Instructional Tool Development for Biodiversity and its Influence on Scientific Literacy and Higher Order Thinking Skills for High School Students

Gito Hadiprayitno[1*], *Muhlis* Muhlis[1], *I Putu* Artayasa[1], *Eni* Suyantri[1], *Ahmad* Sukri[2], *Ayudya* Lestari[3], and *Ismawan* Hariadi[4]

[1]Biology Education Program, University of Mataram, Indonesia
[2]Biology Education Program, Universitas Pendidikan Mandalika, Mataram, Indonesia
[3]Master of Science Education, University of Mataram, Indonesia
[4]SMAN 1 Narmada, Narmada, Indonesia

Abstract. Biodiversity in high school that has been implemented so far has yet to use instructional tools that are oriented towards scientific literacy skills and higher-order thinking. Therefore, this research was intended to develop instructional tools for biodiversity, which aim to improve students' scientific literacy and higher-order thinking skills. To do so, this research was carried out by adopting the Borg and Gall development model, which consisted of 4 stages, namely (1) needs analysis, (2) model design and development, (3) model validation, and (4) dissemination. The instruments included teaching material validation instruments, instructional tool instruments, and learning tool effectiveness instruments. Lastly, the data were analyzed descriptively and using ANCOVA (Analysis of Covariance. The results showed that (1) based on the expert validation of the Biodiversity instructional tools developed in this study, were categorized as feasible to be implemented in learning activities with a score of 3.90; (2) The practicality of the developed Biodiversity learning tools has been well implemented (score 3.78); and responded well by students (score 3.01) and responded very well by teachers (score 3.63); (3) Implementation of Biodiversity learning tools shows better achievement of scientific literacy and higher-order thinking skills compared to conventional learning; and (4) the results of the Ancova test showed that the Biodiversity learning tools had an influence on students' scientific literacy and higher order thinking skills ($p<0.05$). Overall, the results of developing Biodiversity instructional tools are effective in increasing the scientific literacy skills and higher-order thinking of high school students.

[*] Corresponding author: gitohadiprayitno@unram.ac.id

1 Introduction

Learning Biology emphasizes direct experience, studying objects and natural phenomena. However, an important issue in learning Biology is presenting the context of Biology facts and issues to students [1]. The current trend shows students' difficulties in creating relevance between the Biology knowledge being studied and the problems of everyday life [2]. This is because one of the reasons is that students' scientific literacy skills still need to improve [3]. The Program for International Student Assessment defines scientific literacy as the ability to use scientific knowledge, identify problems and draw conclusions based on evidence in order to understand and make decisions about nature and changes that occur in nature as a result of human activities.

The Organization for Economic Co-operation and Development (OECD) published the results of a scientific literacy assessment which showed that the scientific literacy competencies of Indonesian students were still below the average OECD score from 2000 to 2018. In 2018 Indonesian students' scientific literacy achieved an average of 396, which was below the OECD average score of 500 [4]. Low scientific literacy proves that students in Indonesia need to be stronger in linking their scientific knowledge to issues/phenomena that occur in their surroundings [5]. In fact, this ability is very important for students to have [6]. The concept of scientific literacy expects students to have a high sense of concern for themselves and their environment in dealing with everyday life problems and making decisions based on the scientific knowledge they have understood [7].

This issue is due to several factors, one of which is influenced by students' higher-order thinking skills (HOTS) [8–10]. HOTS includes the levels of analysis, synthesis, and evaluation, which are part of the revision of Bloom's taxonomy [11], as well as cognitive mastery in applying routine things in new and different situations [12,13]. It is important for students to have higher-order thinking skills in order to be able to distinguish ideas clearly, argue well, be able to solve problems and understand complex things more clearly [14]. More than that, higher-order thinking skills are expected to improve students' scientific literacy skills [9–13,15]. The low scientific literacy ability of Indonesian students is also influenced by the curriculum and education system, the selection of teaching methods and models by teachers, learning facilities, and teaching materials [16].

