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Title Page

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Higher-order Thinking Test of Science for College Students Using Multidimensional Item Response Theory Analysis

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Appendix 1

TABLE 1. Model Fit item for multiple choice questions

Item	Model			Result		
	1 PL	2 PL	3 PL	1 PL	2 PL	3 PL
A4	0,5732	0,9958	0,5875	fit	fit	fit
A31	0,3301	0,8112	0,8483	fit	fit	fit
B10	0,0089	0,2528	0,0593	misfit	fit	fit
B34	0,2364	0,8689	0,4245	fit	fit	fit
A29	0,9182	0,9991	0,8764	fit	fit	fit
A30	0,0609	0,9621	0,5738	fit	fit	fit
B24	0,0000	0,7868	0,9740	misfit	fit	fit
A11	0,0635	0,5444	0,8396	fit	fit	fit
B14	0,7890	0,8668	0,3083	fit	fit	fit
A21	0,0249	0,5732	0,5108	misfit	fit	fit
B28	0,0000	0,1786	0,8239	misfit	fit	fit
A14	0,5032	0,3952	0,6102	fit	fit	fit
B5	0,0417	0,2135	0,4153	misfit	fit	fit
B15	0,0004	0,1746	0,5570	misfit	fit	fit
B35	0,0065	0,5289	0,6731	misfit	fit	fit
B29	0,0000	0,9854	0,0153	misfit	fit	misfit
B37	0,0000	0,6063	0,0311	misfit	fit	misfit
A5	0,0457	0,6021	0,4927	misfit	fit	fit
A12	0,0075	0,8058	0,8069	misfit	fit	fit
A24	0,0007	0,9616	0,0380	misfit	fit	misfit
A34	0,0000	0,3036	0,0245	misfit	fit	misfit
B6	0,0005	0,9468	0,0148	misfit	fit	misfit
B17	0,4825	0,9300	0,1163	fit	fit	fit
A10	0,8660	0,7164	0,3860	fit	fit	fit
A16	0,0001	0,5023	0,0922	misfit	fit	fit
A27	0,2404	0,8943	0,9934	fit	fit	fit
A37	0,0746	0,9533	0,7636	fit	fit	fit
B7	0,5434	0,8487	0,2120	fit	fit	fit
B20	0,8309	0,8638	0,5522	fit	fit	fit
B27	0,0002	0,7554	0,2211	misfit	fit	fit
B40	0,0011	0,8517	0,0097	misfit	fit	fit
B31	0,0369	0,6640	0,4071	misfit	fit	fit
B32	0,0000	0,6169	0,7279	misfit	fit	fit
B33	0,6416	0,4072	0,8388	fit	fit	fit
A6	0,0016	0,6528	0,1847	misfit	fit	fit
A23	0,7706	0,4017	0,0261	fit	fit	misfit
A33	0,1290	0,5673	0,6403	fit	fit	fit
B8	0,0040	0,3494	0,7479	misfit	fit	fit
B18	0,0772	0,9217	0,5823	fit	fit	fit
B30	0,0572	0,6113	0,0804	fit	fit	fit
B38	0,0012	0,9299	0,6805	misfit	fit	fit
A1	0,0428	0,9666	0,0541	misfit	fit	fit
A13	0,9609	0,9011	0,4321	fit	fit	fit
A22	0,4930	0,8962	0,1814	fit	fit	fit
A32	0,0001	0,7863	0,0312	misfit	fit	misfit
B4	0,9927	0,7294	0,4784	fit	fit	fit
B16	0,0000	0,0971	-	misfit	fit	misfit
B25	0,5775	0,9526	0,8770	fit	fit	fit
B36	0,1344	0,4397	0,8969	fit	fit	fit
A9	0,4815	0,8094	0,1710	fit	fit	fit
A2	0,6378	0,8078	0,0985	fit	fit	fit
A3	0,4694	0,6777	0,5001	fit	fit	fit
A18	0,3979	0,9869	0,2563	fit	fit	fit
A19	0,7895	0,8893	0,9913	fit	fit	fit
A20	0,3975	0,9510	0,5755	fit	fit	fit
A28	0,6230	0,5950	0,2663	fit	fit	fit

Item	Model			Result		
	1 PL	2 PL	3 PL	1 PL	2 PL	3 PL
B1	0,9216	0,4871	0,2442	fit	fit	fit
B2	0,0000	0,1281	0,0621	misfit	fit	fit
B3	0,0070	0,0446	0,0521	misfit	misfit	fit
B11	0,0009	0,5223	0,5252	misfit	fit	fit
B12	0,0017	0,8852	0,6648	misfit	fit	fit
B13	0,8521	0,9823	0,9689	fit	fit	fit
B21	0,0012	0,9317	0,1128	misfit	fit	fit
B22	0,0081	0,1443	0,7384	misfit	fit	fit
B23	0,0544	0,2435	0,0900	fit	fit	fit
A17	0,4158	0,5300	0,4189	fit	fit	fit
B9	0,0000	0,6449	0,1600	misfit	fit	fit
B26	0,0093	0,9988	0,2167	misfit	fit	fit
B39	0,0036	0,8949	0,1111	misfit	fit	fit
A7	0,4430	0,9948	0,6033	fit	fit	fit
A25	0,7249	0,6235	0,7667	fit	fit	fit
A35	0,0115	0,2105	0,0009	misfit	fit	fit
B19	0,5737	0,4752	0,5759	fit	fit	fit
sum				38	72	64

Appendix 2

TABLE 2. The parameter analysis of the multiple-choice type test items

Item	Discriminant Index		Difficulty index		Conclusion
	a_i	Result	b_i	Result	
A4	0.499	Good	0.943	Good	Accepted
A31	0.588	Good	-1.172	Good	Accepted
B10	0.344	Good	1.222	Good	Accepted
B34	0.382	Good	0.142	Good	Accepted
A29	0.483	Good	-2.136	Poor	Revised
A30	1.291	Good	-2.063	Poor	Revised
B24	0.200	Good	-0.049	Good	Accepted
A11	0.333	Good	-1.560	Good	Accepted
B14	0.562	Good	-2.031	Poor	Revised
A21	0.287	Good	0.449	Good	Accepted
B28	0.187	Good	0.237	Good	Accepted
A14	0.709	Good	0.075	Good	Accepted
B5	0.320	Good	1.269	Good	Accepted
B15	0.261	Good	-0.429	Good	Accepted
B35	0.382	Good	-0.647	Good	Accepted
B29	1.875	Good	0.237	Good	Accepted
B37	1.814	Good	-0.255	Good	Accepted
A5	0.927	Good	-1.034	Good	Accepted
A12	0.327	Good	-1.354	Good	Accepted
A24	1.180	Good	1.692	Good	Accepted
A34	1.605	Good	1.589	Good	Accepted
B6	1.643	Good	0.568	Good	Accepted
B17	0.761	Good	-0.635	Good	Accepted
A10	0.521	Good	1.543	Good	Accepted
A16	1.365	Good	-0.189	Good	Accepted
A27	0.963	Good	-2.697	Poor	Accepted
A37	0.365	Good	-1.889	Good	Accepted
B7	0.653	Good	1.313	Good	Accepted
B20	0.492	Good	-0.577	Good	Accepted
B27	1.433	Good	0.054	Good	Accepted

