MULTI-DISCIPLINARY, INTEGRATIVE APPROACH IN WETLAND DELINEATION TRAINING ENHANCED WITH GREENHOUSE GAS ASSESSMENTS

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Abstract

Using an expert-novice paradigm, an integrative-project-based approach was used to team-teach a Wetland Soils course during 2023 after having been taught by a sole instructor in a non-integrative approach in 2013, 2015, 2017, and 2019. The principles taught in 2023 were aimed to allow the students to develop a complete assessment of a potential wetland area through the evaluation of pedologic, hydrologic, botanical, biogeochemical and atmospheric data. At the end of each semester, course evaluations were administered. The ranked responses were used to determine if students' overall comprehension of the class taught during 2023, which combined integrative, problem-based techniques, greenhouse gas assessment, and biogeochmical and atmospheric cycles, was similar to the comprehension reports from the four previous years, which were taught without class enhancements. The majority of the course ratings did not differ ($p > 0.05$) among the five years considered in this study, confirming the idea that a more involved approach, even in presence of a heavier workload, did not negatively impact the students' ability to acquire knowledge from various related disciplines by synthesizing course material applied to a real-life issue. The end-of-the semester written reports indicated that integrative approach additionally challenged the students to improve writing, presentation, and teamwork skills, while also expanding their knowledge of collaborative processes.

Keywords: wetland delineation, integrative approach, multi-disciplinary

In an academic environment, the single-discipline approach to teach scientific subjects often provides a powerful tool to organize knowledge according to the principle of reductionism, where larger systems are divided into smaller elements in order to facilitate concept comprehension and assimilation (Stichweh, 2003). However, recent developments reported by the National Science Education Standards (NSES) highlighted how multi-disciplinary approaches in teaching scientific matters can enhance deductive thinking, critical reasoning, and can lead to greater academic achievements (You, 2017).

Within the interdisciplinary approach in research and education (IDRE) in academic environments, which often requires a high level of involvement among instructors specialized in different disciplines, many barriers have been identified, such as insufficient incentives and rewards for students and instructors, lack of cohesive frameworks, and lack of synergistic integration among scientific disciplines (Lin, 2008). However, funding agencies, such as the National Science Foundation (NSF), are progressively increasing demands for interdisciplinarity and multidisciplinary approaches that encompass not just different disciplines, but the involvement of different staff, equipment, and organizations (Lin, 2008). Multi-disciplinary methodologies in classrooms have been described as successful when a problem-based approach was implemented in contrast to theme-based approaches (Kotter and Balsiger, 1999). In problem-based research, the solution to the question being posed often cannot be achieved with the knowledge or skills developed and acquired from a single discipline (Kotter and Balsiger, 1999).

Developed to address predominantly agricultural matters, soil science, and the teaching of soil science today, represent a clear example of an interdisciplinary approach (Sharma and Aulakh, 2009). Universities in the United States (US) and Canada that include environmental issues in soil science programs have experienced increased enrollment, highlighting how students are reflecting more interest in interdisciplinary material (Sharma and Aulakh, 2009). However, in a survey conducted among soil science courses and curricula in the US, more than 50% of the methodological approach was delivered in a standard lecture format and only 20% was delivered by alternative methods, such as problem-based or active learning (Jelinski et al., 2019). The combination of interdisciplinary and problem-based approaches can represent a challenging, but effective solution to enhance students' skills and expand learning objectives in soil science curricula.

The Soil Science Society of America highlighted how employers expressed the concerning lack of written and verbal communication skills and field experience shown by students with a soil science education (Amador, 2019). The active-learning method aims to increase the employability of students, while enhancing critical thinking (Amador, 2019). Active collaboration from the students that participate in the collection and observation of scientific evidence creates a more attractive teaching method (Hasni and Potvin, 2015). Within the active-learning methodology, the problem-based approach creates experiences for students that go well beyond a standardized lecture, more closely resembling actual research activity and field experience (Neaman et al., 2021). The topic of wetland science offers the unique opportunity to integrate soil, water, atmospheric, social science and botany and apply a problem-based, active-learning methodology to enhance student learning of a complex, interdisciplinary subject.

