The Effect of Environmental Education Open Inquiry Learning Kits on the Environmental Literacy of Pre-service Biology Teachers

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Abstract
Pre-service biology teachers’ environmental literacy is still generally low. It is necessary to improve their environmental literacy through the innovation of open inquiry learning kits. There are two primary aims of this study: (1) to develop appropriate open inquiry learning kits that can foster pre-service biology teachers’ environmental literacy in environmental education courses, (2) to examine the effectiveness of open inquiry learning kits in improving environmental literacy. This study used the procedure of the 4-D Thiagarajan model, i.e., four stages: (1) define, (2) design, (3) develop, and (4) disseminate. The products produced are open inquiry lesson plans, student worksheets, and environmental literacy test instruments. The product validation was carried out by experts in the field of environmental education and biology teaching and learning. The preliminary field testing and the main field testing were carried out in environmental education courses. The data were collected through observation, questionnaires, and written tests. The data were analyzed in a quantitative descriptive way through the calculation of the gain score. The results obtained from the research and development are open inquiry learning kits to improve the environmental literacy of students, which as a whole are suitable to use in environmental education lectures based on expert judgment. These open inquiry learning kits are not very effective in improving students’ environmental literacy based on the calculations of the gain score due to various shortcomings.

Keywords: Environmental education, environmental literacy, open inquiry, pre-service biology teacher.

Introduction
Environmental literacy is one of the issues that has emerged in the twenty-first century (Erol, 2021; Partnership for 21st Century Skills, 2009). Literacy is the ability to read and write, and the condition/quality of one’s knowledge in a particular field. Many people equate environmental literacy only as knowledge about the environment (NEEF, 2015). Environmental literacy is linked to both ecological knowledge and the process
of interacting with the environment. The main components of environmental literacy are a person’s knowledge, attitudes, and behavior. The knowledge domain includes information about the relationship between humans and natural systems, whereas the attitude domain includes personal beliefs, values, and feelings about nature (Lloyd-Strovas et al., 2018). Environmental literacy is more than just awareness or personal knowledge; it is developed in a specific context, whereas behavior can change as a result of changing attitudes and knowledge. Environmental literacy is an important component of every human being’s basic literacy (Loubser et al., 2001).

The lack of environmental literacy is closely related to environmental issues caused by human activity. Fresh water scarcity, global warming, systemic environmental pollution, runoff water pollution, and environmental problems caused by small businesses, housing, and motor vehicles (Coyle, 2005), deforestation, solid waste management problems, air/water pollution, and soil erosion (Kuruppuarachchi et al., 2021), climate change, consumption and waste, endangered species, poverty in children, racial discrimination, and declines in bee populations (Dada et al., 2017) are examples of real environmental problems as a result of low environmental literacy. Other environmental problems that are not directly visible but have a clear impact include nuclear radiation, the ozone hole, the accumulation of greenhouse gases in the atmosphere, the decline in the number of species, and climate change (Kollmuss & Agyeman, 2002). Other problems that can be felt directly, including eutrophication, air, soil and water pollution, and various other environmental problems are also phenomena of environmental degradation (Kollmuss & Agyeman, 2002). The most basic causes of these ongoing problems are mostly related to people’s lifestyles and human activities.

The anthropocentric era that has occurred in the 21st century is also named as an era of wicked problems, an era of uncertainty, and an era of unsustainable development, marked by many emerging crises and environmental problems. This name is closely related to the phenomenon of unsustainability that is often encountered around us when human beings act unwisely towards nature (Salóte et al., 2020).

Fortunately, human consciousness has recently begun to emphasize the importance of keeping a healthy balance between humans and nature (Liang et al., 2018). The development of environmental literacy is seen as important to help overcome environmental problems/crises. The development of student environmental literacy is the task of all educational institutions at various levels (Arnon et al., 2015; Roth, 1992). Especially in higher education, it is important for students to master environmental literacy in order to be environmentally literate (Clair, 2003). Students with good environmental literacy are more responsible for their environment (Hariyadi et al., 2021).

The results of the study of the behavior of the people who care about the environment in Indonesia reveal the fact that the community’s Environmental Care Change Index (ECCI) is relatively low, being at 0.57 (Haerurahman et al., 2017). This indicates that the community’s environmental literacy is also still low because environmental care behavior is one component of environmental literacy. Based on research by Maknun et al. (2017) and Meilinda et al. (2017), environmental literacy of high school students is still low. Many studies have revealed that the environmental literacy of undergraduate students is also still low (Farwati et al., 2017; Liang et al., 2018). Another study also found a group of students who had low environmental literacy (Apriana, 2017). Rather disappointing finding of other studies on pre-service teachers who will later teach students in school also shows low mastery of environmental literacy (Amirshokoohi, 2010; Goul-
Environmental literacy is the expected output of environmental education and is seen as a key element in creating an environmentally literate society (Liang et al., 2018). Through a quasi-experiment, lectures on environmental education are proven to be able to develop students’ environmental literacy (Hsu, 2004). Environmental education has also been shown to have a direct impact on the improvement of the environmental literacy of prospective teacher students (Dada et al., 2017). Specific learning interventions by combining student-centered activities and independent learning have been shown to develop students’ environmental literacy (Bissinger & Bogner, 2018). Developing environmental literacy is done by designing learning activities that involve students directly (Adler et al., 2018). One of the student-centered learning strategies is open inquiry-based learning. Open inquiry learning can be an alternative to developing student environmental literacy (Kidman & Casinader, 2019; Yusup et al., 2021). This model can train students to investigate environmental problems that surround them. Students of this century must have the ability to understand complex global problems through inquiry learning (Scott, 2015). The investigation steps in the open inquiry model also facilitate students to produce findings, suggestions, or solutions to overcome environmental problems (Adler et al., 2018). The development of research-based activities for students is also one way to ensure sustainable education (Dvoryatkina et al., 2021). Since there are not many studies on the subject, it is crucial to create a teaching and learning facility that focuses on creating educational modules and models for sustainable development (Yoo & Jeon, 2022).