B40	1.324	Good	1.844	Good	Accepted
B31	0.303	Good	0.489	Good	Accepted
B32	0.240	Good	0.185	Good	Accepted
B33	0.627	Good	-1.318	Good	Accepted
A6	1.481	Good	0.179	Good	Accepted
A23	0.468	Good	-0.666	Good	Accepted
A33	0.291	Good	-2.062	Poor	Revised
B8	0.272	Good	-0.552	Good	Accepted
B18	1.562	Good	-1.749	Good	Accepted
B30	1.060	Good	1.597	Good	Accepted
B38	1.126	Good	-0.827	Good	Accepted
A1	1.072	Good	1.671	Good	Accepted
A13	0.499	Good	1.406	Good	Accepted
A22	0.790	Good	1.767	Good	Accepted
A32	1.554	Good	-1.092	Good	Accepted
B4	0.600	Good	-0.107	Good	Accepted
B16	0.149	Good	0.658	Good	Accepted
B25	1.021	Good	-2.686	Poor	Revised
B36	0.325	Good	-0.951	Good	Accepted
A9	0.653	Good	1.959	Good	Accepted
A2	0.902	Good	-1.311	Good	Accepted
A3	0.758	Good	0.162	Good	Accepted
A18	0.628	Good	-0.054	Good	Accepted
A19	0.651	Good	-0.996	Good	Accepted
A20	0.577	Good	1.456	Good	Accepted
A28	0.426	Good	2.742	Poor	Revised
B1	0.704	Good	2.207	Good	Accepted
B2	1.352	Good	-0.295	Good	Accepted
B3	1.278	Good	0.788	Good	Accepted
B11	1.215	Good	-0.404	Good	Accepted
B12	1.532	Good	-1.408	Good	Accepted
B13	0.767	Good	-1.929	Good	Accepted
B21	1.143	Good	0.628	Good	Accepted
B22	0.282	Good	-0.635	Good	Accepted
B23	0.402	Good	1.123	Good	Accepted
A17	0.574	Good	-2.469	Poor	Revised
B9	1.503	Good	0.683	Good	Accepted
B26	1.166	Good	-0.422	Good	Accepted
B39	1.173	Good	1.407	Good	Accepted
A7	0.491	Good	0.194	Good	Accepted
A25	1.220	Good	-2.526	Poor	Revised
A35	1.578	Good	-1.915	Good	Accepted
B19	0.651	Good	-2.078	Poor	Revised

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Higher-order Thinking Test of Science for College Students Using Multidimensional Item Response Theory Analysis

MANUSCRIPT SUBMITTED

Abstract

The purpose of this study was to construct a higher order thinking test of science for pre-service elementary school teachers. The test was created using the ADDIE model. The Analyze stage was carried out by identifying the needs and baseline of higher order thinking skills of students from the Department of Primary School Teacher Education in Yogyakarta. The Design stage involved the creation of test blueprints and question cards. The Develop stage involved validating the test's content and construct validity. The content validity test was conducted using the Delphi technique with seven validators, whilst the construct validity test was conducted using item response theory and EFA. This study developed 77 questions, 73 multiple choice questions and four essay questions, all of which were determined to be valid in terms of content and constructions. The HOTS test's content validity test resulted in a V-value of 0.879 (valid with high criteria) based on the average Aiken's V index. Meanwhile, reliability analysis using the Cronbach's Alpha coefficient revealed a score of 0.907 for the 77 test items based on the construct validity test. The discriminatory index (di) classified all items as good, whereas the difficulty index (bi) classified 63 items as good and 10 as poor. The ten items were revised, despite their high index of difference. All of the test questions are appropriate for students whose ability score (θ) ranged from -2.85 to 2.15.

Key words: *higher-order thinking, science, test, ADDIE*

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Introduction

The twenty-first century, with its ultramodern qualities, enables upheaval in several spheres of life, as well as a rapid renewal process that necessitates community preparation. The readiness of the educational environment is one of the absolutes. Education must be standardized to meet the needs of the twenty-first century. Teachers in the twenty-first century will encounter much more problems than in the previous centuries (Andriani, 2010). Teachers are confronted with a far more varied student population, more complicated and demanding subject matter, a higher quality of learning, and increased expectations for students' higher thinking abilities (Darling-Hammond, 2006). This represents a significant challenge for Institutions of Personnel Education (LPTK) in terms of developing teacher candidates who possess these competencies. LPTK graduates must possess strong critical thinking skills to aid in the school-based learning process. In LPTK, the stages of student learning correspond to those of adult learners (andragogy). At this level, students exhibit eight critical qualities of learning: 1) they are self-directed, 2) they are practical and goal-oriented, 3) they are more resistant to change due to their lack of openness, and 4) they learn more slowly and hence require integrative knowledge, 5) they value personal experience as a source of learning, 6) they are highly motivated, 7) they take on multiple responsibilities, and 8) they have high expectations (Pappas, 2013).

Science education is one of the critical lessons that aspiring elementary school teachers at the Department of Primary School Teacher Education (PSTE) must know. Numerous PSTE study programs have a hierarchical structure for science courses based on their study materials and depths. In general, all science courses are designed to provide PSTE students with pedagogical and content knowledge (PCK). As a result, pre-service primary school teachers are competent to create and develop science instruction independently or in conjunction with other subjects. The characteristics of science learning are complex and need advanced analytical and critical thinking abilities, posing a variety of difficulties for students who have not mastered them. Among them include misconceptions about science (Faizah, 2016), learning difficulty in science (Maryani et al., 2018), and poor learning outcomes in science. Another issue that PSTE students face is the overwhelming amount of study materials that must be memorized. In PSTE Department, elementary school students must study five core subjects and additional competency support courses. These students are required to master the principle of each learning model and develop it as an innovative learning in elementary schools. This objective can be met if pre-service teachers possess strong critical thinking skills and the ability to adjust to changing circumstances. This capability is encapsulated in numerous studies on 21st century skills.

Numerous education organizations and experts have conducted research on 21st century skills. The Assessment & Teaching of 21st Century Skills (ATC21S) classifies 21st century skills into four areas, one of which is manner of thinking (Suto, 2013). Not only rich countries are monitoring the issue of 21st century skills; Indonesia is also participating in the study. Critical thinking, problem-solving, communication, and collaboration skills are all necessary in the twenty-first century(Trisdiono, 2013). Cognitive processes establish an individual’s foundation when confronted with life’s issues. A cognitive process is divided into various stages, including remembering, comprehending, applying, analyzing, making a judgement, and decision making. These elements of thinking are then referred to as Higher Order Thinking Skills (HOTS)

Higher Order Thinking Skills (HOTS) assess thinking abilities that go beyond recall and memorization to include features of analysis, synthesis, and evaluation. HOTS are cognitive abilities that result in higher level thinking (Alice Thomas & Glenda Thorne, 2009). Higher-level thinking is intended to be more than the regurgitation of information. Higher Order Thinking Skills are critical for adult learners, particularly in developing scientific concepts and applying them in everyday life, including in all university courses. In a nutshell, HOTS teach individuals how to analyze, synthesize, and evaluate (Alice Thomas & Glenda Thorne, 2009).

Research on pupils’ cognitive abilities has been conducted in Indonesia. One of them demonstrates that elementary school students in Semarang, Indonesia, lack critical thinking skills. The learning process is stymied by evaluation objectives that focus only on lower order thinking skills. Additionally, pupils’ ability to categorize induced thinking is moderate.

Students' capacity to deduce, analyze errors, develop an analytical perspective, make decisions, gain experience, and solve problems is rated as low (Fajriyah & Agustini, 2018). *The low thinking abilities of elementary school pupils in Indonesia are a result of a variety of circumstances, including the continuing emphasis on developing low-level thinking abilities* (Surya et al., 2018)*. Most teachers continue to struggle with teaching and familiarizing their students with higher-order thinking. This is due to a teacher shortage of information about how to plan and administer HOTS instruction* (Kuntarto et al., 2019)*. Similar circumstances exist for elementary school teacher candidates (pre-service teachers). According to studies* (Gradini et al., 2018; Wiyoko & Aprizan, 2020)*, the proportion of pre-service elementary school teachers who fall into the LOTS category is greater than the proportion of pre-service elementary school teachers who fall into the HOTS category.*

Many studies have developed higher order thinking skills (HOTS) tests of science; however, they mostly refer to Bloom's Taxonomy (Yusuf et al., 2018)(Abdullah et al., 2015; Atmojo et al., 2017; Utomo et al., n.d.; Zulfiani et al., 2020), Few have examined the HOTS features of alternative theories that better fit the needs of 21st century learning. With regards to this issue, we believe it is critical to construct a higher order thinking skills (HOTS) test of science that relates to a variety of cognition/taxonomy theories that are tailored to the 21st century's issues.

Method

2.1 Research design

This Research and Development (R and D) study employed the ADDIE development method, which consisted of the following stages: Analysis, Design, Develop, Implement, dan Evaluate (Branch, 2010). The research design is presented in Figure 1.

