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Helping Future Schoolteachers Discover and Teach Soil: An Example of Project-Based Learning

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In addition to fundamental knowledge, the teaching provided at primary school develop children's perceptions of the world, particularly that of the effects of human activities on the environment. However, despite its importance in these issues, soil is virtually absent from school curricula, and even more so from the training of future schoolteachers. In order to provide knowledge about soil and its crucial role in the challenges facing humanity, an educational project has been developed at the University of Lorraine for students on the multidisciplinary bachelor's degree in teaching course during the past 5 years. Over fifty students follow traditional soil science courses and then use their knowledge in an active-learning setting. Within the framework of a project-based learning, they organize and carry out an activity session focusing on soil in a class of elementary school pupils, which is a kind of practice for their future teaching careers. The students follow the different stage in building their project. They design their workshop around a soil-linked theme of their choice, respecting the curriculum expectations. They establish a scientific approach to the chosen question and draw up the timetable for their activity, specifying the learning objectives and the resources to be used. They then carry out their activity session with a class at a partner school. The project is assessed on the basis of the students' concrete achievements, as well as their effective analysis of their work. This type of project-based teaching engages students because it gives them the opportunity to take ownership of the discipline through the production of a tangible output. Building and then carrying out the activity session helps to develop students' independence, creativity, and teamwork while at the same time imposing a framework that they must respect. It also enabled them to create a good quality animation, even though for most of them this was their first introduction to the subject of soils.

Keywords: project-based learning, primary school, teaching soil science, undergraduate student, future schoolteacher

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INTRODUCTION

The main objective of primary education is to provide a common foundation of fundamental knowledge and skills. These skills, like reading and writing, should enable pupils to master the language needed for reflection and communication. Likewise, science teaching develops their capacity for reasoning and practice of the investigative approach. At the end of this learning process, pupils should be in a position to continue their studies, consolidating their knowledge and building their personal, professional, and civic futures.

In France, science teaching in "cycle 3" primary schools (corresponding to fourth and fifth grade, i.e., children between 9 and 10 years old) aims to give pupils the initial scientific and technical culture they need to understand the world and the major challenges facing humanity. A significant proportion of these programs is devoted to the environment: pupils are encouraged to use their knowledge to explain the impact of human activity on health and the environment, and they are made aware of the issues of climate change, biodiversity, and sustainable development.

Although the soil is of central importance in these environmental issues, it is mentioned in cycle 3 guidelines only twice; once in terms of resources, i.e., “Reasonable exploitation and use of resources (water, oil, coal, minerals, biodiversity, soils, wood, rocks for construction purposes, etc.)”; and once in terms of support, i.e., “Observe and describe the soil stand; follow its evolution over the seasons”. Similarly, the links between the various scientific themes covered (biodiversity, origin of food consumed, needs of chlorophyll organisms, decomposers, landscapes, etc.) and soil are numerous, but they are not specifically addressed as the subjects of dedicated teaching. Furthermore, soil science is potentially relevant—but absent from—the plastic arts curriculum (modelling; quality of materials; pigments) and geography (characterizing spaces and their functions; meeting energy, water and food needs), for example[1].

Clearly, the teaching of soil science should be integrated into elementary school curricula to increase pupils’ awareness of the links between people and soil, and thus raise their awareness of major soil-related issues (Brevik et al., 2022a). Indeed, the link between soils and ecosystem services has been the subject of much research (Adhikari and Hartemink, 2016), but despite their essential place in the environment, soils are still poorly understood by the public (Field et al., 2020). It is therefore crucial to raise people’s awareness of soil as a fragile part of our environment and the importance of taking care of it (Field et al., 2020). This is one of the goals of the EU Mission “A Soil Deal for Europe,” leading to a transition towards healthy soils by 2030 and raising people’s awareness of their vital importance. This is also part of Sustainable Development Goal 4 “Quality education,” in which raising awareness of soil, its existence, uniqueness and multiple connections with other ecosystem components is crucial (Lal et al., 2021). To make tomorrow’s citizens aware of the importance of soils, without turning them into specialists, it is necessary to teach about soils from school onwards (Brevik et al., 2022a).