Inquiry learning can run well through the use of appropriate learning kits (Jones & Eick, 2007). Learning kits serve as guidelines for lecturers and guides for students while investigating the issues raised, formulating investigative questions to produce suggestions or problem-solving solutions. This research aims to reveal the effectiveness of integrated learning kits with open inquiry models on environmental literacy of pre-service biology teachers. For prospective teachers in the future, it is important to master environmental literacy well by pre-service teachers (Cheng & So, 2015), especially for biology teachers. Through good mastery of environmental literacy, it is expected that it will be able to teach it to the wider community, particularly students in the future as an endeavour to introduce environmental conservation in order to realize education for sustainable development (Dada et al., 2017). Teacher should have the ability to facilitate learning that can create and provide learning opportunities for students to develop their capacity for sustainability (Saiful & Setyorini, 2022).

Research Method

This study is research and development. It aims to develop a product in the form of integrated environmental education learning kits with an open inquiry learning model, which is expected to be able to foster students’ environmental literacy. The research and development procedure refers to the 4-D “Four D” procedure as shown in Figure 1 (Ekantini & Wilujeng, 2018; Thiagarajan et al., 1976). As the name implies, there are four major phases as research and development steps: define, design, develop, and disseminate. This research begins with the early stages and progresses to the final stage of the 4-D research and development process, which takes one academic semester.
Phase I: Define

The first phase sought to define instructional needs. The majority of the activities during this phase were analytical in nature. At this stage, the goals and boundaries for learning kits were established through analysis. It began with a front-end analysis to investigate the fundamental issues that lecturers face when attempting to improve the quality of student learning. The purpose of the learner analysis was to examine students from the biology education undergraduate study program as research and development subjects. The task analysis was used to identify the main skills that students would acquire, which were then broken down into a set of required sub-skills.

The concept analysis aimed to identify the main concepts that would be discussed in the developed learning kits, arrange the concepts in a hierarchy, break down each concept, and then classify them based on their relevance. Determining instructional objectives was performed by changing the results of the task analysis and concept analysis into the objectives to be achieved through lectures.

Phase II: Design

The second phase aimed to create a design for the developed learning kits in the form of a prototype. It started with the development of a criterion reference test and the transformation of the learning objectives into an outline of the learning kit material. The media selection process was carried out by choosing appropriate and relevant media to support the presentation of learning materials. The developed learning kits in this study took the form of open inquiry lesson plans and lesson units, student worksheets,
and environmental literacy test instruments. The learning kits were created in accordance with the standard format used in the undergraduate biology education study program at Yogyakarta State University (YSU). The initial design was demonstrated by presenting the learning design through the appropriate media and in the appropriate time sequence. Prawestri’s learning steps (Figure 2) were adapted and modified to create the open inquiry learning model used in this study (Prawestri et al., 2016).

Figure 2
Syntax of Open Inquiry Teaching Model

<table>
<thead>
<tr>
<th>Phase I: Develop</th>
</tr>
</thead>
<tbody>
<tr>
<td>The third phase focused on improving the prototype (Figures 3 and 4) of the designed open inquiry learning kits. It began with an expert appraisal to receive an expert assessment, which was a method for obtaining specific recommendations for material improvement. A team of environmental education and biology learning experts was asked to assess the components from both a learning and a technical standpoint. The learning kits was revised in response to feedback to make it more appropriate, effective, usable, and of high quality. During the developmental testing stage, the learning kits were tested with pre-service biology teachers to identify the parts that needed revision. The material was also revised based on their responses, reactions, and comments.</td>
</tr>
</tbody>
</table>

Phase IV: Disseminate

The final phase aimed to disseminate the developed and revised learning kits. The validation testing stage was conducted using a one-group pretest-posttest quasi-experimental design (Figure 5). This experimental design was used to determine the effect of application of a new educational product (Cohen et al., 2018). This stage aimed to determine the effectiveness of the use of integrated learning kits with an open inquiry learning model on environmental literacy of pre-service biology teacher at YSU.
RENCANA PEMBELAJARAN SEMESTER

Program Studi : Pendidikan Biologi
Nama Mata Kuliah : Pendidikan Kependondukan dan Lingkungan Hidup (PKLH)
Kode : EDD230
Jumlah SKS : 2 (teori)
Semester : Genap
MK Prasyarat : Ilologi, Emi Lingkungan, Pendidikan Biologi
Dosen Pengampu : Dr. Anggi Tias Pratama, S.Pd., M.Pd.
Bahasa Pengantar : Bahasa Indonesia
Bebas Kerja : Perkuliahan tatap muka berupa teori selama 100 menit, 120 tugas terstruktur, dan 120 tugas mandiri setiap minggu

Deskripsi mata kuliah:
Mata kuliah ini dikembangkan untuk membekali mahasiswa dengan pengetahuan, keterampilan, sikap dan perilaku yang rasional serta memiliki ruas tanggung jawab terhadap dinamika kependondukan dan lingkungan hidupnya. Dikatakan sebagai era Revolusi Industri 4.0 dan mendukung pencapaian keterampilan abad 21 terutama keterampilan berpikir kritis serta membekali mahasiswa dengan penguasaan tema-tema penting abad 21 khususnya literasi lingkungan. Kegiatan perkuliahan dilaksanakan berbantuan ICT dengan langkah-langsung pembelajaran berbasis inkuiri. Mahasiswa mengikuti kegiatan perkuliahan yang dikelomkan secara klasik, kelompok, maupun individual. Mata kuliah ini memfokuskan pada pengembangan kompetensi mahasiswa melalui pembahasan keterkaitan antara manusia dan faktor lingkungan kedaulatan topik-topik aktual pada kehidupan sehari-hari, yaitu yang berkaitan dengan energi dan sumber daya alam, air, udara, dan darat.

