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Education of 21st century: A proposal of flipped classroom strategy to teach Soil Biology

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ABSTRACT: Flipped Classroom (FC) approach has gained widespread acceptance across various education levels, particularly in higher education settings. Flipped Classroom represents a method employed to stimulate student learning, enhance academic performance, and foster student motivation and engagement. This approach involves the utilization of pre-class materials such as recorded lectures and multimedia resources for student review, while class time is dedicated to exercises, projects, or discussions. Numerous studies have documented enhanced learning outcomes among students of mathematics and science through FC implementation. However, there are currently no documented studies that implemented FC in Soil Biology courses. This study discusses the potential to use FC in Soil Biology courses. In addition, we propose an innovative strategy for integrating FC into Soil Biology education. Flipped Classroom is designed to serve as a dynamic tool for motivating students and facilitating the comprehension of Soil Biology concepts.

Keywords: educational strategies, active learning, soil science.

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THE POTENTIAL OF FLIPPED CLASSROOM

In STEM (Science, Technology, Engineering, and Mathematics) undergraduate courses, traditional teaching methods typically involve lecture-based learning, a method that students passively absorb information (Freeman et al., 2014; Amador, 2019; Zhang et al., 2024). This approach has been categorized as theoretical pedagogy, offering limited opportunities for self-guided, hands-on learning (Laseinde and Dada, 2023). However, a significant challenge facing educators today is student engagement and motivation (Martínez-Jiménez and Ruiz-Jiménez, 2020). Moreover, the prevalence of constant connectivity and smartphone usage, both inside and outside the classroom, presents valuable opportunities for integration into teaching and learning methodologies. Therefore, educational strategies should leverage innovative learning approaches to effectively engage and motivate students (Sherer and Shea, 2011).

Active Learning (AL) has emerged as an alternative to the traditional classroom setting, advocating for a “student-centered” approach to education (Rieber and Carton, 1987; Piaget, 2013; Jesionkowska et al., 2020). This methodology emphasizes the significance of dialogical teaching, inspired by the method proposed by Paulo Freire, over monological instruction, to foster more meaningful learning experiences (Moreira, 2022). Various models of AL incorporating technology have been developed, among which the Flipped Classroom (FC) stands out as an innovative, learner-centered pedagogical approach (Studart, 2021; Ma, 2023). The FC has been implemented across different educational levels (Martínez-Jiménez and Ruiz-Jiménez, 2020), particularly in higher education settings (Walsh, 2024).

The FC model is underpinned by social learning theory and was initially introduced in chemistry classes by professors Bergmann and Sams, who posed a simple question: ‘What is the best use of face-to-face time with students?’ (Bergmann and Sams, 2012). Through their observations, both professors noted that traditional instructional models often emphasized the role of the professor over that of the students, resulting in challenges for students to grasp concepts and solve problems effectively. In contrast, they advocated for a teaching methodology that prioritizes student engagement through hands-on, enriching activities and experiences (Bergmann and Sams, 2012).

Recently, Ma et al. (2024) offered a simple definition and differentiation between the FC and the traditional classroom model, emphasizing a strategic shift: activities traditionally conducted during class time are relocated for completion at home, while tasks typically designed as homework are transitioned into classroom activities (Figure 1).

In the traditional classroom model, students attend lectures delivered by educators during class time and assign tasks afterward (Aljaber et al., 2023). However, this approach often fails to provide students with the necessary support to complete assignments, clarify doubts, and acquire knowledge independently. In contrast, the FC model utilizes assigned instructional materials, such as recorded lectures, readings, or multimedia presentations, for review before attending class, while classroom time is dedicated to engaging in exercises, projects, or discussions (Ma et al., 2024). The FC is built upon two core principles: self-directed learning is facilitated outside the classroom using computers and the internet, which deliver pre-class materials to students, and subsequently, the classroom transforms into a space for collaborative learning activities (Estes et al., 2014).

