**Research Paper**

# A Study on Ferns as Teaching Material

*Toshiyuki KAWAKAMI * and Hideo IKEDA*
*Department of Science Education, Graduate School of Education,*
*Hiroshima University, Higashi-hiroshima 739-8524, Japan*

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**Abstract**

The Japanese national curriculum for elementary school and junior high school was reviewed in 1998 and that for senior high school was reviewed in 1999. The school hours and teaching contents were reduced by about 30% from the former curriculum. From a historical viewpoint, we examined the contents concerning "Ferns" in each version of the Japanese national curriculum and the science textbooks. Ferns were contained in some chapters in textbooks for both elementary and junior high school until the last revision. As a result of the latest revision of the textbooks, the fern was eliminated from the chapters "Investigating Plants in All Seasons" in elementary school and "Life of Plants and Their Kinds" in junior high school in which the fern had been contained. In almost all senior high school science textbooks, the fern has been used in the chapters "Structure" and "Life Cycle," so we developed new teaching materials on fertilization and cell division, because experiments of fern were only culture of spore and observation of vascular system. As a result of new teaching materials, we found that ferns could also be used in other chapters besides "Structure" and "Life Cycle," and we therefore can conclude that ferns are valuable plant material in biology education.

*Key Word: Fern, Japanese biology education, textbook analysis, teaching material*

*Author for correspondence: Toshiyuki Kawakami, Department of Science Education, Graduate School of Education, Hiroshima University, Higashi-hiroshima 739-8524, Japan, TEL. +81-82-424-7109, FAX. +81-82-424-7123, E-mail: m0823044@hiroshima-u.ac.jp

## Introduction

In Japan, the national curriculum "The Course of Study," which prescribes the school teaching contents, is stipulated by the Ministry of Education, Culture, Sports, Science and Technology. "The Course of Study" for elementary schools and junior high schools was stipulated in 1947 and has been reviewed 6 times, the latest review being carried out in 1998. For senior high schools, it was stipulated in 1948 and has been reviewed 7 times, the latest review being carried out in 1999. Since Japanese education has been centralized under the government, all Japanese

school curricula were changed from 2002-03. The transitions in science and biology education in the Course of Study are shown in Table 1.

In the updated "The Course of Study", the teaching contents were reduced from the previous 1989 curriculum, because of the reduction of school days per week from six to five from 2002. The number of unit school hours not only for science but also for all the other subjects was reduced. Some controversial issues about student attitudes to science literacy were raised by the latest review. Such issues were called "Crisis in science education in Japan."

Ferns, having characteristics different from seed plants, are an important plant group to understand the plant kingdom. Their characteristics are as indicated below;

a) The fern is non-flowering plant.

b) Its sporophyte and gametophyte grow separately.

c) It is considered that the fern developed from water to land in the process of plant evolution.

d) The fern is one of the major plants covering the forest floor.

The fern was eliminated from elementary and junior high school science textbooks in the latest review of the curriculum, although it is a key plant group to understand the plant kingdom.

In this study, we made the contents related to ferns in the textbooks clear from the historical viewpoint of Japanese biology education. From the results of this study, we shall discuss various concepts related to ferns to make the relation map in order to clarify the relationship between the concepts and activities.

The second objective of this study was to develop a new teaching material. The reason was that very few experiments could be found in the textbooks surveyed, so we shall discuss how

**Table 1 Transition of science and biology education in Japanese Course of Study**

| Elementary School (1-6) | | Junior High School (7-9) | | Senior High School (10-12) | |
|---|---|---|---|---|---|
| 1947 | Science | 1947 | Science | 1948 | Biology |
| 1952 | Science | 1952 | Science | 1952 | Biology |
| 1958 | Science | 1958 | Science (Second field) * | 1956 | Biology |
| | | | | 1960 | Biology |
| 1968 | Science | 1969 | Science (Second field) * | 1970 | Biology Ⅰ<br>Biology Ⅱ |
| 1977 | Science | 1977 | Science (Second field) * | 1978 | Science Ⅰ<br>Biology |
| 1989 | Science (3-6) ** | 1989 | Science (Second field) * | 1989 | Biology Ⅰ A<br>Biology Ⅰ B<br>Biology Ⅱ |
| 1998 | Science (3-6) ** | 1998 | Science (Second field) * | 1999 | Biology Ⅰ<br>Biology Ⅱ |

