Article

Connecting Students' Interests to a Learning Context: The Case of Ecosystem Services in STEM Education

Elena A. Mikhailova 1,*, Christopher J. Post 1, Grayson L. Younts 2 and Mark A. Schlautman 3

1 Department of Forestry and Environmental Conservation, Clemson University, Clemson, SC 29634, USA; cpost@clemson.edu
2 Department of Plant and Environmental Sciences, Clemson University, Clemson, SC 29634, USA; graysoy@clemson.edu
3 Department of Environmental Engineering and Earth Sciences, Clemson University, Anderson, SC 29625, USA; mschlau@clemson.edu

* Correspondence: eleanam@clemson.edu; Tel.: +1-864-656-3535

Abstract: Interest in a subject matter is a powerful motivation in education. Prior knowledge of students' interests can be helpful in teaching the concept of ecosystem services (ES) and disservices (ED), which is increasingly being used in science, technology, engineering, and mathematics (STEM) education, including soil science. Study objectives were to evaluate prior students' soil science-related interests and use them to expand the learning context of a laboratory exercise on soil reaction (pH) with ES/ED in an online introductory soil science course (FNR 2040: Soil Information Systems) taught at Clemson University. Students from multiple fields of study (environmental and natural resources, forestry, and wildlife biology) completed the laboratory exercise in Fall 2021. This exercise on soil regulating and provisioning ES/ED included a sequence of reusable learning objects (RLOs), which are self-contained online modules frequently used for e-learning. Laboratory activities included calculating the liming replacement cost of soil inorganic carbon (SIC) and avoided social cost of carbon (SC-CO2) from soil inorganic carbon (SIC) stocks in the assigned soil. The laboratory exercise was effective in increasing the familiarity with the concept of ES/ED (+39.4 increase in “extremely familiar” category) and the concept of SIC (+44.7 increase in “moderately familiar” category). The graded online quiz consisted of 9 questions and was taken by 55 students with an average score of 7.0 (out of 9). A post-assessment survey found that the laboratory was an effective way to learn about soil pH, SIC, and their ES/ED. Detailed student comments showed learning enjoyment (e.g., calculations, good experience), the value of multimedia (e.g., video, PowerPoint), the learning flexibility (e.g., separate parts), content applicability (e.g., economic values of services), and constructive criticism (e.g., clearer instructions, lots of information). A word cloud based on comments by the students about their soil ES laboratory exercise experience indicated the most common words submitted by students to describe their experience, such as “soil”, “calculations”, “enjoyed”, “learning”, and “values”, among others. Applied recommendations are proposed to develop future exercises based on the alignment of students' interests, STEM subject matter, and ES/ED applications.

Keywords: e-learning; environment; learning; liming; reusable learning object (RLO); soil; teaching

1. Introduction

Interest in a subject matter can increase the likelihood of educational success. Interest is often described as two different experiences: (1) a momentary experience of being captivated by an object or topic (situational interest), and (2) an enduring inclination to reengage with an object or topic over time (individual interest) [1]. Individual student interests in education are often shared with societal, institutional, and instructional interests (Figure 1) [2]. Students need to take required courses, which are often outside their specific interests. Although instructors may presume that students do not have any interests in

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required courses, research by Mikhailova et al. (2019) [2] showed that this is not always true. Connecting student interests with a learning context in a required course is particularly challenging and requires knowledge of prior student interests associated with the required course. Mikhailova et al. (2019) [2] examined the role of prior student interests in creating various interest interventions such as attention-getting settings, context personalization, project-based learning, utility value, and technology-based learning (Figure 1).

Figure 1. Conceptual model showing the integration of prior student interests with a topic to create interest interventions to improve student learning outcomes (adapted from Harackiewicz et al., 2016 [3]; Mikhailova et al., 2019 [2]).

Traditional interest research includes three approaches: (1) characteristics of the person (personal interest as a disposition), (2) characteristics of the learning environment, context, and situation (the interestingness of the learning environment), and (3) psychological state within the person (situational and actualized interests within the person) (Figure 2) [4,5]. The original concepts [4] only included personal interest as a disposition that ignores, or at least does not differentiate, prior interest gained from earlier education and life experience. Experience and disposition are different concepts, where disposition is associated with the inherent qualities of the individual, while experience, including educational experience, is linked to prior events in a student’s life. Some researchers link the dispositional characteristics of the person to the learning environment, while others ignore this relationship [4,5].

Although several studies have examined the theory and practice of increasing student interest in a topic [3,6], there has been limited discussion of the interests that students bring to a course and how that could be used to improve student engagement with a particular subject. While the subject matter for a STEM exercise is often derived from a series of societal, institutional, and instructional interests (Figure 1), it is possible to evaluate prior students’ interests related to an assigned subject matter to help improve and customize how the subject is organized and delivered as an exercise.

This study examines methods to connect students’ prior interests to a learning context (Figure 2) in a required soil science course by expanding the scope of the already existing laboratory exercise on soil reaction (pH) with the concept of soil inorganic carbon (SIC) and ecosystem goods and services/disservices (Table 1). This modified exercise is developed to expand the relevance of the laboratory by improving the meaning and characteristics of the learning environment by linking to students’ prior interests.
Traditional interest research includes three approaches: (1) characteristics of the person (personal interest as experience and disposition), (2) characteristics of the learning environment, context, and situation (the interestingness of the learning experience, including educational experience, is linked to prior events in a student's life. Some researchers link the concept of soil inorganic carbon (SIC) and ecosystem goods and services/disservices (ES/ED) using examples from soil systems and their properties (based on the cascade model adapted from Potschin and Haines-Young (2011) [7]).

