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Teaching soil science: The impact of laboratory and field components on the knowledge and attitude toward soil

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ABSTRACT: The concept of attitude toward soil is emerging, with a slim choice of scales available to collect hard data. There is also a dearth of standard scales to acquire precise data on students' knowledge of soil. Therefore, the objectives of the present study were: (1) to devise appropriate scales to quantify theoretical soil knowledge and attitude toward soil, and (2) to quantify the effect of laboratory studies and fieldwork on students' theoretical soil knowledge and attitude toward soil. The study is based on data collected from undergraduate students of the introductory soil science course. Participating students were randomly divided into two groups. Teaching of the control group (n = 38) was classroom-based, while teaching of the intervention group (n = 43) was complemented with laboratory studies and fieldwork. Our test design included a pre-test and post-test. It appears that theoretical soil knowledge and students' attitude toward soil can be improved using classroom-based education alone, without any need for laboratory or field components. However, future studies would be needed to develop questionnaires covering hands-on soil knowledge to better gauge the impact of lab work and field classes on student learning. The present study is an important step to elaborate reliable scales suitable for quantifying students' knowledge and attitude toward the soil. It is impossible to test academic assumptions or create theoretical foundations for soil science education without a reliable device to weigh analytical concepts.

Keywords: soil education, soil knowledge, scales, quantitative analysis, environmental attitude.

INTRODUCTION

Soils are extremely important not only as a substrate for growing commercial crops that bring innumerable economic benefits, but also as the life-support system of the entire human civilization (Yaalon and Arnold, 2000). Historians demonstrated that the success or failure of ancient societies often depended on their land management practices (Hillel, 1992; Diamond, 2011). These authors analyzed conditions and techniques that made long-term soil management either sustainable or unsustainable. For instance, cultivation of sloping lands caused water erosion, whereas irrigation of poorly drained valleys led to salinization. The same age-old issues still affect soil management professionals today (Anonymous, 2004). For these reasons, several authors have highlighted the importance of better education in soil conservation to ensure sustainable development (Sewilam et al., 2015; Aytar and Ozsevgec, 2019).

Soil education aims to elucidate the role of soils in human life, and consequently, the significance of soil preservation and sustainable land use (Muggler et al., 2006). These authors believe that soil education can be approached similarly to environmental education. Since environmental education is a very well-established field (Díaz-Siefer et al., 2015), its concepts may prove helpful in our deliberations of the issues of soil education.

For instance, researchers that study environmental education intend to understand the factors that determine ecological behavior (also known as pro-environmental behavior) (Stern, 2000). It was established that it correlates with environmental knowledge (Kaiser et al., 2008; Geiger et al., 2019) and environmental attitude (Milfont and Duckitt, 2004; Otto et al., 2018), among other factors. Several scales have been developed to quantify environmental knowledge and attitude.

Environmental attitude is a well-developed scientific concept, and there are several scales available to researchers for analytical purposes in this area. In contrast, the concept of attitude toward soil is an emerging one (Yaalon and Arnold, 2000), with a slim choice of scales to collect hard data. For instance, Ashoori et al. (2016) developed a scale to gauge farmers' attitudes toward soil conservation. But it is very specific to rice growers and cannot be applied to other groups.

The term "soil knowledge" is also widely used in the scientific literature (Huynh et al., 2020). Teachers of soil science usually quantify their students' knowledge of soil based on written exams, but there is a dearth of standard scales to acquire precise data in this area. It is well known that some soil science concepts are easily addressed in the classroom, while others remain remote and abstract until such a time as the students gain personal, hands-on experience with them (Hartemink et al., 2014). For instance, Amador (2019) claimed that traditional approaches to teaching (such as lectures) are not effective at promoting student learning. On the other hand, laboratory studies and fieldwork are usually considered useful in teaching introductory soil science at the university level (Voronin et al., 1996; Dobrovol'skii, 2007; Hartemink et al., 2014; Siewert et al., 2014; Jelinski et al., 2019). But we are unaware of any quantifiable criteria to demonstrate their positive impact on student learning.