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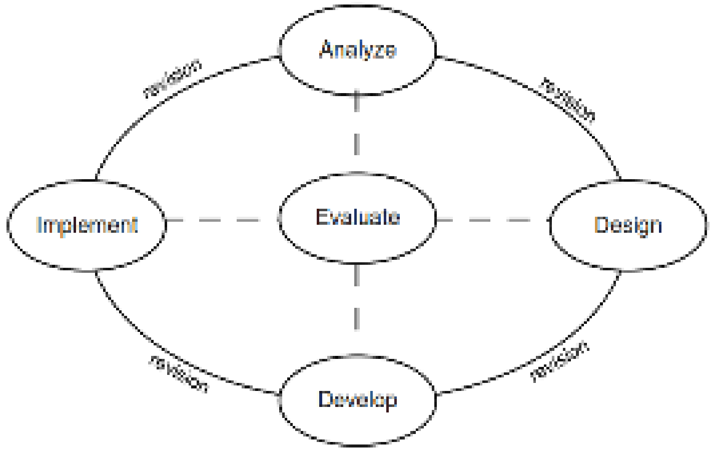

Figure 1. The ADDIE R&D Design (Branch, 2010)

As illustrated in Figure 1, the ADDIE development design comprises of five interdependent stages. At the Analyze stage, needs analysis for HOTS-based test development and problem analysis were performed. At the Design stage, the product design and prototype were generated. At the Develop stage, product revision, content validity test, and construct validity test were carried out to ensure the validity of the final product. The Implement stage was responsible for the overall product implementation process. At each level, the product can be revised, and the process and results of product deployment can be evaluated.

2.2 Participant

The samples has been taken randomly on elementary school teacher eduations' student in Yogyakarta. Seven experts evaluated the content of the product under development, and 268 students participated in the construct validity test.

2.2 Data Collection tools

. The HOTS test were divided down into six indicators, namely logic and reasoning, analysis, evaluation, and creation, problem solving, and judgment. each indicator was developed into 7-10 questions so as to produce 77 questions. Content validity was assessed using a questionnaire while construct validity was measured using the developed questions.

2.2 Data Analysis

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The content validity test was conducted using the Delphi technique. The results of the validity test were analyzed using Aiken's V, whilst the construct validity test findings were evaluated using item response theory.

Findings

This study was successful in creating 77 HOTS test items, which included 73 multiple-choice questions and four essay questions. Validator feedback on the HOTS-based test instrument under development was just as valuable as input on other products. The validators checked the adequacy of learning achievement-learning indicators-question indicators-and items more thoroughly. The usage of analogies and experimental data was re-examined considering their logical consistency under specific settings. The editorial questions, the stimulus, the form of several items from multiple choice to description, as well as the response possibilities for multiple choice questions, have all been altered significantly. The following summarizes the validators' input.

a) Writing
b) For test-item indicators, use the KKO analyzed from books written by Marzano or Anderson dan Krathwoll.
c) Input for the test items
    i. The HOTS instrument should be re-examined to determine whether the posed questions are rational. For instance, question number one says "when throwing a baseball from a distance of 7 meters, can the bounce travel as far as 10 meters with the power of an ordinary person?"
    ii. Question No. 2 is similarly less specific in terms of the ABCD points' position. Are these dots consecutive or non-sequential? Answers are frequently skewed. The solution to Problem No. 6 is ambiguous: the applicable laws are Newton's III and Pascal's laws, but Pascal's laws do not include mechanics.
    iii. The illustration is unclear, as in point No. 4 regarding the top of the hill. Problems can trap students because they believe that what is anticipated is the absence of frictional force, and hence refuse to consider alternative explanations for the correct answer.

iv. Certain questions, particularly those regarding "creation", should be transformed to essay questions.

Following modifications to the HOTS instrument, it was reviewed using an assessment sheet. The HOTS instrument was evaluated on ten dimensions, including a) the items' suitability for learning outcomes; b) the items' suitability for the HOTS indicators; c) the items' suitability for the question indicator; d) the stimulus' novelty (encouraging students to read); e) the stimulus' quality (contextual and implies the answer to the question); f) the suitability of the item with the material being learned; g) the ability to measure HOTS in aspects of logic, reasoning, analysis, evaluation, creation, problem-solving, and judgment; h) clarity of the formulation of the questions; i) clarity and arrangement of answer choices on multiple choice questions (homogeneous); and j) use of language. Additionally, the HOTS instrument makes use of the Likert scale. The instrument's content validity test indicated that the average Aiken V index produced V = 0.879 (highly valid). As a result of expert validation, the HOTS instrument was determined to be valid and was used in the next stage, namely the construct validity test.

The Results of the Construct Validity Test on the HOTS Instrument

a) Test of Unidimensionality Assumption

The criterion for meeting this assumption is that each test item evaluates only one ability. The assumption can be tested using factor analysis, which generates KMO, eigenvalues, explainable variance, and factor components. SPSS 24 was used to conduct the exploratory factor analysis. The following summarizes the findings of the factor analysis.

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.830
Bartlett's Test of Sphericity	Approx. Chi-Square	6260.265
	df	2926

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Sig.	.000

The outcome of factor analysis indicates that the KMO value is 0.830 or greater than 0.50, indicating that the sample size utilized in this trial is adequate. Additionally, the Bartlett test's chi-square value is 6260.265 with 2926 degrees of freedom and a p-value greater than 0.01. Intercorrelation between variables was determined using the KMO-MSA test (Widarjono, 2015). If the matrix has a KMO value greater than 0.5, it can be factored.

A test is considered unidimensional if it is demonstrated to measure only one dominant dimension, namely homogenous ability (Widarjono, 2015). The number of factors created can be determined by the presence of eigenvalues greater than one, which is the indicator factor (Widarjono, 2015). Factor analysis (Appendix 1) identified 27 components with an eigenvalue greater than one. This indicated that the 73 HOTS test items comprise 13 factors. The analysis results indicated that factor 1 is the dominant factor due to its eigenvalue of 12.931, which is greater than the others or the most dominant, implying that the HOTS test is unidimensional.

Statistical analysis also indicated an eigenvalue of 12.931, where the result is more than 2 times the eigenvalue of the second factor with a percentage of variance of 16.79%. Cumulatively, the percentage of the 27 factors is 65.546, suggesting that 65.546% is explained by the 27 existing components. The cumulative percentage of 65.546% has fulfilled the minimal condition for the cumulative value of taking the proper number of variables, which is 50% (Widarjono, 2015). Evidence of cumulative percentage values corroborates the notion that the HOTS test instrument is believed to be unidimensional.

Dimensions recorded in a data can be proven in the scree plot findings, specifically the number of steeps. The number of steeps shows the number of dimensions/factors, while the slope of the change in eigenvalues does not indicate the presence of dimensions (Widarjono, 2015). Therefore, unidimensionality can also be shown from the ensuing scree plot. The test is deemed to be unidimensional when components 1 and 2 in the scree plot have a high enough distance (Furr & Bacharach, 2008).

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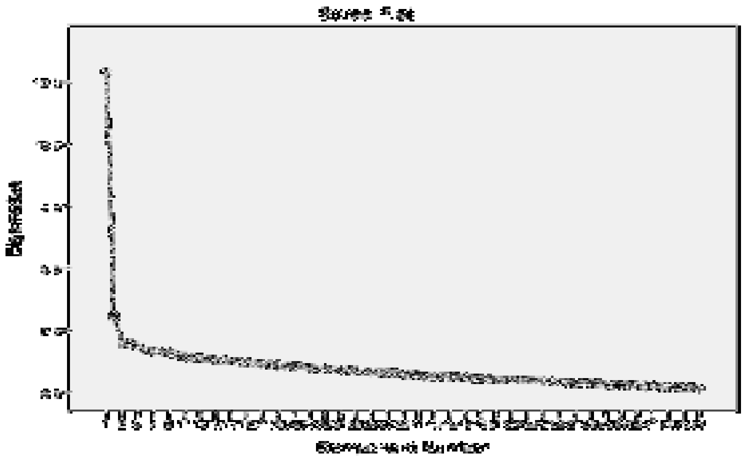

Figure 2. Scree plot of the Exploratory Factor Analysis Results

According to the scree plot in Figure 2, component 1 is located far away from component 2, whereas component 2 is located quite close to component 3 and other components. Additionally, as illustrated in Figure 2, the eigenvalues begin to slope with the third component. This demonstrates a single dominant factor and that other factors contribute significantly to the variance explained. The unidimensional analysis results corroborate the assertion of (Widarjono, 2015) that this HOTS test evaluates at least two components, with the first factor serving as the dominant factor. The scree plot in Figure 2 demonstrates that the HOTS test currently under development is unidimensional.

b) Test of Local Independence Assumption

One of the conditions for IRT analysis is the assumption of local independence. This assumption test is used to determine whether students' abilities are independent of the test questions, which means that their responses to one item do not affect their responses to subsequent items. The unidimensionality of the student response data to the test automatically establishes the local independence assumption test (Widarjono, 2015). The local independence assumption, on the other hand, can be demonstrated using a covariance matrix based on the ability of pupils categorized into many groups. If the correlation between the capability intervals is modest or close to zero, this assumption is fulfilled. Thus, a covariance value near to zero satisfies the local independence assumption. Table 1 contains the covariance matrix.

