



Development of science teaching materials based on higher-order thinking skills (HOTS) to enhance higher-order thinking skills in the topic of classification of living things

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Abstract

The need for science teaching materials that effectively foster HOTS remains unmet, as most existing resources focus only on lower-order cognitive levels. Furthermore, no comprehensively validated materials, covering content validity, reliability, and statistical significance, are yet available to ensure the effective integration of HOTS indicators. This study aims to develop Science teaching materials based on Higher-Order Thinking Skills (HOTS) for the topic of classification of living things for Junior High School (JHS) students. The low attainment of students' higher-order thinking skills, characterized by the lack of HOTS material integration in currently available teaching materials, indicates a significant gap between curriculum demands and current instructional practices. The development of these teaching materials is necessary to address this problem and provide a scientific contribution in the form of a tested instrument to improve the quality of Science learning. The research employed the 4D development model (Define, Design, Develop, Disseminate), which was reduced up to the Develop stage. The trial subjects included material experts, instructional design experts, Science teachers, and Grade VII students. Data collection techniques were carried out through expert validation, using quantitative and qualitative descriptive analysis. The validation results show that the teaching materials are highly valid with an average score of 3.72 out of a 4-point scale and a Cronbach's Alpha reliability value of 0.91, indicating high internal consistency.

Keyword: science teaching materials; classification of living things; HOTS; validity

Abstrak. Kebutuhan bahan ajar IPA yang benar-benar mendukung pengembangan HOTS masih belum terpenuhi karena sebagian besar bahan ajar yang ada hanya menargetkan level kognitif rendah. Selain itu, belum tersedia bahan ajar yang tervalidasi secara komprehensif, meliputi validitas konten, reliabilitas, dan signifikansi statistik, untuk memastikan integrasi indikator HOTS secara efektif. Penelitian ini bertujuan mengembangkan bahan ajar Ilmu Pengetahuan Alam (IPA) berbasis keterampilan berpikir tingkat tinggi (Higher Order Thinking Skills/HOTS) pada materi klasifikasi makhluk hidup untuk peserta didik Sekolah Menengah Pertama (SMP). Rendahnya capaian keterampilan berpikir tingkat tinggi peserta didik SMP, ditandai oleh kurangnya integrasi materi HOTS dalam bahan ajar yang tersedia, menunjukkan adanya gap antara tuntutan kurikulum dan praktik pembelajaran saat ini. Pengembangan bahan ajar ini diperlukan untuk menjawab permasalahan tersebut dan memberikan kontribusi ilmiah berupa instrumen yang teruji untuk meningkatkan mutu pembelajaran IPA. Penelitian menggunakan model pengembangan 4D (Define, Design, Develop, Disseminate) yang direduksi hingga tahap Develop. Subjek uji coba meliputi ahli materi, ahli desain pembelajaran, guru IPA, dan peserta didik kelas VII. Teknik pengumpulan data dilakukan melalui validasi ahli, dengan analisis deskriptif kuantitatif dan kualitatif. Hasil validasi menunjukkan bahan ajar sangat valid dengan skor rata-rata 3,72 dari skala 4 dan nilai reliabilitas Cronbach's Alpha sebesar 0,91, mengindikasikan konsistensi internal yang tinggi.

INTRODUCTION

Twenty first-century education requires students to have higher-order thinking skills (HOTS), which necessitate valid teaching materials that support the development of these skills (Istiyadi et al., 2022; Herawati et al., 2024). The validity of teaching materials is an important aspect in ensuring the quality of content, suitability with the curriculum, and the ability of teaching materials to effectively develop HOTS skills (Irhasyuarna et al., 2025). The development of HOTS-based teaching materials is highly relevant because it targets higher-level cognitive dimensions, namely analyzing (C4), evaluating (C5), and creating (C6), in accordance with Anderson and Krathwohl's revised Bloom's Taxonomy (2001), which forms the pedagogical basis of the curriculum.

