



## Development of TPACK-Based Teaching Materials on Biodiversity Subject to Measure Students' Critical Thinking Skills

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**ABSTRACT:** Teaching materials are auxiliary elements employed to accomplish the goals of the educational process. The observed fact reveals a deficiency in teaching materials that incorporate Technological Pedagogical Content Knowledge (TPACK) for the purpose of developing students' critical thinking abilities. Thus, there is a want for an instructional resource that may assist pupils in enhancing their critical thinking abilities. The objective of this project is to provide TPACK-based teaching materials on biodiversity that are credible, effective, and practical. In addition to elucidating students' critical thinking abilities through the utilization of TPACK-based instructional resources. The methodology employed in this study is Research and Development (R&D) utilizing the ADDIE paradigm. The tool employed is a questionnaire sheet for the purpose of validating materials and media. The study yielded data indicating that teaching materials centered around Technological Pedagogical Content Knowledge (TPACK) were valid and appropriate for learning purposes in the context of Biodiversity. The validity includes a material validation score of 91.25% and a media score of 96.42%, with an N-Gain of 0.75, indicating strong testing performance. Therefore, it can be inferred that educational resources rooted in Technological Pedagogical Content Knowledge (TPACK) and focused on the topic of Biodiversity have a positive impact on students' ability to think critically.

**KEYWORDS:** Biodiversity, Critical Thinking, Teaching, TPACK.

### INTRODUCTION

The increase in information systems and technology indicates the global shift towards the Fourth Industrial Revolution Era. Rapidly evolving technological advancements have a profound impact on every facet of life. These disciplines include economics, health, agriculture, industry, and several others. The sector of education in Indonesia is likewise impacted by this technological progress (Ekasari et al., 2021). The integration of technology in education, via the provision of readily available resources on computers and smartphones, may significantly improve the teaching and learning experience, ultimately fostering student motivation to acquire knowledge. Technology has a profound influence on the educational advancement of Indonesia. Through the utilization of technology in the learning process, students acquire greater autonomy and adaptability in their educational endeavors. In order to streamline this process, it is imperative that we develop educational resources that effectively incorporate technology into the learning experience. Effective teaching materials should also facilitate the integration of technology in the learning process.

We provide educational resources for the purpose of identifying, assessing, and formulating methods in the process of learning. Teaching materials play a crucial role in the process of acquiring knowledge. Teaching materials have a dual role in the learning process. They function as tools and guides for activities, while also serving as an essential part of the information that students learn. The development process takes into account both adaptability and the capacity to clearly elucidate the subject matter (Wijaya et al., 2022). Utilizing instructional resources can enhance student comprehension and academic performance within the classroom setting. Teachers can utilize instructional resources aligned with the TPACK framework (Technological Pedagogical Content Knowledge) to augment learning and facilitate the cultivation of 21st century proficiency among students.

TPACK is the educational phase of Society 5.0 that emphasizes learning methodologies. The TPACK method synergistically combines three primary elements: technology, pedagogy, and content knowledge in the context of learning (Hanik et al., 2022). TPACK is a framework that combines educational and technological approaches to improve students' abilities needed in the 21st century (Herizal et al., 2022). These talents are derived not just from delivering content, but also from the capacity to organize and execute learning. Critical thinking is essential due to the fast advancement of science and technology.



Critical thinking skills enable individuals to effectively handle, evaluate, and recover acquired knowledge. Problem-solving in the 21st century necessitates the use of critical and creative thinking (Setyorini et al., 2019). Presently, there exists a considerable number of pupils who have yet to acquire the ability to cultivate critical thinking abilities. Reduced student engagement in group discussions results in a decline in the frequency of asking questions. In addition, despite the use of HOTS questions during quizzes, a considerable proportion of pupils continue to offer wrong answers. In addition, despite the incorporation of Higher Order Thinking Skills (HOTS) questions in quizzes, a considerable proportion of students persist in providing inaccurate responses. Undoubtedly, this issue poses a significant challenge in developing pupils' abilities to think critically. The objective of this project is to create TPACK-based teaching materials on biodiversity that are valid, effective, and practical. Additionally, it intends to analyze the impact of these materials on students' critical thinking abilities.