Wetlands in Arkansas represent an important component of natural biomes and restorations and represent a fundamental environment for providing valuable ecosystem services (MEA, 2005). In the last several decades, major hydrologic alteration and agricultural expansion into wetland areas have occurred in the Mississippi Alluvial Valley (MAV), including eastern Arkansas and Louisiana and western Mississippi, which has resulted in large losses of wetland area (Jenkins et al., 2010). Consequently, socially and environmentally important ecosystem services have also been lost (Jenkins et al., 2010). To date, the US Army Corps of Engineers is acting to restore and utilize wetlands to prevent flood damage. Section 404 of the Clean Water Act recognized the importance of preserving and restoring wetland areas by establishing a regulatory process to delineate transitional zones and to mitigate the loss of existing wetland areas (i.e., swamps, marshes, bogs, and similar environments) to preserve, conserve, or re-establish the ecosystem services provided by transitional and riparian areas, such as wetlands (ANRC, 2012). However, wetland delineation requires specific, interdisciplinary knowledge and specialized skills to properly identify wetlands because of the subsequent potential political and economic ramifications of labeling an area as a wetland.

Due to the complex nature of and multitude of ecosystem services provided by wetlands (ANRC, 2012), delineating and assessing wetlands are tasks that can be accomplished only through the use of knowledge and skills attained through the combination of several scientific disciplines. Anaerobic, reducing soil conditions, hydrophytic vegetation and specific hydrologic factors are recognized wetland indicators often used in a delineation process. Monitoring seasonal water movement can help to evaluate the effectiveness of a monitoring and/or restoration program. The biogeochemical characteristics of a wetland can be assessed through the evaluation of greenhouse gas (GHG) emissions, particularly carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). Differential soil moisture levels affect the metabolic rate of the microbial community, enhancing and/or limiting CO2, CH4, and/or N2O production and release depending on fluctuating soil conditions (Della Lunga et al., 2021). Furthermore, in a wetland delineation, gas chromatographic analyses can facilitate the coupling of soil biogeochemistry with atmospheric science. While the assessment of factors regulating GHG can be approached through the lens of biogeochemistry, the byproducts of microbial activity directly influence and encompass atmospheric science. However, although theory and application are often included in chemistry curricula, gas chromatography principles and techniques are often not addressed in soil science or environmental science majors (Giarikos et al., 2013). Gas chromatography, the knowledge of which is often requested by various industrial sectors, was recognized as a fundamental tool in Science, Technology, Engineering and Mathematics (STEM) majors (Griffin et al., 2024).

The challenge of conveying the necessary knowledge and teaching the required observational skills to delineate and study wetlands arise from the multi-disciplinary nature of wetland science itself. Therefore, the objective of this study was to evaluate an innovative, integrative, problem-based, multi-disciplinary approach as a teaching tool for wetland science aimed to enhance field skills and competences of undergraduate and graduate students. At the beginning of the semester, students in a combined upper-level undergraduate/graduate-level Wetland Soils course were tasked to evaluate an assigned study area and determine if a wetland was present. It was hypothesized that the inclusion of tools, such as gas chromatography, not typically part of soil science curricula for field assessment of GHG emissions, and complimentary field monitoring instrumentation would enhance student learning and competencies. It was also hypothesized the inclusion of additional novelty topics in the Wetland Soils class would not decrease end-of-the-semester student ratings for the course as obtained in the years when novelty topics were not taught.

Methods

Following the principles of problem-based, active learning approach, a combined upper-level undergraduate/graduate-level Wetland Soils course (CSES 4553/5553) has been a part of the Environmental, Soil, and Water Science (ESWS) undergraduate Bachelor of Science degree program at the University of Arkansas. The ESWS major/program, in general, was developed with a multi-disciplinary vision to include courses in areas such as environmental science, soil science, water science, and the sustainable management of natural resources.

The Wetland Soils course was developed and taught by a sole instructor in 2013 as a mixed lecture-field laboratory class. The class met once per week for 3 hours. The planned learning outcomes included i) understand, identify, and explain the physical and chemical characteristics of wetland (i.e., hydric) soils, ii) understand and explain the principles of wetland delineation, restoration, and mitigation, and iii) identify wetland characteristics in the field and delineate wetland boundaries. The sites used for wetland delineation during the semesters were different, but all possessed similar characteristics. All sites used during the years were located in a position adjacent to a body of water (i.e., stream, creek, or riverbank) where terrestrial and aquatic environments intersect. Sites were divided in sections assigned to groups of four or five students and always encompassed an area greater than ~ 1000 m2 per section.

