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Research paper

Using soil seed banks for ecological education in primary school

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In this study, we developed an educational programme using soil seed banks to promote ecological literacy among primary school-aged children. The programme consisted of seven student activities, including sampling and setting soil seed banks around the school, watering, identifying seedlings, and making observations about the plants and their environments. Research was conducted in two urban elementary schools in Seoul, Korea with 99 fourth-grade students, who were divided into two experimental groups that engaged in the soil seed bank programme and a control group that followed the official textbook-based curriculum for studying lima bean seed growth. After participating in this programme, the level of student concepts about the relationship between plant distribution and the environment increased significantly in comparison with a control group (p<0.01), as did student knowledge about plants and plant ecology (p<0.01). In addition, the programme was associated with increases in eco-centric attitudes among the students (p<0.01), including a shift toward more positive attitudes about plants. According to the participants, the programme better enabled students to recognise and observe temporal changes in plants and nature, providing one indication that their ecological sensibilities were augmented by the student activities in which they engaged. Both the participating students and the teachers leading the activities expressed a belief that the programme benefited the participating students, and that the activities were interesting and useful. This study showed that a programme of activities using soil seed banks and seedling emergence methods promoted ecological literacy by providing simple, hands-on opportunities to experience and inquire about local plants and their environments.

Keywords: soil seed bank; ecological literacy; educational programme; ecological education; ecological sensibility

Introduction

Defined as an aggregation of ungerminated seeds, soil seed banks are important in plant ecology because they have the potential to replace adult annual plants, which die a natural or unnatural death, and perennial plants, which are susceptible to death by disease, disturbance, or consumption by animals (Leck et al. 1989). Since Darwin began to study soil seed banks in 1859 (Christoffoleti and Caetano 1998), they have been a major focus of research in plant ecology. Although there are several methods for studying soil seed banks, the most frequently used is the seedling emergence method, which involves analysing the composition of seeds in soil by identifying seedlings in a lab or greenhouse (Roberts 1981). Because of its simplicity, the use of soil seed banks may provide a brief and easy way for primary school-aged children to experience nature in the classroom (Pascoe 1994). At the same time, a set of activities using soil seed banks can provide children with a wider-reaching ecological experience than a single-seed germination activity might.

Children like to actively engage in the investigation of nature (Leeming et al. 1997); they like hands-on activities with living things (Lindemann-Mathies 2006). For the purposes of ecological education, experiences in nature are very important, especially at primary school ages (Chawla 1998; Tanner 1980). Orr (1992, 86) explained that ecological literacy begins with the ‘sense of wonder’. As children play with plants and insects around the garden or playground, for example, they often come to understand and love living things.
In many urbanised areas, the opportunity for children to come into contact with nature has decreased over time. Louv (2005), among others, has expressed concern over this trend. A great many schools no longer allow children to experience nature first-hand, and instead mainly teach ecology through books and videos (Barker et al. 2002). Teachers tend to avoid outdoor activities that enable children to be in nature because of obstacles such as too many students in a class (Simmons 1998), limited time and financial resources (Pascoe 1994), a lack of confidence about ecological education (Brewer 2002), and other challenges (Tilling 2004).

Soil seed bank experiments are a useful means of overcoming such obstacles to ecological education. Few studies using soil seed banks for ecological education have been conducted, however. Pascoe (1994) suggested soil seed banks experiments as an alternative to other methods for studying plant ecology in school. He argued that this technique not only overcomes many of the logistical problems of other approaches, but provides a unique insight into the dynamics of plant communities. Although Pascoe described the procedure for conducting research with soil seed bank experiments, he did not apply this method to primary school-aged students.

Ecological education, then, should aim to achieve ecological literacy through first-hand experiences in nature (Hale 1993; Orr 1992; Palmer et al. 2004), since experiences in the natural world are essential both to understanding the environment and thinking positively about it (Orr 1992). While scholars have provided a variety of different definitions of ecological literacy (Berkowitz and Brewer 2005; Capra 2009; Cutter-Mackenzie and Smith 2003; Orr 1992), all seem to include three common elements: eco-centric attitudes, ecological sensibilities, and ecological knowledge.