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Table 1. Covariance Matrix of Students' Higher Order Thinking Skills (HOTS)

	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10
K1	0,0726									
K2	0,0227	0,0132								
K3	0,0130	0,0066	0,0036							
K4	0,0250	0,0090	0,0052	0,0098						
K5	0,0077	0,0036	0,0020	0,0031	0,0012					
K6	0,0062	0,0024	0,0014	0,0023	0,0008	0,0006				
K7	0,0233	0,0089	0,0050	0,0089	0,0029	0,0022	0,0083			
K8	0,0092	0,0044	0,0023	0,0034	0,0013	0,0009	0,0033	0,0016		
K9	0,0312	0,0124	0,0070	0,0122	0,0040	0,0030	0,0113	0,0046	0,0156	
K10	0,0813	0,0555	0,0251	0,0300	0,0129	0,0095	0,0327	0,0163	0,0442	0,7280

Table 1 presents the variance-covariance matrix values for several groups of students' skills. The analysis reveals that the covariance variation across groups of students' ability intervals that form a diagonal line is negligible, if not nil. As there is no association between the two variables, the assumption of local independence is satisfied.

c) Test of Parameter Invariance Assumption

The third requirement is parameter invariance. Parameter invariance shows that the test items are independent of the distribution of the students' ability parameter and vice versa, that students' ability parameter is independent of the test items. Students' abilities will not change because of working on a package of questions with distinct item parameters, and the item parameters will remain constant regardless of which group of students is assessed. There are two types of parameter invariance. The first type is item parameter invariance, and the second type is ability parameter invariance. The invariance of item parameter can be determined by dividing the sample (218 students) into two even and odd groups. The estimated grain parameters for each sample are then plotted and associated using a scree plot. If the correlation is positive and significant, the assumption of item parameter invariance is satisfied (Widarjono, 2015). Figure 3 illustrates the estimation results for the invariance of the item parameters.

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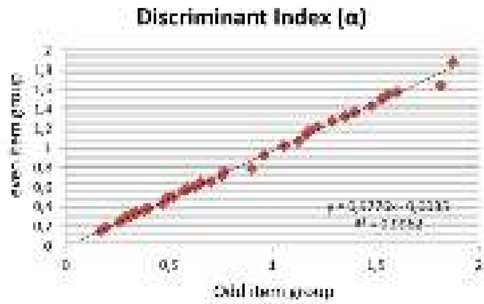

Figure 3. Scree plot of the parameter invariance of the HOTS test's discriminatory power

The scree plot in Figure 3 depicts the estimation of item parameter invariance for item discriminating power after students worked on odd and even questions. As illustrated in Figure 3, the estimated values are spread out and reasonably close to the linear line. The discriminatory power has a strong correlation with the student's response to the odd and even test items (0.9962). The scree plot and correlation analysis indicate that the discriminating power of the test items is invariant. Separation of two groups of test takers, odd and even, was also incorporated in the item parameter analysis for difficulty level. Microsoft Excel was used to conduct the analysis. Figure 4 depicts the correlation between the findings of the analysis.

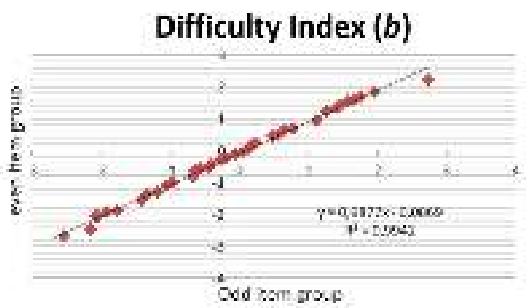

Figure 2. Scree plot of the Parameter Invariance of HOTS Test Difficulty Level

The scree plot of the estimated invariance of items in terms of difficulty level after students worked on odd and even questions is shown in Figure 4. As illustrated in Figure 4, the estimated values are dispersed and somewhat close to the linear line. The correlation coefficient between the difficulty of the questions and the responses of students to odd and

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even items is 0.9942 (high). Figures 3 and 4 indicate that the estimation of the item parameters' invariance in terms of discriminatory power and difficulty level is satisfactory. After splitting the odd and even subtest groups, the invariance of the students' ability parameter can be examined. The estimated ability parameter for each sample was plotted and associated using a scree plot. If the correlation is significant and positive, the assumption of invariance of the student's ability parameters is satisfied (Widarjono, 2015). In general, students' capacity to work on the test is estimated as scattered (Figure 5).

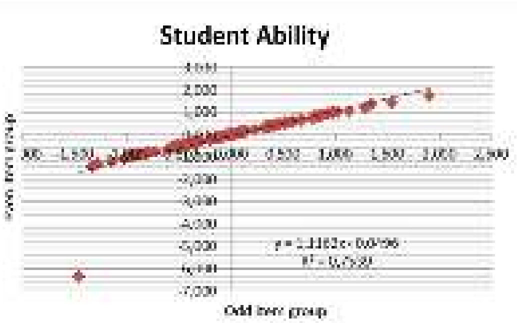

Figure 3. Scree plot of the Parameter Invariance of Students' Ability

The scree plot in Figure 5 depicts the estimated invariance of students' ability following an analysis of the abilities of even and odd numbered students. Additionally, the scree plot findings show why the estimated values are quite close to a straight line with a correlation coefficient of 0.7539 (very high). In conclusion, the ability parameter invariance assumption has been satisfied.

d) Estimation of Reliability

The reliability coefficient of an instrument indicates the degree of confidence in the error-free findings of measurement (the greater the reliability coefficient, the more accurate the measurements). In this study, reliability was estimated using the SPSS 24 program. The Cronbach's Alpha coefficient for 77 items was 0.907 based on confirmed data. According to Mahrens and Lehman, while there is no universal agreement, it is usually believed that the test used to make individual student placement decisions must have a minimum reliability coefficient of 0.85 (Mehrens & Lehmann, 1991). According to the findings of this study and the experts' view, the reliability of the test developed in this study meets the criteria for a reliable test.

e) Model Fit

The three assumptions for the IRT analysis had been well fulfilled, so that the HOTS multiple-choice test was examined for model fit. Seventy-three items were produced. The model fit test for 1-PL, 2-PL, or 3-PL was performed by comparing X^2. The probability value for each test item must fulfill $p > 0.05$. The model fit analysis results summarized in Appendix 1 indicate that the 2-PL model is the best appropriate for the HOTS test instrument. In comparison to the 1-PL or 3-PL models, the 2-PL model accommodates the majority of the HOTS test's multiple-choice items. Since the study requires a 2-PL model, the parameters to examine are the discriminatory power (a) and the difficulty level (b) of each test item. Items that do not match the criteria for a "good item" are omitted from the final product.

After examining the model fit on the -choice test, the HOTS test's four essay items were analyzed. For essay questions, the model fit criteria are identical to those for multiple choice questions. The essay questions, on the other hand, were examined using the R package MIRT program. This was done because the essay questions were scored as polytomus, which prevented them from being examined using the BILOG-MG tool. TABLE 3 summarizes the model fit analysis of the HOTS test essay questions.