To raise schoolchildren’s awareness of soil, it is first necessary to train their teachers. In a study reviewing the integration of environmental issues in primary and secondary education worldwide, over a third of survey respondent indicated that teacher training programs did not include any environment-related content (Unesco, 2021). For those benefiting from such training, the topics covered did not explicitly mention soil, except in context of land protection. As a result, for students intending to become school teachers, the subject is virtually absent from their syllabus: most have no notion of soil and its importance, and they do not see this knowledge as useful for their future profession. It is therefore essential to help students who intend to teach (notably at primary level) to become aware of and familiar with soils, through training that will enable them to teach the basics of soil science with confidence (Brevik et al., 2022b). The use of active teaching methods can be a good way of training these students, who are initially unmotivated by this discipline. In addition, for this type of teaching limited to an introduction to soil science, methods integrating content learning with problem-solving skills proved effective in terms of student engagement (Amador and Görres, 2004). With the development of the Internet and access to a multitude of information, and with the rapid evolution of concepts in the environmental sciences, it is no longer sufficient to simply have students memorize lectures; it is more efficient to teach them how to search for relevant information (Dahms et al., 2020). Furthermore, this work of evaluating and synthesizing the information gathered, and then transmitting it to a public of pupils, is the basis for the future employment of students intending to become school teachers. Throughout history, from Socrates to Montessori, pedagogues have been interested in active teaching methods, but these methods only really became established in higher education with the massive rise in student numbers in the 1960s, necessitating alternative training methods (De Graaff and Kolmos, 2007).

Project-based learning is a student-centered approach that requires students to produce a result, and it takes place at the end of a course when students have acquired sufficient knowledge to undertake a project (Savin-Baden, 2007). Though the realization of an end product is the driving force in such collaborative project work, the success of this approach lies in the knowledge and skills developed throughout the process according to Donnelly and Fitzmaurice (2005). De Graaf and Kolmos (2003) identify three types of project work in order of increasing degree of freedom left to students: the task project with a very high degree of planning and direction by the teacher, the discipline project where disciplines and methods are chosen in advance, the problem project in which the plan of action is not planned in detail by the teacher. This technique of project-based work enables significant achievements, as students are able to find new and original solutions, then apply them to real-life practice, without outside help (Alacapınar, 2008). To succeed with a project-based approach, Kokotsaki et al. (2016) recommend the adoption of the following six points: student support, teacher support, effective group work, balance between didactic instruction with independent inquiry method, assessment emphasis on reflection, self and peer evaluation and student choice and autonomy. Almulla (2020) and Guo et al. (2020) propose encouraging teachers in higher education to implement project-based pedagogy as it engages students in learning and promotes their capacity for innovation through a process of active construction of their knowledge. To achieve this, teachers need to change their role from presenting information as lectures to acting as facilitators, learning guides and coaches (Donnelly and Fitzmaurice, 2005; Özel, 2013). Although this type of pedagogy is attractive to teachers, they are often helpless when faced with this change of role and organization, and are often content to implement active learning methods intuitively. To support teachers in following project-based learning principles

[1]https://www.education.gouv.fr/bo/20/Hebdo31/MENE2018714A.htm

and acquiring their new role, García Martín and Pérez Martínez (2017) have developed a guide for designing activities detailing the phases of definition (objectives, context, resources etc.), support (weaknesses and strengths of students, supporting etc.) and organization (activities, scheduling).

The aim of the present study was to introduce future school teachers to the subject of soil, to fill the gap left by the absence of this discipline in teacher training programs, and despite soil being of crucial interest in environmental issues. For this purpose, an active teaching method was implemented with students intending to teach in primary schools. The aim of creating a concrete project around the theme of soil was firstly to help them acquire knowledge in this area, but also to interest them in this relatively unknown discipline so that they could integrate it into their future teaching. This project-based learning approach in addition aims to develop cross-disciplinary and professional skills that will be useful for their future teaching careers. Lastly, presenting their project in front of a real class (with its current teacher) helps to "bring soil" into the school and may help raise people's awareness of soil issues.

PROFILE OF STUDENTS INVOLVED IN THE PROJECT

Students intending to teach in primary schools (kindergarten and elementary) are required to pass a competitive examination to become a school teacher. The best way to take this exam is to enroll in a Master's degree in Teaching, Education and Training (TET), offered by the French national institutes of higher education. This Master's degree is available in a variety of specializations, and can be accessed after obtaining a bachelor's degree. To enter the "first degree" stream of the TET Master's program and prepare for teaching in primary school, it is necessary to have completed a Bachelor's degree in any subject, although it is advisable to choose a subject taught in primary schools (French, mathematics, science, history, etc.). As there are no soil science courses in Master's programs, future teachers need to be introduced to this discipline during their preparatory studies at Bachelor's level.