In this study, we developed an ecological education programme for primary students using the seedling emergence method with a soil seed bank. In addition, we compared the efficacy of this soil seed bank method with a traditional lima bean germination method for teaching children about plant ecology. The following questions were addressed: Are soil seed bank activities useful for providing ecological education with primary school students? To what extent can soil seed bank activities increase the ecological literacy of students?

**Methods**

**Participants**

Research was conducted in two urban elementary schools in Seoul, Korea. The sample consisted of 99 fourth-grade students in the two schools, all aged 9–10 years old. In the Korean curriculum, science is introduced in the third grade, and fourth-grade students learned about the leaves and stems of plants and the life cycle of insects. In this study, students were divided into two experimental groups consisting of 65 students who participated in the soil seed bank programme between April and July 2009. The other 34 fourth-graders were chosen as a control group and followed the official textbook-based curriculum. The instruction in each of the three classes was mainly conducted by the classroom teachers. The majority of Korean primary school teachers have studied elementary education and have basic competencies for teaching primary science. We supplied guidance and information about the activities to the teachers in the experimental groups before embarking on the programme. Also, we provided teachers in the experimental groups with the materials needed to implement the programme activities with their students.

**The soil seed bank programme**

An educational programme using soil seed banks was created to promote the ecological literacy of primary school students. The programme consisted of a 14-week-long sequence of seven activities. Over this same period, a control group of students grew lima beans, an activity specified in the Korean national curriculum for fourth grade. The seven soil seed bank activities were labelled as follows: Beginning the observation of soil seed banks; My friends, sprouts; Comparing the plant communities of soil seed banks; Why did the soil seed banks change?; How did you get here?; Finding the hidden plants in my school garden; and Asking about the relationship between plants and their environments.

In the first activity, Beginning the observation of soil seed banks, the children sampled soil seed banks from their school garden, set them in trays with bedding soil, and then put them in outer trays in the classroom (Figures 1 and 2). Two or three times a week, they supplied water to the outer trays and soon observed seedlings emerging from the seed banks. The students identified the plants using a simple picture book supplied by the researchers. When a seedling was too
young to identify, the children were instructed to try again once it had grown more. As they observed the growth of the seedlings over time, the children engaged in other activities in the sequence of lessons. In the second activity, My friends, sprouts, the students chose sprouts from the soil seed banks that became their friends, and then observed the growth of these sprouts over time. Because the seedlings were too young to identify at this stage, having children give nicknames to their sprouts was a suitable activity, since it encouraged them to observe the process of their friend’s growth.

In the next activity, Comparing the plant communities of soil seed banks, the children observed and recorded changes in the trays of various soil seed banks. This process facilitated their learning about the names and features of the plants and helped them discover, through observation, the differences in the composition of the various plants situated in different soil seed bank environments. Additionally, this activity helped make students more aware of the life cycle of plants. The following activity, Why did the soil seed banks change involved transferring the trays of soil seed banks to nearby areas with alternate conditions in order to allow students to observe the resulting changes in the trays. For example, when soil seed banks containing many light-sensitive seeds were moved to the open schoolyard, more seedlings were able to emerge. In this way, the children discovered that environmental conditions can affect the germination of seeds.

The purpose of the next activity, How did you get here?, was to help children understand the various ways that seeds are naturally dispersed. The children were given instruction about seed dispersal and were asked to guess how the seeds came to be in their seed banks. Through this activity they gained an understanding about the ways plants use the environment – water, wind, and animals – for the dispersal of their seeds, and how plants adapt to varying environmental conditions in order to perform these strategies. Once some seedlings had been identified, the children began to find naturally occurring plants emerging from soil seed banks in the school yard. This activity, Finding the hidden plants in my school garden, gave the children even more interest in the plants that were growing in the soil seed banks. The final activity, Asking about the relationship between plants and their environments, may have been the most difficult for the children to carry out. When it was time for this activity, most of the plants that had emerged from the soil seed bank were identifiable, so the children were instructed to identify the seedlings and plants in the sampling site and observe the environment in the sampling site. Then, they were asked to analyse and synthesise the relationship between the plant community and its environment.