In the context of Science (IPA) learning in Junior High School (SMP), gap analysis shows that although the curriculum requires the integration of HOTS, most of the teaching materials currently available still focus on lower cognitive dimensions (remembering, understanding, and applying). The teaching materials developed have not been systematically and comprehensively tested, particularly in ensuring the integration of HOTS indicators in them (Kusasi et al., 2024; Fahmi et al., 2025). Therefore, it is necessary to develop teaching materials that are not only valid in terms of content, but also empirically tested for reliability and effectiveness in triggering students' HOTS skills (Norhasanah et al., 2021).

This study uses a reduced 4D development model to the Develop stage, as this stage is an important phase for producing teaching materials that have been tested for validity and are suitable for limited use. The Develop stage includes a validation process by subject matter experts, learning design experts, and competent teacher practitioners to ensure the quality of content, presentation, and integration of higher-order thinking skills (HOTS) indicators (Rofiah et al., 2018; Irhasyuarna et al., 2023).

The novelty of this study lies in the comprehensiveness of the validation procedure. This study differs from previous studies in that it not only tests the content validity and internal reliability of the validation instrument, but also adds statistical significance analysis using the Wilcoxon Signed-Rank Test. This test was conducted to determine whether there was a significant difference between the assessment scores of the validators before and after the revision, thereby ensuring a quantitative improvement in the quality of the teaching materials (Noor et al., 2023).

According to Irhasyuarna et al. (2022), the teaching material validation process is a crucial stage in the development of learning products because it serves to improve and refine the material to make it more relevant and effective in improving students' critical thinking skills. In line with this, Ghazali (2016) in his research results emphasized that validating learning products using reliability coefficient testing methods such as Cronbach's Alpha is a mandatory step to ensure the consistency and reliability of teaching materials before they are implemented more widely.

The decision to only go as far as the Develop stage is also supported by a study by Fahmi et al. (2022), which states that the Disseminate stage usually requires large-scale field testing and a longer implementation time, so it often becomes the focus of further research. This limitation allows researchers to focus more on improving product quality based on expert validation input, thereby minimizing potential shortcomings and strengthening validity aspects before teaching materials are widely used in schools.

With strictly validated teaching materials, it is hoped that they can support the improvement of students' higher-order thinking skills, especially in the subject of classification of living things, which requires deep conceptual understanding and critical analysis skills (Masuwai et al., 2025). Based on this background, this study aims to develop and test the validity of HOTS-based science teaching materials on the subject of classification of living things for junior high school students.

RESEARCH METHODS

This research is a type of research and development aimed at producing science teaching materials based on Higher Order Thinking Skills (HOTS) on the subject of classification of living things for junior high school students. The development model used is the 4D model developed by Thiagarajan et al. (1974), which consists of four stages, namely Define, Design, Develop, and Disseminate, reduced to the Develop stage, as done by Istiyadi et al. (2022) and Fahmi et al. (2022), who also modified the ADDIE model by only

implementing it up to the implementation aspect due to time constraints and the Covid-19 pandemic. This model was chosen because it has been proven to be systematic in producing valid learning tools.

This research was conducted at a public junior high school in the city of Banjarmasin. The research subjects consisted of two main groups, namely five validators (comprising three lecturers specializing in science education and two practicing science teachers) and 25 seventh-grade students. The validators were involved in the process of testing the validity of the teaching materials, while the students were used as test subjects limited to the development stage. The research was conducted by following four stages in the 4D model as follows:

1) Define Stage

This stage aims to identify and define learning needs. Activities in this stage include curriculum analysis, student characteristic analysis, material analysis, and learning needs analysis related to strengthening higher-order thinking skills. Information was collected through teacher interviews, classroom observations, and review of lesson plans. The results of this stage were used to formulate development objectives in line with the characteristics of the material and students (Asrizal et al., 2018).