Many universities offer a preparatory course for the teaching profession within the framework of various Bachelor's degrees. This is the case at the University of Lorraine, which offers a multidisciplinary teacher training program linked to several science-related Bachelor's degrees: mathematics, physics, chemistry, life sciences, and Earth sciences. The program takes place in the 3rd year of a Bachelor's degree, and it is open to students from 2nd year scientific courses. Since it opened in September 2018 on the Metz site (University of Lorraine), this course has welcomed over fifty students from a variety of 2nd year backgrounds (**Figure 1**), all of whom participated in the project presented in this study. This course therefore has a fairly heterogeneous student body in terms of areas of scientific knowledge, with around two thirds of students not having studied life and Earth sciences since high school, and who therefore have no knowledge of soil science when they enter the multidisciplinary Bachelor's degree in teaching. This heterogeneity can also be used to develop students' interest in soil science through its sub-disciplines (soil chemistry, soil physics, etc., Churchman (2010)) with which they can identify.

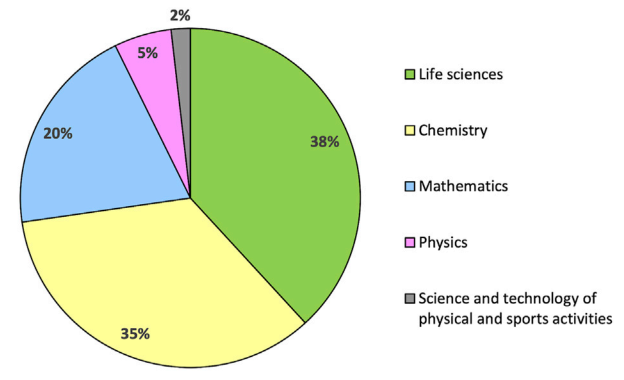

FIGURE 1 | Origin (Bachelor's degree, 2nd year) of students (*n* = 55) in the multidisciplinary Bachelor's degree in school teaching.

The program of this training includes courses preparing for entry into the TET Master's degree with a strong scientific focus, including a 55-hour life and Earth science course each semester (details of the program are provided in the **Supplementary Material**). In the first semester, the basics of geology and biology necessary for future science teaching are covered. These lessons are also an opportunity to make a link with soil sciences (types of rocks, plant needs, notions of ecosystems, etc.). In the second semester, additional lessons in Earth sciences are devoted to soil sciences (25 h). Given that the number of hours allocated to this teaching is relatively limited, it is difficult to provide students a solid grounding in soil science over such a short period. In addition, it should be remembered that these students are not destined to pursue studies in this field, and that soil science is not, for the moment, on the TET Master's program. It therefore seemed appropriate to provide a basic knowledge of soils by means of project-based learning in order to use the available time volume efficiently and to mobilize students on a subject that many have never approached and that they will probably never study again. For this type of introductory soil science course, project-based learning is a viable alternative to more classical methods (Amador and Görres, 2004).

USING PROJECT-BASED LEARNING

Project Framework

Students are tasked with creating an activity session for primary school pupils, with the aim of introducing them to the major issues related to soil. The choice of the type of activity (video, exercises, classic course) is entirely free in order to develop the creativity of the student and reinforce their motivation. The classes concerned have always been double classes, in 4th and 5th grade (corresponding to children aged 9–10), with an average of around twenty pupils per class. Certain constraints are imposed, such as the duration of the activity (45 min) and the date of the session. These constraints are established upstream between the higher education teacher who supervises the project (referent teacher) and the schoolteacher hosting the activity in their class. The theme of the activity must deal with soil, but the students are free to choose the angle from which they approach the subject (while respecting the expectations of the official program of the classes concerned). This mixture of autonomy and constraints places the students in their future professional situation from the start of the project in terms of analysis and respect of school programs; choice among different approaches for the development of a pedagogical sequence; and adaptation to the level of the pupils.

Project Organization

Soil science courses (25 h) take place in the second semester of the academic year (January–June) and start at the beginning of the semester with a presentation of the project-based approach, specifying objectives, constraints, assessment methods and general organization (1 h).

To ensure that students quickly gain a knowledge base that enables them to get involved in their project, classic classroom courses in soil science are given at the beginning of the semester. Over 12 h, these lessons present the basics of the discipline: soil definition; horizon concepts; soil constituents and properties; and an overview of the ecosystem services provided by soils and the threats affecting them. As this teaching is very dense in relation to the time devoted to it, students have access to an online course (on Moodle) created by the referent teacher, which enables them to review some concepts, access photographs or illustrations different from those in the course, and take part in short self-assessment quizzes. A two-hour field trip enables them to observe a local soil type (color, texture, structure, horizons, humus, etc.) and make connections between geological context, plant cover, and land use. At the end of these preparatory courses, an initial assessment of the knowledge acquired is carried out, and this counts for 40% of the final grade (of the soil science course).