* First Field (Chemistry, Physics)
Second Field (Biology, Earth & Space)

** 1-2 : Life Environment Studies

to carry out new experiments. The studies on teaching materials using ferns were carried out by Yuasa (1984), Chilton and Graham (1988), and Watanabe and Ikeda (1994). They used living spores and sperms, but to observe fertilization they used only fixed materials. Thus, there were no reports on the fertilization of ferns using living materials. Therefore, we developed a new observation method on fern fertilization.

## Chapters and Exercises Dealing with Ferns in Japanese Science Textbooks

*For Elementary Schools*

The chapters in elementary school science textbooks which dealt with ferns and how ferns are used in these chapters are shown in Table 2. In these textbooks, the fern had been covered in the chapters "Investigating Plants in All Seasons," "Forest Development" and "Evolution.

Ferns had been used in the chapter "Investigating Plants in All Seasons" until the latest review, however they were eliminated from this chapter in the 1989 version. The main exercise was field activity to collect young plants of *Equisetum arvense* and *Osmunda japonica* in spring season.

The chapter "Forest Development" was in the science textbook contents from the 1952 version to the 1977 version, and the main exercise was field observation. In this chapter, a few kinds of fern, such as *Gleichenia japonica* and *Cyrtomium fortunei* that grow in various parts of Japan, had been presented as shade plants. However, this chapter was eliminated in the 1989 version.

The chapter "Evolution" occurred in textbooks until the 1952 review and the fern was used in this chapter. However, in this chapter there were only explanations of tree ferns, e.g. *Calamites* and *Lepidodendron*, but no exercises were included.

*For Junior High Schools*

The chapters in junior high school science textbooks which dealt with ferns and how ferns are used in these chapters are shown in Table 3.

In these textbooks, the fern had been used in the chapter "Life and Kinds of Plants" until 1989 review. In this chapter, the structure of sporophyte and spores was the major topic concerning ferns in observation activities. A few textbooks

**Table 2 Chapters and Exercises Dealing with Fern in Japanese Elementary School Science Textbooks**

| Year of publication | Chapter | | |
|---|---|---|---|
| | Investigating Plants in All Seasons | Forest Development | Evolution |
| 1947 | Field Observation | *No Chapter* | Explanation |
| 1952 | Field Observation | Field Observation | Explanation |
| 1958 | Field Observation | Field Observation | *No Chapter* |
| 1968 | Field Observation | Field Observation | *No Chapter* |
| 1977 | Field Observation | Field Observation | *No Chapter* |
| 1989 | *No Exercise* | *No Chapter* | *No Chapter* |
| 1998 | *No Exercise* | *No Chapter* | *No Chapter* |

**Table 3 Chapters and Exercises Dealing with Fern in Japanese Junior High School Science Textbooks**

| Year of publication | Chapter | | | |
|---|---|---|---|---|
| | Life and Kinds of Plants | Reproduction | Evolution | Classification |
| 1947 | Explanation | Observation (Spore)<br>Explanation<br>(Asexual Reproduction) | Explanation | Explanation |
| 1952 | Observation<br>(Structure･Spore) | Explanation<br>(Asexual Reproduction) | Explanation | Explanation |
| 1958 | Observation<br>(Structure･Spore) | Explanation<br>(Asexual Reproduction) | Explanation | Explanation |
| 1969 | Observation<br>(Structure･Spore) | *No Fern* | Explanation | Explanation |
| 1977 | Observation<br>(Structure･Spore) | *No Fern* | Explanation | Explanation |
| 1989 | Observation<br>(Structure･Spore) | *No Fern* | Explanation | Explanation |
| 1998 | *No Fern* | *No Fern* | *No Fern* | *No Fern* |

dealt with the culture of spores. In these observation activities, *Athyrium niponicum* which grows in various parts of Japan was commonly used.