The principles taught were aimed to allow the students to develop a complete assessment of a potential wetland area through the evaluation of pedologic, hydrologic, and botanical principles and data, combined with biogeochemical, hydrodynamics and statistical methods and approaches.

The necessary background pedologic material included techniques of identification, description of soil profiles, and collection and preparation of soil samples at different depths according to the soil profile description developed by the students. A lecture addressing techniques and elements to consider while describing soil profiles preceded field activities putting classroom material into practice. Additionally nutrient cycles and related biogeochemical processes were discussed. In the field, students worked in small groups to describe the soil profile within the boundary of a sub-section of a study area using the Munsell soil color book, hand-texturing methods, and visual descriptions of pedogenic properties and horizons. Students were supervised by the instructor in the field but were left free to choose observation locations and replications.

Necessary background hydrologic material was covered in lecture prior to conducting field activities. Field activities included the installation of 2-m-deep monitoring wells and 30-cm-deep piezometers for continuous monitoring of water depth and soil saturation levels in the study area. Students installed three wells and three piezometers within each sub-section of the study area following procedures described by the Corps of Engineers Wetlands Delineation Manual (US Army Corps of Engineering, 1987). Students directly installed the hydrologic monitoring equipment and decided on the sampling strategy. Sampling strategies included piezometers and wells installed along an imaginary line parallel (i.e., transect) or perpendicular (i.e., transect) to the predominant slope of the subsection or installed in triangular arrangement (i.e., triangulation). Hydrologic data, such as the water level in the piezometers and depth of water table in the monitoring wells, were measured on a weekly basis for the entirety of the semester (16 weeks). Each student was tasked with visually identifying, describing, and classifying primary and secondary hydrologic indicators that may be present at the study site, such as drift deposits, water marks, water-stained leaves, and sediments, on a weekly basis. Results of the hydrologic assessments were combined with the pedologic assessments to address the concepts of drainage classes, hydric soils, and redoximorphic features.

The necessary background material for the botanical components of the class was covered in the field under the guidance of the instructors throughout the semester. More relevance was given to the characteristic of hydrophytic vegetation and the system of classification developed by the U.S. Army Corps of Engineers and catalogued in the National Wetland Plant List where indicator species are listed by region. Visual guides and material were made available to the student to easily recognize botanical species within the study area. At the end of the semester, student groups, commonly formed by four or five students led by a graduate or senior undergraduate student, prepared a written report, including graphical and/or tabular representations of collected data, and gave an oral presentation substantiating whether an actual wetland was present in their sub-section of the study area. The class was taught again in 2015, 2017, and 2019 based on the aforementioned procedures, with an enrollment that ranged from 20 students in 2017 to 25 students in 2015 (Table 2).

In 2023 the class was expanded to include soil oxidation-reduction (i.e., redox) potential monitoring, microbially mediated gas emissions concepts and data collection. Soil property assessments in the field to complement and extend the prior pedologic, hydrologic, and botanical components of the classroom lecture material and field activities were added. New teaching methods involved the integration of interactive lectures among three instructors instead of one, group discussions, classroom laboratory activities, and new field procedures. At the beginning of the 2023 semester, students enrolled in the Wetland Soils class were divided into five groups. Each group, led by a graduate or undergraduate senior student, was assigned a section of ~ 1800 m2 on a floodplain adjacent to a channelized stream to address one simple question: Is the area a wetland?

Lecture Format

Enrolled students possessed a general background in soil science, but no specific skill or experience in wetland delineation protocols. No immediate path was provided to the students to reach a conclusion to the open question posed at the start of the semester. A series of procedures were taught in lecture on how to collect and assess soil, hydrologic, botanical, environmental, and atmospheric properties. Each formal lecture was characterized by a group activity aimed to reinforce the concept explained the very same day. Interactive quizzes, worksheets, hands-on lab activities, and field practices were used to incentivize learning outcomes for each specific section of the course. Particular emphasis was placed on the atmospheric section, which was new for the 2023 course compared to the previous semesters, where analysis and interpretation of GHG emissions was introduced. Students possessed no previous experience in gas chromatography. Principles of gas behavior in the soil, gas diffusion in the atmosphere along with sample preparation, gas sampling procedures and gas chromatography analyses were introduced as lecture and field practices.

