

# Development of Pteridophyte Taxonomic Learning Resource to Foster Cognitive and Psychomotor Learning Outcomes

Harmita Aprilanti<sup>1</sup>, Enni Suwarsi Rahayu<sup>2\*</sup>, Lutfia Nur Hadiyanti<sup>2</sup>

<sup>1</sup>Science Education Study Program, Post Graduate Program, Universitas Negeri Semarang,

<sup>2</sup>Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Negeri Semarang, Jalan Raya Sekaran, Gunungpati, Semarang, Indonesia 50229. (024) 8508033.

\*Correspondence Author: [enni\\_sr@mail.unnes.ac.id](mailto:enni_sr@mail.unnes.ac.id)

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**Abstract.** Authentic learning resources are meaningful for Biology learning, particularly in conceiving Plantae topic. The availability of plants, especially Pteridophyte in school environment is very limited and require more adequate plant learning resources. This study aimed to develop a Pteridophytes Taxonomic Learning Resource (PTLR) and tested its validity, practicality, and effectiveness. Research and Development were done by using the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) model. The PTLR (Pteridophyte Taxonomic Learning Resource) was validated by a taxonomist and instructional media expert. The practicality was observed from the responses of teachers and students, while the effectiveness was explored based on cognitive and psychomotor learning outcomes. The PTLR was developed by container gardening method with 29 fern species representing the classes of Pteridophyte and showed specific characteristics which organized in their taxonomic groups. The results showed that PTLR was very valid with average score of 85.5% and considered practical by teachers (81.25%) and students (90.65%). The PTLR was also effective in achieving two basic competencies by Curriculum of 2013 of Biology with cognitive outcome N-gain of 0.57 (moderate) and psychomotor 86.34% (very good). In summing up, the PTLR is recommended as a learning resource of Plantae topic at senior high school. This research result enriches the types of innovative biology learning resources.

**Key words:** cognitive, fern, psychomotor, Pteridophytes Taxonomic Learning Resources

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## INTRODUCTION

The topic of Plantae in Curriculum 2013 of Biology Subject for senior high school has two basic competences, 1) apply the classification principle to classify plants into divisions based on the morphological observation, and link their roles in the continuity of life, and 2) present data of morphology and the role of plants in various aspects of life in the form of written reports (Departemen Pendidikan dan Kebudayaan, 2013). To achieve these competencies students should straightly observe the plants. Therefore, the learning should use original learning resources in the form of plants.

Pteridophyte is a plant division that has certain characteristics. Students' achievement on the topic of Pteridophyte is low. Data from Biology Teacher Association of Semarang City show that the average of senior high school students' score is 51.25 for this topic (Chief of Biology Teacher Association of Semarang City 2018. pers.com.). The low score was predicted due to several factors, (1) limited availability of the plants as authentic learning resources around the schools, especially

Pteridophytes, (2) unrelated learning approach, (3) inaccurate ferns figure in the textbooks, and (4) no opportunity for students' psychomotor activities. Consequently, the ability to present data in a kind of reports also cannot be trained. The problems were predicted could be solved by planting ferns in a kind of learning resource. Therefore, students could observe the morphological characteristics of each type of plants and apply the principles of classification on it.

Authentic resources from the environment will help biology teachers to convey the knowledge accurately, precisely, clearly, and easily. The environment is an effective and efficient learning resource with a positive impact on student learning outcomes (Burt et al., 2017, Suyanto et al., 2022). Therefore, it is necessary to provide a collection of plants in the school environment such as the Pteridophyte Taxonomic Learning Resource (PTLR) to improve the learning outcomes.

The PTLR is an area in school with some plant species and organized following their taxonomic groups. In addition to be a learning resource, it also provides an aesthetic function. The ferns species planted in PTLR represented some classes

in the Pteridophyte and showed specific features of the division. This division can be classified into four classes namely Psilopsida (ancient fern), Lycopsidea (wire fern), Equisetopsida (horse-tail fern), and Pteropsida (true fern) (Simpson, 2010). The specific characteristics of ferns are 1) the rooting system is fibrous, 2) stems are generally located in the ground and in the form of the rhizome, and 3) leaves generally curl when they are young and open up when they are adults. The reproduction of fern generally through spores formed on sporophyll or sporocarp. The leaves can be divided into tropophyll leaves as the photosynthetic organ and the sporophyll as spore producers as well as its photosynthetic function. The optimal habitat of fern is generally a shady place with high humidity, which includes soil (terrestrial ferns), weathered stone or wall (lithophyte ferns), water (aquatic ferns), or stick on the roots or trunk of trees (epiphytic fern) (Simpson, 2010).