Pengembangan selanjutnya adalah pembahasan tentang kerusakan lingkungan akibat perilaku manusia, apa yang perlu dilakukan sebagai bentuk tanggung jawab terhadap kehidupan yang berkembang, dan pelestarai alam dalam pembahasan etika lingkungan. Pencak dari pengembangan tersebut yaitu pembahasan masalah-masalah yang dihadapi kampung Indonesia yang berhubungan dengan lingkungan regional maupun global. Penilaian dilakukan dalam bentuk ujian, penilaian portofolio, observasi partisipasi mahasiswa, dan tugas mandiri.

Program Learning Outcome (PLO) yang dibayakan pada mata kuliah ini:
PLO 1: Menunjukkan sikap bertanggung jawab, mandiri, sikap kewirausahaan, leadership, adaptif dalam menjalankan tugas.
PLO 2: Memahami biologi dasar dan pengetahuan lain yang relevan dengan matematika dan ilmu pengetahuan alam.
PLO 3: Mampu berkomentar dan berkolaborasi, secara lisan dan tulisan dengan baik.

Course Learning Outcome (CO):
CO 1: Menghargai peran sehat dan diperlukan terhadap lingkungan dalam perspektif etika lingkungan
CO 2: Menganalisis berbagai macam pola interaksi manusia dengan lingkungan dalam etika lingkungan
CO 3: Menganalisis prinsip utama etika lingkungan
CO 4: Menghargai prinsip etika lingkungan yang berkembang
CO 5: Memahami nilai-nilai etika lingkungan dalam kehidupan sehari-hari
CO 6: Menganalisis peran pendidikan lingkungan hidup dalam mendukung pembangunan yang berkelanjutan
CO 7: Bekerja secara individu atau kelompok dalam kegiatan diskusi kelompok dan mengkomunikasikan hasilnya dengan baik.


Dalam mengatasi berbagai permasalahan lingkungan tersebut, maka pendekatan yang paling tepat dilakukan adalah ...

- a. egoentrisme
- b. antroposentrisme
- c. pemanfaatan masalah sektoral
- d. green consumerism
- e. penegakan hukum

15. Tingginya kepadatan penduduk di suatu wilayah cenderung akan dilukui * 1 poin dengan memerlukan kualitas air bersih. Alasan yang tepat untuk membatasi pernyataan tersebut adalah...

- a. Tingginya kepadatan penduduk mengakibatkan meningkatnya aktivitas penduduk sehingga kecenderungan untuk mencari air bersih akan semakin tinggi pada
- b. Tingginya kepadatan penduduk mengakibatkan meningkatnya kesadaran penduduk untuk mengelola air, sehingga kecenderungan penduduk untuk mengelola air kotor menjadi air bersih semakin meningkat
- c. Tingginya kepadatan penduduk menyebabkan meningkatnya konsumsi air bersih, sehingga air bersih yang tersedia semakin berkurang
- d. Tingginya kepadatan penduduk menyebabkan meningkatnya kebutuhan akan tempat tinggal, sehingga terjadi allung fungi dan penyempitan lahan yang pada akhirnya sebagai dasar resapan air menjadi area perumahan
- e. Tingginya kepadatan penduduk mengakibatkan meningkatnya pula pemborosan air sehingga menyebabkan berkurangya ketersediaan air bersih
Figure 4

Example of Student Worksheet

![Worksheet Image]

Notes:

- $X$ = Open inquiry learning kit (experimental treatment)
- $O_1$ = Students’ environmental literacy pretest scores
- $O_2$ = Students’ environmental literacy posttest scores
Following the completion of the validation testing stage, the learning kits were packaged and fully prepared for implementation. These open inquiry model-integrated learning kits were packaged into YSU’s learning management system, the Besmart. The diffusion and adoption stage aimed to widely distribute materials to lecturers and students, as well as to encourage material adoption and utilization.

This study population consists of all Yogyakarta State University Biology Education Study Program students who enrolled in environmental education courses in 2020/2021 academic year. The cluster random sampling technique was used to establish the research sample. The experimental group was biology education class A, which had 33 students.

The research instrument used was an open inquiry model-integrated learning kit that had been developed previously, including lesson plans, student worksheets, and student environmental literacy assessment instruments. All of these research instruments had undergone through the stages of construct validation and face validation by experts in their fields of expertise. In addition, validation process was also carried out through the calculation of the Gronlund sensitivity index (Triyuni, 2016). The Kappa Index was calculated to guarantee that the instrument used was reliable (Subkoviak, 1988).

To assess the environmental literacy of the students, a questionnaire and a written test were used. The questionnaire was used to measure the aspects of disposition (affective) and responsible behavior towards the environment. A written test in the form of a multiple-choice item test was used to measure students’ environmental literacy in the knowledge (cognitive) and skill competency aspects. The data on student answers were obtained by using a questionnaire and multiple-choice item test which were carried out twice, before (pretest) and after (posttest) a course that utilized open inquiry learning kits.

Environmental literacy in this study refers to the framework proposed by the North American Association for Environmental Education (Hollweg et al., 2011). Based on this framework, the measured environmental literacy of students includes aspects of knowledge (cognitive), disposition (affective), environmentally responsible behavior, and skill competence. Each aspect consists of several sub-aspects as shown in Table 1 below.