**METHODS**

"Research and development" is the word used to describe the systematic process of carrying out research activities. Aldoobe (2015) employed the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) research and development framework. The research was undertaken by the Biology Education Study Program at FKIP Universitas Tadulako from February to July 2023. Our data collecting strategies encompass the utilization of surveys, observations, and interviews.

We conducted an analysis of the questionnaire data in order to have a deeper understanding of the instructional materials that were utilized. The creation of educational resources involves the integration of RPS (Research, Problem Solving, and Self-Regulation) and TPACK (Technological Pedagogical Content Knowledge) frameworks to evaluate students' capacity for critical thinking in relation to biodiversity-related subjects. Pearson presents a method, referred to as the product moment formula, for assessing the validity of an instrument.

$$r_{xy} = \frac{N\sum XY - (\sum X)(\sum Y)}{\sqrt{\{N\sum X^2 - (\sum X)^2\} \{N\sum Y^2 - (\sum Y)^2\}}}$$

Information:

- $r_{xy}$  = Correlation coefficient
- $X$  = Number of grains
- $Y$  = Number of scores
- $\sum X$  = Number of scores  $X$
- $\sum Y$  = Total score  $Y$
- $N$  = Number of respondents

Furthermore, instrument reliability tests were carried out with the *Alpha* method, as follows:

$$R11 = \left[ \frac{k}{k-1} \right] \left[ 1 - \frac{\sum \sigma^2}{\sigma_t^2} \right]$$

Information:

- $R11$  = Instrument reliability
- $k$  = number of question items or number of questions
- $\sigma^2$  = number of grain variances
- $\sigma_t^2$  = Varian total

Analysis of student concept comprehension tests is carried out with the N-gain test, which is carried out by processing student pretest and post test score data. The normalized gain (N-gain) is calculated by the equation:

$$g = \frac{S_{Postest} - S_{Pretest}}{S_{Max} - S_{Pretest}}$$



Information:

$g$  = Normalized gain

$S_{Pretest}$  = Initial Test Score

$S_{Postest}$  = Final Test Score

$S_{max}$  = Maximum score from initial test and final test

**Table 1. N-Gain Score Criteria**

Interval Score	Criteria
$g \geq 0,7$	Higher
$0,7 \geq g \geq 0,3$	Midle
$g \leq 0,3$	Lower

## RESULTS AND DISCUSSION

Findings from the research The ADDIE approach for research and development (R&D) consists of five stages: analysis, design, development, implementation, and evaluation.

### TPCAK-Based Teaching Material Analysis

This research consisted of two stages: curriculum analysis and needs analysis. The instructors of the biodiversity course study group conducted the initial examination of the curriculum with the objective of determining the Recommended Program of Study (RPS). The intended aim of this instructional material is to facilitate students in attaining their objectives and enhancing their aptitude for critical thinking. The Indonesian National Curriculum (KKNI) requires that every student, whether working alone or in groups, be able to articulate the fundamental principles, methodologies, and tiers of biodiversity.

We do the second study, known as a requirements analysis, while closely watching the process of learning. The goal of the requirements analysis is to assess the students' proficiency in the biodiversity course. Currently, we have carried out interviews with a total of five students who have completed the biodiversity course. The interview findings indicated that the teaching materials utilized in biodiversity courses are restricted in scope and fail to address particular biodiversity subjects. In addition, the restricted use of print media in educational resources hampers the adaptability of self-directed learning for pupils. Thus, students have the opportunity to create and employ TPACK-based instructional resources to improve their understanding in biodiversity courses.