Field Work

The study area used for the 2023 class field component was located at the University of Arkansas Division of Agriculture, Milo J. Shult Agricultural Research & Extension Center in Fayetteville, AR, on a floodplain adjacent to a channelized creek. The study area extended ~ 300 m in the east-west direction, was gently sloping downward to the west with a gradient between 0 and 1%, and extended about 30 m to the south, perpendicular to the creek channel. The soil within the study area was mapped as a Leaf silt loam series (USDA-NRCS, 2019, 2014), a very deep, poorly drained, very slowly permeable Albaquult (USDA-NRCS, 2019).

Following one class lecture related to microbial and pedologic interactions in wetlands areas, students were guided in the installation of 30-cm-diameter, plastic base collars used to collect gas samples over a period of 1 hour at the 0, 20, 40, and 60 minute marks (Parkin and Venterea, 2010). Gas samples were analyzed by one of the instructors within 48 hours of collection by gas chromatography for carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). Students were guided on the installation of one soil redox sensor, one thermocouple recording soil redox potential hourly, and soil temperature hourly for the duration of field activities. Students participated in the collection of gas samples, gas analysis, and data manipulations to obtain hourly gas fluxes (Della Lunga et al., 2021). Students collected soil samples were processed and analyzed for various soil properties, including soil pH, electrical conductivity, soil organic matter, total C, total nitrogen, and extractable nutrient (i.e., phosphorus, potassium, iron, manganese, sodium, and zinc) concentrations (Tucker, 1992; Nelson and Sommers, 1996).

In all semesters, student groups prepared a written report of measured data and gave oral presentation substantiating whether a wetland was present in their sub-section. Each group was free to use any combination of data collected during the semester from their sub-section of the study area. The group project (i.e., final written report plus oral presentation) represented 40% of the students' final grade, highlighting the problem-based, multi-disciplinary group activity.

Course Evaluations

At the end of each semester, course evaluations were administered. Students anonymously assigned numeric 1 to 5 ratings (i.e., 1 as "strongly disagree", 2 as "disagree", 3 as "undecided", 4 as "agree", and 5 as "strongly agree") associated with specific institution-determined questions. Students provided written feedback about the class in open-response comments. The ranked responses were used to determine if students' overall satisfaction and comprehension of the 2023 curriculum was similar to the evaluations from four previous years taught without the addition of atmospheric science and greenhouse gas analyses. Six of 14 institutionally determined core questions consistent across all semesters and years were selected for analysis (Table 1). Responses from 2021 were not considered in the current study, as the class was taught online in accordance with University policies during the COVID pandemic.

Table 1

Selected core questions consistently posted as part of the online course evaluation to students enrolled in Wetland Soils during the 2013, 2015, 2017, 2019, and 2023 years at the University of Arkansas.

Core Question	Question
1	The teaching methods used in this course enable me to learn?
2	Meaningful feedback on test and other work is provided?
3	The content of this course is consistent with the objective of the course?
4	This course builds understanding of concepts and princples?
5	This course effectively challenges me to think?
6	This course gives me an excellent background for further study?

Statistical Analyses

Students' numeric responses to the questions were anonymous, voluntary, and based on a Likert scale. All responses from all years were included in the analysis. A frequency table for selected questions for each year was created to determine the distribution of five response categories (i.e., 1 as "strongly disagree", 2 as "disagree", 3 as "undecided", 4 as "agree", and 5 as "strongly agree") across questions and years.

Due to the ordinal nature of the data, the non-parametric Kruskal-Wallis test was performed in R (version 4.3.2, R Foundation for Statistical Computing, Vienna, Austria) to statistically compare scores of each individual question. Additionally, using a Kruskal-Wallis test, the scores of each individual question from the year when the class was taught with an integrative/enhanced approach (i.e., 2023) were statistically compared with the score of the same question from all other years (i.e., 2013, 2015, 2017, and 2019) grouped together [i.e., standard sole-instructional approach]. The interaction effect between years and approach was not considered in the current study due to the inability of the Kruskal-Wallis test to address multiple fixed factors and due to the single replication of the integrative approach teaching method.