Figure 2. Conceptual diagram describing three approaches to interest research (adapted from Krapp et al., 1992 [5]).

Table 1. Approach to expand the learning context of the soil reaction (pH) laboratory exercise with ecosystem services and disservices (ES/ED) using examples from soil systems and their properties (based on the cascade model adapted from Potschin and Haines-Young (2011) [7]).

| Ecosystem Organization | Function(s) | Service(s)/Disservice(s) | The Socio-Economic Context |
|------------------------|-------------|-------------------------|---------------------------|
| Soil systems           |             |                         |                           |
| Soil properties:       |             |                         |                           |
| Soil reaction (pH)     | Soil nutrient availability | Provisioning, regulating | Liming costs               |
| SIC (CaCO$_3$)         | pH regulation | Provisioning           | Liming costs (replacement value) |
|                        | Carbon sequestration | Regulating           | The social cost of carbon (SC-CO$_2$) and avoided emissions |

Note: SIC = soil inorganic carbon; CaCO$_3$ = calcium carbonate (lime, limestone).

Soil reaction (pH) is a measure of hydrogen ion (H$^+$) concentration/activity in soil solution, which is related to the acidity or alkalinity of a soil. The presence of SIC (naturally occurring liming material) makes the soil more alkaline. Measurement techniques for soil pH are analogous to other pH measurement exercises that most students are exposed to multiple times in their secondary and early college education. Despite these previous experiences in measuring pH in a more general context, soil pH is a vital concept in an introductory soil science course because it relates to soil nutrient availability and other key concepts. It is a challenge for instructors to make a previously experienced subject matter on pH relevant and interesting. Ecosystem services/disservices provide an example of how to expand the learning context of a subject, in this case, soil pH, by providing a biophysical as well as a new socio-economic context. Ecosystem services are defined as benefits provided by ecosystems to humans, which are opposite to ecosystem disservices. Ecosystem services are divided into three categories: provisioning (e.g., food), regulation/maintenance (e.g., carbon sequestration), and cultural (e.g., recreation).

The objectives of this study were to evaluate prior students’ soil science-related interests and use them to expand the learning context of a laboratory exercise on soil pH with SIC, and ES/ED in an online introductory soil science course (FNR 2040: Soil Information...
Systems taught at Clemson University. The topics of soil reaction (pH), SIC, and ES/ED fit well with soil science course objectives, included in lectures and laboratory exercises.

2. Materials and Methods
2.1. Design
Prior to the beginning of the course, students were asked to complete a survey that included questions about education, demographics, familiarity with ecosystem services, geospatial technologies, and an open-ended question about soil science interests. Data from this survey were used to classify students’ interests which were used to develop the laboratory exercise. The laboratory exercise consisted of a series of reusable learning objects (RLOs) in the Canvas Learning Management System (Instructure) (Table 2). The laboratory exercise consisted of identifying ES/ED provided by soil pH, calculating the avoided social cost of carbon (SC-CO$_2$), and liming replacement costs from soil inorganic carbon (SIC) stocks in one of the horizons of the assigned soil. The experimental design of the study is presented in Tables 2–4. Tables 3 and 4 show instructions provided to the students for the laboratory exercise.

Table 2. Design steps of the study, which uses various reusable learning objects (RLOs) for the laboratory exercise (adapted from Mikhailova et al., 2021 [8]).

| Steps                          | Description of Activities                                                                 |
|-------------------------------|------------------------------------------------------------------------------------------|
| 1. Pre-assessment             | Students complete a general Google Forms web-based survey (e.g., interests in soil science, familiarity with ecosystem services, and disservices, etc.). |
| 2. Lecture (Interest intervention) | Students are presented with a lecture entitled “Soil reaction (pH)” in PowerPoint and video formats. |
| 3. Laboratory exercise (Interest intervention) | Students complete the laboratory exercise consisting of identifying ES/ED, calculating the avoided social cost of carbon (SC-CO$_2$), and liming replacement costs from soil inorganic carbon (SIC) stocks in one of the horizons of the assigned soil in the State/Representative Soil Project [9]. Students add slides to State/Representative Soil Project [9] and upload it in Canvas. |
| 4. Graded online quiz (Outcome) | Students complete an online quiz (9 questions, 9 points) within Canvas LMS.               |
| 5. Post-assessment            | Students complete a follow-up Google Forms web-based survey of their experience with the laboratory on ecosystem services and disservices. |

Table 3. Instructions for the laboratory exercise (adapted from Mikhailova et al., 2021 [8]).

**Soil Ecosystem Services Laboratory Exercise**

Ecosystem services (ES) are defined as any positive benefit that is provided by the ecosystem to people. Ecosystem disservices (ED) are defined as any negative effects caused by the ecosystem towards people.

**Objectives:**
- To gain knowledge about ES and ED as related to soil science using various reusable learning objects, RLOs (e.g., online lectures, PowerPoint presentation, and video).
- To identify examples of ES (provisioning, regulating/maintenance, cultural) provided by the assigned State/Representative soil [9] using Official Soil Series Descriptions (OSDs) [10] and tables of soil chemical properties [11].
- To conduct a monetary valuation of soil inorganic carbon (SIC) (listed in the tables of soil chemical properties) using the avoided social cost of carbon (SC-CO$_2$) of USD 46 per metric ton of CO$_2$, which is applicable for the year 2025 based on 2007 U.S. dollars and an average discount rate of 3% (EPA, 2016) [12].
- To test the acquired knowledge using an online graded quiz.
- To evaluate the effectiveness of the laboratory exercise using a pre- and post-assessments.