Previous studies have reported enhanced learning outcomes in various disciplines including Mathematics, Experimental Sciences, Chemistry, Algebra, Statistics, Economics, Engineering, Sociology, Humanities, Physiology, Health Sciences, Calculus, Science, Technology, English, Business, and Instructional Technology (Mattis, 2015; Jeong et al., 2018; Estrada et al., 2019; Say and Yildirim, 2020; Amarilla et al., 2022). However, research on the FC method in Soil Science remains limited. To date, there are no studies investigating the application of FC in teaching Soil Biology, a field that warrants exploration due to its significance, particularly considering its complex nature that often demands imaginative understanding. Therefore, leveraging technology within the FC approach could effectively motivate students and facilitate a more accessible comprehension of soil biology concepts.

CURRENT USE OF FC IN SOIL SCIENCE

Education in Soil Science focuses on enabling students to comprehend the multifaceted roles of soils in agriculture, environmental sustainability, and human well-being, underscoring the imperative to preserve soils and advocate for their sustainable utilization (Neaman et al., 2021). Typically, the organization of Soil Science disciplines aims to foster understanding and learning about the formation, evolution, and characterization of soils over spatial and temporal scales (Brevik et al., 2022). However, traditional teaching approaches have predominated in Soil Science courses, where professors primarily disseminate knowledge to students (Amador, 2019). This traditional method has persisted for decades in classes worldwide (Jelinski et al., 2019).

Recently, the FC model has been adopted to instruct students in Soil Science, and compared to traditional formats, this method has yielded positive outcomes, enhanced student perceptions of soils and improved their performance in tests (Radcliffe et al., 2016; Keck et al., 2020; Ramirez et al., 2022). For instance, a previous study comparing the traditional format with FC, evaluated student interest and cognitive engagement in Soil Science. The findings revealed that 50 % of students experienced increased engagement, while 75 % reported a heavier workload with professors (Keck et al., 2020). Moreover, in Soil Physics, FC implementation led to improved post-test performance among students at three American universities, with correct answer rates of 66, 68, and 69 % at North Dakota State University, Auburn University, and the University of Georgia, respectively (Radcliffe et al., 2016). Professors reported higher student engagement and reduced time required to explain calculus fundamentals in Soil Physics classes.