Various studies have been conducted to find the right combination of learning to improve students' scientific literacy and higher-order thinking skills. One method used is to implement a learning model [17,18]. In addition to the use of learning models, the development of instructional tools is also believed to increase students' scientific literacy. Other researchers have have developed learning tools through the TPACK (Technological Pedagogic Content Knowledge) approach to improve students' scientific literacy [19], but it is unclear how these tools can influence and improve students' scientific literacy skills. One of the ways that can be done to overcome this problem is by developing a Biodiversity instructional tool for Biology learning.

The development of Biodiversity instructional tools is an alternative instructional option that is oriented to the potential of the local area, which emphasizes the process of understanding the concept of the role and use of each organism and its environment [20]. The development of instructional tools for biodiversity is believed to improve students' scientific literacy and higher-order thinking skills. This is because scientific literacy is knowledge that is used by individuals related to everyday life [21], while biodiversity is a new paradigm in learning that studies living natural resources and their relationship with the surrounding community. On the other hand, the preparation of instructional tools for biodiversity can improve students' higher-order thinking skills because problem-solving abilities are needed to solve problems found in everyday life.

In addition, the study of Biology that has been applied so far only refers to textbooks that are based on something other than local wisdom in the environment around students (Biological Diversity), so the learning became less meaningful for students. We have recently shown that 54.77% of high school students on Lombok Island had difficulties with the material taught at school and 85.64% of students were unable to relate the concepts they got to phenomena in everyday life [22,23]. Therefore, it is necessary to develop instructional tools for Biology that use an environmental approach and local wisdom (Biodiversity) in an effort to increase scientific literacy and high-level thinking skills for high school students.

2 Research Method

The development of instructional tools carried out in this study adopts the development model suggested by Borg and Gall by integrating Nieveen's theory regarding the requirements of a product which consists of 4 stages, namely (1) needs analysis, (2) design and model preparation, (3) model validation, and (4) dissemination of the results [24].

2.1 Needs Analysis

The needs analysis stage was intended to map the school's carrying capacity for the instructional tools to be developed. At this stage, data is collected regarding the implementation of learning tools that are implemented in the instructional process through observation, deep interviews with teachers and students, documentation, as well as observing various supporting factors in the implementation of instructional tools that would be developed.

2.2 Design and Model Preparation

The design stage was intended to produce instructional tools consisting of lesson plans, teaching materials, student worksheets, scientific literacy assessment instruments, and higher-order thinking skills. At this stage, the determination of learning objectives, learning methods, and assessment was conducted, then proceeded to the stage of compiling the product development model.

2.3 Model Validation

This stage was intended to test the validity/feasibility of the instructional tools that have been developed, consisting of content validation and construct validation. This process was carried out through Focus Group Discussion (FGD) involving experts in the field of tool development. The end result of this activity is a product in the form of a valid Biodiversity instructional tool for improving students' scientific literacy and higher-order thinking skills.

2.4 Dissemination

The dissemination stage is a stage that aims to implement validated instructional tools on research subjects. This implementation was carried out in two test groups, namely the control group of 80 students and the experiment of 59 students, using a nonequivalent control group research design. The implementation trial was aimed to determine the teacher and student responses to the products developed. Besides that, this trial was intended to determine the effect of the development of instructional tools on the scientific literacy and higher-order thinking skills of high school students.

2.5 Research Instrument

The instrument of need analysis was arranged to collect information regarding the school's capacity to develop instructional tools. The process of obtaining this information involved a questionnaire analyzing the needs of teachers and students. Meanwhile, the validation instrument of the developed learning tool was intended to obtain data regarding the assessment and opinions of experts (validators) on the products that have been compiled. The assessment results using the questionnaire were used as a basis for decision-making in revising the instructional tool based on constructive suggestions and improvements from the validator. Instructional tools developed are said to be valid if they meet the valid level ($3 \leq Va \leq 4$). Meanwhile, the practicality instrument consisted of an observation sheet used to observe the implementation of the learning tool and a teacher and student response questionnaire used for student responses regarding the ease and practicality of the instructional tool. The instructional tool criteria are said to be practical if (1) the minimum average of implementation is in the implemented category ($3 \leq Rk \leq 4$); (2) the average teachers' response is in the good category ($2.5 \leq Rg \leq 3.5$); and (3) the average students' responses are in the good category ($2.5 \leq Rs \leq 3.5$).