Table 3. Model Fit Test on HOTS Essay Questions

Item	X^2				Remarks
	Statistics	df	RMSEA	P-Value	
A26	0.581	4	0.000	0.965	Fit
A8	3.771	5	0.000	0.583	Fit
A36	7.614	3	0.076	0.055	Fit
A15	4.749	4	0.026	0.314	Fit

According to TABLE 3, all test items fit the 2-PL model applied. The examination of the multiple-choice items and essay questions reveals that the 2-PL model is the best fit for the HOTS test items. The parameters measured in both types of questions are the same, namely discriminatory power (a) and degree of difficulty (b) of each test item.

f) Parameter of Time Item

The 2-PL model was used to determine the characteristics of a good test item. The test items that fit the 2PL model were re-analyzed to determine their properties. According to the 2-PL model, the requirements for a good item are based on the discriminatory power (ai) and level of difficulty (bi) of each item. Discriminating power is regarded to be good if it is between 0 and 2. Additionally, a good difficulty index should range between -2 and +2 (Widarjono, 2015). This study found the discriminant index and the difficulties index of 73 questions (Appendix 2). These findings indicate that all items have a high discriminatory power index (ai), while 63 test items have a good difficulty level (bi) and ten items have a low difficulty level (bi). Although the 10 items showed a high discrimination index, they had a low difficulty level. Therefore, the ten items (A29, A30, B14, A27, A33, B25, A28, A17, A25, and B19) were revised.

The analysis of the multiple-choice test parameters was then continued with the analysis of the HOTS essay questions. The essay questions were analyzed using the R-Program. The results of the parameter analysis of the essay questions are shown as follows.

Table 2. The Results of Parameter Analysis on the HOTS Essay Questions

Item	Discriminatory Power		Difficulty Level				Conclusion
	a	Remarks	b	b2	b mean	Remarks	
A26	7.717	Poor	-0.981	-0.130	-0.555	Good	Revised
A8	0.07	Good	-0.851	-0.434	-0.642	Good	Accepted
A46	1.402	Good	-0.865	1.871	0.503	Good	Accepted
A15	0.173	Good	-0.260	-	-0.260	Good	Accepted

As shown in Table 5, item A26 has a low discrimination index of 7.717. Nevertheless, items A8, A46, and A15 have high discriminatory indices. All essay items have a reasonable difficulty index. Based on these findings, item A26 has a low discriminatory index but a high difficulty index; hence, item A26 must be amended and items A8, A46, and A15 were accepted.

g) Information Function and Standard error of measurement (IF SEM &)

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The test information function is equal to the sum of the test item functions. The relationship between the test information function and the standard error of measurement (SEM) is inverse, with a higher test information function indicating a smaller measurement error and vice versa. Figure 6 illustrates the IF and SEM curves.

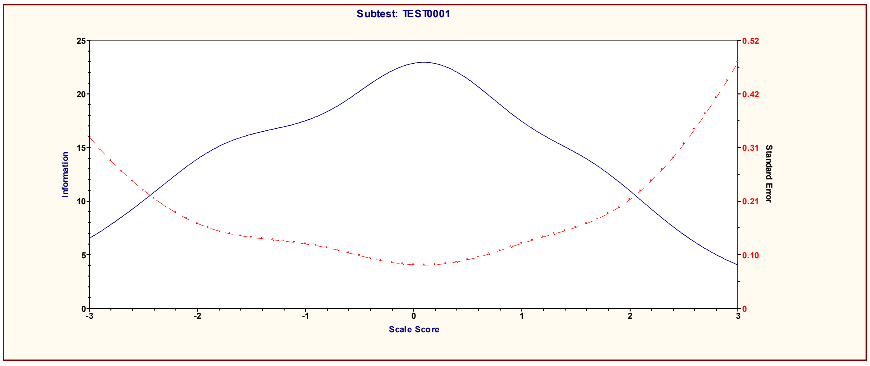

Figure 4. IF & SEM Curves

The analysis of the 2-Parameter Logistics (2-PL) model using BILOG-MG yields discriminating power (ai) and item difficulty level (bi), which were then utilized to determine the information function value for each HOTS test item. The test information value was calculated by adding the information functions of each item. The maximum test information function is found in ability = 0.1, with a value of 23.2 and a measurement error of 0.7. Additionally, Figure 6 illustrates that the HOTS test instrument covers the interval's lower and higher bounds. The interval's lower and upper bounds are the ability scores at which the graphs of the information function and standard error of measurement overlap. Based on the intersection line, it was determined that the HOTS test established in this study is appropriate for assessing higher order thinking skills in students with an ability (θ) of -2.85 to 2.15.

Discussion

Higher order thinking skills (HOTS) are higher-level cognitive abilities, not only memorization. HOTS entail a number of mental processes, including analyzing, evaluating, and producing, all of which are embedded in the problem-solving process. According to (Lewy, 2011), any ability that requires analysis, evaluation, and production is classified as a higher order thinking skill. Bloom's Taxonomy is the most frequently accepted hierarchical arrangement of HOTS in the field of education, as it examines the levels of thinking from knowledge to evaluation (Ramos et al., 2013). However, the new paradigm of educational research frequently references Marzano's Taxonomy, which includes comparing, classifying, inductive reasoning, deductive reasoning, error analysis, construction support, perspective analysis, abstracting, decision making, investigation, problem solving, experimental inquiry, and invention (Heong et al., 2011, 2016; Marzano, 1993; Marzano & Kendall, 2006).

According to the Marzano's Taxonomy, higher order thinking skills (HOTS) enable the development of student learning outcomes (SLO), class activities, and learning performance (Dubas & Toledo, 2016; Toledo & Dubas, 2016). Students that possess higher order thinking skills are capable of learning, improving their performance, and overcoming their weaknesses (Yee et al., 2011). Students who received thinking skills training improved their reading comprehension and academic performance. This demonstrates the critical nature of thinking skills in resolving learning challenges, stimulating competitive thinking, creating intellectuals, and avoiding cognitive errors (Heong et al., 2011). Higher order thinking skills are classified according to level of cognition (cognitive capacity). The most often used classification of thinking abilities is Bloom's Taxonomy or its modification, which includes the following: 1) remembering, 2) comprehending, 3) applying, 4) analyzing, 5) evaluating, and 6) creating (C. A. Anderson & Krathwohl, 2014; L. W. Anderson et al., 2000). Numerous scholars classify HOTS into three categories: analysis, evaluation, and creation.

Marzano defines knowledge as "information, mental procedures, and psychomotor procedures." Following that, the domain is separated into six hierarchical cognitive processes: retrieval, comprehension, analysis, knowledge utilization, metacognition, and self-system thinking. Marzano defines HOTS as the following: comparing, classifying, inductive reasoning, deductive reasoning, error analysis, construction support, perspective analysis, abstracting, decision-making, investigation, problem-solving, experimental inquiry, and invention (Heong et al., 2011, 2016; Marzano, 1993; Marzano & Kendall, 2006).

Along with Bloom, Anderson, and Marzano, Webb (2002) provides stages of thinking that are commonly employed in standard measurement in many nations. This thinking stage consists of four levels, namely 1) recall and reproduction, 2) skills and concepts, 3) strategic thinking, and 4) extended thinking. The SOLO (Structure of Observed Learning Outcomes) Taxonomy is another cognitive taxonomy that is commonly used in Australia, New Zealand, Canada, and the United Kingdom. SOLO is a hierarchical taxonomy of cognitive abilities that focuses on distinct elements and their relationships. This hierarchy is divided into five levels: pre-structural, unistructural, multi-structural, relational, and extended abstract. Brookhart (2010) constructs HOTS indicators using

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slices from all four taxonomies. According to Brookhart (2010), HOTS consist of logical ability and reasoning, analysis, evaluation, and creation, problem solving, judgment, and creativity and creative thinking. However, this study used a taxonomy that is tailored to the demands of future primary school science instructors

Conclusion

This study developed 77 questions, 73 multiple choice questions and four essay questions, all of which were determined to be valid in terms of content and constructs. The content validity test, calculated using the average Aiken V index, produced V = 0.879, indicating that the HOTS test is highly valid. Cronbach's Alpha coefficient for 77 items is 0.907 based on the construct validity test. The analysis of the multiple-choice items and essay questions revealed that the 2PL model was the most appropriate form of IRT model for analyzing the test items. Each HOTS test item has a discriminatory power index (ai) in the good category. However, in terms of difficulty level index (bi), there were 63 items in good category and 10 items in bad category. As a result, the ten test items needed to be altered. The 10 items had a high discriminatory index but a low level of difficulty. Items that needed to be revised included A29, A30, B14, A27, A33, B25, A28, A17, A25, and B19. Item A26 in the essay question section showed a low discrimination index, but a high difficulty level. Therefore, item A26 was revised, but items A8, A46, and A15 were accepted. All the test questions generated in this study are appropriate for assessing the higher order thinking skills of students with ability (θ) ranging from -2.85 to 2.15.