Once the traditional lessons have been completed, the remaining 10 h are devoted to developing the project under the referent teacher's supervision. Sessions are staggered throughout the semester, so as to meet regularly with students before the activity date (end of April or end of May, depending on the year). Given the low number of hours, students are required to work on their projects outside of the sessions, which can entail a significant amount of personal work. During the sessions, monitoring by the referent teacher is fundamental, and this is one of Kokotsaki et al. (2016) recommendations for a successful project-based approach. The teacher must do more than simply answer students' questions; they must guide them to find answers themselves and warn them of certain pitfalls that could jeopardize their project (purchase of materials, time management, etc.). The role of the referent teacher here is to guide students, not direct them. It is a difficult balance between student motivation (answering all their questions will not encourage them think on their own) and frustration (ignoring their legitimate questions risks demobilizing them) (Morgan and Slough, 2013).

Project Implementation

Students are first divided into groups of four to seven people, either by the teacher (to mix profiles) or freely by the students. This division into small groups encourages collaborative work and facilitates teacher supervision. Due to the relatively small class sizes, two groups are formed each year. For the first year of the degree's existence (2018–19), only one group was formed due to the very low number of students. Nine students worked on the same theme (soil and water, **Table 1**), each taking charge of a different session (the water cycle, water storage in the soil, water pollution). This choice was also made because no school could be found to host the activity, so the students worked on a theoretical project. In the following years (2019–20 and 2020–21), two groups were formed and worked on separate topics, which were then carried out in different classes. Unfortunately, the COVID-19 pandemic triggered strict lockdown from March 2020, and the students were unable to carry out their activity in class. Although the rules were relaxed (classroom lessons could resume in April or June 2020, depending on the zone), outsiders were not allowed to intervene in classes. In 2021, the situation deteriorated further, and strict health protocols made it impossible to run the activity session face-to-face, so the students had to transform it into a distance-learning version. In 2021–22, the two groups worked on the same theme, one with a face-to-face version and one with a remote version in anticipation of a possible re-confinement, which did not occur but taught students how to prepare distance-learning sessions and master the skills needed (creating an e-book, for example). Finally, in 2022–23, the two groups were able to work on two different themes and carry out their activities in two classes. This somewhat complex series of events as disrupted by the pandemic enabled different types of group work (whole class or small groups) and different teaching methods (face-to-face, unscheduled distance learning, planned distance learning) to be evaluated. In all, over the 5 years of its existence, this project has involved just over fifty students (**Table 1**) and, counting only face-to-face actions, has reached around sixty elementary school pupils.

The topics chosen by the students (**Table 1**) relate to water (soil and water, soil water retention, soil water erosion) or soil biology (soil decomposers, soil fauna). Two themes (searching for treasure, the treble clef) are based on the discovery of treasure using soil-based clues, e.g., the type of soil on the boot-soles of the person that buried the treasure, or the type of soil in which the treasure chest key has been hidden. Another topic (soils of Lorraine), which will be detailed later, uses the same activities (study of color, texture, etc.) but for a different purpose. Students are totally free to choose their own theme, which is decided fairly quickly through group discussions (usually as early as the 2nd session). The referent teacher validates the chosen theme during a presentation where students explain the links between their theme and the school curriculum. It should be pointed out here that students are not asked to create an activity session from nothing; they are allowed to draw inspiration from anything they find in their research (mostly on the web), as this will later

TABLE 1 | Chosen themes and activities produced.

Year	Number of students	Themes	Activity type	Partner school
2018–19	9	- Soil and water	Theorical	none
2019–20	13	- Searching for treasure - Soil decomposers	Cancelled (COVID-19)	La Patrotte J. Moulins (57050 Metz)
2020–21	11	- The treble clef[a] - Soil water erosion	Distant (COVID-19)	La Ballastière (57300 Hagondange)
2021–22	11	- Soil water retention	Distant and presential	G. Hoffmann (57000 Metz)
2022–23	11	- Soil fauna - Soils of Lorraine	Presential	G. Hoffmann (57000 Metz)

[a]*French word game: the treble clef corresponds to the G clef in French, where the G note is called "sol", which also means soil.*

be part of their work as schoolteachers. Many examples of experiments on the theme of water or soil fauna can be found on the Internet. Students can use these examples, provided they make the effort to understand them correctly, examine them critically, and adapt them if necessary (to the audience, the material available, etc.).