This study hypothesized that laboratory and field components of an introductory soil science course would enhance students' theoretical soil knowledge and attitude toward the soil. This study aimed: (1) to devise appropriate scales to quantify theoretical soil knowledge and attitude toward soil, and (2) to quantify the effect of laboratory studies and fieldwork on students' theoretical soil knowledge and attitude toward soil. Both scales were developed to suit the students of an introductory soil science course.

MATERIALS AND METHODS

The study is based on data collected from undergraduate students of the introductory soil science course at the School of Agriculture, Pontifical Catholic University of Valparaíso, Quillota, Chile. Socio-demographic characteristics of participants are summarized in table 1. Participating students were randomly divided into two groups (hereafter, control and intervention groups).

The control group's learning experience was structured around traditional lectures and students' self-prepared presentations on specific subjects. There was no laboratory component, and only one practical exercise in soil mapping was conducted. In other words, the teaching of the control group was classroom-based. The intervention group's learning experience also included traditional lectures. However, these were complemented with a lot of lab work on a number of subjects, such as: the impact of sulfur and lime on soil pH; the impact of fertilizers with different solubility on soil electrical conductivity; the impact of alfalfa and straw on soil nitrogen availability; the impact of organic matter on soil redox potential under water-logged conditions; and the impact of soil texture on cation exchange capacity. In addition, lab component comprised work to establish bulk density using the clod and undisturbed core sample method for clayey soil and the cylinder method for sandy soil. A field project was undertaken to establish the soil infiltration rate, and field classes were given on the following topics: soil biological restoration; calcareous soils; mottled soils; and the impact of soil parent material on soil properties. An exercise in soil mapping was also conducted at the experimental station of the School of Agriculture.

The study of Pooley and O'Connor (2000) suggests that emotions, rather than knowledge, need to be addressed in environmental education programs. This idea might also be helpful in soil education. Thus, the learning experience of the intervention group also incorporated the screening of the *Symphony of the Soil* (symphonyofthesoil.com).

Our test design included a pre-test and post-test. The pre-test questionnaire was completed at the beginning of the first class, in both the control and the intervention groups. The post-test was completed at the end of the last class of the semester. The questionnaire used a confidential code to match the two tests to individual students. Specifically, students were asked to indicate the initials of their mothers' first and last names and dates of birth. In Chile, women do not change their last names after marriage. Therefore, the initials of their last names could not compromise the test's confidential nature.

The soil knowledge scale was based on veridical knowledge, i.e., true or false questions (Geiger et al., 2019), similar to scales on environmental knowledge (Díaz-Siefer et al., 2015). Specifically, the knowledge scale comprised 20 true-or-false questions on the topics covered during the semester, whereas the attitude scale consisted of 22 statements on student attitude toward soil. A Rasch-type model (Bond and Fox, 2007) was used to compute individual scores for each of the two scales. Preference was given to a Rasch-type

Table 1. Socio-demographic characteristics of participants

Variable	Control		Intervention	
	Pre-test	Post-test	Pre-test	Post-test
Total participants	38	35	41	43
Matched participants	28	28	29	29
Age	21 ± 2.0	21 ± 2.0	21 ± 2.0	21 ± 2.0
Gender				
Female (%)	35	43	15	21
Male (%)	65	57	85	79
Live in...				
Urban area (%)	61	69	73	74
Rural area (%)	40	31	27	26

model over classical test theory because scale design under classical test theory, which is based on sum scores, frequently results in a narrow range of item difficulty, making it hard to recognize people with disparate levels of the measured variable. Rasch models, on the other hand, support a wider range of item difficulties. In the present study, both scales displayed a wide range of item difficulties, as was our intention, thus allowing us to recognize people with varying levels of knowledge and attitude toward soil.

Both scales exhibited excellent reliability (Table 2). Likewise, both scales exhibited good item fit, with values of the infit MS (mean square) ≤1.2. Only one item of the attitude scale exhibited still acceptable fit, with values 1.2< MS ≤1.3 (Wright et al., 1994).