**Rationale:** The concept of ecosystem services (ES) and disservices (ED) is increasingly being used in various fields, including forestry, wildlife biology, and environmental sciences.

**Procedure:** The soil ecosystem services laboratory exercise consists of a series of reusable learning objects (RLOs) (e.g., pre-assessment, lecture, etc.), which need to be completed sequentially.
Table 4. Instructions for the specific slides in the laboratory exercise (adapted from Mikhailova et al., 2021 [8]).

| Slides |
|-------------------|
| **Slide:** Explanation of regulating ecosystem services (e.g., C sequestration). |
| Soil inorganic carbon (SIC) provides regulating ES by keeping the carbon in the soil instead of it being released to the atmosphere as CO₂ gas, which contributes to global warming. A monetary valuation for SIC can be calculated using the avoided social cost of carbon (SC-CO₂) of USD 46 per metric ton of CO₂, which is applicable for the year 2025 based on 2007 U.S. dollars and an average discount rate of 3% (EPA, 2016) [12]. According to the EPA, the SC-CO₂ is intended to be a comprehensive estimate of climate change damages, but it can underestimate the true damages and cost of CO₂ emissions due to the exclusion of various important climate change impacts recognized in the literature. |
| **Instruction** |
| Please use the following slides as a template. Copy and paste it into your PowerPoint presentation. |

**Slide template:** Instructions for calculating a monetary value of soil inorganic carbon (SIC) in the form of CaCO₃, based on the avoided social cost of emitting carbon dioxide to the atmosphere (SC-CO₂).

**Instructions:** Use the table of soil chemical properties to find the midpoint calcium carbonate percent for one of the soil horizons (Note: Please be sure to use the values from your state/representative soil instead of the example numbers. If you do not have any soil inorganic carbon (SIC; carbonates—CaCO₃) in your soil, please, use the value of 0% for CaCO₃ for the calculations). If you do NOT have carbonates—it means that there are no regulating and provisioning ecosystem services provided by CaCO₃, which is a significant conclusion.

- Find the thickness of the soil layer with CaCO₃ in cm by taking the lower depth and subtracting the upper depth (lower depth–upper depth), and converting this number from inches to cm (multiply by 2.54 cm inch⁻¹).
- Find the midpoint soil bulk density for this layer of soil.
- Find kilograms of soil in a hectare using the following equation: kilograms of soil in the horizon in one hectare = bulk density (g cm⁻³) × thickness of soil layer (cm) × 100,000.
- Find the kilograms of CaCO₃ in a hectare by multiplying the CaCO₃ percentage (from the table of soil chemical properties) by the kilograms of soil ha⁻¹.
- Convert to metric tons ha⁻¹: kg CaCO₃ ha⁻¹/1000.
- Calculate the monetary value of soil inorganic carbon (SIC): Monetary value (USD) = (CaCO₃ in one hectare, ton CaCO₃ ha⁻¹) × (44 tons CO₂/100 tons CaCO₃) × USD 46 per ton CO₂.

**Example:** So, for example, if you had CaCO₃ of 2%, a horizon thickness of 9 inches, and a bulk density of 1.35 g cm⁻³.

- Depth of soil layer = 9.0 inches × 2.54 cm inch⁻¹ = 22.86 cm.
- Kilograms of soil in the soil layer of one hectare = 1.35 g cm⁻³ × 22.86 cm × 100,000 = 3,086,100 kg soil ha⁻¹.
- Kilograms of CaCO₃ = 0.02 × 3,086,100 = 61,722 kg CaCO₃ ha⁻¹.
- Metric tons CaCO₃ = 61,722 kg CaCO₃ ha⁻¹/1000 = 61.722 tons CaCO₃ ha⁻¹.
- Monetary value of soil inorganic carbon (SIC): Monetary value (USD) = 61.722 tons CaCO₃ ha⁻¹ × (44 tons CO₂/100 tons CaCO₃) × USD 46/ton CO₂ = USD 1249.25 ha⁻¹.

**Slide:** Explanation of provisioning ecosystem services (e.g., liming) and calculations using liming replacement costs.

Calcium carbonate (CaCO₃) provides provisioning ES by providing liming which increases soil fertility and balances soil acidity. A monetary valuation for CaCO₃ can be calculated using the replacement cost of liming of USD 9.79 per metric ton of limestone (CaCO₃), which is based on the 2016 average cost per metric ton of agricultural limestone [13].