Once the theme has been validated, the students work on designing the activity. They have to research the knowledge they need in relation to the theme and any existing resources on the subject. They then select the format of the activity (traditional course, in-class manipulations, games and riddles, etc.). They are required to have pupils practice the successive stages of the scientific approach, i.e., problem, questioning, hypotheses, experiments and/or observations, interpretations, and conclusions. The students also prepare documents (for the pupils and for the schoolteacher) and materials (video, soil and fauna samples, magnifying glasses, etc.) needed for their presentation. They also have to test their experiments and modify them if necessary, to make sure they work properly in the classroom. Throughout these sessions, the referent teacher assists students with theoretical aspects (acquisition of knowledge), practical aspects (help in choosing soils, loan of small equipment, etc.) and pedagogical aspects (advice on choosing vocabulary adapted to the audience, for example). The challenge for the referent teacher here is to avoid responding directly to students, rather encouraging them, wherever possible, to find their own solutions or answers to their questions or needs.

Finally, the concrete result of the project is the presentation of the activity to a class. The schoolteacher hosting the activity introduces the students to the pupils, then the students perform the various steps of their activity (information on the theme, questioning, presentation of equipment, division of pupils into small groups, management of experiments, summary on the blackboard). During the activity session, the students manage 'their' class on their own, with neither the schoolteacher nor the referent teacher intervening in the process. After the activity, the schoolteacher gives the students feedback on what went well and what could be improved. Lastly, a final exchange between the students and the referent teacher takes place to draw up an assessment of the project.

Student Evaluation

The assessment method varied from year to year depending on the number of students and the constraints imposed by the COVID-19 pandemic. The project grade counts for 60% of the final mark, and the assessment method has stabilized as follows: A mark is assigned by the referent teacher to the project as a whole in terms of structuring, quality of documents produced, scientific approach, in-class implementation, etc. All students in the group working on the same project have the same mark at this point. This score is then personalized for each student by applying bonus or penalty points. These points are awarded according to three aspects: First, the teacher evaluates each student's behavior throughout the project. These points are rather difficult to award, because while the teacher has a fairly clear view of what takes place during the classroom sessions, it is more difficult to assess a student's contribution outside these sessions. This is corrected by the application of points based on a second aspect: student peer-assessment within a group. Each student fills in a grid evaluating the behavior of other students on the basis of criteria such as their contributions (and their relevance), the responsiveness of each, responses to the solicitations of others, the organization of meetings, their coordination, influence in the group, conflict management). The teacher then compiles all these grids and has a clearer picture of everyone's involvement. However, care must be taken when awarding points to avoid any cronyism or unfair judgments on the part of students. Final points are awarded on the basis of the quality of the report produced by the students: on completion of the project, all students are required to write a report detailing their involvement, their feelings and their reflective analysis of the project, which is an important practice for future teachers (Loughran, 2002).

Example of Realization

It seems useful to detail here an example of an activity session to show what can be achieved by students with no prior knowledge of soil science (other than the 14-hour course at the start of the project). The example presented is "Soils of Lorraine" because of its originality and because it was one of the most accomplished projects.

The activity begins with questions asked by students to pupils: "Where do the vegetables we eat grow?", "What are our clothes