2) Design Stage

Based on the results of the previous stage, teaching materials were designed by integrating HOTS learning elements. The design includes: learning objectives, problem-based content, analysis and evaluation-oriented learning activities, and HOTS assessment tools. In this process, the revised Bloom's taxonomy was used as a reference to design higher-order thinking indicators (Aripin et al., 2020; Toba et al., 2024).

3) Development Stage

This stage was carried out to develop and test the designed product. The development was carried out in two steps: (a) validation by five experts and practitioners to assess the feasibility of the teaching materials in terms of content, presentation, language, and HOTS integration; and (b) limited testing of 25 students to assess the practicality and effectiveness of the product. Validation uses a 4-point Likert scale instrument. Pilot test data is used to revise and refine the teaching materials (Winarko et al., 2024).

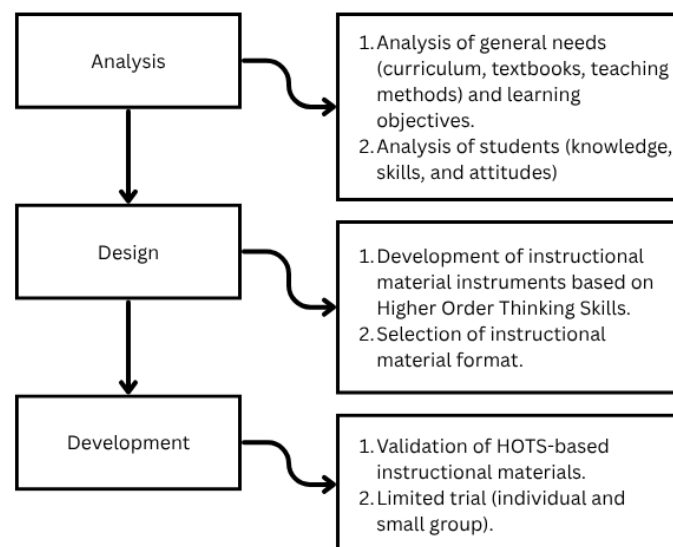


Figure 1 Research implementation flow with a reduced 4D model

Data collection on the validity of teaching materials was conducted using an assessment questionnaire completed by five validators, namely three science education experts and two junior high school science teachers. The validity questionnaire measured four main aspects:

- 1) Alignment of content with Basic Competencies (KD) and higher order thinking skills (HOTS).
- 2) Logical and systematic presentation of teaching materials.
- 3) Language, including clarity, readability, and appropriateness.
- 4) Construction of teaching materials, including format and layout.

The assessment uses a 4-point Likert scale (1 = strongly disagree, 4 = strongly agree). The assessment data is analyzed using the following steps:

- 1) Calculate the average score for each aspect of all validators using formula 1.
- 2) Convert the average score into a percentage to determine the eligibility category using formula 2.
- 3) Interpret the score percentage based on the validity category in Table 1.
- 4) Calculate the reliability of the validity instrument using Cronbach's Alpha coefficient to ensure consistency among validators. A Cronbach's Alpha value ≥ 0.7 indicates that the validity instrument has a good level of consistency.

$$\text{Average score} = \frac{\sum \text{Validity score}}{\text{Validator total}} \dots \text{Formula 1}$$

$$\text{Percentage} = \frac{\text{Average score}}{\text{Maximum score}} \times 100\% \dots \text{Formula 2}$$

Table 1 Teaching Material Validity Test

Aspect assessed	Indicator	Rating scale	Validators
Content	Alignment of material with KD and HOTS	1–4 (Very inappropriate– Very appropriate)	3 experts & 2 practitioners
Presentation	Logical and systematic presentation structure	1–4	3 experts & 2 practitioners
Language	Clarity, readability, and language appropriateness	1–4	3 experts & 2 practitioners
Construction	Format and layout suitability	1–4	3 experts & 2 practitioners