The PTLR can be designed in the 'Container Gardening' method, where the plants are planted in pots. The final appearance of the learning resource forms a "mini-garden" which involved hard-scape and soft-scape elements. Hardscape elements involve plant shelve, pot, and plant media, while soft scape is the fern vegetation (Berezowitz *et al.*, 2015; Burt *et al.*, 2017). Species of terrestrial, lithophyte, and aquatic ferns are planted in pots and arranged on shelves to ensure space efficiency, while epiphytic ferns are affixed to the trees. The composition of ferns in the PTLR is organized following three classes of the Pteridophyte Division. The Psilopsida class is not displayed because it is already extinct. The pots are managed based on the primitive to modern phylogenetic relationship and evolution of ferns. The ferns in the same class are close to each other (Aprilanti *et al.*, 2019).

The PTLR is believed to be able to train the students' scientific skills since it is an authentic resource which helps the contextual and meaningful learning process especially through observation and group discussion. This is in line with several research results before. Garden can be used to enrich learning materials (Passy *et al.*, 2010) because it is a natural laboratory for student-centered learning (Haw *et al.*, 2022). Observing gardens in biology instruction would improve understanding of science concepts and skill, provide direct experience, positively affect students' self-esteem, and enhance environmental

awareness (Malberg & Wistoft, 2018; Lohr *et al.*, 2021; Austin, 2022). It has an impact on students' cognitive achievement (Sellmann & Bogner, 2013; Tan *et al.*, 2020). Learning through taxonomic gardens is essentially the outdoor learning process. Garden-based learning provides opportunities for students to learn science tangibly and fosters students' interest in learning (Williams *et al.*, 2018; Karpudewan & Chong, 2022).

The problem is the plants in school's environment are not arranged based on their taxonomic rank but are planted randomly. Plant species are also not selected based on their suitability for learning resources of Plantae (particularly Pteridophytes) topics (Oberlee *et al.*, 2021). Based on these facts, this study aimed to develop a model of PTLR and analyzed the validity, practicality, and effectiveness. The innovation of this research is to develop a learning resource which has never been done at senior high schools in Indonesia. The PTLR that was developed had a specific characteristic that did not exist before, namely the arrangement based on the taxonomic position of the species. The existence of PTLR was predicted to be able to provide opportunities for students to learn contextually and to practice the science process skills, which were classifying plants and presenting data of observation as the expected by core competencies in learning Plantae.