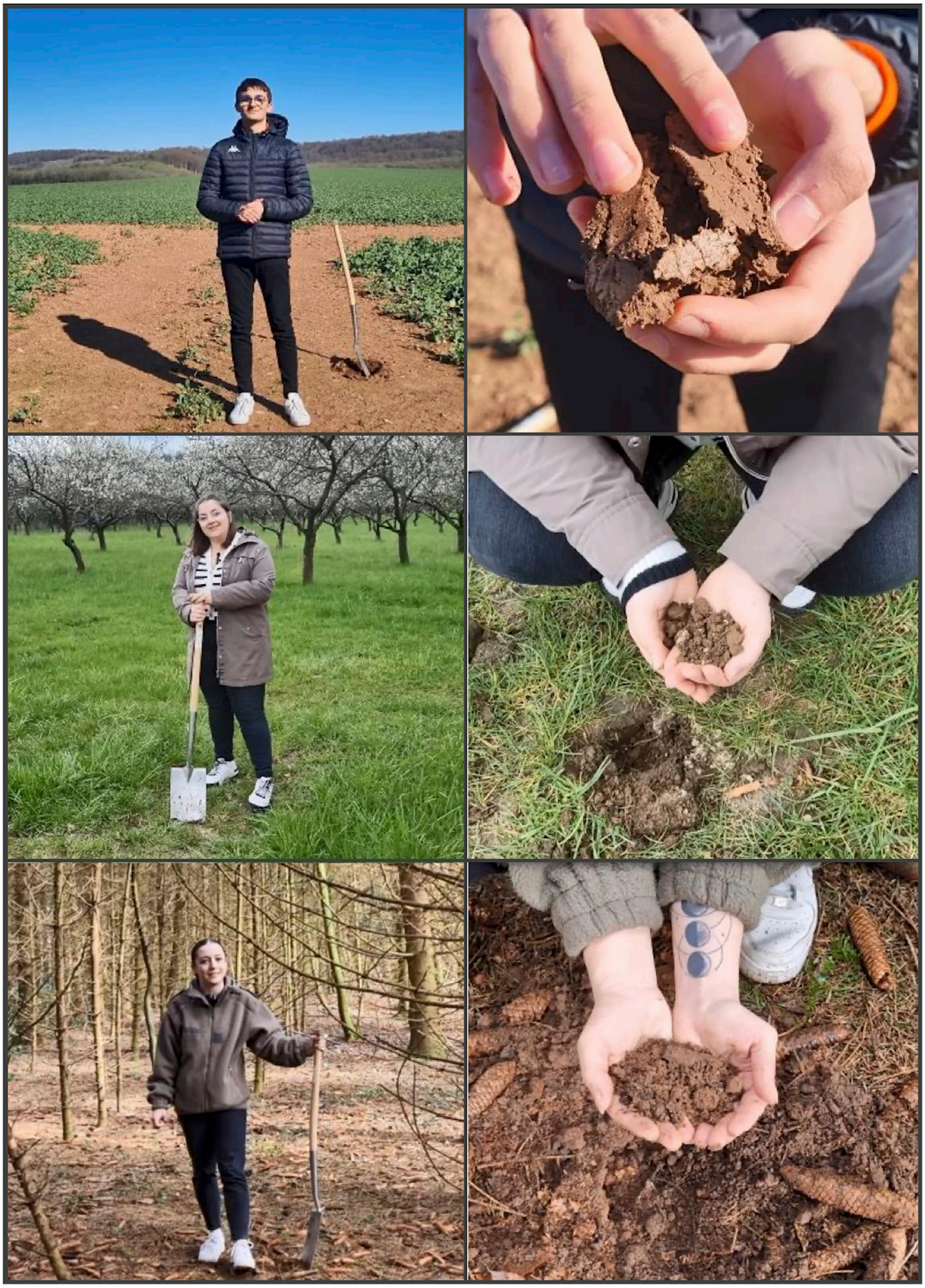

FIGURE 2 | Screenshots of the video showing three types of occupation (left) and their corresponding soils (right).

made of?", "Where do we get our cotton?", "Where does the wood we put in the stove, or the wood that makes up part of our houses, come from?" The aim of this question-and-answer game is to have pupils make the link between ecosystem services (food production, etc.) and the soil. Pupils are then invited to consider this diversity of services in relation to different soils using a short video (7 min). The video was created by the students on the model of a famous French TV program, "C'est pas sorcier"

FIGURE 3 | In-class activities. **(A)** Correction of the grid. **(B)** Observations and manipulations. **(C)** Synthesis on the board. **(D)** Distribution of the diploma. Photo credits: A and D: Delphine Aran, B and C: Christophe Deloison.

(that can be translated as "It's not rocket science"), which deals with science popularization for children. The video shows three types of land use in Lorraine (field, orchard, and forest) and describes the three related soils in terms of color, texture, etc. (**Figure 2**). As the video is shown, pupils fill in a questionnaire to help them identify important information (the soil under forest cover is sandy, for example). At the end of the viewing, students proceed with a correction to check that the correct information has been recorded (**Figure 3A**).

The class is then divided into three groups, each with one of the three soil samples. The game here is to have the pupils believe that the students in the video forgot to note the soil type on the bags and only put a number, so they'll have to work out which soil corresponds to which occupation type. Each group is supervised by a student who guides them in observing the soil and filling in the description grid. Pupils note color, presence of stones, texture (by touch), pH (using a pH measurement kit), and presence of limestone (HCl test) (**Figure 3B**). When the soil description is complete, a pupil from each group comes to the blackboard to record the observation results (**Figure 3C**), and it is then possible to link each soil sample to an occupancy mode (crop, orchard, forest).

The activity ends with an overview by the students of the diversity of soil properties and functions, and the variety of uses that can be made of it. They emphasize the importance of soil protection and make the link with the school curriculum (sustainable exploitation and use of resources, origin of food consumed, landscapes, etc.). At the end of the session, the students award each pupil a diploma as an "apprentice soil scientist" (**Figure 3D**).

ANALYSIS OF THIS APPROACH

The main aim of this project-based approach was to train students in soil science, enabling them to apply this knowledge to their future teaching careers.