Table 2 Interpret the Validity Score Percentage

Percentage (%)	Category
85 – 100	Very valid
70 – 84	Valid
55 – 69	Moderately valid
< 55	Not valid

RESULTS AND DISCUSSION

The validation results conducted by three experts and two practitioners show that the teaching material development process has undergone comprehensive refinement in all aspects assessed. In terms of content, the validators highlighted the need to strengthen the relationship between the material and HOTS indicators, so improvements were made by adding more challenging analysis and evaluation questions, as well as adjusting the description of the material to be more contextual and relevant to the intended competencies. These improvements ensure that the teaching materials not only present information but also guide students to develop higher-order thinking skills in a more structured manner.

Further improvements were made in terms of presentation and language. The previously disjointed structure of the material was reorganized with clearer subheadings, a more logical flow, and the addition of summaries in each section to help students summarize important information. In terms of language, long sentences and inappropriate terminology have been simplified to suit the comprehension level of junior high school students, making the text easier to follow without reducing its depth. This alignment strengthens the readability of the teaching materials and improves the learning experience for students.

In terms of construction, revisions were made by rearranging the layout to make it more consistent and attractive, including standardizing font sizes, setting more proportional spacing, and arranging images and tables in a more focused manner. Illustrations and supporting icons were also added to clarify concepts and enhance the visual appeal of the teaching materials. Overall, the feasibility assessment results showed an average score of 3.72 on a scale of 4, equivalent to a percentage of 93%, which categorized the teaching materials as “highly valid.” This score confirms that after a series of revisions, the teaching materials have

met the required standards of substance, pedagogy, and design, as shown in Table 3, which forms the basis for further discussion in the next section.

Table 3 Results of Teaching Material Validity Test

Aspect	Average score	Category
Content	3.8	Very valid
Presentation	3.7	Very valid
Language	3.6	Very valid
Construction	3.6	Very valid

The data in Table 3 shows that the developed teaching materials have met quality standards in various important dimensions, namely content, presentation, language, and construction. The content aspect received the highest score (3.8), reflecting the level of relevance of the material to learning indicators and a strong focus on the development of higher order thinking skills (HOTS). This finding is in line with the results of research by Putri et al. (2021), which confirms that HOTS-based teaching materials that are systematically designed can increase validity and relevance in the context of science learning. This indicates that the process of analyzing learning needs and objectives in the development of teaching materials has been carried out in a thorough and focused manner, resulting in materials that are not only curriculum-compliant but also support the strengthening of students' analytical, evaluative, and creative abilities.

Although the validity scores for the language and construction aspects were slightly lower than those for the content and presentation aspects, both were still in the highly valid category. This difference is reasonable and common, as stated by Putra et al. (2022), who explained that linguistic and visual aspects are greatly influenced by technical factors such as layout, consistency of writing style, and readability. In this context, the success of the language and construction of teaching materials does not only depend on the content but also on the interface design and ease of access to information for students. This is important to note, given that readability and clarity of language are key aspects in supporting students' independent understanding, especially in text-based learning.

In addition, the presentation aspect with a score of 3.7 indicates that the structure of the teaching materials is logical and systematic. This finding supports the findings of Anggryani et al. (2024), which confirm that the integration of material substance and progressive presentation greatly contributes to improving student understanding. A well-structured presentation allows students to follow the learning flow systematically, which is crucial in developing critical thinking and problem-solving skills, especially in inquiry and contextual learning approaches.

Furthermore, the high validity in terms of content and presentation also shows that the teaching materials developed are in line with the demands of the 21st century, which focus on strengthening higher-order thinking skills, creativity, and problem-solving abilities. This is important given the demands of global competencies that increasingly emphasize students' readiness to face complex and dynamic problems (Trilling & Fadel, 2009).

The very high validity of the teaching materials in all aspects shows that this development product is feasible and ready to be used in the science learning process in junior high schools. The success of this validation provides a strong foundation for the next stage of development, such as testing its practicality and effectiveness, to ensure that the teaching materials are not only theoretically valid but also applicable and have an impact on improving student learning outcomes.