Fixed factors in this study were “year” (i.e., 2013, 2015, 2017, 2019, and 2023) and approach (i.e., standard sole instructional for 2013, 2015, 2017 and 2019 and integrative/enhanced for 2023). When a significant difference was identified for a fixed factor, a Dunn test was performed in R to evaluate the pairwise multiple comparison among levels of the significant fixed factors. Significance was judged at the 0.05 level. Content and concept analyses (Neumann et al., 2010; Stephen and Margolis, 2007) were performed on students’ individual, end-of-the-semester written project reports to summarize which datasets and what type of statistical approaches were included in the decision process to answer the problem-based assignment. Concept analysis was also used to highlight how evidence from the different data types were combined and assessed in the end-of-the-semester written project reports. Concept analysis simply refers to the breakdown of complex ideas into smaller and easier to comprehend sections, in order to clarify the meaning and use of the constituent parts within the overall objective (Neumann et al., 2010; Stephen and Margolis, 2007).

Results and Discussion

The result of the current study are not meant to be considered applicable to all curricula but are intended to provide useful tool and elements to help the scientific teaching to progress toward a multi-disciplinary approach. The course evaluation at the end of each semester was used as a guiding tool to assess the overall perception of the new teaching methodology adopted during 2023 compared to the previous several years. The six questions extracted from the online course evaluation investigated the students’ assessment of course content and material application (Table 1), which allowed for the comparison with previous years when the teaching approach differed and the GHG analysis was not included. Results of the current study provided important inputs to potentially develop a guideline to improve and expand the idea that an integrative approach can be used effectively in a combined, upper-level, undergraduate and graduate class. Therefore, outcomes and results from the analysis conducted in the present study were not considered definitive, but mostly preliminary indications to better re-direct the effort in the effective development of a multi-disciplinary curriculum.

Student enrollment among the five years was generally consistent (Table 2). Course evaluation responses varied across years, with 45% of enrolled students providing answers to the course evaluation in 2013 and 2017, 36% in 2015, 42% in 2019, and 80% in 2023 (Table 2). The different student response rates over the years represents a possible confounding factor.

During the five years considered in the current study, 0% of the students answered any of the six questions with a numeric response of 1 (i.e., strongly disagree). In all five years, the majority of students’ responses resided in one of the two largest ranks (i.e., 5, strongly agree or 4, agree, Table 2).

The sample size for the five years was substantially different with a skewed distribution of ratings in each year (Table 2). The Kruskal-Wallis non-parametric test was selected to account for potential deviations from the necessary assumptions for analysis of variance (Nwobi and Akanno, 2021). The Kruskal-Wallis test, the non-parametric equivalent of the one-way analysis of variance for ordinal data, showed that only questions 1 and 6 (Table 1) significantly differed ($p < 0.05$) by year and by approach (Table 3).

The effect size, calculated as eta (η) squared, showed a large and small effect for year and approach, respectively, for question 1 and a moderate effect for both year and approach for question 6 (Table 3). Effect-size results suggests that there was a clear divergence (i.e., moderate effect size) among years and between approaches in the perception of the course material as a valid background for further studies (question 6) and a substantial difference (i.e., large effect size) among years in the ability of the students to learn the course subjects (question 1) (Table 3). The effect-size results also highlighted the partial relevance of the significant difference between approaches (Table 3), reinforcing the concept that multi-disciplinary and integrative approaches in academic settings represent at least a perceivable variation from the more common teaching methodologies adopted in the classroom, as occurred in the previous four years of the Wetland Soils course being taught.

Table 2

Summary of class enrollment, number of respondents, and frequency table for the numeric responses to the selected core questions as part of the online course evaluation from students enrolled in Wetlands Soil during the 2013, 2015, 2017, 2019, and 2023 years at the University of Arkansas. The grading scale was defined as strongly agree (5), agree (4), undecided (3), disagree (2), and strongly disagree (1).

Year	Class Enrollment	Number of Respondents	Core Question	Grading Scale				
				5	4	3	2	1
2013	22	10	1	8	2	0	0	0
			2	8	2	0	0	0
			3	7	2	1	0	0
			4	7	3	0	0	0
			5	7	3	0	0	0
			6	8	2	0	0	0
2015	25	9	1	6	3	0	0	0
			2	5	3	1	0	0
			3	6	3	0	0	0
			4	5	4	0	0	0
			5	5	4	0	0	0
			6	6	3	0	0	0
2017	20	9	1	2	6	1	0	0
			2	3	4	2	0	0
			3	4	4	1	0	0
			4	4	4	1	0	0
			5	6	2	1	0	0
			6	5	4	0	0	0
2019	24	10	1	2	4	2	2	0
			2	3	3	3	1	0
			3	3	5	0	2	0
			4	4	3	2	1	0
			5	4	5	0	1	0
			6	4	3	2	1	0
2023	25	20	1	4	11	3	2	0
			2	6	11	2	1	0
			3	6	11	2	1	0
			4	6	11	2	1	0
			5	7	12	1	0	0
			6	7	6	6	1	0