Table 1

<table>
<thead>
<tr>
<th>Environmental Literacy Frameworks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspect</td>
</tr>
<tr>
<td>Knowledge (cognitive)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Disposition (affective)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

See next page for continuation of table
Continuation of Table 1

<table>
<thead>
<tr>
<th>Environmentally responsible behavior</th>
<th>Real examples of preventing environmental pollution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Changing behavior to be pro-environment</td>
</tr>
<tr>
<td></td>
<td>Responsible behavior in the classroom</td>
</tr>
<tr>
<td></td>
<td>Responsible behavior in the community</td>
</tr>
<tr>
<td></td>
<td>Avoiding frontier mentality behavior</td>
</tr>
</tbody>
</table>

| Skills competence                   | Identifying environmental issues                   |
|                                     | Asking questions related to environmental conditions and issues |
|                                     | Analyzing environmental issues                      |
|                                     | Conducting investigations on environmental issues (scientific and social aspects of environmental problems from primary and secondary sources) |

The calculation of pretest and posttest gain score data was used to examine the effectiveness of using the open inquiry model-integrated learning kit in environmental education lectures on student environmental literacy (Bao, 2006; Suratno et al., 2020). The gain score is calculated using the following formula:

\[
g = \frac{\text{Posttest Score} - \text{Pretest Score}}{\text{Maximum Score} - \text{Pretest Score}}
\]

After the gain score for student environmental literacy was known, it was continued by looking at the level of the effect based on Table 2 below (Nismalasari et al., 2016).

Table 2
Criteria of Gain Score

<table>
<thead>
<tr>
<th>Normalized gain score</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.70 ≤ g ≤ 100</td>
<td>High</td>
</tr>
<tr>
<td>0.30 ≤ g &lt; 0.70</td>
<td>Medium</td>
</tr>
<tr>
<td>0.00 &lt; g &lt; 0.30</td>
<td>Low</td>
</tr>
<tr>
<td>g = 0.00</td>
<td>No Increase</td>
</tr>
<tr>
<td>-1.00 ≤ g &lt; 0.00</td>
<td>Decrease</td>
</tr>
</tbody>
</table>

Findings and Discussion

Expert Appraisal

Table 3
Expert Appraisal Result

<table>
<thead>
<tr>
<th>No</th>
<th>Learning kits</th>
<th>Expert 1</th>
<th>Category</th>
<th>Expert 2</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Lesson plan</td>
<td>3.29</td>
<td>Good</td>
<td>3.14</td>
<td>Good</td>
</tr>
<tr>
<td></td>
<td>· Adequacy of lesson plan components</td>
<td>3</td>
<td>Good</td>
<td>4</td>
<td>Very good</td>
</tr>
<tr>
<td></td>
<td>· Completeness of lesson plan identity</td>
<td>3.5</td>
<td>Very good</td>
<td>3.5</td>
<td>Very good</td>
</tr>
<tr>
<td></td>
<td>· Conformity of the study plan with the program learning outcome</td>
<td>3.29</td>
<td>Good</td>
<td>3</td>
<td>Good</td>
</tr>
</tbody>
</table>

See next page for continuation of table
The Effect of Environmental Education Open Inquiry Learning Kits...

Continuation of Table 3

<table>
<thead>
<tr>
<th></th>
<th>Expert 1</th>
<th>Expert 2</th>
<th>Expert 1</th>
<th>Expert 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Suitability of learning resources</td>
<td>3.5 Very good</td>
<td>3 Good</td>
<td>3.5 Very good</td>
<td>3 Good</td>
</tr>
<tr>
<td>The suitability of lecture activities with open inquiry characteristics</td>
<td>3 Good</td>
<td>3 Good</td>
<td>3 Good</td>
<td>3 Good</td>
</tr>
<tr>
<td>2. Student worksheet</td>
<td>3.23 Good</td>
<td>3.26 Good</td>
<td>3.23 Good</td>
<td>3.26 Good</td>
</tr>
<tr>
<td>• Eligibility of material content</td>
<td>3.14 Good</td>
<td>3.43 Sufficient</td>
<td>3.14 Good</td>
<td>3.43 Sufficient</td>
</tr>
<tr>
<td>• Authorship approach</td>
<td>3.4 Good</td>
<td>3.2 Good</td>
<td>3.4 Good</td>
<td>3.2 Good</td>
</tr>
<tr>
<td>• Learning</td>
<td>3.14 Good</td>
<td>3.14 Good</td>
<td>3.14 Good</td>
<td>3.14 Good</td>
</tr>
<tr>
<td>• Appearance</td>
<td>3.2 Good</td>
<td>3 Good</td>
<td>3.2 Good</td>
<td>3 Good</td>
</tr>
<tr>
<td>• Language</td>
<td>3.33 Good</td>
<td>3.33 Good</td>
<td>3.33 Good</td>
<td>3.33 Good</td>
</tr>
<tr>
<td>3. Environmental literacy test</td>
<td>3.24 Good</td>
<td>3.22 Good</td>
<td>3.24 Good</td>
<td>3.22 Good</td>
</tr>
<tr>
<td>• Material content</td>
<td>3.33 Good</td>
<td>2.86 Good</td>
<td>3.33 Good</td>
<td>2.86 Good</td>
</tr>
<tr>
<td>• Construction</td>
<td>3 Good</td>
<td>3.5 Very good</td>
<td>3 Good</td>
<td>3.5 Very good</td>
</tr>
<tr>
<td>• Language</td>
<td>3.4 Good</td>
<td>3.4 Good</td>
<td>3.4 Good</td>
<td>3.4 Good</td>
</tr>
</tbody>
</table>

The results of the expert appraisal conducted by biology teaching and learning and environmental education experts as expert validators are shown in Table 3. These results indicate that the developed open inquiry learning kits are in a good category. Based on expert appraisal testing of this research product, Expert 1 and Expert 2 agreed that the lesson plan, student worksheet, and environmental literacy test were “worthy of trial in the field with revisions”. The expert appraisal stage was also used to evaluate the face validity and construct validity of the developed research instrument. In addition to providing quantitative assessments, Expert 1 and Expert 2 also provided qualitative assessments in the form of inputs and suggestions as follows.