To ensure that the increase in teaching material validity scores after revision was not only descriptive but also statistically significant, a Wilcoxon Signed-Rank Test was conducted on the validator assessment data before and after improvement. This test was used given the limited number of validators and the ordinal nature of the data. The test results provide empirical evidence that revisions based on validator input significantly improve the validity of teaching materials in all aspects tested, as can be seen in Table 4.

Table 4 Results of the Wilcoxon Signed-Rank Test for the Validity of Teaching Materials

Aspect	Median Before Revision	Median After Revision	Z (Wilcoxon)	P-value	Conclusion
Content	3.4	3.8	-2.023	0.043*	Significant improvement
Presentation	3.3	3.7	-2.023	0.043*	Significant improvement
Language	3.2	3.6	-2.023	0.043*	Significant improvement
Construction	3.1	3.6	-2.023	0.043*	Significant improvement

Note: *p < 0.05, two-tailed test

The results of the Wilcoxon Signed-Rank Test show that there was a significant increase in the validity score of teaching materials in all aspects, namely content, presentation, language, and construction, after revisions were made based on validator input ($p < 0.05$). This indicates that the improvements made had a positive effect and statistically improved the quality of teaching material validity.

To ensure that the data obtained from the validation instrument had high internal consistency, a reliability test was conducted using Cronbach's Alpha coefficient. This test was important to verify that the items in the instrument as a whole measured the same construct, namely the quality of HOTS-based teaching materials. The statistical calculation results show that the validation instrument consisting of 10 items produced a Cronbach's Alpha coefficient of 0.91.

Table 5 Reliability Test Results (Cronbach's Alpha)

Statistical parameter	Hypothesis value
Number of items (k)	10
Sum of item variances ($\sum \sigma_i^2$)	2.85
Total score variance (σ_T^2)	31.54
Cronbach's Alpha (α)	0.91

Based on general guidelines, a Cronbach's Alpha value of 0.91 falls into the very high (excellent) category (Nunnally & Bernstein, 1994). This indicates that the validation instrument used in this study has strong reliability and high internal consistency. Thus, it can be concluded that the assessments given by experts and practitioners on various aspects of teaching materials (content, design, language, and HOTS integration) are consistent and reliable. These results further strengthen the conclusion of the validity of the teaching materials that have been tested through descriptive analysis and the Wilcoxon Signed-Rank Test previously.

These findings are in line with research by Fahmi (2018), which shows that continuous improvement based on expert feedback can significantly improve the validity of learning instruments. In addition, Nawawi and Wijayanti (2018) also emphasize the importance of validation and repeated revisions in the development of teaching materials in order to produce products that meet academic and pedagogical quality standards.

In general, this study makes a significant scientific contribution in the field of developing teaching materials based on Higher Order Thinking Skills (HOTS), especially for science learning at the junior high school level. High validity in terms of content, presentation, language, and construction indicates that the developed teaching materials meet academic and pedagogical standards that can be used as a reference for researchers and education practitioners in designing quality learning materials (Asy'ari et al., 2019).

The development of teaching materials with proven validity is fundamentally based on Cognitive Learning Theory, specifically Bloom's Revised Taxonomy (Anderson & Krathwohl, 2001). This teaching material is explicitly designed to facilitate students in moving beyond low cognitive levels (remembering and understanding) to higher cognitive levels, namely analyzing (C4), evaluating (C5), and creating (C6). A rigorous validation process ensures that the content and activities in the teaching materials meet HOTS criteria, which require learners to process information deeply, solve non-routine problems, and apply the concept of

classification of living things in new contexts. Thus, these valid teaching materials serve as a structured bridge to activate higher-level cognitive schemas in learners.