Data sources
Pre- and post-tests
Diagnostic data were collected through pre- and post-tests, interviews, and questionnaires about the programme. Pre- and post-tests were conducted with experimental and control groups to explore the extent to which the programme improved the ecological literacy of students. Interviews and questionnaires were carried out with the experimental group only to inquire about the reactions of the participants to the developed programme. The pre-test contained one open-ended question. The post-test consisted of this same open-ended question and 10 true–false questions developed by two biology education specialists from Seoul National University. The open-ended question in pre- and post-tests was: Why do various plants live in diverse environments? This question was designed to test student understandings about concepts related to the distribution of plants by the environment. The true–false test about plants and plant ecology was contained in the post-test only because such tests are easily memorised and a pre-test may have biased the results; it consisted of 10 questions related to knowledge of plants and plant ecology (see Appendix 1).

The responses were analysed according to three criteria: (1) a change in the concept level of the response, (2) the inclusion of ecological elements in the response, and (3) a change in the eco-centricity of attitudes (see Appendix 2). The analysis was conducted by biology education specialists in the Department of Biological Education at Seoul National University (SNU), who first independently analysed the responses, and then came together to discuss their coding. In the cases in which the two specialists coded a response differently, they resolved the difference either by adopting the other’s category, or redoing the analysis of those responses altogether. Cases with a missing value in the pre- or post-test were not included in the analysis. The inter-rater agreement coefficients were calculated using Cohen’s Kappa coefficient (Cohen 1960) for qualitative items; the values (κ) of this analysis ranged from 0.82 to 0.90. The results of the true–false questions were analysed by ANOVA to determine the extent of difference in knowledge of plants and plant ecology in the experimental and control groups.
Interviews

A second data source was interviews with students and teachers in the two experimental groups. A question was presented to students on paper and then in one-on-one interviews. The primary question was, ‘What has changed for you as a result of this programme?’ Students first wrote the answer to this question on paper and then answered the question in individual interviews with the researchers. If the student responses could not be understood or were deemed insufficient, additional follow-up questions were asked. The answers of the students were analysed in terms of what they revealed about the ecological knowledge, ecological sensibilities and eco-centric attitudes of students. The teachers were asked, in one-on-one interviews, to describe what they thought about the programme; their answers were recorded and transcribed.

Questionnaire

A third source of data was a questionnaire asking students and teachers to evaluate the entire programme. The questionnaire used a five-point Likert scale and contained questions in four areas: general impression, usefulness, motivation and ecological sensibility.

Results

Pre- and post-tests

Table 1 shows the level of the children’s thinking about the relationship between the distribution of plants and their environment before and after participating in the soil seed bank programme. Before the programme, only 13 of 64 students in the experimental groups demonstrated high-level concepts about plants and their environments. At the time of the post-test, the number of students with high-level concepts increased to 46 ($p=0.001$). The number of responses that included ecological elements increased from 12 to 37 ($p=0.001$). The students whose responses indicated an eco-centric attitude increased to 26 ($p=0.001$). These results indicate that the programme positively affected the ecological knowledge and attitudes of students in the experimental groups.

The soil seed bank programme also had an impact on the children’s knowledge of plants and plant ecology, as shown in Table 2. Students in the experimental groups averaged 6.77 on a 10-point scale measuring such knowledge, a significantly higher score than that of the control group (5.12, $p=0.001$).