The instrument for measuring scientific literacy is the Scientific Literacy Assessment (SLA) test which has been developed by Fives [25] and then converted by Purwanto with the following categories: ≤54% = Very Less, 55% -59% = Less, 60%-75% = Fair, 76%-85% = Good and 86%-100% = Very Good [26]. Meanwhile, the instrument for measuring higher-order thinking skills is a test that was analyzed descriptively and then converted into four categories adopted from Merta Dhewa et al. as follows: 1-25 = Not good, 26-50 = Fairly good, 51-76 = Good, and 76-100 = Very Good [27].

2.6 Data Analysis

Analysis of the data was carried out using descriptive and inferential statistics. Pretest and post-test data on scientific literacy and higher-order thinking skills were analyzed descriptively to determine the increase in achievement in the aspects tested. This increase is known based on the comparison of the average pretest score with the average post-test score. Meanwhile, inferential statistical analysis was tested using Ancova (Analysis of Covariance), and the pretest value was used as the covariate [28]. This was intended to determine the effect of implementing Biodiversity learning tools on students' scientific literacy and higher-order thinking skills.

3 Results and Discussion

The preparation and design of instructional tools require basic information that can be used as a form of support for the development of Biodiversity instructional tools. The following deep interviews with Biology teachers can be seen in **Table 1**.

Table 1. The Results of Teachers' Needs Analysis.

No	Questions	Problem Identifications	Conclusion
1	100% of teachers understand the instructional tools of the 2013 curriculum implemented in schools.	Implementation of instructional tools of the 2013 curriculum.	Teachers develop instructional tools based on the 2013 curriculum.
2	100% of teachers remark on the aspects of content, context, and process in preparing instructional tools.	The preparation of learning tools includes aspects of content, context, and process.	Teachers consider aspects of content, context, and process.
3	100% of teachers answered that the learning tools were sufficient to facilitate students' needs.	instructional tools only meet the standardization of student learning needs.	There is no development of instructional tools to maximize student learning needs.
4	87.5% of teachers answered that teaching materials were sufficient to facilitate students in practicing scientific literacy skills.	Teachers only rely on teaching materials to facilitate students' scientific literacy.	The use of materials alone is not effective enough in training students' scientific literacy.
5	91.7% of teachers answered that teaching materials are sufficient to facilitate students in practicing higher-order thinking skills.	Teachers only rely on teaching materials to facilitate students' higher-order thinking skills.	The use of teaching materials alone is not effective enough in training students' higher-order thinking skills.
6	91.7% of teachers answered that the instructional tools that have been used so far have not optimally contained aspects of students' daily lives.	instructional tools that have been prepared pay little attention to aspects of students' daily lives.	Issues/phenomena in the environment around students have not been included in the learning tools.
7	100% of teachers know that the lack of content on these issues/phenomena limits students from exploring real learning experiences.	Limitations of students in exploring real learning experiences.	The limited content of issues/phenomena results in the limited ability of students to explore learning experiences.
8	95.8% of teachers know the importance of integrating problems into instructional tools.	The fact is that the learning tools used are not fully integrated with problems that are close to students' lives.	Substances related to the problems of students' daily lives have not been included in the instructional tools.
9	100% of teachers know and understand the methods of practicum activities in providing direct learning experiences.	Application of practicum activity methods in classroom learning.	The teacher uses the practicum activity method.
10	83.3% of teachers answered that teaching materials were not fully aligned with students' daily lives.	There is no compatibility between teaching materials and students' daily lives.	The teaching materials used by the teacher do not have continuity with the daily lives of students.
11	100% of teachers answered student worksheets make students understand material easier.	Student worksheets are used as a tool during the learning process.	Teachers use student worksheets to support the achievement of learning objectives.
12	95.8% of teachers answered that the scientific approach	Activities on student worksheets use a scientific approach.	Teachers only rely on scientific approaches