Apart from this chapter, the fern had also been used in the chapter "Reproduction," i.e., asexual reproduction such as sporic reproduction and the proliferation by subterranean stems.

The objectives of these observations were comparison with flowering-plant and could be developed the knowledge into the topics "Classification" and "Evolution."

However, in the latest version the fern was eliminated completely.

*For Senior High Schools*

The chapters in senior high school science textbooks which dealt with ferns and how ferns are used in these chapters are summarized in Table 4.

In these textbooks, the fern was used for exercise in the chapters "Reproduction" and "Structure".

In the chapter "Reproduction," the fern had been explained the life cycle using the terms of sporophyte, spore, prothallium, sperm, antheridium and archegonium, until the latest review when the life cycle of the fern was eliminated. Although the observation activities appeared in a few textbooks.

In the chapter "Structure," the fern had also been used until the latest review, it had been used for the observation of vascular bundle in a few textbooks.

There are some other chapters in which the fern have been used still the updated textbooks,

**Table 4 Topics and Activities Dealing with Ferns in the Japanese High School Biology Textbooks**

| Year of publication | Chapter | | | | | |
|---|---|---|---|---|---|---|
| | Structure | Reproduction | Classification | Phylogeny | Evolution | Distribution |
| 1948 | Observation (Vascular bundle) | Observation (Spore) | Explanation | | Explanation | Explanation |
| 1952 | Observation (Vascular bundle) | Observation (Spore・Sperm) | Explanation | | Explanation | Explanation |
| 1956 | *No Fern* | Observation (Spore) | Explanation | | | Explanation |
| 1960 | Observation (Vascular bundle) | Observation (Spore・Sperm) | Explanation | | Explanation | Explanation |
| 1970 | Explanation | Observation (Spore) | Explanation | | | Explanation |
| 1978 | Explanation | Observation (Spore) | Explanation | | | Explanation |
| 1989 | Explanation | Observation (Life Cycle) | Explanation | | Explanation | Explanation |
| 1999 | *No Fern* | Explanation (Asexual Reproduction) | Explanation | | Explanation | Explanation |

such as “Classification,” “Phylogeny,” “Evolution” and “Distribution.” However, there were only explanations and no exercises were presented.

**Discussion on Teaching Materials**

There were a lot of studies about using ferns as teaching material. *Ceratopteris thalictroides* (Kato, 1987) and *Adiantum* (Kudo, 1988) were introduced into the study of the life cycle. *C. thalictroides* is an edible wild plant found domestically in Japan. Its life cycle is known to be very short, about 2 months. In the USA, a material kit for studying the fern life cycle using *Ceratopteris* is being sold (Hickok and Warne, 1998). *Adiantum* can be used for the observation of life cycle and spores in all seasons, if the plant is kept in warm temperatures. The plant is easy to get and to culture since it is sold in gardening shops.

*Osmunda* which has the smallest chromosome number 2n = 44 in Filicales has been used for the observation of the mitotic and meiotic cell division by the common squash method. *Osmunda japonica* has commonly been used as a material for study mitotic cell division (Takamiya, 1988) because it is easily obtainable in Japan as it is one of the familiar edible wild plants in this country.

Unfortunately, spore formation of *O. japonica* is limited in spring. Therefore, this species is not good for the observation of meiotic cell division. On the other hand, *Osmunda banksiifolia* has been proved to be useful to culture sporophyte and prothallium *in vitro*. Since a

young sporophyte forms fertile leaves and roots *in vitro*, we can use them to observe the cell division at any time of the year. Using this species, we could observe all the phases of mitotic cell division using the root tip cells and could count 2n = 44 chromosomes in metaphase. Using sporangia of this species, we also could observe meiotic cell division and spore formation and could count n = 22 bivalent chromosomes in metaphase I (Kawakami and Ikeda, in preparation).

In addition to this new material, we developed a new method for the observation of the fertilization process using living material. The material used in this experiment was *Pteridium aquilinum*.