Interviews

The students’ responses to the question, ‘What changed for you as a result of this programme?’ were analysed in terms of ecological knowledge, eco-centric attitudes, and ecological sensibilities (Tables 3–5). Half of the participants (44.8%) reported that they learned the names of various plants from the programme. Seven students reported that they learned about seed dispersal, and six said they learned about the distribution of different plants in the environment. Of the students, 82.8% expressed satisfaction with the programme in terms of knowledge gained.
About half of the participants (46.6%) thought that their ecological sensibility increased as a result of this programme, as shown in Table 4. As one student stated, ‘This programme changed me. I walk slowly these days when hiking with mommy. Why? I began to like calling out the names of the plants. I think they like that, too.’ The responses of about 33% of the children included eco-centric attitudes, as shown in Table 5. This result and those reported in Table 1 indicate that the programme positively affected children’s eco-centric attitudes.

After conducting the programme, the teachers of the children in the experimental groups expressed their opinions of the program. One stated:

This teacher, then, was satisfied the programme content, which she saw an effective inquiry into plants and their environment. She noted that ecological inquiry is often hard to conduct, but that this programme made it easy. Another teacher expressed her opinion about the programme in this way:

Children liked and were amazed at the germination of seeds in the soil itself. They had more interest in the pots of soil seed banks than in other pots of plants. They might think about the differences between planted and sowed pots. In the case of typical pots of plants, the students might think that the plants were already there. In this programme, they sampled, set, and watered the seeds by themselves. Moreover, the concept of a soil seed bank, of the spreading of seeds in soil, itself was very fresh to the children. Children expected the moment of the germination and were pleased in that moment.

This teacher was pleased with the programme as well. She told us her students were interested in the soil seed banks and amazed at the germination of the seeds.

### Questionnaire

Most students reported that the activities in the programme were useful (4.29/5.00) and they would like to do them again (4.19/5.00), as shown in Table 6. These results indicate that the programme impressed the students favourably. The majority of the students in the experimental group said that the activities helped them understand the process of germination (4.48/5.00), the inquiry method as applied to the environment (4.23/5.00), and the various names of plants (4.34/5.00). The students thought that the programme was very helpful in these respects. Moreover, a number of the students responded that they observed plants more carefully, liked plants better (4.25/5.00), and felt that plants were more beautiful (4.23/5.00) following the programme.

### Discussion

The objective of this study was to investigate the applicability and efficacy of a soil seed bank experiment (a typical method used by ecologists) for the purposes of ecological education. This effort was in line with the demands of educational experts who have advocated for the promotion of ecological literacy through active experiences with nature (Lindemann-Mathies 2006; Magnitorn 2007; Rottle and Johnson 2007).

Experiments using soil seed banks have been used by scientists since the time of Darwin (Christoffersen and Caetano 1998). Because this method is simple and makes it easy to observe the growth of seedlings, it is a
highly appropriate means for teaching ecological education to primary students. In this study, almost all students participating in the soil seed bank activities were satisfied with the use of this method in the programme we developed. Our findings suggest that, with a few alterations, classroom experiments such as those conducted in this study can be successful (Figure 3 and Table 6).

The results of this study, particularly in terms of improved ecological literacy, are consistent with earlier studies conducted with only outdoor activities (Lindemann-Mathies 2006; Magniorn 2007; Malone and Tranter 2003). Students in the experimental groups had a higher level of ecological knowledge after participating in the programme as compared with the control group, who received traditional textbook-based instruction and germinated single lima bean seeds. Teachers reported that students inquired actively about the plants in the soil seed bank and their environments, and attributed this interest to the seedling emergence method. Thus, teachers believed that students had more interest in the plants and their environments because they sampled, watered, and observed the soil seed banks themselves. In addition, the idea that plants preserve their own seed in soil for survival stimulated their curiosity. Such heightened interest among students can provide more motivation for learning (Krapp 1999).