In terms of the students' feelings, their perception evolves over time and goes through different stages. At the beginning of the project, students feel unable to carry out the project due to a lack of knowledge: "I was a bit puzzled [. . .] I did not think I had enough knowledge to be able to run an educational activity on the theme of soils," "This project seemed difficult to me because it involved teaching a scientific field I knew nothing about," "I was anxious because I do not have a good grasp of pedology and [. . .] I did not have any ideas for topics," "this project scared me to death [. . .] I was afraid of being a drag for my group." But as the project progressed, this anxiety phase gave way to a phase of unblocking: "A rewarding discussion about the project with one of my classmates reassured me," "As the sessions progressed, our activity idea became clearer to me, and I was able to project myself fully," "I then had a lot of ideas on how to organize the activity in class, which really relieved me," "It was only a few days before our first hour [of project-based learning] that I realized it was not impossible, and that together with our group and everyone's ideas, we were going to be able to carry out an activity." At the end of the project, most students were quite satisfied with the experience: "This presentation project [. . .] to an elementary school was an enriching and captivating experience," "I felt involved throughout the preparation [. . .] I was also proud of what we achieved together," "I really enjoyed doing this educational activity with a class. It's a project out of the ordinary that we probably would not have done without this course," "The whole project was very rewarding and fun to do. The realization of the project was wonderful."

The students particularly appreciated the training aspect of this project with regard to their future profession: "I realized how difficult it could be to create a work for pupils [. . .] I found this approach interesting for us as future school teachers," "This event gave us the opportunity to come face-to-face with the teaching profession, while receiving constructive feedback from a schoolteacher," "It allows us to better project ourselves into the situations that will face us in the future [. . .] this project has been [. . .] a very useful exercise which has enabled us to think like the teachers we would like to become."

For some of them, the project strengthened their choice of career direction: "In addition to the internship, it reinforced the fact that this was really the job I wanted to do," "I also loved presenting the experiments in front of the pupils [. . .] the interaction with the pupils and their enthusiasm were motivating factors, reinforcing the desire to become a school teacher," "Doing this educational activity in front of the children gave me another opportunity to experience what it's like to be a teacher. I felt at ease in front of the pupils and enjoyed watching them manipulate."

It is above all in terms of student motivation that the project-based learning delivers good results. Creating the activity and performing it in front of an audience of schoolchildren anchors their work in the real world and induces a strong sense of authenticity (Condliffe, 2017). Building an end product puts theoretical learning into practice and gives them a sense of pride. During this project, students developed professional skills (program analysis, classroom management), pedagogical skills (creation of documents for pupils), and cross-disciplinary skills (group work). The freedom given them in making choices develops their autonomy, which helps them take ownership of their learning (Kokotsaki et al., 2016). Through the project, they also become more critical of their web searches and learn to adapt (when classroom experimentation does not yield the expected results, for example).

In terms of soil science knowledge, the results are a little less convincing. The classic courses in soil science given at the start of the project were particularly useful for students who had never had access to this subject before (the majority of them, **Figure 1**), and it was here that the contribution of knowledge was most significant. This "preparatory" teaching is fundamental to ensuring that students have the basic knowledge and skills to tackle the project work aspect more easily (Kokotsaki et al., 2016). As part of their project, the students had to deepen their knowledge of some parts of the chosen theme: biodiversity and the trophic chain in the soil, the water storage capacity of the soil, the different types of soil in Lorraine, etc. They gain knowledge during the course of the project, but this is necessarily limited to the project's theme. On the other hand, it is through this deepening of knowledge that students become aware of the complexity of this environment. This awareness should encourage them to go deeper into other aspects of soil when teaching their pupils later on.

Teaching soil science to non-specialists requires more effort from the teacher to have students interested and involved, and project-based learning is a good way of achieving this, combining various teaching methods (Hartemink et al., 2014). Fieldwork is also a fundamental aspect of this discipline and is appreciated by students (Hartemink et al., 2014). Although the field trip is very limited (lasting just 2 hours, which means that only one type of soil and environment can be observed), it is nonetheless crucial, as this is where students will gain an understanding of soil as an ecosystem component and the links with other disciplines (Field et al., 2011). This field trip allows hands-on activities to be carried out (sampling of different horizons, texture, HCl test, pH measurement, etc.), which are known to be a powerful learning tool, particularly as this is not in the students' initial area of interest (Abit et al., 2018). It is also probably the only real contact most students will have with the soil, and it can also be a source of inspiration for the activity session.