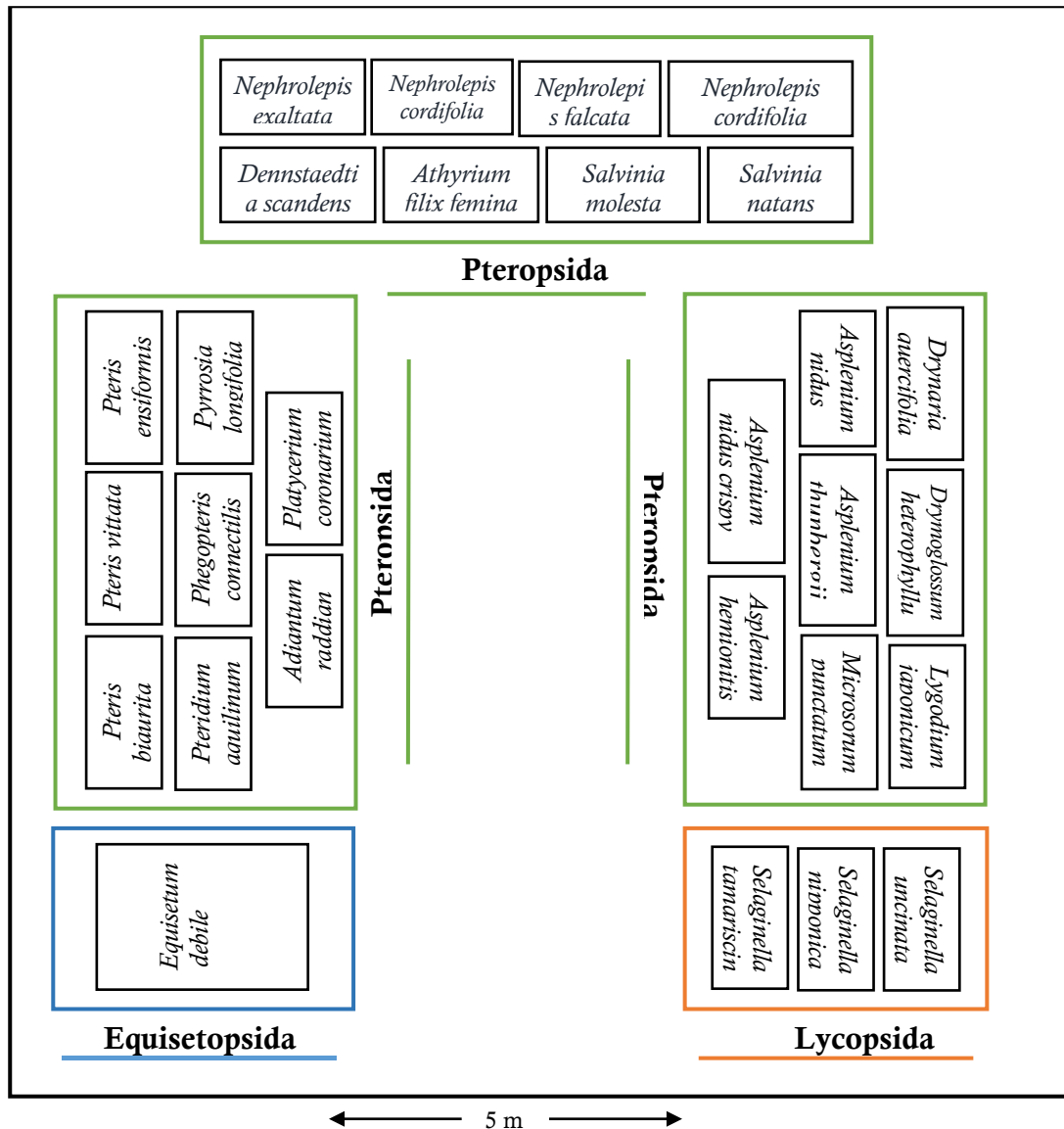
## METHODS

### Research design

This research was an R&D design using ADDIE model. The model covered the steps of 1) analysis, 2) design, 3) development, 4) implementation and 5) evaluation (Aldoobie, 2015). Each step of the development was explained as follows.

#### (1) Analysis of the learning resource

School's problems and potential which involved ferns were analyzed in this stage. The problems were found by giving formative test in MA Al Asror Semarang. The observation found that the formative score of the Pteridophyte had not yet reached the expected mastery since the basic competences were not achieved. This happened partly because learning took place conceptually without observations due to the lacked of fern types. Based on these problems, the school needed adequate learning resources for direct observation purposes.



**Figure 1.** The PTLR layout design based on the taxonomic relationship

(2) Design of the learning resource

The initial design of PTLR was built on a 5m x 7m plot of land planted with ferns. Container gardening method was managed with rows of plants with around 30 cm spacing between pots and between rows so that for certain plants the plant canopy overlaps. This initial design upset students' observation and restricted their movement. The collection of pots from one class to another was also about 30 cm. Each pot was labeled with the same color name for all classes. The arrangement of pots was grouped based on the classes in the Pteridophyte but were not sorted phylogenetically (Fig.1).

(3) Development of the learning resource

This development stage was carried out in accordance with the previous design that had been made. Content expert and learning media expert validated the PTLR before its implementation.

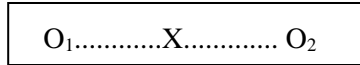
First validation showed many weaknesses. Improvements were then made based on the validator's suggestions.

Content validation was done by a taxonomist expert in Biology Department, Universitas Negeri Semarang. Substantial aspects validated include the accuracy of selection and completeness of species, the completeness of the specific organs of each species, and unknown facts of each species. Learning media expert aspect validated the aspects of PTLR's ability to achieve basic competences, the ease of observation by students, benefits, and its maintenance.