Next, we computed Pearson's correlations between knowledge and attitude. We also examined the effect of the teaching method on knowledge and perspective at pre- and post-test time points using a repeated-measure analysis of variance (ANOVA) with the following two factors. The first factor was the teaching method (control or intervention); the second factor was the time point (pre-test or post-test). Confidential code was used to match these two tests to individual students (Tables 3 and 4). However, there was a substantial number of students whose pre- and post-intervention questionnaires could not be matched because students did not remember the exact dates of birth of their mothers. For these cases, the ANOVA analysis was performed without the use of the confidential code (Tables 5 and 6).

RESULTS AND DISCUSSION

As a result of the introductory soil science course, students of both groups displayed greatly enhanced soil knowledge (Figure 1 and Tables 3 and 5; $p < 0.001$), which attests to our scales' efficiency in quantifying student knowledge. There was a slight difference in the pre-test values of soil knowledge in the control and intervention groups (Figure 1). However, the interaction term between the factors used in the ANOVA analysis was not statistically significant (Tables 3 and 5), which means that the students of both the control and intervention groups learned equally well.

Thus, it appears that theoretical soil knowledge can be improved only using classroom-based education, without any need for laboratory or field components. However, there are different types of knowledge. For instance, in the field of environmental education, system ("know what") and action ("know how") environmental knowledge can be distinguished (Kaiser and Fuhrer, 2003; Frick et al., 2004). The present study measured only theoretical knowledge about soil, whereas practical knowledge (e.g., how to determine soil properties in a lab or describe soil characteristics in the field) was not considered. Thus, future studies would be needed to develop questionnaires covering hands-on soil knowledge to better gauge the impact of lab work and field classes on student learning.

Both teaching methods caused a remarkable positive shift in students' attitude toward soil (Figure 1 and Tables 4 and 6; $p<0.001$), but the control and intervention groups were statistically indistinguishable, contrary to expectations. It appears that students' attitude toward soil can be improved only by means of classroom-based education, without any need for laboratory or field components.

Table 2. Descriptive statistics of the scales used in the study

Scale	Mean ± SD	Range	Reliability	Items with 1.2< MS ≤1.3	Items with MS >1.3
Soil knowledge	-0.28 ± 1.39	-4.34 - 2.52	0.83	0	0
Soil attitude	0.52 ± 1.60	-3.71 - 4.84	0.86	1	0

SD: standard deviation; MS: mean square.

It must be pointed out that some students assigned the highest rating of 5 to the majority of the attitude items in the pre-test. Therefore, any improvements in these items could not be measured due to the so-called “ceiling effect” (Lieflӓnder and Bogner, 2018), which made it impossible to ascertain if they had any improvement in their attitude toward soil as a result of the course. In other words, the attitude items turned out to be too easy for some of our agriculture students.