The prothallium of *Pteridium aquilinum* was cultured *in vitro*. The prothallium matured about 1.5 months after germination (Fig. 1A). On a matured prothallium, some archegonia (Fig. 1B) and antheridia (Fig. 1C) were formed. Antheridia were formed at the basal part, and archegonia were formed at the central part of the prothallium. When the antheridium was soaked in water, the cap cell opened (Fig. 2A), then many spermatocytes went out into the water. Immediately the spermatocytes changed their shape to sperms (Fig. 2B), and they swam in the water using cilia. When the archegonium was soaked in water, the neck cell opened, and the antheridogen which is a substance attractive to the sperms went out into the water (Fig. 3A). The sperms led by antheridogen swam to the open neck cell and entered into the archegonium (Fig. 3B). Unfortunately, it was impossible to observe the following fertilization process directly from outside of the whole archegonium. To solve this problem, we made a vertical section of archegonium using a razor blade carefully so as not to damage the egg (Fig. 3C). After this treatment, sperm suspension was poured onto the archegonium specimen. Then, we could observe the sperms going to the egg cell and the fertilization process taking place (Fig. 3D). This

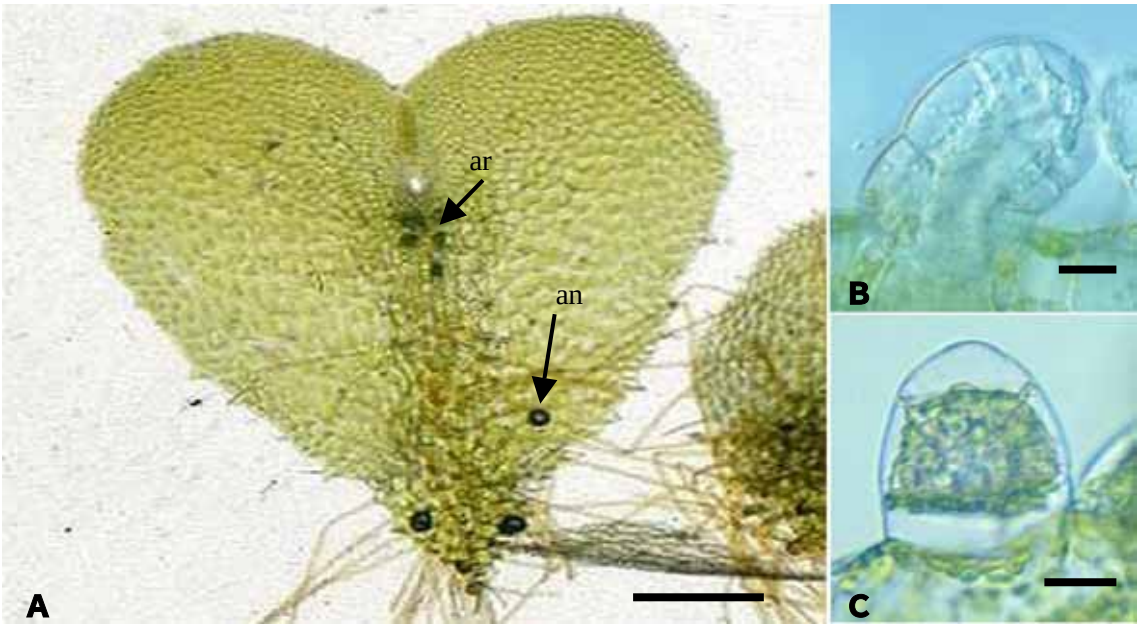


**Figure 1 A prothallium of *Pteridium aquilinum* cultivated *in vitro***
A: Prothallium (1.5 months after germination); B. Archegonium (ar); C. Antheridium (an). Bars: for A, 1mm; for B-C, 10μm.