“The allocation of total time in the lesson plan needs to be fixed!”

“Population education topics should be incorporated into learning kits, so it can be used more extensively in the demography and environmental education courses!”

“Other questions as discussion material that can lead to the achievement of instructional objectives are required in the student worksheets!”

“There is an issue with the numbering of the question instructions in the environmental literacy test instrument, and therefore the number of question instructions must be adjusted!” – Expert 1

“Student worksheets on the one hand have the potential to facilitate students to conduct and develop scientific process skills in an open inquiry manner. On the other hand, environmental literacy does not seem explicit. It is necessary to add a component of discussion questions that can accommodate both, while taking into account the open inquiry criteria.” – Expert 2

A qualitative assessment, such as the one described above, is then incorporated into the revision process of the learning kits. After expert advice was followed, the learning kits were completely ready to go through developmental testing.
Developmental Testing

Table 4

Developmental Testing Result

<table>
<thead>
<tr>
<th>Number of student</th>
<th>Total scores</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>33</td>
<td>3.40</td>
<td>Very good</td>
</tr>
</tbody>
</table>

Table 4 shows the result of the developmental testing conducted on students. The result indicates that the developed open inquiry learning kits are in a very good category. In addition to providing quantitative assessments, in this limited trial, qualitative assessments in the form of comments and suggestions are also provided by students. Some examples of comments or suggestions given by students are as follows.

“Environmental Education learning about Environmental Ethics material is quite impressive, because students are invited to analyze up-to-date environmental problems and find solutions to problems that arise.” – Student 1

“My suggestion, for the assignment to be clarified again, because there are some parts that I don’t understand, so it needs to be read repeatedly, but the rest is good.” – Student 2

“Student worksheet is designed in stages so as to make students trained to think in detail and sequentially, the choice of discourse is also not boring and quite interesting to study.” – Student 3

“Student worksheet activities are interesting and can pave the way for gaining a lot of knowledge beyond what is obtained in class through scientific literacy.” – Student 4

“This student worksheet is very systematic so that it is easy to understand, I think this activity is a boxing mindset because only one case is discussed, suggestions to be more broad-minded about environmental ethics, it is better if the students’ assignments are divided into several groups and have different topics so that learning becomes more varied. and can get a lot of new information.” – Student 5

Validity and Reliability

The research instrument was validated for its face validity and construct validity, and it was carried out during the expert appraisal process. In addition, the fulfillment of validity was also carried out by calculating the sensitivity index of the environmental literacy assessment instrument (Grondlund, 1977; Triyuni, 2016). The result of the calculation of the sensitivity index of the environmental literacy assessment instrument in the experimental class was a score of 0.171.

The measurement of the instrument reliability was done by calculating the Kappa index on the environmental literacy test instrument (Gitomer et al., 2021; Subkoviak, 1988). Kappa index calculation was based on the values of $r$ and $z$ obtained. The $r$-value obtained for the environmental literacy assessment instrument was 0.766, while the
z-value obtained for the environmental literacy assessment instrument was 1.07. From these two values of \( r \) and \( z \), when matched into the Kappa index coefficient table, the Kappa Index value was 0.53. The Kappa index value of 0.53 was in the range between 0.41 and 0.60, which means it is feasible (Landis & Koch, 1977).

The Effect of Open Inquiry Learning Kits on Student Environmental Literacy Aspect of Knowledge (Cognitive)

Table 5

<table>
<thead>
<tr>
<th>No</th>
<th>Sub-aspect</th>
<th>Pretest score</th>
<th>Postest score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Physical and ecological systems</td>
<td>22.73</td>
<td>22.73</td>
</tr>
<tr>
<td>2.</td>
<td>Social, cultural, and political systems</td>
<td>63.64</td>
<td>65.16</td>
</tr>
<tr>
<td>3.</td>
<td>Environmental problems</td>
<td>74.25</td>
<td>74.25</td>
</tr>
<tr>
<td>4.</td>
<td>Various solutions to environmental problems</td>
<td>16.67</td>
<td>28.79</td>
</tr>
<tr>
<td>5.</td>
<td>Community participation and strategy-action</td>
<td>57.58</td>
<td>68.19</td>
</tr>
</tbody>
</table>

Total Mean: 47.27, 51.52
Max: 74.25, 74.25
Min: 16.67, 22.73
SD: 25.95, 23.91

Table 5 shows the result of environmental literacy test on aspects of students’ cognitive knowledge before and after the use of the learning kit in environmental education lectures. The data shown in Table 5 were collected using an objective test with five answer choices and only one correct answer to determine the adequacy of students’ cognitive knowledge about environmental concepts. It was observed that there was a difference in the mean scores of the pretest and posttest on the aspects of cognitive knowledge, where the posttest score (\( M = 51.52 \)) tended to be higher than the pretest score (\( M = 47.27 \)). The highest pretest score was found in the sub-aspect of environmental problems, while the lowest pretest score was found in the sub-aspect of various solutions to environmental problems. The posttest score for the environmental problem sub-aspect also got the highest score, while the physical and ecological system was the sub-aspect with the lowest posttest score.