(4) Implementation of the learning resource

The valid product from previous stage was then implemented in X class learning activities of MA Al Asror Semarang. Pre-test was given at the beginning of learning to find out their prior knowledge. Learning process was done by

observation using PTLR as a learning resource accompanied by worksheets which was developed by Aprilanti et al. (2019). Post-test to determine cognitive learning outcomes proved its effectiveness PTLR (Fig. 2).



**Figure 2.** The one group pretest-posttest design

The student learning outcomes measured were cognitive and psychomotor aspects according to the basic competencies that must be achieved in *Plantae* topic based on the Curriculum 2013 of Biology Subject. An objective test measured the cognitive learning outcome, and an observation sheet measured the psychomotor learning outcome. Multiple-choice test for cognitive outcome was arranged based on the two basic competencies required. Before being used, the questions were tested in classes that were not used for implementation. The number of items tested was more than needed. The 25 items used were reliable, valid, had sufficient and good difference power, and the difficulty level was mostly moderate. At the end of learning, posttest was given to measure students' learning improvement by PTLR.

The psychomotor aspect was observed during learning process by some observers. The observation sheet for psychomotor outcome was validated its structure and content. The psychomotor aspects measured were 1) the activities when students making observations (observing the morphological characteristics of ferns, the location and structure of the ferns, classification of ferns and analysis of the phenetic and phylogenetic relationships of ferns) and 2) the skills of making reports (compiling reports, providing further explanation, making conclusion and bibliography).

#### (5) *Evaluation of the learning resource*

Evaluation in this study was in a formative evaluation. The evaluation related to product development from a series of testing processes to develop suitable final product. In addition, observations and questionnaires were also carried out to determine the practicality and effectiveness of PTLR.

Practicality of PTLR was observed by the teacher and the student response questionnaires. The content and construct validity of the questionnaire had been tested previously. The questionnaire was given to teachers and students after learning using PTLR. The aspects assessed in

the student questionnaire included ease of observation, completeness of type, benefits in understanding the material, benefits in encouraging enthusiasm for learning, benefits of making a pleasure in learning; while the aspects in the teacher's questionnaire included the benefits of helping students learn, stimulating student curiosity, facilitating student observation activities, the ability to help achieve basic competences, aesthetics, and ease of maintenance (Zuiker & Riske, 2021).

The cognitive learning outcome were tested by N-gain, while the psychomotor used the average score of observation and reporting activities. Psychomotor learning outcomes were analysed descriptively in percentage, namely the score obtained divided by the maximum score, expressed in percentage. The psychomotor aspects achieved included the skills of observing the morphological characteristics of ferns, observing the location and structure of the ferns, classifying ferns, analysing phenetic and phylogenetic relationships of ferns, compiling reports, providing further explanations, drawing conclusions, and compiling suggestions and bibliography.

PTLR development is stated valid when the validation score of the experts reaches a minimum of 71% out of maximum score (100%). It is called practical when the response of the teachers and students reach >71%, and declared effective when the N-gain of cognitive learning outcome reaches a minimum of 0.3, the score of each student achieves >71, and psychomotor learning outcome reaches > 71%.

## RESULTS AND DISCUSSION

### Validity of PTLR

The initial design of PTLR, with narrower area, square-layout, and same colour label, were validated by the content and media expert. They also advised improving the PTLR design. There were several improvements made based on the validator's suggestion. First, the PTLR was expanded to widen the distance between shelves and between plant's pots. It aimed to make students freer to do observations. Second, the layout of the plant's pot was changed into a circular shape to ease students' observation and to enhance aesthetical appearance. Third, the colours of the shelves were made different among classes. In addition, the park needed to be given a PTLR signboard to make it more attractive.

Based on the validator's suggestion, PTLR

improvements were also done in terms of substance. First, plant's pots were labelled with the name of the species. Second, they are added with *Marsilea* ferns, an aquatic fern with a unique

spore-producing organ shape. Therefore, there were 29 species of ferns planted in PTLR (Table 1).