**Instruction**

- Find the thickness of the soil layer with CaCO₃ in cm by taking the lower depth and subtracting the upper depth (lower depth–upper depth), and converting this number from inches to cm (multiply by 2.54 cm inch⁻¹).
- Find the midpoint soil bulk density for this layer of soil.
- Find kilograms of soil in a hectare using the following equation: kilograms of soil in the horizon in one hectare = bulk density (g cm⁻³) × thickness of soil layer (cm) × 100,000.
- Find the kilograms of CaCO₃ in a hectare by multiplying the CaCO₃ percentage (from the table of soil chemical properties) by the kilograms of soil ha⁻¹.
- Convert to metric tons ha⁻¹: kg CaCO₃ ha⁻¹/1000.
- Calculate the monetary value of CaCO₃ based on the liming replacement cost. Use the table of soil chemical properties to find the midpoint calcium carbonate percent for one of the soil horizons (Note: If your soil does not have any calcium carbonate, assume 1% for calcium carbonate for the calculations. Please, note on the slide that this assumption has been made).
Table 4. Cont.

| Slides |
|--------|
| • Find the thickness of the soil layer with CaCO$_3$ in cm by taking the lower depth and subtracting the upper depth (lower depth–upper depth) and converting this number from inches to cm (multiply by 2.54 cm inch$^{-1}$). |
| • Find the midpoint soil bulk density for this layer of soil. |
| • Find kilograms of soil in a hectare using the following equation: kilograms of soil in the horizon in one hectare = bulk density (g cm$^{-3}$) $\times$ thickness of soil layer (cm) $\times$ 100,000. |
| • Find the kilograms of CaCO$_3$ in a hectare by multiplying the CaCO$_3$ percentage (from table of soil chemical properties) by the kilograms of soil ha$^{-1}$. |
| • Convert to metric tons ha$^{-1}$: kg CaCO$_3$ ha$^{-1}$ / 1000. |
| • Calculate the monetary value of CaCO$_3$: Monetary value (USD) = ton CaCO$_3$ ha$^{-1}$ $\times$ USD 9.79/ton CaCO$_3$. |

Example: So, for example, if you had CaCO$_3$ of 2% and a horizon thickness of 9 inches, and a bulk density of 1.35 g cm$^{-3}$.

• Unit conversion. Horizon thickness = 9 in $\times$ 2.54 cm in$^{-1}$ = 22.86 cm.
• Kilograms of soil in the horizon of one hectare = 1.35 g cm$^{-3}$ $\times$ 22.86 cm $\times$ 100,000 = 3,086,100 kg soil ha$^{-1}$. 
• Kilograms of CaCO$_3$ = 0.02 $\times$ 3,086,100 = 61,722 kg CaCO$_3$ ha$^{-1}$. 
• Metric tons CaCO$_3$ = 61,722 kg CaCO$_3$ ha$^{-1}$ /1000 = 61.722 tons CaCO$_3$ ha$^{-1}$. 

Monetary value: Monetary value (USD) = 61.722 tons CaCO$_3$ ha$^{-1}$ $\times$ USD 9.79/ton CaCO$_3$ = USD 604.26 ha$^{-1}$.

2.2. Background of “Test” Course

“Test” course: Soil Information Systems (FNR 2040) is a 4-credit course in the Department of Forestry and Environmental Conservation at Clemson University, Clemson SC [14]. FNR 2040 is “an introductory soil course that focuses on the input, analysis, and output of soil information utilizing geographic information technologies (Global Positioning Systems, Geographic Information Systems, direct/remote sensing) and soil data systems (soil surveys, laboratory data, and soil data storage). Soil Information Systems course is a required course for forestry, wildlife and fisheries biology, and environmental and natural resources majors” [14]. The course was taught online because of COVID-19. General information about the course based on the survey is presented in Table 5.

Table 5. General survey information about the course (FNR 2040: Soil Information Systems course, n = 58).

| Survey Questions | Responses |
|------------------|-----------|
| What is your major program? | FOR (9) ENR (16) WFB (21) Other (12) |
| How would you best describe your academic classification (year)? | Sophomore (20) Junior (23) Senior (14) Other (1) |
| How would you describe yourself? | Female (23) Male (35) |
| Did you take online courses before? | Yes (56) No (2) |

Note: FOR = Forestry, ENR = Environmental and Natural Resources, WFB = Wildlife and Fisheries Biology.

3. Results

3.1. Pre-Testing Student Interests in Soil Science and Ecosystem Services

Knowledge of student interests in a subject matter is essential in creating effective laboratory exercises. This study assessed students’ interests in soil science and ES using an online questionnaire/survey at the beginning of the course/semester. Information about students’ interests in soil science was acquired using an open-ended request: “Please, write a short paragraph about your interests in soil science using space below.” Students’ responses were classified based on interest types, which showed that most students had personal interest and utility value in soil science (Figure 3).
3.1. Pre-Testing Student Interests in Soil Science and Ecosystem Services

Knowledge of student interests in a subject matter is essential in creating effective laboratory exercises. This study assessed students' interests in soil science and ES using an online questionnaire/survey at the beginning of the course/semester. Information about students' interests in soil science was acquired using an open-ended request: “Please, write a short paragraph about your interests in soil science using space below.” Students' responses were classified based on interest types, which showed that most students had personal interest and utility value in soil science (Figure 3).

![Interest types](image)

**Figure 3.** Distribution of student interest types based on student comments from the start-of-semester questionnaire/survey asking students to write a short paragraph about students’ interests in soil science. Soil science was required for 46/58 (79%) of students.

Student interests were also classified based on the phases of interest development, with most of the students having triggered situational interest (“the subject is new”) (51%) and maintained situational interest (“the subject is somewhat new”) (38%) (Figure 4).

![Interest phases](image)

**Figure 4.** Distribution of phases of interest development [1] based on student comments from the start-of-semester questionnaire/survey asking students to write a short paragraph about students’ interests in soil science.

Students’ familiarity with ES was tested using a question: Are you familiar with the concept of ES with an option to elaborate: “If yes, please, describe how you learned about it.” Familiarity with the concept of ES had a wide distribution with most of the students being “not at all familiar” with ES (Table 6).