Table 3

Summary of Kruskal-Wallis test and effect size on the effect of year and approach on the selected core questions as part of the online course evaluation posed to students enrolled in Wetland Soils during the 2013, 2015, 2017, 2019, and 2023 years at the University of Arkansas.

Core Question	Source of Variation		Effect Size - Year	Effect Size - Approach
	Year	Approach		
	p			
1	**< 0.01†**	**0.04**	0.241	0.055
2	0.06	0.31	-	-
3	0.14	0.14	-	-
4	0.19	0.12	-	-
5	0.33	0.13	-	-
6	**0.04†**	**0.02**	0.109	0.076

† Bold values are significant at the 0.05 level

The pairwise multiple comparison results, however, indicated that the last three years (i.e., 2017, 2019, and 2023) did not differ ($p > 0.05$) in terms of student ratings for both questions 1 and 6 (Table 4). In contrast, the 2013 and 2015 years had different ($p < 0.05$) ratings for both questions compared to the 2023 ratings (Table 4). Similarly, ratings differed ($p < 0.05$) between the 2013 and 2019 years for both questions 1 and 6, and differed between 2013 and 2017 and between 2015 and 2019 for question 1 (Table 4). Mean ratings among years suggest generally decreasing rating trends for both questions 1 and 6 (Figure 1). It is important to highlight that a mean of ordinal values in a rating scale does not carry mathematical meaning, as the actual distance between ratings cannot be expressed in numeric terms (Verhulst and Neale, 2021). However, the graphical representation of means of ordinal values can facilitate the interpretation of the statistical results. The ratings for questions 1 and 6 in 2023 were significantly ($p < 0.05$) lower than in 2013 and 2015, with the largest average rating reported in 2013 and the lowest in 2019 (Figure 1). Differences between 2023 and early years of the class are not necessarily attributable to the introduction of new teaching practices and might instead represent a different factor that changed over the years (Figure 1).

Despite the increased workload and the added section on GHG, the ratings for questions 1 and 6 did not differ ($p > 0.05$) from the ratings in 2017 and 2019, suggesting that students' perception of the teaching methods and the overall class material were in the upper portion of the Likert scale for the standard sole instructional and for the multi-disciplinary approach (Figure 1). However, when grouped together, the years under the standard sole instructional approach had significantly ($p < 0.05$) greater ratings for questions 1 and 6 compared to the integrative approach used in 2023 (Table 3). The majority of the course ratings did not differ ($p > 0.05$) among the five years considered in the current study, as hypothesized. Results of the current study, although preliminary and limited by different students providing the ratings each year, suggest that,even in the presence of aheavier workload, did not negatively impact the students' ability to acquire, synthesize, and apply knowledge from various disciplines in the pursuit of a real-life issue was not susbtantially impacted.