Aspect of Disposition (Affective)

Table 6

<table>
<thead>
<tr>
<th>No</th>
<th>Sub-aspect</th>
<th>Pretest score</th>
<th>Postest score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Sensitivity</td>
<td>91.52</td>
<td>95.15</td>
</tr>
<tr>
<td>2.</td>
<td>Attitude and concern for the environment</td>
<td>87.88</td>
<td>91.22</td>
</tr>
<tr>
<td>3.</td>
<td>Assumption of personal responsibility</td>
<td>83.94</td>
<td>87.58</td>
</tr>
<tr>
<td>4.</td>
<td>Locus of control/self-efficacy</td>
<td>81.52</td>
<td>84.85</td>
</tr>
<tr>
<td>5.</td>
<td>Motivation and intention to act</td>
<td>83.94</td>
<td>85.76</td>
</tr>
</tbody>
</table>

See next page for continuation of table
Table 6 shows the result of environmental literacy testing on the aspect of disposition (affective) before and after the use of the learning kit in environmental education lectures. The data shown in Table 6 were collected using a five-point Likert scale questionnaire, and they indicated the level of disposition/affective aspects of students towards the environment. It was observed that there was a difference between the average pretest score and posttest score on the aspect of disposition (affective), where the posttest score \((M = 88.91)\) tended to be higher than the pretest score \((M = 85.76)\). The highest pretest score was related to student sensitivity, while the lowest pretest score was in the locus of control/self-efficacy sub-aspect. The posttest score of the student sensitivity sub-aspect also turned out to be the highest test score, while locus of control/self-efficacy was the sub-aspect with the lowest posttest score.

**Aspect of Environmentally Responsible Behavior**

**Table 7**

<table>
<thead>
<tr>
<th>No</th>
<th>Sub-aspect</th>
<th>Pretest score</th>
<th>Postest score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Real examples of preventing environmental pollution</td>
<td>80.00</td>
<td>82.42</td>
</tr>
<tr>
<td>2.</td>
<td>Changing behavior to be pro-environment</td>
<td>70.91</td>
<td>78.18</td>
</tr>
<tr>
<td>3.</td>
<td>Responsible behavior in the classroom</td>
<td>79.39</td>
<td>84.85</td>
</tr>
<tr>
<td>4.</td>
<td>Responsible behavior in the community</td>
<td>84.85</td>
<td>87.27</td>
</tr>
<tr>
<td>5.</td>
<td>Avoiding frontier mentality behavior</td>
<td>66.06</td>
<td>73.33</td>
</tr>
<tr>
<td>----</td>
<td>------------------------------------------------</td>
<td>---------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Total Mean</td>
<td></td>
<td>76.24</td>
<td>81.21</td>
</tr>
<tr>
<td>Max</td>
<td></td>
<td>84.85</td>
<td>87.27</td>
</tr>
<tr>
<td>Min</td>
<td></td>
<td>66.06</td>
<td>73.33</td>
</tr>
<tr>
<td>SD</td>
<td></td>
<td>7.59</td>
<td>5.54</td>
</tr>
</tbody>
</table>

Table 7 shows the results of environmental literacy tests on the aspect of environmentally responsible behavior before and after the use of the learning kit in environmental education lectures. The data shown in Table 7 were collected using a five-point Likert scale questionnaire, and they indicated the level of student responsibility behavior towards the environment. It was observed that there was a difference between the pretest and posttest mean scores in this aspect, where the posttest score \((M = 81.21)\) tended to be higher than the pretest score \((M = 76.24)\). The highest pretest score was related to responsible behavior in the community, while the lowest pretest score was found in the sub-aspect of avoiding frontier mentality behavior. The posttest related to being responsible in the community also turned out to be the highest test score, while avoiding frontier mentality behavior was the sub-aspect with the highest score in the posttest.
Aspects of Competence

Table 8

Result of Research on Aspects of Competence

<table>
<thead>
<tr>
<th>No</th>
<th>Sub-aspect</th>
<th>Pretest score</th>
<th>Postest score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Identifying environmental issues</td>
<td>45.45</td>
<td>48.48</td>
</tr>
<tr>
<td>2.</td>
<td>Asking questions related to environmental conditions and issues</td>
<td>57.58</td>
<td>60.61</td>
</tr>
<tr>
<td>3.</td>
<td>Analyzing environmental issues</td>
<td>18.18</td>
<td>21.21</td>
</tr>
<tr>
<td>4.</td>
<td>Conducting investigations on environmental issues</td>
<td>48.48</td>
<td>48.48</td>
</tr>
<tr>
<td></td>
<td>Total Mean</td>
<td>42.42</td>
<td>44.70</td>
</tr>
</tbody>
</table>

Table 8 shows the results of environmental literacy tests on the aspect of competence before and after the use of the learning kit in environmental education lectures. The data shown in Table 8 were collected by using an objective test with five answer choices and only one correct answer to measure student competence in environmental issues. It was observed that there was a difference between the mean score of the pretest and posttest on the aspect of competence, where the posttest score (M = 44.70) tended to be higher than the pretest score (M = 42.42). The pretest score on the sub-aspect of asking questions related to environmental conditions and issues got the highest score, while the lowest pretest score was found in the sub-aspect of analyzing environmental issues. The sub-aspect of asking questions related to environmental conditions and issues also got the highest posttest score, while analyzing environmental issues was the sub-aspect with the lowest posttest score.