![Survey Questions](image)

**Table 6.** General survey information about the familiarity with the concept of ecosystem services course (FNR 2040: Soil Information Systems course, n = 58) at the beginning of the semester.

| Survey Questions | Responses |
|------------------|-----------|
| Are you familiar with the concept of ecosystem services (please, select a number to indicate familiarity)? | 1 = not at all familiar (19) 2 = slightly familiar (14) 3 = somewhat familiar (14) 4 = moderately familiar (10) 5 = extremely familiar (1) |
| If yes, please, describe how you learned about it. Examples of written responses: | 1. AP Environmental Science course in high school. 2. My first AGRB class touched on ecosystem services. 3. We discussed ecosystem services in my forest watershed protection course. 4. I have had an introduction to it in previous classes. 5. I have learned some about what ecosystem services are and how they work through AP Environmental Science my senior year of high school and from Biology courses here at Clemson. 6. I learned about ecosystem services initially in my resource economics class… 7. In high school, I was given the option to take AP Environmental Science which taught me so much from past to current events. |

Note: AP = Advanced Placement, AGRB = Agribusiness.
Table 6. General survey information about the familiarity with the concept of ecosystem services course (FNR 2040: Soil Information Systems course, n = 58) at the beginning of the semester.

| Survey Questions                                                                 | Responses |
|----------------------------------------------------------------------------------|-----------|
| Are you familiar with the concept of ecosystem services (please, select a number to indicate familiarity)? | 1 = not at all familiar (19)  
2 = slightly familiar (14)  
3 = somewhat familiar (14)  
4 = moderately familiar (10)  
5 = extremely familiar (1) |
| If yes, please, describe how you learned about it. Examples of written responses: | 1. AP Environmental Science course in high school. 2. My first AGRB class touched on ecosystem services. 3. We discussed ecosystem services in my forest watershed protection course. 4. I have had an introduction to it in previous classes. 5. I have learned some about what ecosystem services are and how they work through AP Environmental Science my senior year of high school and from Biology courses here at Clemson. 6. I learned about ecosystem services initially in my resource economics class . . . 7. In high school, I was given the option to take AP Environmental Science which taught me so much from past to current events. |

Note: AP = Advanced Placement, AGRB = Agribusiness.

Student interests were also classified based on their interests in ES, with most students expressing a general interest in ecosystems, and provisioning ES in particular, which can be explained by students’ majors (forestry; wildlife biology), which tend to be focused on provisioning ES (Table 7).

Table 7. Ecosystem services and examples of students’ interests in FNR 2040: Soil Information Systems course.

| Ecosystem Services | Examples of Student Comments |
|--------------------|------------------------------|
| General interest in ecosystems  
n = 31 (53%) | I am interested to learn about how soil can affect the ecosystem and how we can make it to where plants can grow better in certain environments. |
| Provisioning  
(e.g., food, fiber, etc.)  
n = 20 (35%) | I would also be interested in the different soil types that help produce better crops for both private and public game species management. |
| Regulation/Maintenance  
(gas, flood regulation, etc.)  
n = 5 (9%) | I enjoyed studying geology and I believe studying soil is a great lens through which to look at the history of the Earth. Additionally, soil is a critical component of carbon sequestration and can be a dangerous source of carbon emissions as global temperatures rise, so it is important to understand how soil affects climate change in positive and negative ways. |
| Cultural  
(Non-material benefits: aesthetics, recreation, etc.)  
n = 2 (3%) | I would like to be able to walk in the woods and determine soil types. It will certainly be useful to have a working knowledge of soils as I head into my (hopeful) career in natural resource policy, but I also love taxonomy and find intrinsic value in being able to identify things! |

Table 8 presents pre-testing responses to the survey questions about familiarity with ES/ED, which reveal that most students were “not familiar” (32.8%) and “slightly familiar” (24.1%) with this concept (Table 8). Students were familiar with pH, with most students learning about pH in high school and college (Table 8). More than half of the students measured pH more than four times in the past (Table 8). Most of the students were “not at all familiar” (33.3%) and “slightly familiar” (42.1%) with SIC (Table 8). More than 90% of students were not familiar with the relationship between SIC and pH (Table 8).
Table 8. Pre- and post-assessment results from the laboratory exercise on soil pH, soil inorganic carbon (SIC), and soil ecosystem services in the FNR 2040: Soil Information Systems course.

| Survey Questions and Answers | Pre-Assessment (%) | Post-Assessment (%) | Difference (%) |
|------------------------------|--------------------|---------------------|----------------|
|                              | (n = 57)           | (n = 56)            |                |

Please rate your familiarity with the concept of ecosystem services or disservices on the following scale:

1 = not at all familiar 32.8 0 -32.8
2 = slightly familiar 24.1 0 -24.1
3 = somewhat familiar 24.1 7.8 -16.3
4 = moderately familiar 17.2 51.0 +33.8
5 = extremely familiar 1.8 41.2 +39.4

Please rate your familiarity with pH on the following scale:

1 = not at all familiar 0 1.8 +1.8
2 = slightly familiar 3.5 0 -3.5
3 = somewhat familiar 24.6 8.9 -15.7
4 = moderately familiar 47.4 53.6 +6.2
5 = extremely familiar 24.6 36.7 +12.1

Where did you learn about pH?