Table 4

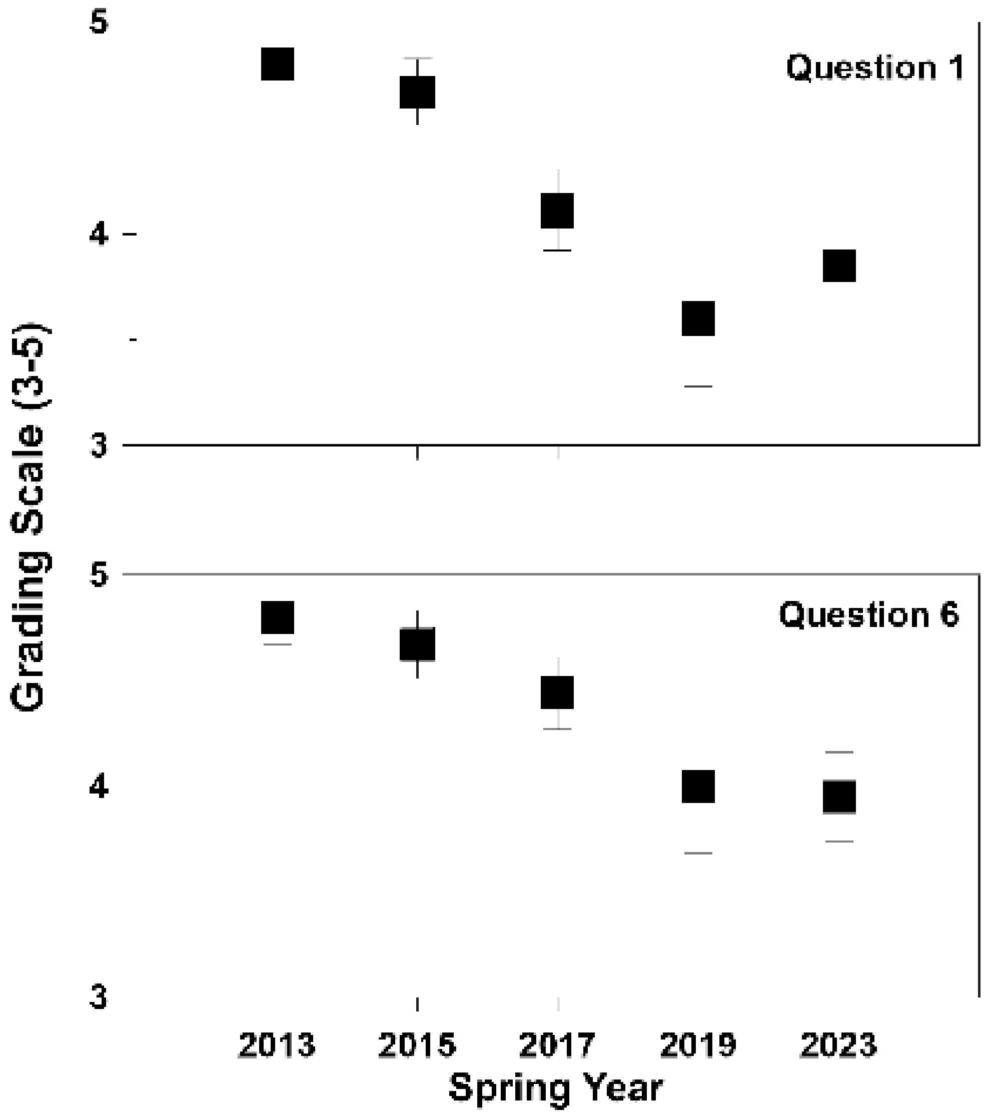
Summary of Dunn pairwise multiple comparison among years (i.e., 2013, 2015, 2017, 2019, 2023) for the core questions 1 and 6 posed as part of the online course evaluation to students enrolled in Wetlands Soil during the 2013, 2015, 2017, 2019, and 2023 years at the University of Arkansas.

Contrast		Core Question	
Group 1	Group 2	1	6
		p	
2013	2015	0.65	0.65
2013	2017	**0.03†**	0.41
2013	2019	**< 0.01**	**0.04**
2013	2023	**< 0.01**	**0.01**
2015	2017	0.10	0.71
2015	2019	**< 0.01**	0.13
2015	2023	**0.01**	**0.04**
2017	2019	0.39	0.25
2017	2023	0.60	0.11
2019	2023	0.63	0.79

† Bold values are significant at the 0.05 level

Figure 1

Means and standards errors for core questions 1 and 6 posted as part of the online course evaluation to students enrolled in Wetlands Soils during the 2013, 2015, 2017, 2019, and 2023 years at the University of Arkansas. the y-axes depict a portion (i.e., 3 to 5) of the full grading scale (i.e., 1 to 5).



When a difference was observed, results indicated a slightly more negative outcome for the integrative than for the standard sole instructional approach, suggesting that additional work and organization is required to refine the integrative approach and smoothly transition from the standard sole instructional teaching method. The contextualization of inter-disciplinary subjects represents a considerable challenge in classroom settings (Yang, 2009), although appropriate learning outcomes and effective integrative approach should be cultivated and implemented into the curriculum of science-based academic programs (Yang, 2009).