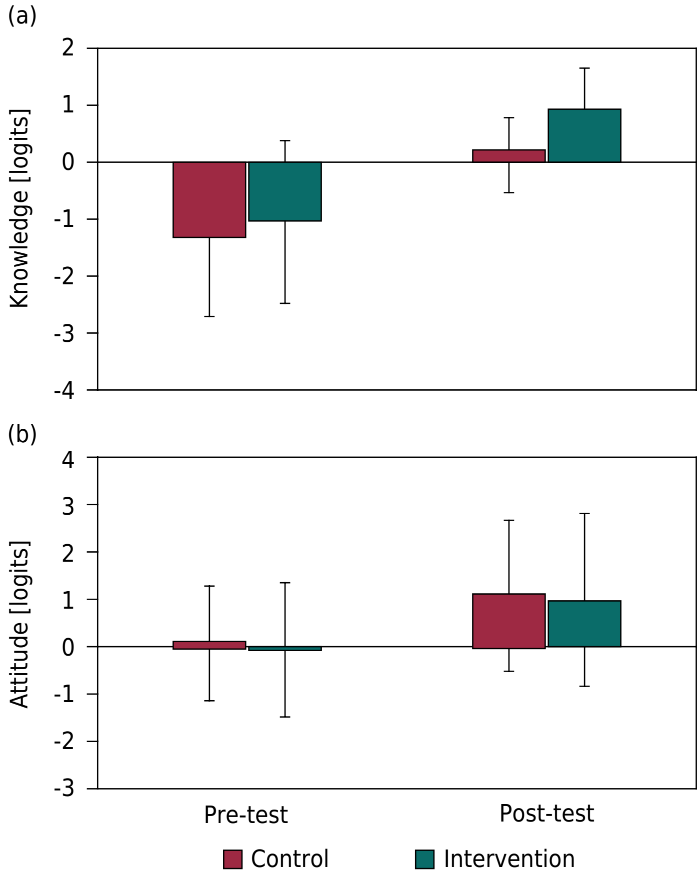

Figure 1. Quantification of the impact of laboratory and field components on (a) soil knowledge and (b) attitude toward the soil. Error bars mean standard deviation. The scores for each scale were expressed in logits. For the attitude scale, the logit stands for the natural logarithm of the positive/negative attitude ratio. Likewise, the logit stands for the natural logarithm of the correct/incorrect response ratio for the knowledge scale. For instance, logit values are negative when correct responses are given to less than 50 % of all the questions; positive with correct responses to more than 50 % of the questions; and equal to zero when correct responses match 50 % of the questions.

Table 3. A repeated-measure two-way analysis of variance (ANOVA) for soil knowledge

Effect	F(1, 54)	p-value
Group	5.52	0.02
Time	87.53	<0.001
Group*time	1.97	0.17

n = 56; one student did not fill in knowledge responses in pre-and post-tests.

Table 4. A repeated-measure two-way analysis of variance (ANOVA) for attitude toward soil

Effect	F(1, 55)	p-value
Group	0.34	0.56
Time	26.43	<0.001
Group*time	0.00	0.98

n = 57.

Table 5. Two-way analysis of variance (ANOVA) for soil knowledge. Confidential code was not considered in this analysis. n = 155; one student did not fill in knowledge responses in pre-and post-tests

Effect	F(1, 151)	p-value
Group	8.24	0.005
Time	102.69	<0.0001
Group*time	2.00	0.16

Table 6. Two-way analysis of variance (ANOVA) for attitude toward soil. Confidential code was not considered in this analysis

Effect	F(1, 153)	p-value
Group	0.25	0.61
Time	17.8	<0.0001
Group*time	0.02	0.88

n = 157.

From experiences in environmental education, we know that people's attitude toward the environment is largely determined by how they feel about it (Pooley and O'Connor, 2000). In other words, positive emotions about nature are an important part of environmental education, and these can be enhanced through exposure to nature (Otto et al., 2019). For this reason, many soil educational programs emphasize the importance of field courses (Siewert et al., 2014). Therefore, in future studies, we would have to update our attitude scale by incorporating more difficult items and to examine more carefully the effect of lab work and field classes on students' attitudes toward the soil.

Summarizing all the data from both groups and tests, Pearson's correlation between knowledge and attitude comes to 0.29 (n = 155; p = 0.0002). While the correlation appears low, it is actually close to that between knowledge and attitude in the field of environmental education (Liefländer and Bogner, 2018 and references therein). Thus, students who had a positive attitude toward soil from the outset were more enthusiastic learners and thus obtained greater knowledge during the semester. Likewise, students with greater knowledge about soil were likely predisposed to have a more positive attitude toward soil. Similar trends were found in the field of environmental education (Dopelt et al., 2019).

CONCLUSIONS

This study is an important step toward elaborating reliable scales suitable for quantifying students' knowledge and attitude toward the soil. Further, it is impossible to test academic assumptions or create theoretical foundations for soil science education without a reliable device to weigh analytical concepts.

SUPPLEMENTARY DATA

Supplementary data to this article can be found online at https://www.rbcsjournal.org/wp-content/uploads/articles_xml/1806-9657-rbcs-45-e0210040/1806-9657-rbcs-45-e0210040-suppl01.pdf

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