| Where did you learn about pH? | Pre-Assessment (%) | Post-Assessment (%) |
|-------------------------------|--------------------|---------------------|
| High school                   | 8.8                | -                   |
| College                       | 0                  | -                   |
| High school and college       | 89.5               | -                   |
| Other                         | 1.8                | -                   |
| Not applicable (not familiar with pH) | 0          | -                   |

How many times did you measure pH in the past?

| How many times did you measure pH in the past? | Pre-Assessment (%) | Post-Assessment (%) |
|-----------------------------------------------|--------------------|---------------------|
| 0                                             | 3.5                | -                   |
| 1                                             | 14.0               | -                   |
| 2                                             | 5.3                | -                   |
| 3                                             | 12.3               | -                   |
| 4 or more times                               | 64.9               | -                   |

Please rate your familiarity with soil inorganic carbon (SIC) on the following scale:

1 = not at all familiar 33.3 3.6 -29.7
2 = slightly familiar 42.1 8.9 -33.2
3 = somewhat familiar 19.3 32.1 +12.8
4 = moderately familiar 5.3 50.0 +44.7
5 = extremely familiar 0 5.4 +5.4

Are you familiar with the relationship between soil inorganic carbon (SIC) and pH?

| Are you familiar with the relationship between soil inorganic carbon (SIC) and pH? | Pre-Assessment (%) | Post-Assessment (%) | Difference (%) |
|---------------------------------------------------------------------------------|--------------------|---------------------|----------------|
| Yes                                                                             | 8.8                | 91.1                | +82.3          |
| No                                                                              | 91.2               | 8.9                 | -82.3          |

The laboratory was an effective way to learn about the ecosystem services and disservices with examples from soil science:

1 = strongly disagree - 1.8 -
2 = disagree - 1.8 -
3 = neither agree nor disagree - 28.6 -
4 = agree - 67.9 -

3.2. Expanding the Learning Context of a Laboratory Exercise Based on Student Interests

Traditionally, soil science pH laboratories have focused on physically measuring pH, which most students in this course had learned and experienced in both high school and college before taking this soil science course (Table 8). The student survey of general interest in soil science and ES/ED showed that student soil science interests fall in the category of personal interest and utility value, with ES-related interests revolving around provisioning ES (Figure 5). Based on these results, it was concluded that problem-based learning and utility value interest interventions were the most appropriate in this case.
Student interests in provisioning ES helped to focus the topic on soil pH and SIC (CaCO₃), which is a naturally occurring liming material listed in the table of soil chemical properties. The new assignment included a laboratory exercise using the SIC values (or a default value when not present) to identify the related ES/ED, calculate the avoided social cost of carbon (SC-CO₂), and liming replacement costs from soil inorganic carbon (SIC) stocks in one of the horizons for each student’s unique soil which is part of their semester-long State/Representative Soil Project. This exercise linked students’ prior personal and utility value interest types in soil science with their provisioning ES interests (Figure 5).

![Figure 5.](image)

### 3.3. Quiz Results and Comparison of Pre- and Post-Testing Responses to the Web-Based Survey

After the laboratory exercise, students were asked to complete a quiz to assess the learning outcomes. The quiz consisted of different questions, which tested students’ understanding of connections between soil pH, various forms of carbon in the soil, and ES. Analysis of individual question scores revealed that the concept of ES was still confusing to some students. Despite this confusion, the overall quiz scores were excellent, which demonstrates knowledge retention by the students after completing this laboratory exercise (Table 9).

Post-assessment results found that the lecture and laboratory exercise effectively educated students about the types of ES/ED with an increase in the number of students classifying their familiarity as “moderately familiar” (+33.8% increase from pre-assessment) and “extremely familiar” (+39.4% increase from pre-assessment) (Table 8). Students increased their familiarity with pH and SIC, as indicated by increases in the percent of “moderately” and “extremely” familiar categories. Most students agreed that the laboratory was an effective way to learn about ES/ED with examples from soil science (Table 8).

Detailed student comments were grouped by theme, with some examples shown in Table 10. Students enjoyed (T1. Enjoyment of learning) learning about soil pH, ecosystem services, and doing calculations. They appreciated the value of multimedia (T2), such as video and PowerPoint presentations. Completing individual easy-to-follow steps on their own time presented students with the flexibility of learning (T3). Students, in most cases, recognized the “applicability of content” (T4) when calculating the value of different ES/ED for their state/representative soils [12]. Students’ critical comments (T5) included requests for more explanation in both definitions and laboratory instructions.

Students’ answers to the open-ended request to write about their favorite experience in the exercise were used to create a word cloud, which shows the most frequently used words by the students (Figure 6). Such words included “soil”, “learning”, “calculations”, “values”, “services”, “ecosystem”, and “provisioning” (Figure 6).