	was sufficient to be used in student worksheets.		without considering other types of approaches.
13	95.8% of teachers answered questions on student worksheets referring to the results of observations.	Questions on the worksheet adjust to the results of student observations.	The questions on the worksheet are not broad enough to explore questioning skills.
14	95.8% of teachers understand the importance of compiling evaluation questions by considering the achievements being measured.	The teacher's awareness that evaluation questions are used as a tool to measure competence achievements.	Teachers use evaluation questions to measure student learning outcomes.
15	79.2% of teachers answered evaluation questions that were not fully able to measure students' scientific literacy and higher-order thinking.	Evaluation questions only measure the level of students' understanding of the concept of the material.	Teachers use evaluation questions to measure competency achievement, not considering the measurement of scientific literacy/higher-order thinking aspects.
16	95.8% of teachers answered that the use of school facilities as a supporting factor for teaching and learning activities was not optimal.	Teacher awareness of the importance of the environment as a learning resource.	Existing facilities are not optimal in supporting smooth teaching and learning activities in the classroom.
17	95.8% of teachers know and understand well that the environment can be used as a learning resource in developing students' scientific literacy and higher-order thinking.	The fact is that learning resources such as the environment have yet to be utilized optimally.	Teachers pay less attention to supporting learning resources such as the environment in developing scientific literacy and higher-order thinking.

From the results of the needs analysis, high school biology teachers on Lombok Island realized that the learning tools used had yet to fully facilitate students' scientific literacy skills and higher-order thinking skills. This is because, so far, teachers have paid little heed to other learning methods. The preparation and design of learning tools are only limited to meeting the standardization of student learning needs and paying little attention to other types of approaches. On the other hand, teachers are also aware of the lack of attention to learning resources that are close to students' lives and the harmony between material concepts and examples of problems in the surrounding environment. The carrying capacity of the environment as a learning resource is believed to provide a real learning experience. Therefore, teachers are strongly encouraged to use Biodiversity learning tools to improve scientific literacy and higher-order thinking skills. So, it is expected to help teachers and students in the process of achieving learning objectives.

Meanwhile, the results of the analysis of student needs in supporting the development of instructional tools can be seen in **Table 2**.

Table 2. The Results of Students' Needs Analysis.

No	Questions
1	74.9% of students need learning tools that make it easier for them to understand material concepts, foster motivation and curiosity
2	70.2% of students need real examples of presenting problems whose solutions are based on material concepts
3	78.0% of students answered that the illustrations displayed in the teaching materials were general and non-specific
4	75.7% of students need assignments and evaluation questions that are effective in increasing understanding and competency development
5	75.6% of students need additional information in building biology concepts on worksheets and teaching materials
6	75.6% of students need teaching materials using examples closest to students' daily lives

Table 2 shows that more than 50% of students need teaching materials that can foster motivation and curiosity and make it easier for them to understand the material. Among the types of needs above, most students need specific examples that they can easily recognize and find around them, as well as illustrate material concepts through presenting issues/phenomena that often occur in students' daily lives. This is solely intended so that students can prove the truth of the material concepts they have learned so far.

3.1 The Validation of Instructional Tool

In general, the Biodiversity Instructional tool shows a score of 3.90, with a very valid category. The validation results for each aspect can be seen in **Table 3**.

Table 3. Results of Validation of Biodiversity Learning Tool.

Rated Aspects	Average	Validity
Lesson Plan	3.87	Very Valid
Teaching Materials	3.82	Very Valid
Student worksheet	4.00	Very Valid
Instrument of Assessment for Students' Science Literacy and Higher Order Thinking	3.91	Very Valid
Average	**3.90**	**Very Valid**

From the results of the validation test, several comments and suggestions for improvement were found from the validator. One of them is in presenting pictures explaining animal and plant species. It is better to use specific examples of pictures that can represent local species. This is solely aimed at introducing the surrounding natural conditions and providing direct learning experiences to students. Thus, the application of knowledge possessed by students becomes more meaningful.

3.2 The Practicality of Learning Tool

The results of the practicality test show that the quality of learning tools is practical, as presented in **Table 4**. Based on the table, the assessment of the practicality of learning tools was assessed based on the average implementation of learning tools with $Rk \geq 3$, the average teacher response with $Rg \geq 3.5$, and the average student response with $Rs \geq 2.5$ teacher and student responses.

Table 4. Practical Test Results for Biodiversity Learning Tool.