Giving students opportunities to experience nature first-hand encourages learning about diverse species (Lindemann-Mathies 2006). In this study, the students’ knowledge about plants increased because the soil seed bank activities provided them with a chance to have frequent contact with a variety of local plants. The regular interactions involved in sampling, setting, and observing the soil seed banks helped the students become familiar with the names of the plants, the features of the organisms, and the ecological character-

**Table 6. Results of the soil seed bank programme by participant (N = 57)**

<table>
<thead>
<tr>
<th>Category</th>
<th>Evaluation item</th>
<th>M (5 scale)</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interest in the activities</td>
<td>These activities were useful.</td>
<td>4.29</td>
<td>0.876</td>
</tr>
<tr>
<td></td>
<td>I want to do these activities again.</td>
<td>4.19</td>
<td>0.827</td>
</tr>
<tr>
<td></td>
<td>I learned what seeds need for germination through these activities.</td>
<td>4.48</td>
<td>0.741</td>
</tr>
<tr>
<td></td>
<td>I learned what plants need to live through these activities.</td>
<td>4.39</td>
<td>0.690</td>
</tr>
<tr>
<td>Usefulness of the activities</td>
<td>I learned the inquiry method about the environment through these activities.</td>
<td>4.23</td>
<td>0.857</td>
</tr>
<tr>
<td></td>
<td>I learned various plant names through these activities.</td>
<td>4.37</td>
<td>0.834</td>
</tr>
<tr>
<td></td>
<td>These activities were helpful to my school learning.</td>
<td>4.13</td>
<td>0.939</td>
</tr>
<tr>
<td></td>
<td>I want to participate again in an inquiry activity about plants like this.</td>
<td>3.69</td>
<td>1.080</td>
</tr>
<tr>
<td>Motivation</td>
<td>I want to learn more about plants.</td>
<td>3.76</td>
<td>1.003</td>
</tr>
<tr>
<td></td>
<td>After doing these activities, I want to be a scientist (or botanist).</td>
<td>2.84</td>
<td>1.186</td>
</tr>
<tr>
<td></td>
<td>After doing these activities, I observe plants carefully.</td>
<td>4.31</td>
<td>0.827</td>
</tr>
<tr>
<td>Ecological sensibility</td>
<td>I like plants better than before doing these activities.</td>
<td>4.25</td>
<td>0.869</td>
</tr>
<tr>
<td></td>
<td>I feel plants are more beautiful than before.</td>
<td>4.23</td>
<td>0.804</td>
</tr>
</tbody>
</table>

![Figure 3. Photo of actual setting. Taken by Eun Jeong Ju](image-url)
istics of species. Thus, students effectively learned about the plants that live around them through the soil seed bank programme.

The soil seed bank programme implemented in this study combined outdoor with indoor activities. In the beginning, children sampled the soil and observed the plants and plant environments in their schoolyard several times. The major focus of the activities in this programme, however, involved the process of managing and observing the sprouts from the classroom soil seed banks, which the children did indoors. Nevertheless, the soil seed bank experiment provided the chance for the children to have contact with living organisms in the classroom, and these experiences were similar to those that might take place in nature. Clearly, experiences in nature can promote ecological literacy (Lou 2005; Orr 1992). This soil seed bank programme was successful in this regard, since it enabled students to experience a sense of wonder through their observation of germination, in turn leading them to have more enhanced ecological attitudes and sensibilities.

For the typical primary school teacher, providing experiences in nature might be impossible or highly difficult without a method like the one studied herein. Some ecologists have asserted that experiments have been lacking in the field of ecological education (Finn et al. 2002). As Lindemann-Mathies (2006) pointed out, major obstacles restricting outdoor activities include the high number of pupils in a class, timetable problems, and the erroneous beliefs of the teacher. Moreover, problems related to time and money are often present. This soil seed bank programme studied presents an alternative to outdoor activities for ecological education. Although outdoor activities were minimised in this study, experiences with local plants were maximised. Through analysing the relationship between species in the seed banks, and between the plants and their environments, students increased their ecological knowledge (Tables 1 and 2) and eco-centric attitudes (Tables 1 and 5).