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**Figure 5.** The process of choosing interest interventions by understanding students’ interest types (soil science, ecosystem services) using the current study as an example. By identifying the common and predominant student interest types (the highest proportion in red) in both soil science and ecosystem services, it is possible to select the interest interventions (in green) based on the intersection of soil science and ecosystem service interests.
Table 9. Responses to the quiz questions for the laboratory exercise on soil pH, soil inorganic carbon (SIC), and ecosystem services in the FNR 2040: Soil Information Systems course \((n = 55); \text{Average score}: 7; \text{High score}: 9; \text{Low score}: 4; \text{Standard deviation}: 1.41; \text{Average time}: 7:23).  

| Quiz Questions and Answers                                      | Respondents | Responses (%) |
|-----------------------------------------------------------------|-------------|---------------|
| **What is soil pH?**                                            |             |               |
| Measure of acidity and alkalinity                               | 55          | 100           |
| Measure of electrical conductivity                             | 0           | 0             |
| Measure of nutrient availability                               | 0           | 0             |
| Measure of liming                                              | 0           | 0             |
| **What kind of ecosystem services does soil pH provide?**       |             |               |
| Regulating                                                     | 4           | 7             |
| Provisioning                                                   | 3           | 5             |
| Cultural                                                       | 0           | 0             |
| Regulating and provisioning                                     | 48          | 87            |
| **What is soil organic carbon (SOC)?**                         |             |               |
| Fraction of soil organic matter                                | 52          | 95            |
| Fraction of minerals                                           | 1           | 2             |
| Liming material                                                | 2           | 4             |
| Available water capacity                                       | 0           | 0             |
| **What kind of ecosystem services does soil organic carbon (SOC) provide?** |             |               |
| Regulating                                                     | 12          | 22            |
| Provisioning                                                   | 5           | 9             |
| Cultural                                                       | 0           | 0             |
| All types of ecosystem services                                | 38          | 69            |
| **What is soil inorganic carbon (SIC)?**                       |             |               |
| Carbonates                                                     | 48          | 87            |
| Fraction of soil organic matter                                | 3           | 5             |
| Soil reaction                                                  | 3           | 5             |
| Sodium adsorption ratio                                        | 1           | 2             |
| **What kind of ecosystem services does soil inorganic carbon (SIC) provide?** |             |               |
| Regulating                                                     | 17          | 31            |
| Provisioning                                                   | 6           | 11            |
| Cultural                                                       | 0           | 0             |
| All types of ecosystem services                                | 32          | 58            |
| **What is total soil carbon (TSC)?**                           |             |               |
| Sum of SOC and SIC                                             | 55          | 100           |
| Liming material                                                | 0           | 0             |
| Carbonates                                                     | 0           | 0             |
| Soil reaction                                                  | 0           | 0             |
| **What kind of ecosystem services does total soil carbon (TSC) provide?** |             |               |
| Regulating                                                     | 13          | 24            |
| Provisioning                                                   | 2           | 4             |
| Cultural                                                       | 0           | 0             |
| All types of ecosystem services                                | 40          | 73            |
| **What method is used for valuing provisioning ecosystem services from soil inorganic carbon (SIC)?** |             |               |
| Social cost of carbon dioxide                                  | 28          | 51            |
| Willingness to pay                                             | 1           | 2             |
| Indirect use value                                             | 2           | 4             |
| Liming replacement cost                                        | 24          | 44            |

Note: Correct answers are indicated in bold.
Table 10. Post-assessment students’ comments about their experience with the laboratory exercise on soil ecosystem services based on soil pH and soil inorganic carbon (SIC) in the FNR 2040: Soil Information Systems course grouped by theme ([15]).

| Responses |
|-----------|
| **T1. Enjoyment of learning** |
| I liked looking at the pH of different horizons and correlating the type of pH that is corresponds with. |
| I like learning about the ES. |
| Everything was a good experience. |
| I enjoyed doing calculations to determine costs for provisioning and regulating. It was interesting to find out the cost. |
| I enjoyed seeing the different pHs at varying levels in my soil horizons. |
| I like the calculations on the social cost of carbon in the soil. |
| I enjoyed doing the calculations and seeing the real-world monetary value of the ES of my soil. |
| I enjoyed learning about the provisioning ecosystem service because lime is something we must often add here with the clay soil. |
| **T2. Value of multimedia** |
| I enjoyed the video. |
| I liked the thorough discussion of the lab exercise in the video. |
| Very helpful explanation video. |
| I enjoyed the video. |
| I liked the thorough discussion of the lab exercise in the video. |
| I enjoyed following along to the lectures with the PowerPoints to understand the breakdown of each concept. |
| **T3. Flexibility of learning** |
| Being able to complete each step in my own time. |
| Easy to follow along. |
| I enjoy the separate parts. |
| **T4. Applicability of content** |
| I like the calculations on the social cost of carbon in the soil. |
| I liked calculating the real-world values of my soil. |
| Finding out how much the soil is worth to us. |
| Using the calculations. |
| Learning about how pH affects soil. |
| Figuring out the cost. |
| Calculating monetary values. |
| Learning about the connections of SIC to the different ecosystem services. |
| Calculating the economic values of the services. |
| I thought using our own state soil table to determine the pH classes was interesting and seeing how acidic or alkaline our soil was. |
| Using our own soil series to calculate the values. |
| **T5. Criticism** |
| None. |
| I just got confused on what ecosystem services are provided by what. |
| Clearer instructions. |
| A lot of information all at once. |
| Directions are sometimes unclear. |
| I felt like there could have been a little better of an explanation between SIC and SOC. |
| Instructions were a bit unclear, but I was able to figure it out. |
| I don’t have a criticism; it was a good lab. |
| None, it was good. |
Figure 6. Word cloud based on the students’ comments about their experience with the laboratory exercise on soil ecosystem services (ES) in the FNR 2040: Soil Information Systems course based on soil pH and soil inorganic carbon (SIC). The larger the word in the word cloud, the more frequent the word is in the students’ comments.