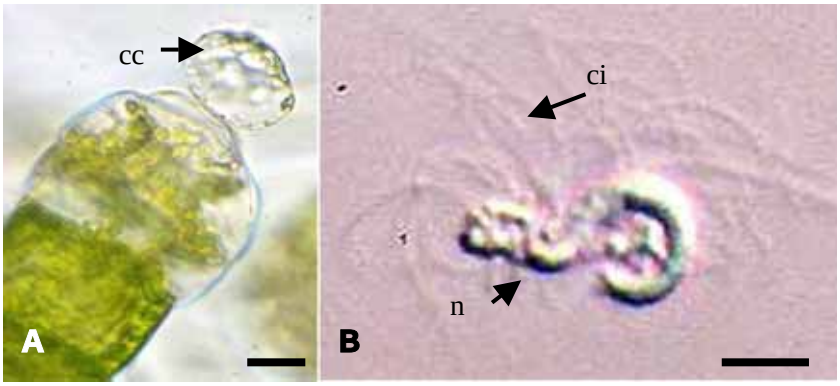


**Figure 2 Release of sperm from an antheridium**
A: The Cap Cell (cc) opening; B: Sperm (n: nucleus, ci: cilium). Bars: for A, 10μm; for B, 5μm.

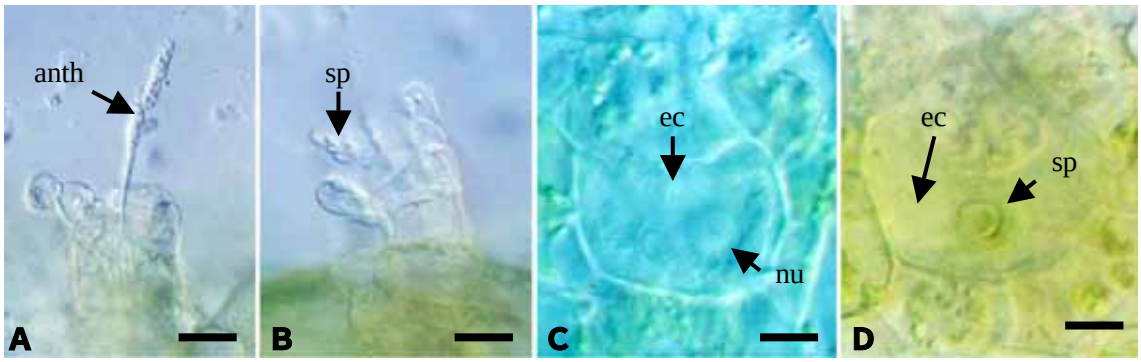


**Figure 3 Process of fertilization in an archegonium**
A: The neck cell opens and antheridogen (anth) come out into the water; B: Sperm (sp) enters into archegonium; C: Section of an archegonium (ec: egg cell, nu: nucleolus); D: Sperm in the archegonium. Bars: for A-B, 20μm; for C-D, 10μm.

method allows us to observe the fertilization process *in vitro*.

## Suggestions to Biology Classes

The fern is a very important plant group to understand the plant kingdom because it is a link between moss and flowering plants in the course of plant evolution.

We analyzed the topics related to the fern in Japanese science textbooks and picked up 11 characteristics (Fig. 4). From this Figure, we found that all characteristics of the fern had some connections to certain activities. These characteristics and related exercises would be covered in the chapters "Vegetation and Ecosystem," "The Cell and Its Function," "Reproduction and Development" and "Evolution and Phylogeny." Especially, "Reproduction and Development" are basal concepts to understand the evolution, classification, phylogeny, and distribution of the plant kingdom in the sequence of Japanese biology education.

Observation of ferns is not difficult, since special instruments except the microscope are not needed. Students can understand the "Vegetation and Ecosystem" by observation of plants in a forest.

"Reproduction and Development" can also be understood through simple experiments by

using the fern as the experimental material. It is possible to observe all the stages including spore formation and fertilization. It is well-known among biology teachers that the observation of the embryo sac of the angiosperm is difficult, because the organ is surrounded by