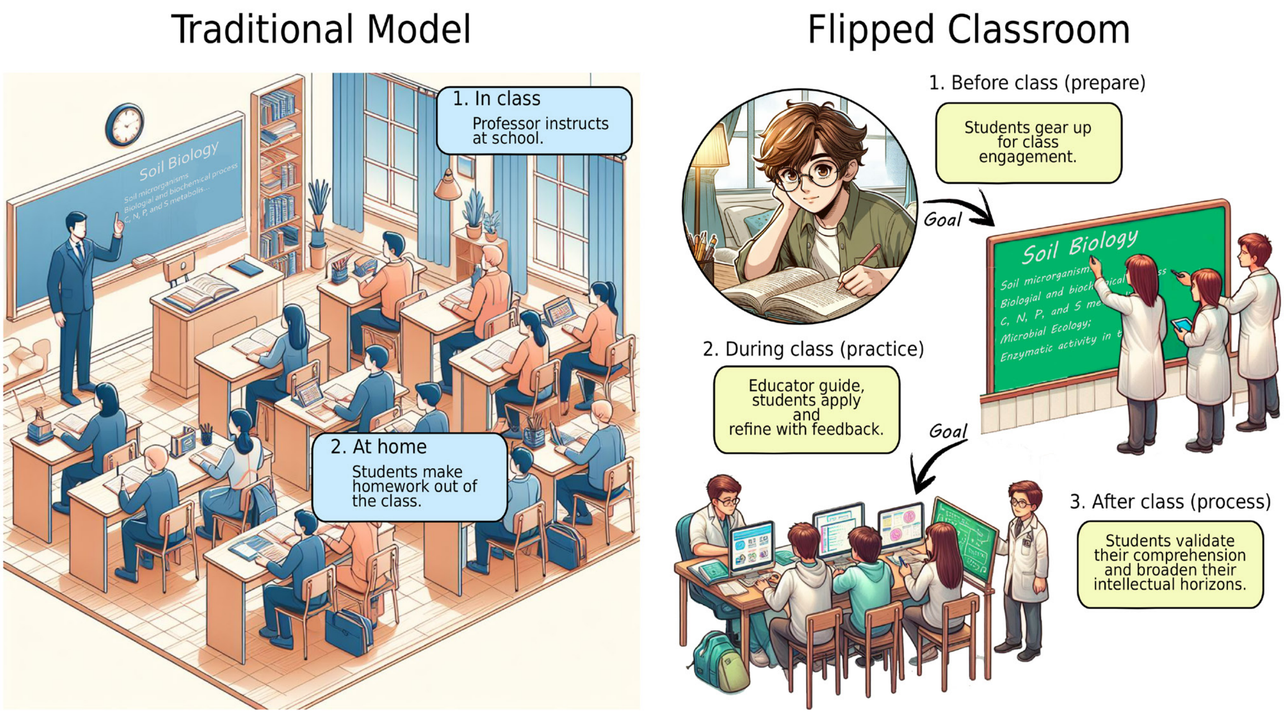

Figure 1. Comparison between traditional and flipped classroom models.

On the other hand, integrating the traditional classroom method with the FC approach has demonstrated effectiveness in Soil Science classes, particularly due to the necessity of applying landscape observations and conducting use fieldwork. This integration has provided students with engaging, hands-on training experiences that foster higher levels of engagement and enhance learning outcomes (Hinckley and Fendorf, 2022). For example, combining traditional teaching models with discussion sessions (26 %) and FC (12 %) has yielded beneficial outcomes for Canadian students, offering innovative and diversified instructional approaches (Krzic et al., 2018). Similarly, in Turkey, Candaş et al. (2022) conducted a study evaluating the association between traditional and FC methods in teaching Soil Chemistry, with results indicating a positive impact on prospective learning outcomes, thus suggesting the advantageous utilization of this model in soil science education.

POTENTIAL OF THE FLIPPED CLASSROOM IN SOIL BIOLOGY COURSE

Soil constitutes a complex habitat that harbors a vast diversity of organisms, interacting with its physical matrix and chemical properties, rendering soil the most diverse environment across all ecosystems (Geisen et al., 2019). Consequently, teaching Soil Biology and related disciplines presents a considerable challenge, primarily due to limitations in observing organisms, including microscopic and unculturable ones (Bruns and Byrne, 2004). The curriculum in Soil Biology encompasses a broad spectrum of topics, including soil microbial ecology, nutrient cycling, and plant-soil interactions (Creamer et al., 2022). These subjects frequently hold implications for agriculture, environmental management, and ecosystem restoration, necessitating the development of critical thinking and problem-solving skills. However, the traditional format of teaching Soil Biology is often constrained by its focus on rote memorization of concepts imparted by professors, without meaningful integration with practical applications (Neaman et al., 2021).

The FC model has the potential to address the limitations of the traditional format in Soil Biology learning by actively engaging students with concepts, theories, and applications before class through pre-recorded lectures, readings, or videos online (Jensen et al., 2018). This approach allows class time to be utilized for discussions, problem-solving activities, and hands-on exercises. By implementing these strategies, students are incentivized to develop a deeper understanding of Soil Biology and actively apply it during class sessions. Indeed, Jensen et al. (2018) applied the pre-class learning strategy and observed high effectiveness and performance among students, particularly through video lectures, which proved superior to traditional textbook-style readings.