Practicality	Average	Category
Implementation of Learning Tool	3.78	Well Conducted
Student Responses to Learning Tool	3.01	Good
Teacher Response to Learning Tool	3.63	Very Good

3.3 Students' Scientific Literacy and Higher-Order Thinking Skills

Data on students' scientific literacy abilities were obtained from the pretest and post-test scores in the control and experimental groups, which can be seen in **Fig. 1**.

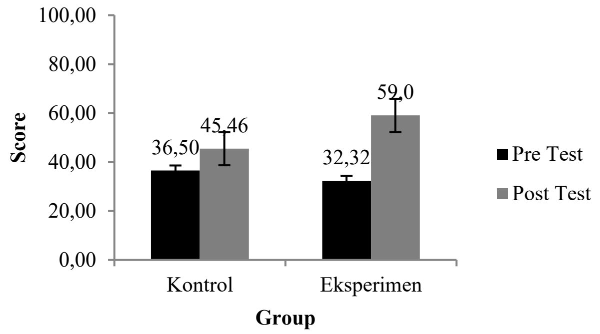

Fig. 1. Average Score of Students of Science Literacy.

Fig. 1 shows that the average pretest scores for the control and experimental groups were not much different, with successive values of 36.50 and 32.32 in the very low category. However, after being given the treatment of implementing the biodiversity learning tools in the experimental group, an increase of 26.72 was obtained, so the average post-test score was 59.04 in the less category. Meanwhile, in the control group with conventional learning, an increase of 8.96 was obtained so that the average post-test score was 45.46 in the low category. From the difference in the increase, the learning outcomes of the experimental group were better than the control group. This increase indicates that the biodiversity learning tool is one of the solutions to overcoming the low ability of students' scientific literacy in Indonesia. On the other hand, integrating aspects of local wisdom into learning activities is considered effective in increasing scientific literacy. This is felt to be able to create a new learning atmosphere for students in obtaining direct learning experiences, creating a positive influence on attitudes, goals, and learning outcomes [29–33]. The environment also has a significant influence on developing scientific literacy, sensitivity, and the formation of student character [34]. In general, it can be said that scientific literacy plays an important role in students' daily lives amidst current technological developments and modernization.

Data on students' higher-order thinking skills were obtained from the average pretest and post-test scores in both the control and experimental groups presented in **Fig. 2**.

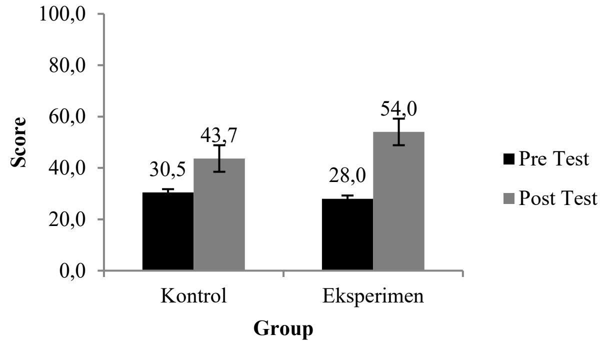

Fig. 2. Average Students' Higher-Order Thinking Skills Scores.

Based on **Fig. 2**, the average pretest scores for the control and experimental groups were not much different from the respective values of 30.5 and 28.0 in the fairly good category. However, following the implementation of the biodiversity learning tools, an increase of 26.0 was obtained in the experimental group, so the average post-test score was 54.0 in the good category. Meanwhile, in the control group with conventional learning, an increase of 13.2 was obtained so that the average post-test score was 43.7 in a fairly good category. Based on the difference in the increase, it can be said that the learning outcomes of the experimental group are better than the control group. This increase is allegedly due to the content of aspects of local wisdom in the biodiversity material developed in learning tools. Another opinion states that the environment has the potential to improve higher-order thinking skills and is a must for Biology learning to integrate into the current 21st-century [35–39].

3.4 The Influence of Instructional Tools on Scientific Literacy and Higher Order Thinking Skills of the Students

In order to determine the effect of implementing Biodiversity learning tools on scientific literacy skills, the Ancova test (Analysis of Covariance) was carried out. The results can be seen in **Table 5**.

Table 5. Ancova Test (Analysis of Covariance) Science Literacy.