Suggestion

This study recommends further research to be able to promote HOTS through a learning approach. This aims to increase the HOTS of students throughout Indonesia.

Limitation

This research is limited only to the development of Physics Science test instruments. This is based on a pre-research needs analysis. Development in other fields is recommended.

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Higher-order Thinking Test of Science for College Students Using Multidimensional Item Response Theory Analysis

HASIL REVIEW

Abstract

The purpose of this study was to construct a higher order thinking test of science for pre-service elementary school teachers. The test was created using the ADDIE model. The Analyze stage was carried out by identifying the needs and baseline of higher order thinking skills of students from the Department of Primary School Teacher Education in Yogyakarta. The Design stage involved the creation of test blueprints and question cards. The Develop stage involved validating the test's content and construct validity. The content validity test was conducted using the Delphi technique with seven validators, whilst the construct validity test was conducted using item response theory and EFA. This study developed 77 questions, 73 multiple choice questions and four essay questions, all of which were determined to be valid in terms of content and constructions. The HOTS test's content validity test resulted in a V-value of 0.879 (valid with high criteria) based on the average Aiken's V index. Meanwhile, reliability analysis using the Cronbach's Alpha coefficient revealed a score of 0.907 for the 77 test items based on the construct validity test. The discriminatory index (di) classified all items as good, whereas the difficulty index (bi) classified 63 items as good and 10 as poor. The ten items were revised, despite their high index of difference. All of the test questions are appropriate for students whose ability score (θ) ranged from -2.85 to 2.15.

Key words: *higher-order thinking, science, test, ADDIE*

Introduction

The twenty-first century, with its ultramodern qualities, enables upheaval in several spheres of life, as well as a rapid renewal process that necessitates community preparation. The readiness of the educational environment is one of the absolutes. Education must be standardized to meet the needs of the twenty-first century. Teachers in the twenty-first century will encounter much more problems than in the previous centuries (Andriani, 2010). Teachers are confronted with a far more varied student population, more complicated and demanding subject matter, a higher quality of learning, and increased expectations for students' higher thinking abilities (Darling-Hammond, 2006). This represents a significant challenge for Institutions of Personnel Education (LPTK) in terms of developing teacher candidates who possess these competencies. LPTK graduates must possess strong critical thinking skills to aid in the school-based learning process. In LPTK, the stages of student learning correspond to those of adult learners (andragogy). At this level, students exhibit eight critical qualities of learning: 1) they are self-directed, 2) they are practical and goal-oriented, 3) they are more resistant to change due to their lack of openness, and 4) they learn more slowly and hence require integrative knowledge, 5) they value personal experience as a source of learning, 6) they are highly motivated, 7) they take on multiple responsibilities, and 8) they have high expectations (Pappas, 2013).

Science education is one of the critical lessons that aspiring elementary school teachers at the Department of Primary School Teacher Education (PSTE) must know. Numerous PSTE study programs have a hierarchical structure for science courses based on their study materials and depths. In general, all science courses are designed to provide PSTE students with pedagogical and content knowledge (PCK). As a result, pre-service primary school teachers are competent to create and develop science instruction independently or in conjunction with other subjects. The characteristics of science learning are complex and need advanced analytical and critical thinking abilities, posing a variety of difficulties for students who have not mastered them. Among them include misconceptions about science (Faizah, 2016), learning difficulty in science (Maryani et al., 2018), and poor learning outcomes in science. Another issue that PSTE students face is the overwhelming amount of study materials that must be memorized. In PSTE Department, elementary school students must study five core subjects and additional competency support courses. These students are required to master the principle of each learning model and develop it as an innovative learning in elementary schools. This objective can be met if pre-service teachers possess strong critical thinking skills and the ability to adjust to changing circumstances. This capability is encapsulated in numerous studies on 21st century skills.

Numerous education organizations and experts have conducted research on 21st century skills. The Assessment & Teaching of 21st Century Skills (ATC21S) classifies 21st century skills into four areas, one of which is manner of thinking (Suto, 2013). Not only rich countries are monitoring the issue of 21st century skills; Indonesia is also participating in the study. Critical thinking, problem-solving, communication, and collaboration skills are all necessary in the twenty-first century(Trisdiono, 2013). Cognitive processes establish an individual's foundation when confronted with life's issues. A cognitive process is divided into various stages, including remembering, comprehending, applying, analyzing, making a judgement, and decision making. These elements of thinking are then referred to as Higher Order Thinking Skills (HOTS)

Higher Order Thinking Skills (HOTS) assess thinking abilities that go beyond recall and memorization to include features of analysis, synthesis, and evaluation. HOTS are cognitive abilities that result in higher level thinking (Alice Thomas & Glenda Thorne, 2009). Higher-level thinking is intended to be more than the regurgitation of information. Higher Order Thinking Skills are critical for adult learners, particularly in developing scientific concepts and applying them in everyday life, including in all university courses. In a nutshell, HOTS teach individuals how to analyze, synthesize, and evaluate (Alice Thomas & Glenda Thorne, 2009).

Research on pupils' cognitive abilities has been conducted in Indonesia. One of them demonstrates that elementary school students in Semarang, Indonesia, lack critical thinking skills. The learning process is stymied by evaluation objectives that focus only on lower order thinking skills. Additionally, pupils' ability to categorize induced thinking is moderate. Students' capacity to deduce, analyze errors, develop an analytical perspective, make

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decisions, gain experience, and solve problems is rated as low (Fajriyah & Agustini, 2018). *The low thinking abilities of elementary school pupils in Indonesia are a result of a variety of circumstances, including the continuing emphasis on developing low-level thinking abilities* (Surya et al., 2018)*. Most teachers continue to struggle with teaching and familiarizing their students with higher-order thinking. This is due to a teacher shortage of information about how to plan and administer HOTS instruction* (Kuntarto et al., 2019)*. Similar circumstances exist for elementary school teacher candidates (pre-service teachers). According to studies* (Gradini et al., 2018; Wiyoko & Aprizan, 2020)*, the proportion of pre-service elementary school teachers who fall into the LOTS category is greater than the proportion of pre-service elementary school teachers who fall into the HOTS category.*

Many studies have developed higher order thinking skills (HOTS) tests of science; however, they mostly refer to Bloom's Taxonomy (Yusuf et al., 2018)(Abdullah et al., 2015; Atmojo et al., 2017; Utomo et al., n.d.; Zulfiani et al., 2020), Few have examined the HOTS features of alternative theories that better fit the needs of 21st century learning. With regards to this issue, we believe it is critical to construct a higher order thinking skills (HOTS) test of science that relates to a variety of cognition/taxonomy theories that are tailored to the 21st century's issues.

Method

2.1 Research design

This Research and Development (R and D) study employed the ADDIE development method, which consisted of the following stages: Analysis, Design, Develop, Implement, dan Evaluate (Branch, 2010). The research design is presented in Figure 1.