### TPACK-Based Teaching Material Design

The design phase is crucial as it significantly influences the resulting output in terms of learning objectives and the utilization of instructional resources. According to a study done by Maghdalena et al. in 2020, it is important to follow instructional guidelines while creating teaching materials, as they are intended to facilitate the learning process (Magdalena et al., 2020). The design phase involves the creation of instructional materials specifically focused on the development of TPACK-based Biodiversity content. This instructional material is composed of multiple sections, specifically: Cover, Introduction, Content, and Conclusion. The products are created using the applications Microsoft Word, Canva, and Anyflip.com. The educational material product will be finalized and prepared in flip PDF format to enhance reader engagement and interest. According to a study done by Rosida et al. in 2022, the product they produced is an electronic tool called Flip TPACK-based pdf. This tool has been found to assist students in effectively grasping the subject they are learning (Rosida et al., 2022). The TPACK teaching material development items are illustrated in Figure 1.



Figure 1. TPACK-based Teaching Material Products with flipbooks

**Development of TPACK-Based Teaching Materials**

This phase of development represents a sophisticated level in the design process. Upon the completion of the product design stage, we will provide first instructional materials. We created instructional resources on biodiversity using the TPACK framework, using the Aldoobe research paradigm. The research model consists of three stages: The five stages of the process include analysis, design, development, implementation, and evaluation (Aldoobe, 2015). The objective of this stage is to develop prototype instructional materials that are appropriate for review, considering feedback from specialists in both content and medium. Once the material and media have been approved, we proceed to update the instructional materials.

The TPACK-based teaching materials for biodiversity were evaluated by experts, and the average score obtained was 3.63. The acquisition rate for each score is 91.25%, which includes the "Very Decent" category. The findings of the validator assessment are shown in Table 2.



Table 2. Results of Validation Analysis by Material Experts

No.	Penilaian	Skor Validasi
1	Material completeness	4
2	Breadth of material	4
3	Depth of material	3
4	Accuracy of facts	4
5	Conceptual truth	3
6	Accuracy of illustrations	4
7	Truth principles/laws	4
8	Conformity with scientific developments	4
9	Current examples and references	4
10	Contextual	4
11	Conservation-minded	4
12	Suitability to developmental level students' critical thinking	4
13	Message understandability	3
14	Suitability of illustrations to the substance of the material	4
15	Grammatical accuracy	3
16	Spelling accuracy	2
17	Completeness of meaning in chapters, sub-chapters and paragraphs	4
18	Linkages to sub-chapters, paragraphs and sentences	4
19	Consistency in the use of terms	3
20	Accuracy in writing scientific names	4
Mean		<b>3.63</b>
Percentage		<b>91.25%</b>

The media expert evaluation of TPACK-based Teaching Materials for Biodiversity yielded an average media validation score of 3.85, corresponding to a percentage of 96.42%. This places the materials in the "Very Feasible" category. The validator assessment findings may be observed in table 3.

Table 3. Results of Validity Analysis of Teaching Materials by Media Experts

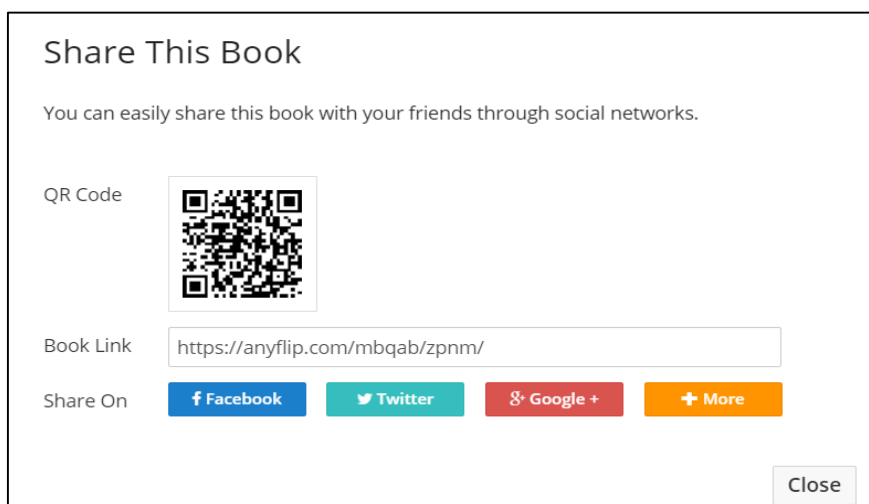
No	Question	Score
1	Accurate text size used	4
2	Clarity of the text size used	4
3	Accuracy of the form of text used	4
4	Accuracy of the text color used	4
5	Accuracy of text color with background used	4
6	Quality of images used to support display	4
7	Color composition of the image used	4
8	Appropriate color of the images used	4
9	Conformity of size (A4) with ISO Standards (size A4, A5 or B5)	4
	Benefit Aspect	
10	Using teaching materials can help learning process	4
11	The use of teaching materials can motivate students to study	3