**Table 1.** List of names and habitats of ferns in Pteridophyte Taxonomic Learning Resource (PTLR)

No	Class / Scientific name	Habitat
<b>A</b>	<b>Pteridopsida</b>	
1	<i>Nephrolepis exaltata</i>	Terrestrial, lithophyte, epiphyte
2	<i>Nephrolepis cordifolia</i>	Terrestrial, lithophyte
3	<i>Nephrolepis exaltata</i>	Terrestrial, lithophyte
4	<i>Nephrolepis cordifolia handy</i>	Terrestrial, lithophyte
5	<i>Dennstaedtia scandens</i>	Terrestrial
6	<i>Athyrium filixfemina</i>	Terrestrial
7	<i>Salvinia molesta</i>	Aquatic
8	<i>Salvinia natans</i>	Aquatic
9	<i>Pteris biaurita</i>	Terrestrial
10	<i>Pteris vittate</i>	Terrestrial
11	<i>Pteris ensiformis</i>	Terrestrial
12	<i>Pteridium aquilinum</i>	Terrestrial
13	<i>Phegopteris connectilis</i>	Terrestrial
14	<i>Pyrosia longifolia</i> ,	Terrestrial
15	<i>Adiantum raddian</i>	Terrestrial
16	<i>Platycerium coronarium</i>	Epiphyte
17	<i>Drynaria quercifolia</i>	Epiphytes, lithophytes
18	<i>Lygodium japonicum</i>	Terrestrial, epiphyte
19	<i>Asplenium nidus</i>	Epiphytes, lithophytes
20	<i>Asplenium thunbergii</i>	Epiphyte
21	<i>Asplenium scolopendrium</i>	Epiphyte
22	<i>Asplenium hemionitis</i>	Epiphyte
23	<i>Microsorium punctatum</i>	Terrestrial
24	<i>Drymoglossum heterophyllum</i>	Epiphyte
25	<i>Marsilea crenata</i>	Aquatic
<b>B</b>	<b>Lycopsida</b>	
1	<i>Selaginella tamariscina</i>	Terrestrial
2	<i>Selaginella uncinata</i>	Terrestrial
3	<i>Selaginella nipponica</i>	Terrestrial
<b>C</b>	<b>Equisetopsida</b>	
1	<i>Equisetum debile</i>	Aquatic

The layout arrangement was started from Pteropsida, Equisetopsida, and Lycopsida. The containers were placed on multilevel shelves made of iron and white painted. These modifications were expected to make students easier to

formulate the general characteristics of the Pteridophytes, compare the features of each class and analyse the phenetic relationships. The modified PTLR (Fig. 3) was then further validated.



**Figure 3.** The PTLR model developed in this research

The ferns plants were selected which had a variety of habitats, namely terrestrial, lithophytes, epiphytes, and aquatic. It was also chosen based on variations in morphological features. Variations in the specific characteristics of organs

displayed were microphyll, macrophyll, trophophyll, sporophyll, sporocarp, and young leaves (Fig. 4). Some ferns were naturally living, and others were designated since the ferns existed did not completely represent all fern classes.



**Figure 4.** Some of the ferns planted on PTLR. A. *Platycerium*, an example of epiphytic fern. B. *Adiantum*, an example of terrestrial fern. C. *Salvinia*, an example of aquatic fern. D. *Asplenium*, with curled young leaves. E. *Pteris*, with curled young leaves. F. *Equisetum*, an example of entail fern forming microphylls. G. *Microsorium*, an example of sporophyll with a sorus located along the leaf nerve. H. *Platycerium*, an example sporophyll with sorus at the leaf tips. I. *Marsilea*, an aquatic fern with sporocarp, added to PTLR as the validator's suggestion.

The validation results showed that PTLR was categorized as 'very valid' criteria both in terms of substance (number and type of ferns) and the arrangement of the garden (Table 2). This meant

that the developed PTLR had met the provisions of plant characteristics indicators, including Pteridophyte and garden characteristics as learning resources.

**Table 2.** The result of PTLR validation

Validator	Validation aspect	Score (%)	Criteria of validity
Taxonomist	Species of ferns	83.5	very valid
Learning media expert	The arrangement of garden	87.5	very valid
Average		85.5	very valid

### The practicality of PTLR

The PTLR received a positive response from students. Almost all the seven indicators had good responses or more than 82% of the maximum score. Even the response to the completeness of fern available in the PTLR was very high, which was between 92-95%. Students argued that PTLR provided various types of fern habitat so that they could distinguish terrestrial, epiphytic, and aquatic ferns. PTLR helped them to observe the morphological characteristics of ferns (sporophyll, tropophyll, microphyll, macrophyll, and young curling leaves) directly.