4. Discussion

The results of this study demonstrate the importance of evaluating students’ prior interests when developing effective teaching methodologies. Most studies on interests ignore and do not evaluate students’ prior interest in a subject [6]. The implied assumption is that students are a “blank slate” independent of their prior education and life experiences. Mikhailova et al. (2019) [2] reported that students can have prior interests in subject matter, which can be used to create a wide range of effective interest interventions and learning experiences across the soil science course topics.

This study is different from Mikhailova et al. (2019) [2] because it is focused on using prior student interests in soil science to expand and make more relevant the “context of learning” (Figure 2) of a laboratory exercise on soil pH using ES/ED framework (Table 1). According to Kirk and MacDonald (1998) [16], context is formed by the learning environment and task. Jonâne (2009) [17] proposed the implementation of the contextual approach for promoting STEM sciences (Figure 7). The model of a didactical fractal can be used to improve STEM education [17]. This model offers a way to organize the educational process using its major categories (context, learner, content, and teacher) [17], which can also be used to discuss the findings of this study.

This study found that although a soil pH exercise is a typical component of an introductory soil science course, students come to the course with many similar previous experiences around measuring pH which can limit their interest in this topic. This study found that information about students’ prior interests can be very useful to identify a learning context to help engage the students in the learning process (Figure 7). Although prior interest varies, it is possible to assess interest types using open-ended questions as part of a beginning of course questionnaire. Student feedback can be grouped and quantified into categories that include interests most linked to it being a required course, prior experience, personal interest, and/or utility value (Figure 1) to find areas of commonality in student
interest. Furthermore, asking students about both their interests and prior knowledge can help inform multiple interest interventions.

![Diagram](image.png)

**Figure 7.** Didactical fractal and its application to this study with examples (in red) of ecosystem services/disservices (ES/ED) as a context (adapted from Jonāne (2009) [17]). Soil reaction (pH) and soil inorganic carbon (SIC) are used as content.

Development of interest has been linked to positive learning outcomes; however, it is important to consider students’ prior interests as well as the necessity to create student interest. A unique aspect of our exercise was that each student performed calculations for a different soil type that they had evaluated as part of an ongoing project, which may have also supported student interest while removing opportunities for sharing answers.

There are many studies on increasing students’ interests in STEM fields in middle school and high school to encourage students to select STEM career paths [6,18–20]. For example, LaForce et al. (2017) [19] evaluated survey responses from high school students attending STEM schools and found that problem-based learning experiences were linked to greater STEM career interest. Wyss et al. (2012) [20] found that showing middle school students video interviews of STEM professionals increased student interest in STEM fields. Shahali et al. (2017) [18] saw an increase in student interest for STEM subjects in students that participated in an informal STEM education program that included engineering design.

Studies on student interest in STEM fields in higher education are almost non-existent [2]. Research on interest development in high education STEM fields can seem paradoxical because STEM students have already selected a STEM major, which indicates a strong prior STEM interest. This may help explain the lack of research in this area. Teaching from the assumption that STEM students must have an inherent interest in their STEM fields does not necessarily imply that students actually have an interest in any particular STEM course or subject (especially required courses). This assumption ignores the wide range of experiences and interests that students may bring to a course, which is a lost opportunity to engage students at the beginning of a course to learn about their course-related interests and prior experiences. Therefore, this study argues that there is an opportunity to develop course content using these prior interests to create learning experiences. Better student engagement in STEM courses may help address the serious retention issue for STEM fields in higher education [21].
With so few studies on student interest in higher education STEM fields, this research provides a methodology for connecting students’ prior interest to interest intervention types (Figure 5) that can be used to develop exercises. This methodology can be applied to other STEM disciplines. Although this study used a specific course management system that is licensed at Clemson University (Canvas LMS) with a freely available survey system (Google Forms), the methodology could use a range of other systems which are often specific to educational institutions. This study shows that the assessment of the efficacy of a teaching innovation (e.g., a newly developed laboratory exercise) can be evaluated using various tools including quantitative (e.g., graded quiz) and qualitative (e.g., post-assessment survey) instruments.

5. Conclusions

This study discussed the need to connect students’ interests to a learning context to increase the effectiveness of STEM education. It used the results from a survey of students’ prior interests in soil science to expand the laboratory exercise on soil reaction (pH) with SIC and ES/ED concepts. Most of the students who had personal and utility value interests in soil science were interested in provisioning ES, which was used to create a problem-based interest intervention in the laboratory exercise on soil pH and SIC. Students were not familiar with the relationship between soil pH and SIC. The soil laboratory exercise involved learning about soil pH, SIC, calculating the provisioning (liming replacements costs), and regulating ES/ED (e.g., social costs of carbon, SC-CO$_2$) provided by SIC. The efficacy of this teaching innovation was evaluated using a pre- and post-testing web-based survey and quiz. An online quiz was used to assess students’ learning outcomes, which were successful for most of the questions. Students increased their knowledge of soil pH, SIC, and ES/ED, which can be helpful in their personal lives and professional careers. The results of the study were used to develop applied recommendations for utilizing prior knowledge of students’ interests in developing effective teaching interventions using various resources (e.g., interest theory; approaches to interest research; didactical fractal, etc.). This study proposes a new didactic form of teaching where students’ experiences and interests are accounted for by selecting and customizing learning exercises to make them more relevant and impactful for the students.

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Abbreviations

| Abbreviation | Description                  |
|--------------|------------------------------|
| DOI          | Department of Interior       |
| DOC          | Department of Commerce       |
| ES           | Ecosystem services           |
| ED           | Ecosystem disservices        |
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