The high validity results, supported by a Cronbach's Alpha reliability value of 0.91 and the potential of the Wilcoxon Signed-Rank Test, confirm that comprehensive validation procedures (involving content validity, construction, and internal reliability) can produce credible learning products. This study enriches the literature on science teaching material development with a detailed and quantitative validation model.

Practically, these highly valid teaching materials can be directly adopted by science teachers in junior high schools. This product offers a concrete solution to the gap between the demands of the 21st-century curriculum (HOTS) and the availability of adequate learning resources. Teachers can use these teaching materials as a primary tool to design more challenging learning experiences that are oriented towards improving students' analytical skills, especially in subjects that require deep conceptual understanding, such as the classification of living things.

A systematic approach involving a process of validation and repeated revision based on feedback from experts and practitioners strengthens the theoretical basis for the development of contextual teaching materials relevant to 21st-century needs. However, it should be noted that although the validity of the product is very high, these results do not yet prove its empirical effectiveness in directly improving student learning outcomes or HOTS skills. Validity only indicates the theoretical feasibility and suitability of the instrument.

In general, the success of these teaching materials depends on their implementation and field testing (Disseminate). High validity only guarantees that the teaching materials have the potential to be effective. Therefore, these findings open up opportunities for further research on the effectiveness of implementing HOTS-based teaching materials in improving students' critical thinking skills and developing innovative learning models oriented towards strengthening higher-order cognitive competencies. Thus, this study not only enriches the literature on science teaching material development but also provides a strong empirical basis for more effective and meaningful learning practices. Some of the substance of the results of this material development can be seen in Figure 2.

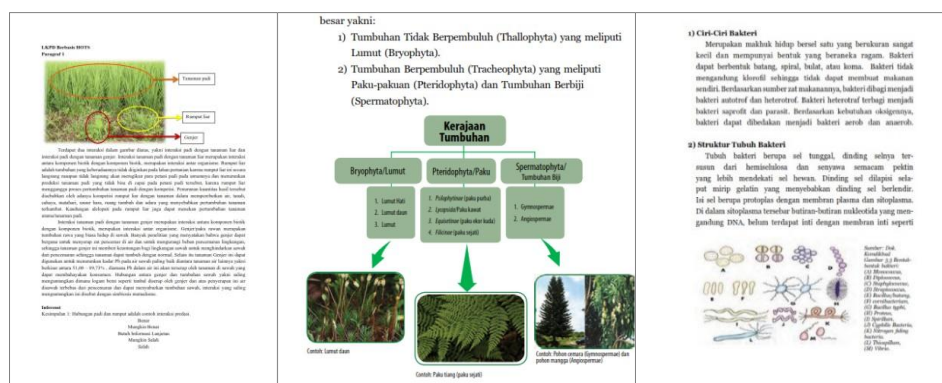


Figure 2 Several substances from the results of developing HOTS-based science materials (in Indonesian)

CONCLUSION

Based on the results of research and analysis conducted, the Higher Order Thinking Skills (HOTS)-based Natural Sciences (IPA) teaching materials developed have been proven to meet very high validity criteria. This validity category is supported by an average expert validation score of 3.72 out of a maximum scale of 4.00 in terms of content, presentation, language, and construction. In addition, the internal reliability of the validation instrument is very strong, as confirmed by a Cronbach's Alpha coefficient of 0.91. This numerical data confirms that the teaching materials are theoretically and pedagogically suitable for use in science learning at the junior high school level and ensures that the assessments given by the validators are consistent and reliable. Thus, the development of HOTS-based teaching materials is a relevant and strategic effort in supporting the implementation of 21st-century learning, and these high validity results provide a strong basis for proceeding to the practicality and empirical effectiveness testing stages.

ACKNOWLEDGMENT

We would like to express our gratitude to the Institute for Research and Community Service (LPPM) of Lambung Mangkurat University for providing funding for this research in 2025 with contract number 1794/UN8/LT/2025 dated June 10, 2025, and we would also like to thank all those who have been involved in this research.

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