Estimation of the Gain Score

Table 9

Students’ Environmental Literacy Gain Score

<table>
<thead>
<tr>
<th>No</th>
<th>Aspects</th>
<th>Gain score (g)</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Knowledge (cognitive)</td>
<td>0.08</td>
<td>Low</td>
</tr>
<tr>
<td>2.</td>
<td>Disposition (affective)</td>
<td>0.22</td>
<td>Low</td>
</tr>
<tr>
<td>3.</td>
<td>Environmentally responsible behavior</td>
<td>0.21</td>
<td>Low</td>
</tr>
<tr>
<td>4.</td>
<td>Competence</td>
<td>0.04</td>
<td>Low</td>
</tr>
</tbody>
</table>

Table 9 shows the result of the calculation of the environmental literacy gain score of prospective biology prospective-teacher students after they attended environmental education lectures. It was observed that there was a difference between the gain score of each aspect of the environmental literacy variable. The highest gain score was found in the aspect of disposition/affective (g = 0.22), followed by the aspect of environmentally responsible behavior (g = 0.21) and the aspect of cognitive knowledge (g = 0.08). Mean-
while, the lowest gain score was in the aspect of competence \( (g = 0.04) \). Based on the calculation of the gain score, it can be interpreted that all aspects of environmental literacy have a low gain score.

### Discussion

This study aims to develop an open inquiry-based learning kit that is expected to foster the environmental literacy for pre-service biology teachers. In addition, this study also tested its effectiveness in increasing the environmental literacy of prospective biology teachers. The developed learning kits are used in one of the courses that is part of the environmental education course, especially on the topic of environmental ethics, emphasizing the implementation of the open inquiry learning model.

Colburn (2000) points out that inquiry learning refers to student activities that foster knowledge and understanding of scientific concepts, as well as an understanding of how scientists conduct research in the natural world. Inquiry-based education includes a wide range of strategies, from teacher-directed, structured and guided inquiry to student-directed open inquiry. As noted by Adler et al. (2019), the most complex level of inquiry-based learning is open inquiry. This type of inquiry enables students to design or select their own questions and approaches to inquiry, while the teacher only determines the knowledge framework within which the inquiry will be carried out. As a result, students are continuously involved in decision making throughout the open inquiry process, beginning with the stage of identifying interesting phenomena to investigate. Open inquiry mimics and reflects the type of research and experimental work done by scientists, and it necessitates higher order thinking skills (Zion & Mendelovici, 2012).

Inquiry-based teaching is very likely applied to teach environmental sustainability to prospective teacher (Alghamdi & El-Hassan, 2020). This innovation can give new learning experiences to biology education students who are also prospective biology teachers in the future. Lectures with the open inquiry model emphasize student-centered teaching-learning processes (Kang & Keinonen, 2018). Through learning like this, students can be provided with unlimited opportunities to study environmental issues and other phenomena found from the students’ own point of view. Students experience themselves learning about the important processes of scientific inquiry (Bjønness & Kolstø, 2015). The implementation of this teaching can provide students with benefits when it is carried out in a structured manner by raising certain topics that involve students actively in group discussions to conduct an assessment of the topics raised.

Each stage of teaching and learning syntax in open inquiry activities contributes to the success of the other steps. Irdalisa et al. (2020) suggest that students can collaborate in groups to investigate problems and find answers through scientific investigation. At the first stage, students observe and identify problems in groups. After that they are invited to formulate the problems that have been identified previously in the form of questions that are focused/linked to the pattern of relationships that occur between humans and the environment, which is the relationship of problems associated with the main principles of environmental ethics and the effects that can be generated from current community environment ethics.

At the third stage, students are given the opportunity to design appropriate research questions to solve the formulated problems. Research questions are designed in detail and operationally so that they can be answered through open inquiry activities. At the
fourth stage, students develop designs for scientific investigation methods and solve environmental ethical problems through open inquiry as a step to answer research questions. Problem-solving-oriented lectures accompanied by open inquiry lectures have the potential to develop student environmental literacy (Kidman & Casinader, 2019).

At the fifth stage, students carry out investigative activities or collect data. In groups, they compile information related to relevant activities in order to solve the problems that have been planned at the previous stage. This investigative activity is filled with the activities of looking for solutions and expectation that can be implemented in finding alternative answers to the solution of the environmental ethical problems raised from various sources. Students can conduct observation, surveys, interviews, literature studies, or other relevant activities, and tools and materials can be used if necessary. The investigative process is part of the inquiry activity when students are involved in a process marked by an explanation, both from their own knowledge and from the knowledge obtained as a result of an ongoing investigation. Students use investigations to find answers to their own questions. They also sort out information and are willing to revise explanations and consider new ideas when gaining knowledge (building understanding) (National Science Foundation, 2001).

At the sixth stage, students in groups analyze data. At this stage, they make a comprehensive analysis that discusses cause-and-effect relationships, namely, the patterns of human relationships/activities that occur among humans and their consequences on the environment, and then they relate the patterns of human relationships/activities with the main principles of environmental ethics. They question which principles are neglected and which ones should be followed, and, finally, they are asked to formulate appropriate expectations/solutions in order to create a sustainable environmental ethic.

At the final stage, the students draw conclusions and the findings from the results of the previous data analysis. In groups, they present the results of group discussions and participate in discussions and presentations from other groups. At this stage, they are trained to develop knowledge, skills, and attitudes toward the care for the environment through open inquiry lectures to solve problems related to environmental ethics and to encourage the creation of sustainable environmental ethics. Responsible environmental behavior is a response to or an action from the results of the learning process. As the ultimate goal of environmental education, it is synonymous with environmental literacy (Moseley, 2000).

The result of the study shows that in general there is a tendency for higher environmental literacy obtained by students at the end of environmental education learning that implements the open inquiry learning kit when compared to their previous environmental literacy. This difference can be observed in all aspects of environmental literacy. This is in line with the findings of Derman et al. (2016) that environmental education lectures are proven to increase the dimensions of attitude, use, and concern for prospective teachers’ environmental literacy. Other studies have also found that the behavior towards the environment of prospective teachers after they attend environmental education increases in a positive direction (Gwekwerere, 2019).