12	The teaching materials developed make things easier for lecturers carry out evaluation/assessment in learning	3
13	Teaching materials can help students in biodiversity activities	4
14	Teaching materials can provide information about biodiversity and conservation efforts	4
<b>Mean</b>		<b>3.1</b>
<b>Percentage</b>		<b>96.4</b>

**Implementation of TPACK-Based Teaching Materials**

Implementation is the fourth phase of the ADDIE development paradigm. The validator assesses the viability of the teaching materials and then puts them into practice in the classroom. A total of 39 pupils took part in the execution, and the class had 14 sessions for a 3-hour instructional period. Learning activities start with sessional activities, which serve to inspire students and communicate the intended learning outcomes.

The Biodiversity Subject Group utilizes WhatsApp medium to provide instructional materials throughout the fifth semester. The Biology Education Study Program at FKIP Universitas Tadulako adheres to a structured study timetable that incorporates online education. Researchers can utilize the Zoom application and Google Meeting to facilitate learning. Researchers employ a collaborative project paradigm for instruction, using TPACK-based instructional materials that consist of PowerPoint presentations on biodiversity. The student teaching materials can be accessed using the specified URL and QR code. This is a picture depicting the link page of the website anyflip.com.



**Figure 2. Share Link and QRcode Page Display TPACK-Based Teaching Materials**

**Evaluation of Learning Outcomes of TPACK-Based Teaching Materials**

Currently, researchers provide questions to students. This issue is a High Order Thinking Skills (HOTS) problem that is included in TPACK-based teaching resources for biodiversity. The questionnaire has five inquiries accompanied by an essay format that serves to refine students' aptitude for critical thinking. A total of 39 individuals who were enrolled in the Biodiversity course were provided with a set of questions. The initial encounter entails a lecture agreement and includes a preliminary assessment to gauge fundamental understanding of biodiversity. Subsequently, the posttest is administered at the conclusion of the lecture during the final meeting. The objective is to assess the efficacy of instructional materials in enhancing students' critical thinking abilities in biodiversity courses. The findings from the examination of the pretest and post test are presented in Table 4.



Table 4. Results of Analysis of Student Pretest and Posttest Scores

No.	Student	Score	
		Pre-Test	Post-Test
1	JP	65	95
2	AY	78	95
3	NWR	61	93
4	ND	61	95
5	HZ	60	93
6	NLAM	52	93
7	SI	54	89
8	UNR	62	85
9	IAA	71	89
10	RK	65	93
11	HI	54	93
12	NSL	62	89
13	DPEK	60	93
14	AP	48	85
15	AH	57	94
16	MIJ	48	95
17	MDF	57	85
18	LK	68	89
19	APB	40	93
20	AR	68	85
21	EL	65	93
22	AAD	68	89
23	TS	54	85
24	VA	60	89
25	RF	68	95
26	ZR	57	89
27	IF	62	85
28	GSBP	71	89
29	LK	68	95
30	YN	65	85
31	AA	55	93
32	ER	65	95
33	NA	78	95
34	IH	71	95
35	RI	57	85
36	AWW	68	85
37	NI	52	89
38	AAPI	69	93
39	HFA	68	93
<b>Mean</b>		<b>61.84</b>	<b>90.71</b>