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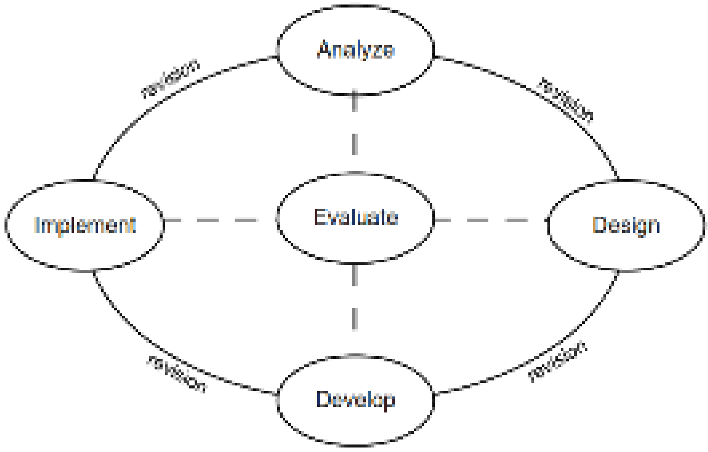

Figure 1. The ADDIE R&D Design (Branch, 2010)

As illustrated in Figure 1, the ADDIE development design comprises of five interdependent stages. At the Analyze stage, needs analysis for HOTS-based test development and problem analysis were performed. At the Design stage, the product design and prototype were generated. At the Develop stage, product revision, content validity test, and construct validity test were carried out to ensure the validity of the final product. The Implement stage was responsible for the overall product implementation process. At each level, the product can be revised, and the process and results of product deployment can be evaluated.

2.2 Participant

The samples has been taken randomly on elementary school teacher eduations' student in Yogyakarta. Seven experts evaluated the content of the product under development, and 268 students participated in the construct validity test.

2.2 Data Collection tools

The HOTS test were divided down into six indicators, namely logic and reasoning, analysis, evaluation, and creation, problem solving, and judgment. each indicator was developed into 7-10 questions so as to produce 77 questions. Content validity was assessed using a questionnaire while construct validity was measured using the developed questions.

2.2 Data Analysis

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The content validity test was conducted using the Delphi technique. The results of the validity test were analyzed using Aiken's V, whilst the construct validity test findings were evaluated using item response theory.

Findings

This study was successful in creating 77 HOTS test items, which included 73 multiple-choice questions and four essay questions. Validator feedback on the HOTS-based test instrument under development was just as valuable as input on other products. The validators checked the adequacy of learning achievement-learning indicators-question indicators-and items more thoroughly. The usage of analogies and experimental data was re-examined considering their logical consistency under specific settings. The editorial questions, the stimulus, the form of several items from multiple choice to description, as well as the response possibilities for multiple choice questions, have all been altered significantly. The following summarizes the validators' input.

a) Writing
b) For test-item indicators, use the KKO analyzed from books written by Marzano or Anderson dan Krathwoll.
c) Input for the test items
    i. The HOTS instrument should be re-examined to determine whether the posed questions are rational. For instance, question number one says "when throwing a baseball from a distance of 7 meters, can the bounce travel as far as 10 meters with the power of an ordinary person?"
    ii. Question No. 2 is similarly less specific in terms of the ABCD points' position. Are these dots consecutive or non-sequential? Answers are frequently skewed. The solution to Problem No. 6 is ambiguous: the applicable laws are Newton's III and Pascal's laws, but Pascal's laws do not include mechanics.
    iii. The illustration is unclear, as in point No. 4 regarding the top of the hill. Problems can trap students because they believe that what is anticipated is the absence of frictional force, and hence refuse to consider alternative explanations for the correct answer.

iv. Certain questions, particularly those regarding "creation", should be transformed to essay questions.

Following modifications to the HOTS instrument, it was reviewed using an assessment sheet. The HOTS instrument was evaluated on ten dimensions, including a) the items' suitability for learning outcomes; b) the items' suitability for the HOTS indicators; c) the items' suitability for the question indicator; d) the stimulus' novelty (encouraging students to read); e) the stimulus' quality (contextual and implies the answer to the question); f) the suitability of the item with the material being learned; g) the ability to measure HOTS in aspects of logic, reasoning, analysis, evaluation, creation, problem-solving, and judgment; h) clarity of the formulation of the questions; i) clarity and arrangement of answer choices on multiple choice questions (homogeneous); and j) use of language. Additionally, the HOTS instrument makes use of the Likert scale. The instrument's content validity test indicated that the average Aiken V index produced V = 0.879 (highly valid). As a result of expert validation, the HOTS instrument was determined to be valid and was used in the next stage, namely the construct validity test.

The Results of the Construct Validity Test on the HOTS Instrument

a) Test of Unidimensionality Assumption

The criterion for meeting this assumption is that each test item evaluates only one ability. The assumption can be tested using factor analysis, which generates KMO, eigenvalues, explainable variance, and factor components. SPSS 24 was used to conduct the exploratory factor analysis. The following summarizes the findings of the factor analysis.

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.830
Bartlett's Test of Sphericity	Approx. Chi-Square	6260.265
	df	2926

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Sig.	.000

The outcome of factor analysis indicates that the KMO value is 0.830 or greater than 0.50, indicating that the sample size utilized in this trial is adequate. Additionally, the Bartlett test's chi-square value is 6260.265 with 2926 degrees of freedom and a p-value greater than 0.01. Intercorrelation between variables was determined using the KMO-MSA test (Widarjono, 2015). If the matrix has a KMO value greater than 0.5, it can be factored.

A test is considered unidimensional if it is demonstrated to measure only one dominant dimension, namely homogenous ability (Widarjono, 2015). The number of factors created can be determined by the presence of eigenvalues greater than one, which is the indicator factor (Widarjono, 2015). Factor analysis (Appendix 1) identified 27 components with an eigenvalue greater than one. This indicated that the 73 HOTS test items comprise 13 factors. The analysis results indicated that factor 1 is the dominant factor due to its eigenvalue of 12.931, which is greater than the others or the most dominant, implying that the HOTS test is unidimensional.

Statistical analysis also indicated an eigenvalue of 12.931, where the result is more than 2 times the eigenvalue of the second factor with a percentage of variance of 16.79%. Cumulatively, the percentage of the 27 factors is 65.546, suggesting that 65.546% is explained by the 27 existing components. The cumulative percentage of 65.546% has fulfilled the minimal condition for the cumulative value of taking the proper number of variables, which is 50% (Widarjono, 2015). Evidence of cumulative percentage values corroborates the notion that the HOTS test instrument is believed to be unidimensional.

Dimensions recorded in a data can be proven in the scree plot findings, specifically the number of steeps. The number of steeps shows the number of dimensions/factors, while the slope of the change in eigenvalues does not indicate the presence of dimensions (Widarjono, 2015). Therefore, unidimensionality can also be shown from the ensuing scree plot. The test is deemed to be unidimensional when components 1 and 2 in the scree plot have a high enough distance (Furr & Bacharach, 2008).

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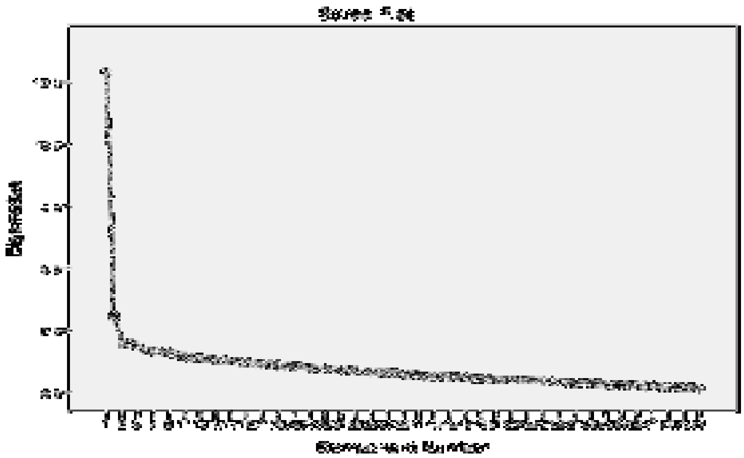

Figure 2. Scree plot of the Exploratory Factor Analysis Results

According to the scree plot in Figure 2, component 1 is located far away from component 2, whereas component 2 is located quite close to component 3 and other components. Additionally, as illustrated in Figure 2, the eigenvalues begin to slope with the third component. This demonstrates a single dominant factor and that other factors contribute significantly to the variance explained. The unidimensional analysis results corroborate the assertion of (Widarjono, 2015) that this HOTS test evaluates at least two components, with the first factor serving as the dominant factor. The scree plot in Figure 2 demonstrates that the HOTS test currently under development is unidimensional.

b) Test of Local Independence Assumption

One of the conditions for IRT analysis is the assumption of local independence. This assumption test is used to determine whether students' abilities are independent of the test questions, which means that their responses to one item do not affect their responses to subsequent items. The unidimensionality of the student response data to the test automatically establishes the local independence assumption test (Widarjono, 2015). The local independence assumption, on the other hand, can be demonstrated using a covariance matrix based on the ability of pupils categorized into many groups. If the correlation between the capability intervals is modest or close to zero, this assumption is fulfilled. Thus, a covariance value near to zero satisfies the local independence assumption. Table 1 contains the covariance matrix.