The PTLR also received a positive response from teachers with an average score 81.25. Four of the 10 response indicators were scored 87.50 – 100 and considered very good, while the rest were score 75 and deemed to be good. The PTLR was considered appropriate as a source of learning to achieve the basic competencies of Plantae (particularly Pteridophyte) and in accordance with the scope of the material. The species of fern plants were complete and strongly supported contextual learning. They were also easy to apply in learning, although it required extra time when doing preparations. In general, it can be stated that the PTLR was very beneficial for students and schools and was practical to use in Pteridophyte learning.

### The effectiveness of PTLR

PTLR which had been validated and revised based on expert advice was then implemented in actual learning. The students achieved an N-gain of 0.57 and all of them obtained score more than 71 after studying using PTLR. Therefore, the PTLR was effectively used as a learning resource.

The analysis showed an increase in average post-test scores compared to pre-test with N-gain including moderate criteria. Based on observation of learning activities using PTLR, the teachers seemed capable of applying the PTLR well in learning Plantae (particularly Pteridophyte) with the discovery learning approach. The learning process began with the apperception step to relate students' experiences to the fern and other plants. Then students were given a worksheet as the observation guideline at PTLR.

The results showed that the psychomotor skills of students, namely the observation skills and report preparation skills reached optimum results with an average score 86.34. Most aspects of the observation skills and preparation of reports reached very good categories (with a range of score between 87.50 to 93.33), except for two aspects, i.e. analysing phyletic and phylogenetic relationships and giving further explanations which obtained good categories with a range of score 75.00 – 80.00.

The PTLR was considered very valid and practical and lead it to be effective to be used as a learning resource. The students achieved an N-gain of 0.57 for cognitive learning outcomes after studying Plantae (particularly Pteridophyte) using PTLR. It means that there was an increase in student cognitive learning outcomes between before and after learning. Although the result was classified as moderate, it was considered good enough considering the relatively short learning period which were only three-time meetings. Ideally, significant changes in learning outcomes required a learning phase with a long trial period so that the students able to adapt to a new learning approach or media. As a result, they would be able to obtain significant changes in learning outcomes.

The increase of students' cognitive learning outcomes in learning using PTLR was due to the contextual learning process. Contextual learning emphasizes the relationship between learning topics and the real-life world (Ridlo & Alimah, 2013, Benade, 2019) and causes the students to easier to understand the learning topic. Students could interact directly with real-life because the PTLR provided various types and species of ferns that their morphology could be directly observed. Moreover, the students could differentiate species ferns based on taxonomic relationships because the ferns were arranged in such a way to show their class and phenetic relationships. Also, by studying at PTLR students learned the theory and interacted directly with nature. Therefore, students' understanding of concepts came from natural observations. Previous study shows that students who learn through practice directly can improve their cognitive abilities, and the concepts

learned are easier to understand and remember (Ahn & Class, 2011). This is also in accordance with the conclusion of Murti et al. (2014) that laboratory-based learning can help students find facts about the concept that they learn.

The result was in line with some previous studies which conclude that students who use authentic learning resources have better performance in science activities. Specifically, original learning resources in the form of parks can be used as a means for teaching and enriching learning curricula (Passy et al., 2010; Cramer & Tichenor, 2021). The natural laboratories have been proven to generate a positive impact on academic performance and student achievement (Berezowitz et al., 2015). The real laboratory activities promote aspects of personal relevance, uncertainty and student negotiation (Widodo et al., 2017), and these aspects can increase performance in a science activity.

Psychomotor learning outcomes also obtained a very good category. The skills were observed when students performed observations at PTLR using worksheets and compiled the report after observation. A very high score was achieved in the aspect of 'observation of fern morphology'. The very high score was due to the characteristics and structure of fern plants that were very easily observed because all parts of the plant body were visible. Consequently, in this activity, the students seemed enthusiastic, happy, and interested to inspect the organs of fern plants directly that had never been seen. The score for the aspect of 'skills in classifying the ferns based on similarities and differences of characteristics' were lower than the score of morphology observation, but it was still classified as very good criteria. In this process, some students were less able to distinguish a type of fern with another that classified in one genus because the shape was very similar. The lower score was also obtained in the aspect of 'analyzing the relationship of fern'. Nevertheless, the score was still classified as a good criterion. In learning using plants as learning resources, the psychomotor learning outcomes achieved good criteria because the students' experiences some activities, not only watch, but also hold, observe, and interact directly (Gallardo-Ruiz et al., 2013). According to Bucher (2017) and Burt *et al.* (2017), learning in school gardens is more interactive and fosters environmental care skills and attitudes (Kissi & Dressman, 2018).