Furthermore, the values obtained are analyzed to find the average learning outcomes and *N-gain* which are briefly in Table 5 below:



Table 5. N-gain Test Results Average

N	Pre-Test	Post-Test	N-Gain	Interpretation N-Gain
39	61.84	90.71	0.7504	Higher

Mean Initial assessment The student learning results prior to engaging with TPACK-based instructional materials were measured at 61.84. The examination of student learning outcomes reveals a noticeable improvement in critical thinking abilities after employing TPACK-based teaching materials on biological variety. The average rating posttest was 90.71. To ensure that the generated product encompasses the "Effective" category. According to a study done by Permatasari et al. in 2022, the use of TPACK in education has an impact on the development of critical thinking abilities (Permatasari et al., 2022). Implementing TPACK in education enhances both critical thinking and problem-solving abilities (Imas Tesia Putri et al., 2022). The N-gain number indicates a significant improvement in comprehension or proficiency of concepts, with a score of 0.75 being into the "High" range. Below is a graph illustrating the values before and after the test.

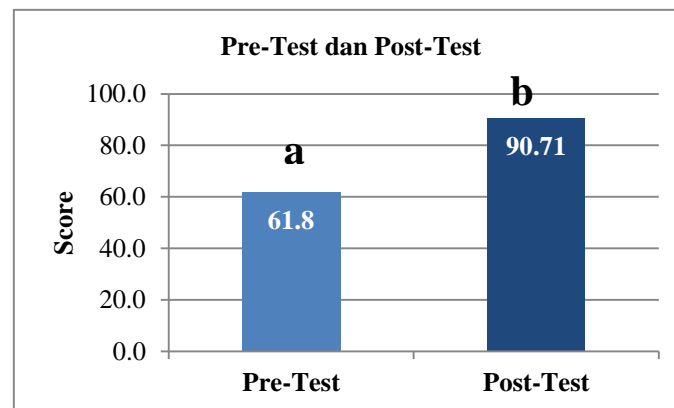


Figure 2. Pretest and Posttest Value Diagram

Subsequently, the researcher performed a t-test on the pretest and posttest samples to determine any disparities. Table 6 below presents the test results.

Table 6. Sample Test Results t Test on Pretest and Posttest Paired Samples Test

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pretest - Posttest	-28.87179	8.45166	1.35335	-31.61151	-26.13208	-21.334	39	.000

The t-test findings for the pretest and posttest samples showed a significant value of 0.00, which is below the threshold of 0.05. This indicates a significant difference between the two sets of data. This demonstrates a notable impact on the disparity in the treatment provided to each variable.

Researchers not only assessed students' critical thinking skills but also evaluated their capacities. Measurement is conducted by assigning pupils project tasks that they must complete as films. Assignments have been incorporated into the TPACK-based teaching materials at the last conference. Once the product has undergone validation by experts and has been tested by students





using TPACK-based teaching materials on biodiversity, it was further tested by a substantial group of 39 students. The questionnaire questions are formatted in the Google Forms style. The investigation reveals that the average feasibility rate of TPACK-based instructional materials for students is 82.05%. According to this proportion, it is categorized as eligible. Consequently, the goods formulated by researchers are well-suited for utilization as instructional resources in biodiversity courses. A total of 14 questions were presented, and it was observed that 91.67% of students responded affirmatively to the notion that the arrangement of pictures and text is optimal, hence facilitating readability (Budiarti et al., 2021).

## CONCLUSION

Teaching materials that are grounded on Technological Pedagogical Content Knowledge (TPACK) and focus on the topic of Biodiversity are appropriate and effective for use in the learning process. Teaching tools that utilize Technological Pedagogical Content Knowledge (TPACK) for the topic of Biodiversity have been found to be highly helpful in enhancing students' critical thinking abilities.

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