (https://environment.govt.nz/what-you-can-do/agricultural-emissions-calculator/) and decided Paul would be interviewed: Paul’s farm absorbs carbon while Johnson’s farm emits carbon, so Paul’s farm is the well-suited farm to be interviewed.

5. Future Plans/Advice to Others

This integrated STEM design provides a template for educators teaching the carbon cycle and carbon emissions. However, some minor issues need to be improved in the actual application. When teachers use this mini unit, they should make the computer accessible to the students, because a mobile phone is not as convenient as a computer due to its small interface. Access to a computer provides students with a comprehensive understanding of the carbon emissions associated with different agricultural activities and easily compare the carbon emissions from different farm settings. Additionally, scaffolding the introduction of the farming Lesson 3 enhances relevance, motivation, and engagement before students begin working on the worksheet. Using models or visual aids may help capture students’ interest, while having them read alone could reduce their motivation and engagement.

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