An intriguing and challenging aspect of teaching Soil Biology lies in its multidisciplinary nature, encompassing elements of microbial ecology, agronomy, and environmental science. The FC model offers professors the opportunity to integrate materials from these diverse disciplines into the curriculum (Dalbani et al., 2022), providing students with a more comprehensive understanding of Soil Biology and its practical implications. This integration can facilitate problem-based learning activities (Hu et al., 2019), including case studies in various scenarios related to soil degradation, soil fertility management, or soil pollution, and developing strategies to address these issues. By actively engaging with soil management problems, students enhance their ability to apply Soil Biology concepts to real-world situations and develop critical thinking and problem-solving skills (Baig and Yadegaridehkordi, 2023). It is worth noting that FC strategies offer flexibility in accessing all educational materials at any time and from any location, as they utilize online lectures, videos, and interactive simulations to deliver content outside the classroom (Limniou et al., 2018). This accessibility and flexibility enhance student engagement and promote deeper learning in Soil Biology.

A SUGGESTIVE PROPOSAL TO USE THE FC MODEL IN SOIL BIOLOGY LEARNING

Although the FC has been established as an excellent strategy for enhancing student engagement, motivation, self-regulation, and encouraging students to reflect on their own learning process (Amarilla et al., 2022), there is currently no known instance of this educational model being applied in Soil Biology. A recent bibliometric study analyzing approximately 3,000 documents from the Web of Science dataset did not identify any applications of the FC model in Soil Biology (López-Belmonte et al., 2021). Despite the challenges associated with observing soil organisms, including those that are microscopic and unculturable (Bruns and Byrne, 2004), along with the interdisciplinary nature of soils (Brown et al., 2022), which renders Soil Biology learning challenging, there is a high number of texts, online materials, and videos available to students that can be integrated into FC strategies.

Therefore, we propose implementing an FC strategy for an undergraduate course in Soil Biology. For example, in a 16-week course in Brazil, the curriculum could be divided into four stages (Table 1). The course materials would include texts (such as book chapters, journal articles, and papers), videos (approximately 20 min in length), and case studies. Students would be tasked with completing these activities in and out of class, with questions released before in-person activities.

During class sessions, guided discussion of the homework questions would be conducted in pairs or groups to address basic and complex problems. Subsequent stages would involve formative and advanced example questions, incorporating real case studies, and fostering deeper guided discussions in pairs or groups. Finally, a summative assessment comprising approximately 30 questions of increasing complexity would be administered, which could be divided between in-class and out-of-class components. Alternatively, this assessment could be conducted in class with open-book access. Furthermore, the effectiveness of the FC strategy could be evaluated using quantitative and systematic methods (Gong et al., 2023), providing feedback and cross-validation of the instructional model as new components are introduced to enhance student performance in STEM disciplines.

FURTHER PERSPECTIVES

This manuscript comprehensively explored the potential of using FC approach in Soil Biology. Although no reports of using and evaluating FC in Soil Biology courses have been found, we introduce an innovative approach for implementing the FC method in the realm of Soil Biology. However, further studies should be done to evaluate the effectiveness of FC approaches in Soil Biology learning and assess student performance, motivation, and engagement.

DATA AVAILABILITY

Not applicable. This opinion text brings information and a proposal for using FC in Soil Biology. The authors did not use numerical data obtained by own study and experiment.

Table 1. Proposal for applying FC in Soil Biology (adapted from Francis et al., 2020)

Week 1, 4, 7, 10 and 13	Week 2, 5, 8, 11 and 14	Week 3, 6, 9, 12 and 15	Week 16
Texts released by professors; videos (~20 minutes); recorded class; case study.	Instructed discussion of homework questions in pairs or groups	Formative and advanced examples questions discussed in class (in pairs or groups)	Summative assessment with ~30 questions of increasing complexity

Week 1: Soil organisms; Soil ecology; Rhizosphere; Week 4: Nutrient cycling (C, N, P, and S); Week 7: Biological N fixation (symbiotic and associative); Week 10: Mycorrhizae; Week 13: Soil bioremediation; * Class could include lab and field practices; ** This framework can be adapted according to the duration of course.

AUTHOR CONTRIBUTIONS

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