Based on the cognitive and psychomotor learning outcomes obtained in the learning of Plantae (particularly Pteridophyte) material using

PTLR, it could be stated that the basic competencies according to the Curriculum of 2013 of Biology Subject could be achieved. In learning process, the learning resource facilitated students to achieve some basic competences which involved applying the principle of classification to classify plants based on morphological observations. The facilitation was done through a contextual learning approach with the observation method carried out in worksheet and group discussions. The method required students to observe morphology and classified plants directly so that their psychomotor skills were trained; and made it easier for them to remember and comprehend the material then improve their cognitive skills.

The students could apply the classification principle to classify plants through observations of plant morphology, and presented data of the observation results in the form of written reports. Accordingly, the PTLR was effective in achieving the basic competencies. This also appeared from the good teacher response and excellent student response to PTLR. Most students expressed their pleasure and were motivated to learn at PTLR (Saura & Mamaoag, 2023). According to Gallardo-Ruiz *et al.* (2013), the characteristics of the success of psychographic aspects can be seen from the enthusiasm of students in implementing the learning process, especially in laboratory activities.

The implementation result showed that the PTLR considered valid, practical and effective in optimizing the learning outcomes of two domains. The development of instructional media is declared successful if it meets the criteria of validity, effectiveness, and practicality. The effectiveness of PTLR in improving learning outcomes was characterized by the higher post-test scores than the pre-test ones, while developing students' skills in observing and compiling reports were identified by flying scores of the skills. In addition, practicality could be seen from the teacher's recognition that PTLR could be applied easily although it required a lot of time to prepare. The PTLR acceptance for students could be seen from the students' enjoyment in studying at PTLR.

The PTLR developed in this research had bigger advantages than other learning resources. In contrast to pictures in books or screens that were only in two dimensions and could only be seen, the PTLR provided three-dimensional structure, its surface could be touched, and it could be smelled. These features gave a deep impression for students' minds and memories. This is in



accordance with Edgar Dale's theory which was modified in 1969 about learning media. In the cone of experience, the description of experience from the most concrete (bottom) to the most abstract (top) is as follows: (1) direct purposeful experience, experience with a specific purpose, (2) contrived experience, (3) dramatized expertise, (4) demonstrations, (5) study trips, (6) exhibitions, (7) educational television, (8) motion pictures, (9) radio, recordings, still images, (10) visual symbols, and (11) verbal symbols (Edgar Dale in Sari, 2019). According to the cone of experience, the PTLR developed in this study involved direct purposeful experience, experience with specific goals. The effective learning was achieved by applying strategies at the bottom of the Edgar Dale pyramid using direct and purposeful learning experiences that simulate "doing the real thing," and representing reality or the closest things to real (Davis & Summers, 2014; , Stringer & Jhagroo et al., 2012).

Compared to other learning resources as in public parks, the PTLR has superiority in plant layout settings. The types of plants in PTLR were arranged according to their classification position so that it was easier for the students to compare the similarities and differences and the phenetic kinship between ferns. Thus, PTLR could enrich and improve the existing learning resources. It was recommended to other senior high schools to develop a PTLR as a learning resource for Plantae topic (particularly Pteridophyte). Senior high school with large yard has a great opportunity to develop the PTLR. When there is no yard with an adequate area, the vertical garden system can be quite an appropriate choice.

## CONCLUSION

The PTLR model with the container gardening on an area of 5m x 12m has been realized. Species of terrestrial, lithophytes and aquatic ferns were planted in pots, while epiphytic ferns were hooked up on trees. Plant pots were arranged systematically according to the taxonomic position. This model was declared to be very valid with average score of 85.5% (very good) and considered practical by teachers (81.25%) and students (90.65%). The PTLR was also effective in achieving two basic competencies by Curriculum 2013 of Biology Subject with cognitive outcome N-gain of 0.57 (moderate) and psychomotor 86.34% (very good). The results showed that the PTLR developed has met the criteria of validity, practicality, and effectiveness; and recommended to be used in learning of

Plantae topic (particularly Pteridophyte) in senior high school. The study contributes to the development of contextual and innovative learning resources in teaching biology in senior high school.

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