Tests of Between-Subjects Effects					
Dependent Variable: post_test					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	23676.382[a]	2	11838.191	108.246	.000
Intercept	11804.011	1	11804.011	107.934	.000
pre_test	17420.081	1	17420.081	159.286	.000
Listerasi_sains	9525.163	1	9525.163	87.096	.000
Error	14873.447	136	109.364		
Total	403345.852	139			
Corrected Total	38549.829	138			
a. R Squared = .614 (Adjusted R Squared = .609)					

Analysis of the data in **Table 5** reveals that the Sig. for the pretest is 0.000. Because the value of Sig.,000 <0.05, then H0 is rejected. This means that the pretest has a significant effect on scientific literacy skills. These results also show that there is a linear relationship between the pretest and students' scientific literacy skills. After controlling for the covariate in the form of pretest scores, it was found that there was a significant influence of the biodiversity learning tools on increasing the scientific literacy abilities of high school students on Lombok Island. The resulting significant influence can be caused by several factors that strengthen the learning process through the implementation of Biodiversity learning tools in this study. A number of basic skills are needed to build students' scientific literacy competencies, such as reading skills and evaluating scientific literature [40]. Statistically, critical reading skills have a positive impact on scientific literacy skills [41]. Through reading, students are directed strategically in applying the context of science. Several studies have proven that the application of science through a scientific investigation has a significant effect on the achievement of scientific literacy competence [42,43].

Meanwhile, to find out the effect of implementing the Biodiversity learning tool on higher-order thinking skills, an Ancova test (Analysis of Covariance) was carried out using the SPSS version 17.0 application which can be seen in **Table 6**.

Table 6. Ancova Test of Higher-Order Thinking.

Tests of Between-Subjects Effects					
Dependent Variable: post_test					
Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Corrected Model	24941.611[a]	2	12470.805	95.027	.000
Intercept	10298.649	1	10298.649	78.476	.000
pre_test	21313.357	1	21313.357	162.407	.000
HOTS	5413.239	1	5413.239	41.249	.000
Error	17847.809	136	131.234		
Total	363813.880	139			
Corrected Total	42789.420	138			
a. R Squared = .583 (Adjusted R Squared = .577)					

Table 6 shows that the Sig. for the pretest is 000 (Sig.,000 <0.05). This means that the pretest has a significant effect on students' higher-order thinking skills. These results also show that there is a linear relationship between the pretest and the students' higher-order thinking skills. After controlling for the covariate in the form of pretest scores, it is known that there is a significant influence of the biodiversity learning tools on improving the high-level thinking skills of high school students on Lombok Island. Several related research results reveal that the environment is a real learning resource that is very close to students' daily lives and contributes positively to improving higher-order thinking skills [44,45]. Another opinion states that developing local potential without ignoring its impact on the environment is considered an effort to support contextual learning [46,47].

In fact, higher-order thinking skills are needed in any educational setting. These skills have an important role in cultivating a positive attitude and training analytical skills [48]. Other research concluded that thinking skills have a positive relationship with students' scientific literacy [15]. This means that an increase in students' thinking skills will be followed by good scientific literacy skills. Besides meeting the minimum standard of competency and the ability to remember or memorize information, it is necessary to develop other competencies such as critical literacy, critical numeracy, and cross-curricular in order to support the achievement of higher-order thinking [49,50]. Bloom's taxonomy is often used as a guide in determining a person's level of thinking. The highest level in this taxonomic system includes analysis, synthesis, and evaluation. According to Khan & Inamullah, higher-order thinking skills are classified at the highest level of Bloom's Taxonomy [51].

4 Conclusion

The development of instructional tools is always needed to achieve maximum learning objectives. The development in this study focuses on Biology that integrates local resources and wisdom on Biodiversity material. The conclusions in this study are (1) Classical Biodiversity instructional tools meet the very valid category (Va=3.90); (2) The implementation of learning tools reached the category of well implemented (Rk = 3.78), the teacher's response to the learning tool components was in the very good category (Rg = 3.63), and student responses showed a positive response to the use of instructional tool (Rs =3.01); (3) Increasing scientific literacy skills and higher order thinking skills on a small scale test of 26.72 and 26.0 respectively; and (4) Biodiversity learning tools have a significant effect on increasing scientific literacy and higher order thinking skills (Sig.,000<0.05).

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