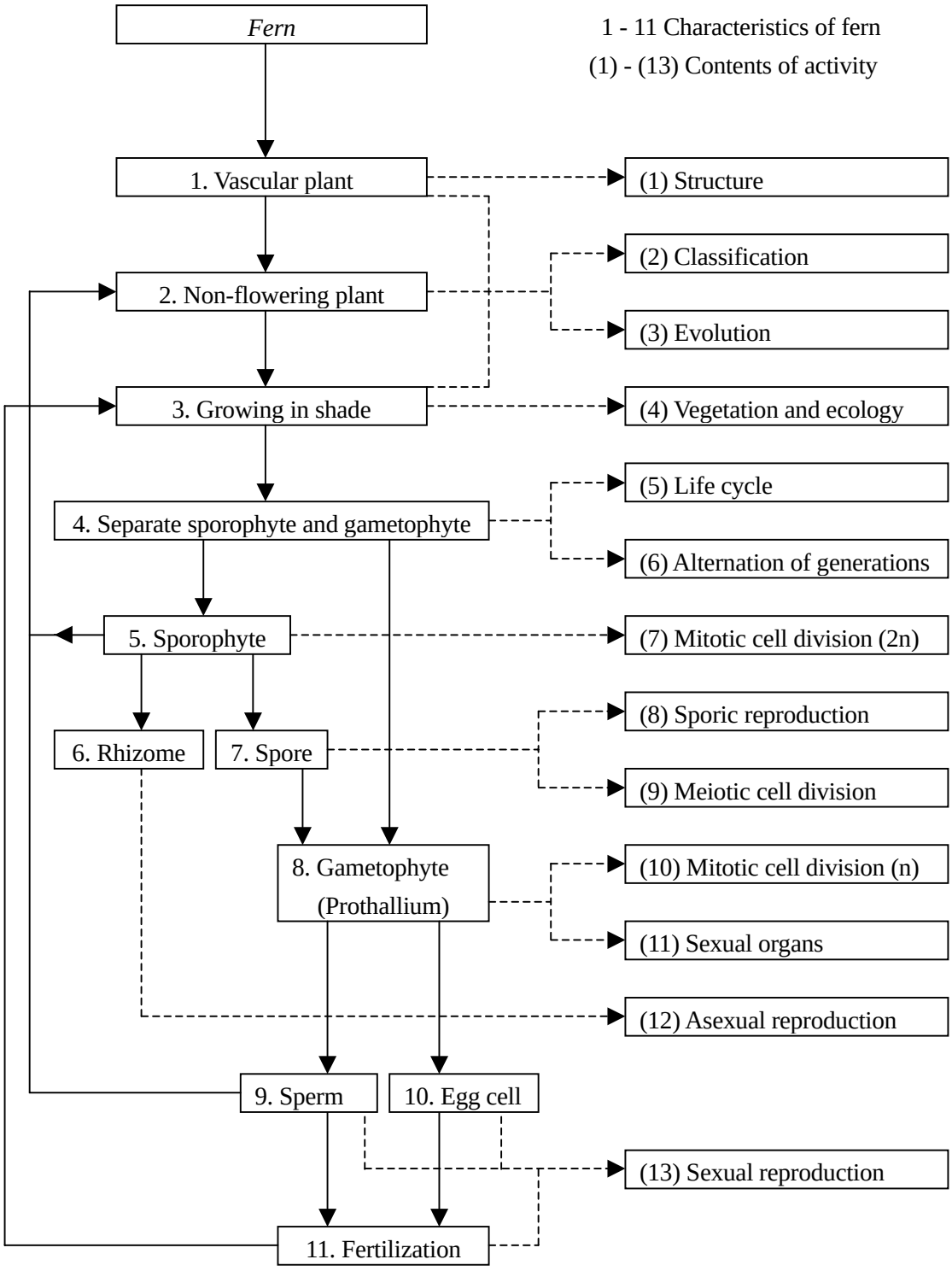


Figure 4 Characteristics of ferns as teaching material

some layers of cells, is embedded in the nucellus and integuments of the ovule. The archegonium and the antheridium of the fern, however, can be observed easily under the microscope. The egg and fertilization process can also be observed by the method mentioned above. It is easy to observe the generations of both sporophyte and gametophyte since they grow separately.

Recently environmental education is becoming important as it reflects contemporary social conditions. The understanding of the ecosystem is one of the important elements in the study of environment. The fern is one of the main plants in forest ecosystems. Although the fern tends to be eliminated in "The Course of Study" in Japan, it should be noted that the fern is a very important plant group to understand terrestrial ecosystems as well as other biological phenomena such as reproduction, life cycle, and the evolution of higher plants. Therefore, in conclusion we would strongly recommend insist that the fern be taught more to students in biology classes.

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