**Educational implications**

Soil seed banks are a powerful tool for ecological education in the classroom. The first-hand activities with living plants that are provided by soil seed banks give teachers the opportunity to effectively promote ecological knowledge, attitudes, and sensibilities. In this study, the ecological literacy of children improved through the experiences of sampling the soil, watering the pots, and observing the plants that sprouted. Such moments with nature very likely generated the sense of wonder that is associated with the beginnings of ecological literacy (Orr 1992).

This programme was significant in that it provided an alternative to outdoor activities for the purposes of ecological education. However, while there are clearly a number of advantages to outdoor activities with children, the use of soil seed banks enables teachers to promote ecological literacy in a simple and effective manner. Just by sampling, setting, and watering soil, children can observe a variety of local plants and their life cycles. In addition, because the pots are placed in the classroom, children can approach and observe them as frequently as the teacher allows.

Traditional science activities included in textbooks, like the lima bean experiment conducted by the control group, can lead to an oversimplified understanding of plants. Such activities do not prepare pupils for a twenty-first century world in which an appreciation for the complexity of the natural environment is necessary. The soil seed bank programme examined in this study is more appropriate than traditional methods for effective ecological education in elementary schools.

This programme can be implemented not only with fourth-graders but with students of other ages. A variety of interesting experimental themes can be considered when using this programme for high-school or undergraduate students. At the same time, it is ideal for primary-age or even preschool students, who can even make their own small pots (with paper cups, for instance) and observe them. More studies about the educational applications of soil seed banks should be conducted for students of diverse ages.

**Acknowledgements**

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**References**


Appendix 1. Post-test true/false questions

1. The dandelion flower is yellow.
2. The seeds of garden balsam generally disperse far and wide.
3. Water is important for the germination of plants, but sunshine is not.
4. Soil must be observed to learn about the conditions under which plants grow.
5. Small centipede\* was named for the shape of a flower.
   (*The Korean name means the grass is shaped like a bald head.)
6. Foxtail plants do not have flowers.
7. Fleabane plants have flowers, the centre of which is yellow and the outside white.
8. The soil in the playground does not have any seeds in it.
9. Morning glory plants have stem tendrils.
10. Yellow juice is observed when the stem of a celandine plant is cut.

Appendix 2

<table>
<thead>
<tr>
<th>Category</th>
<th>Explanation and sample answer to the question: ‘Why do plants live in diverse environments?’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Levels of concepts High-level concepts</td>
<td></td>
</tr>
<tr>
<td>Scientific or correct concepts</td>
<td>Example: ‘Because of their environments. The favourite place of each plant is different. Some plants like wet places and others like dry places.’ Example: ‘Each plant lives in its own proper place.’</td>
</tr>
<tr>
<td>Unscientific or incorrect concepts</td>
<td>Example: ‘For making fresh air and showing beautiful flowers.’ Example: ‘More plants are more beautiful. If there is a kind of plant, it may not look appealing.’</td>
</tr>
<tr>
<td>Ecological elements</td>
<td>Mention the relationship with environment or other organisms</td>
</tr>
<tr>
<td>An example that includes ecological elements</td>
<td>Example: ‘Because plants need different environments.’</td>
</tr>
<tr>
<td>An example that does not include ecological elements.</td>
<td>Example: ‘Because they supply fresh air and look beautiful.’</td>
</tr>
<tr>
<td>Eco-centric attitude</td>
<td>The attitude that nature is valuable in itself</td>
</tr>
<tr>
<td>Eco-centric</td>
<td>Example: ‘Because each plant has a different environment in which it lives best.’</td>
</tr>
<tr>
<td>Anthropo-centric</td>
<td>The attitude that nature is merely surroundings for humans</td>
</tr>
<tr>
<td>Anthropo-centric</td>
<td>Example: ‘Because they supply fresh air and look beautiful.’</td>
</tr>
<tr>
<td>Value-neutral</td>
<td>An attitude that is neither eco-centric nor anthropo-centric</td>
</tr>
<tr>
<td>Value-neutral</td>
<td>Example: ‘Because the seasons change.’</td>
</tr>
</tbody>
</table>