The aspects of students’ disposition (affective) is the aspect with the highest score in this study and followed by the aspect of environmentally responsible behavior. Saribas, Teksoz and Ertepınar (2014) state that the affective aspect has a greater effect on behavior, emotional bonding, and sensitivity to nature so that it affects environmental literacy. In line with these findings, attitudes towards the environment, perceived behavior, and
concern for the environment seem to be stronger than the aspect of students’ knowledge (Saribas et al., 2014).

The aspects of knowledge (cognitive) and competence in this study seem to be the aspects with the lowest score achievement. Goldman’s study yielded similar results, on the aspect of knowledge, prospective teachers have insufficient knowledge that is considered feasible. One of the reasons is that there are no specific courses relevant to environmental education in the teacher education program (Goldman et al., 2006).

Environmental education is needed to improve the knowledge aspects of prospective biology teachers. An adequate mastery of the aspects of environmental knowledge combined with pedagogical knowledge in the learning process can guarantee the success of teaching environmental literacy to students in the future (Goldman et al., 2006).

Salóte et al. (2021) state that students should be able to gain new experiences through learning. New experiences support a more holistic understanding of personal experience and they increase the use of the unique capabilities from adaptive learning to make more prototypes for personal knowledge. Good personal knowledge is the capital to build a more sustainable higher education.

A fundamental challenge that society faces today is sustainable development, the debate continued on how to develop our world socially and economically while achieving environmental sustainability (Echegoyen-Sanz & Martín-Ezpeleta, 2021). There are three pillars of sustainability: the environment, the economy, and society (Echegoyen-Sanz & Martín-Ezpeleta, 2021). Sustainability means keeping these three in balance so that they can coexist. Chacko (2000) stated that sustainability implies that the environment should be protected and preserved in order to provide equal opportunities to future generations. The wise use of the environment and available resources is referred to as sustainability. In other words, sustainability is concerned with minimizing risks while maximizing opportunities to improve people’s quality of life at the local, regional, and global levels (Ogunyemi et al., 2022).

The implementation of sustainability is unimaginable without education because education plays a significant role in developing learners’ cognitive and affective dimensions, resulting in knowledgeable, skilled, and healthy citizens who are aware of and inspired to live more sustainably and to care for future generations (Tavakkoli & Rashidi, 2020). Higher education institutions are known to be the dominant drivers on the journey to a more sustainable society, with teachers as key players. To promote education for sustainable development, the starting point should be to put sustainability at the center of institution education, research, and services (Yoo & Jeon, 2022). One of the prerequisites for sustainability is environmental literacy.

According to the research findings, there is a positive increase in all aspects of environmental literacy at the pretest and posttest, but the gain score calculation results show that the increase is relatively small. The low gain score as an indicator of the effectiveness of open inquiry-based environmental education learning kit for increasing environmental literacy in this study is possible because the implementation process is still lacking. In line with Thiagarajan et al. (1976), many innovative treatments in education fail during their summative evaluation because they are not implemented as intended by the developer. There are three main problems that can cause a discrepancy between the plan and the results of the implementation of a learning kit, namely: time problems, problems in the sequence of implementation, and problems in completion.
In addition to implementation problems that are not in accordance with the initial plan, the low effectiveness of open inquiry-based environmental education learning kit to improve student environmental literacy is also possible because all lecture activities are carried out online. Lectures that are conducted entirely online are the impact of the Covid-19 pandemic in Indonesia (Amalia & Sa’adah, 2020; Argaheni, 2020). A lot of university lecturers, teachers and researchers are concerned by new challenges in the education and science process (Peregrym et al., 2022). Other countries are also experiencing the same thing as a result of the Covid-19 pandemic that has hit the whole world, causing learning to be done entirely online (Kapenieks & Kapenieks, 2020). Gwekwerere (2019) suggests that, in order for environmental education lectures that are oriented to the development of environmental literacy for prospective teachers to be effective, they must be carried out with a balanced method, being balanced in terms of lectures by lecturers, hand-on activities/action-oriented activities, inviting guests, and activities that give students the opportunity to express their opinions.

Conclusions

The open inquiry learning kits that have been developed consist of lesson plans, student worksheets, and environmental literacy test instruments, and they are declared suitable for use in environmental education courses because they have passed a series of expert appraisal test, developmental test, validity test, and reliability test. The learning kits have passed the revision stage based on the results of the assessment and suggestions during the expert appraisal test process.

The developed open inquiry learning kits have a low effect on student environmental literacy. Although its effect is low, it still has an impact on the increase of environmental literacy of pre-service biology teachers. This is proven by the difference in the environmental literacy scores of the students on the posttest, which are slightly higher than their environmental literacy scores on the pretest. The low effectiveness of open inquiry learning kits is possibly due to the lack of implementation process (lack of time), problems in implementation, problems in completion, and all lecture activities carried out online.

Future research should include the combination of synchronous and asynchronous learning methods that use online or offline learning designs. More research is needed on the combination of these four factors in order to figure out the most effective learning recipes for teaching environmental literacy to future biology teachers. Blended learning, flipped classrooms, hybrid learning, and other examples that have begun to be used in contemporary learning must be considered. Aside from that, other student-centered learning models that are similar to open inquiry should be considered for use in environmental education lectures. Considering the relevance of the material in the environmental education curriculum and the allocation of time are required, utilizing local potential/local wisdom is also an important future suggestion.
References


The Effect of Environmental Education Open Inquiry Learning Kits.


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