Evaluation of Written Reports

Concept analyses applied to the final written reports each student prepared at the end of the semester showed a wide spectrum of technical approaches, connecting biogeochemical processes related to microbial activity and atmospheric science prinicples to a various array of scientific dicipines. The analyses and data presentation tools adopted by the students highlighted the importance of a teaching method that allows flexibility and room for critical thinking. The five student groups showed substantially different approaches in the attempt to identify and delineate potential wetland areas within the boundary of the study areas assigned to them. Additionally, within each group, students utilized a unique, logical path to reach a conclusion that was clearly achieved as a collective, group effort. Only the members of one group individually reported different conclusions regarding the delineation of the wetland, where some students in the group identified wetland area while other students in the group considered the information analyzed not sufficient for an informed decision.

Across all the groups, almost 50% of the students started the written report assessing the type of vegetation within the assigned study area; and 30% of all students presented and described the GHG emissions data as concluding evidence for the presence or absence of wetland characteristics. More than 95% of the students used GHGs data toward the wetland delineation process, although data were presented in a variety of different ways. Almost 70% of the students used time trends in graphical form to depict the GHG data collected over the course of the semester, while 25% opted for a tabular format with values interpolated between sample dates. The majority (i.e., 56%) of students that included a GHG analysis in the written report indicated an increase in CH4 production as evidence of anaerobic conditions that were reached and maintained for a period of at least two weeks due to a shallow water table and saturated soil conditions, which are known characteristics necessary for determining the presence of hydric soils that represents one of the main components of wetlands (Vepraskas, 1994). The remaining portion of the students evaluated the suppression of CO2 production over time as an indication of a reduction in soil respiration processes commonly observed in soil profiles with water contents close to or at saturation (Della Lunga et al., 2020).

In the results and discussion section of the written reports, 20% of the students paired CH4 with soil oxidation-reduction potential to reinforce the aerobic or anaerobic conditions of the topsoil in the study areas, while 15% of the class focused on the GHG fluxes and soil properties that addressed the pools of nutrients as main drivers of microbial activity. Students used a variety of tools to characterize the study area assigned to them, including Web Soil Survey, United States Geological Survey maps, National Wetland Inventory Database, and Google Earth. Data analyses and graphical representation of the results were carried out using different software, such as R-studio (version 4.3.2, R Foundation for Statistical Computing, Vienna, Austria) Grapher (version 11, Golden Software, Golden, Colorado), and Excel (Microsoft Corporation, Redmond, Washington). The multitude of approaches and variety of logical paths adopted by the students to answer the open question posed at the beginning of the semester likely represented the greatest success the integrative approach had with the students. Although more work will be necessary to improve the integrative approach in order to enhance efficiency with the teaching methodology, instructor and student experiences in 2023 encourage further efforts to promote an integrative and multi-disciplinary way of teaching science. Specific assignments tailored to GHG assessment and the early introduction in class to the type of data students are going to handle during the semester, represent two clear directions the instructors felt the need to address for future years. While the quality of teaching goes side by side with experience, instructors also recognized the necessity to create more evident links between topics and disciplines in the lecture while providing at the same time clear expectations for the field work.

Summary

A team of three professors and one post-doctoral fellow created an integrative, innovative, problem-based approach to teach Wetland Soils during the 2023 year, with the long-term goal to apply the multi-disciplinary initiative outlined by the NSF and IDRE programs. The curriculum involved the delineation of study areas as potential wetlands using specific skills in soil science, hydrology, botany, and atmospheric science. The integrative approach provided new and beneficial scientific skills for students to apply and develop critical thinking related to a real-scenarios that environmental and soil scientists might face in the line of work.

Through the evaluation of selected questions in the online course evaluation, the students' perception of the new integrative method did not result in a negative outcome compared to four previous years when the class was taught using the standard sole instructional approach. The intense workload and field experience with the integrative approach was evaluated positively by students, as evidenced by the high frequency of highly ranked responses in the course evaluations. Individual written reports students prepared at the end of the semester showed a variety of different approaches, analyses, and connections among the different datasets that highlighted the potentials of the integrative teaching method as a tool that not only contributes to improved critical thinking, but also exposes students to addressing real-life, meaningful issues (i.e., wetland delineation). The integrative, multi-disciplinary approach challenged students to build teamwork, improve writing and presentation skills, and expand their knowledge of collaborative processes. Although much more work is needed to establish a well-developed transition from standard sole instructional to the integrative approach, results of the current study provided essential information that allowed the team of instructors to assess proper next directions and areas to improve to further enhance the students' learning environment.

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