As student evaluation had to adapt to the constraints of COVID-19 pandemic, it's not possible to compare the different student cohorts or draw any general trend. Nevertheless, one constant has been students working in teams (except in the first year 2018–19, when students worked on the project more individually due to their low numbers). This teamwork is precisely what makes student assessment complex in a project-based learning. It is therefore important for the grade to accurately reflect everyone's involvement in the group and the quality of each person's work (Field et al., 2011; Kokotsaki et al., 2016). The referent teacher has to set up tools to assess each individual's contribution (regular meetings, intra-assessment, individual reports, etc.) and be vigilant in awarding marks. But apart from the grade, students are attracted by the fact that project-based learning is a good way to demonstrate their learning, in a different way to traditional tests (Grant, 2011). Here, presenting the activity to a schoolchildren audience can be seen as a concrete representation of the students' learning (Condliffe, 2017). The schoolteacher's evaluation of the activity is also perceived positively by the students. Immediately after the activity, the schoolteacher analyzes how it was run and gives advice to the students, particularly in terms of adapting it to the target audience. The various teachers from the partner schools always played along, even during the pandemic when they had to judge on documents alone, and always gave constructive feedback to the students. Students are very sensitive to the opinions of people who are practicing their chosen profession, and this feedback gives them a sense of pride more important than a simple grade.

A subsidiary purpose of the project was to "bring soil" into the school and to reach pupils and their teachers (current and future). As this type of classroom activity is not very common, pupils should remember it fondly. Students always make the choice to provide pupils with an opportunity for hands-on activity, which is particularly beneficial for learning (Field et al., 2011), and soil science is particularly well suited to this. The themes chosen by the students are appropriate for this audience, in line with the official school curriculum, and follow Mori et al. (2020) recommendations on fundamental themes to be addressed in elementary school.

At the end of the activity, the pupils were made aware of the soil and its functions. For the students, this work can be valued in their future profession, when they are in charge of a class. They will be able to repeat the activity in their classrooms, with the improvements suggested by the schoolteachers. The latter can also carry out this activity in the class they will have the next year. Finally, emphasis was given to the implementation of a scientific approach so that pupils could practice it. It also enables students, future teaching staff, to prepare themselves. This is one of the recommendations of the Cavailles and Julien 2023 report,[2] which highlights the inadequate preparation for the scientific approach in the training of school teachers in France.

CONCLUSION

The aim of the soil science project presented here was to train future primary schoolteachers in this discipline, which has received very little attention in their curriculum. Is project-based learning a better approach for preparing students for this purpose compared with traditional methods? Given the heterogeneous nature of the student population and the relatively limited time available, placing students into a real-life professional situation by creating an activity session about soil seems to be an effective method, particularly in terms of motivating them. In carrying out this project, the students acquired knowledge and skills both in the field of soil science and for their future teaching profession. By practicing this project-based learning, they will also be able to apply this type of active pedagogy in their future teaching.

A secondary effect of this project was to raise public awareness of soil-related issues. The project reached out to three different audiences: elementary school pupils, their current teachers, and future teachers. The project also showed that students, most of whom had no initial knowledge of soil science, could be mobilized to organize an effective activity that raises awareness of soil protection among schoolchildren. Thanks to this action, current and future schoolteachers can consider soil as an interesting teaching tool for tackling different themes in the school curriculum (from environmental protection to artistic activities).

This project has only been running for 5 years, and restrictions linked to the COVID-19 pandemic (change of school, switch to distance learning) meant that the impact of this awareness-raising initiative on pupils and their teachers could not be fully monitored. Similarly, it was not possible to accurately assess the benefits of this project for students intending to become teachers, other than in terms of motivation and interest in the subject. With this situation now apparently stabilized, this project could be expanded. Schoolteachers could work with their pupils before the event to prepare the issues addressed and/or return later to assess what has been retained and understood. The students would then need to prepare the documents required for these various actions. Another possibility would be for an event prepared by one group of students to be taken up the following year by the new group of students, keeping the same class of schoolchildren. This would enable the theme to be explored in greater depth with the pupils in that class, and to be followed up. In addition, the progress made by pupils could be observed by means of tests carried out before and after the activity, in order to quantify their learning. A more effective tool should also be used to assess what the students have actually retained and understood thanks to this project. Ideally, it would be useful to interview them once they are in place, to see to what extent they have integrated soils into their teaching.

Finally, considering that the de-artificialization of schoolyards is a topical issue, students could take advantage of the project to raise awareness of this issue in schools. Students could also organize activities outside the school, to observe the soil in a more natural environment. This nature-based teaching, which redeveloped during the COVID-19 pandemic, promotes learning and is an effective way of training environmentally friendly people (Kuo et al., 2019).

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

The manuscript presents research on animals that do not require ethical approval for their study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

DA: conception, realization, student supervision, manuscript writing.

CONFLICT OF INTEREST

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

[2]J.A. Cavaillès & S. Julien (2023). Rapport N° 21-22 099A, IGÉSR, https://www.enseignementsup-recherche.gouv.fr/sites/default/files/2023-05/rapport-igesr-21-22-099a-27785.pdf

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontierspartnerships.org/articles/10.3389/sjss.2024.12280/full#supplementary-material

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