Table 1. Covariance Matrix of Students' Higher Order Thinking Skills (HOTS)

	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10
K1	0,0726									
K2	0,0227	0,0132								
K3	0,0130	0,0066	0,0036							
K4	0,0250	0,0090	0,0052	0,0098						
K5	0,0077	0,0036	0,0020	0,0031	0,0012					
K6	0,0062	0,0024	0,0014	0,0023	0,0008	0,0006				
K7	0,0233	0,0089	0,0050	0,0089	0,0029	0,0022	0,0083			
K8	0,0092	0,0044	0,0023	0,0034	0,0013	0,0009	0,0033	0,0016		
K9	0,0312	0,0124	0,0070	0,0122	0,0040	0,0030	0,0113	0,0046	0,0156	
K10	0,0813	0,0555	0,0251	0,0300	0,0129	0,0095	0,0327	0,0163	0,0442	0,7280

Table 1 presents the variance-covariance matrix values for several groups of students' skills. The analysis reveals that the covariance variation across groups of students' ability intervals that form a diagonal line is negligible, if not nil. As there is no association between the two variables, the assumption of local independence is satisfied.

c) Test of Parameter Invariance Assumption

The third requirement is parameter invariance. Parameter invariance shows that the test items are independent of the distribution of the students' ability parameter and vice versa, that students' ability parameter is independent of the test items. Students' abilities will not change because of working on a package of questions with distinct item parameters, and the item parameters will remain constant regardless of which group of students is assessed. There are two types of parameter invariance. The first type is item parameter invariance, and the second type is ability parameter invariance. The invariance of item parameter can be determined by dividing the sample (218 students) into two even and odd groups. The estimated grain parameters for each sample are then plotted and associated using a scree plot. If the correlation is positive and significant, the assumption of item parameter invariance is satisfied (Widarjono, 2015). Figure 3 illustrates the estimation results for the invariance of the item parameters.

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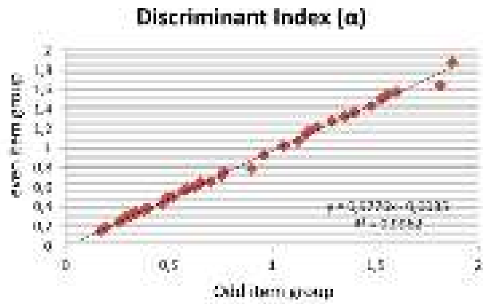

Figure 3. Scree plot of the parameter invariance of the HOTS test's discriminatory power

The scree plot in Figure 3 depicts the estimation of item parameter invariance for item discriminating power after students worked on odd and even questions. As illustrated in Figure 3, the estimated values are spread out and reasonably close to the linear line. The discriminatory power has a strong correlation with the student's response to the odd and even test items (0.9962). The scree plot and correlation analysis indicate that the discriminating power of the test items is invariant. Separation of two groups of test takers, odd and even, was also incorporated in the item parameter analysis for difficulty level. Microsoft Excel was used to conduct the analysis. Figure 4 depicts the correlation between the findings of the analysis.

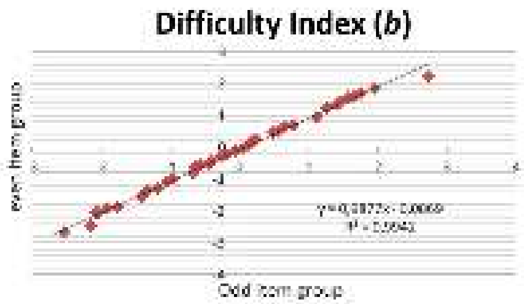

Figure 2. Scree plot of the Parameter Invariance of HOTS Test Difficulty Level

The scree plot of the estimated invariance of items in terms of difficulty level after students worked on odd and even questions is shown in Figure 4. As illustrated in Figure 4, the estimated values are dispersed and somewhat close to the linear line. The correlation coefficient between the difficulty of the questions and the responses of students to odd and

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even items is 0.9942 (high). Figures 3 and 4 indicate that the estimation of the item parameters' invariance in terms of discriminatory power and difficulty level is satisfactory. After splitting the odd and even subtest groups, the invariance of the students' ability parameter can be examined. The estimated ability parameter for each sample was plotted and associated using a scree plot. If the correlation is significant and positive, the assumption of invariance of the student's ability parameters is satisfied (Widarjono, 2015). In general, students' capacity to work on the test is estimated as scattered (Figure 5).

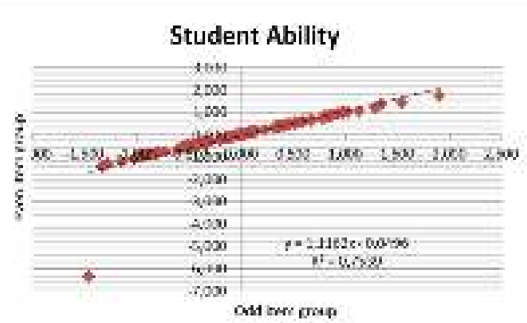

Figure 3. Scree plot of the Parameter Invariance of Students' Ability

The scree plot in Figure 5 depicts the estimated invariance of students' ability following an analysis of the abilities of even and odd numbered students. Additionally, the scree plot findings show why the estimated values are quite close to a straight line with a correlation coefficient of 0.7539 (very high). In conclusion, the ability parameter invariance assumption has been satisfied.

d) Estimation of Reliability

The reliability coefficient of an instrument indicates the degree of confidence in the error-free findings of measurement (the greater the reliability coefficient, the more accurate the measurements). In this study, reliability was estimated using the SPSS 24 program. The Cronbach's Alpha coefficient for 77 items was 0.907 based on confirmed data. According to Mahrens and Lehman, while there is no universal agreement, it is usually believed that the test used to make individual student placement decisions must have a minimum reliability coefficient of 0.85 (Mehrens & Lehmann, 1991). According to the findings of this study and the experts' view, the reliability of the test developed in this study meets the criteria for a reliable test.

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e) Model Fit

The three assumptions for the IRT analysis had been well fulfilled, so that the HOTS multiple-choice test was examined for model fit. Seventy-three items were produced. The model fit test for 1-PL, 2-PL, or 3-PL was performed by comparing X^2. The probability value for each test item must fulfill $p > 0.05$. The model fit analysis results summarized in Appendix 1 indicate that the 2-PL model is the best appropriate for the HOTS test instrument. In comparison to the 1-PL or 3-PL models, the 2-PL model accommodates the majority of the HOTS test's multiple-choice items. Since the study requires a 2-PL model, the parameters to examine are the discriminatory power (a) and the difficulty level (b) of each test item. Items that do not match the criteria for a "good item" are omitted from the final product.

After examining the model fit on the -choice test, the HOTS test's four essay items were analyzed. For essay questions, the model fit criteria are identical to those for multiple choice questions. The essay questions, on the other hand, were examined using the R package MIRT program. This was done because the essay questions were scored as polytomus, which prevented them from being examined using the BILOG-MG tool. TABLE 3 summarizes the model fit analysis of the HOTS test essay questions.

Table 3. Model Fit Test on HOTS Essay Questions

Item	X^2				Remarks
	Statistics	df	RMSEA	P-Value	
A26	0.581	4	0.000	0.965	Fit
A8	3.771	5	0.000	0.583	Fit
A36	7.614	3	0.076	0.055	Fit
A15	4.749	4	0.026	0.314	Fit

According to TABLE 3, all test items fit the 2-PL model applied. The examination of the multiple-choice items and essay questions reveals that the 2-PL model is the best fit for the HOTS test items. The parameters measured in both types of questions are the same, namely discriminatory power (a) and degree of difficulty (b) of each test item.

f) Parameter of Time Item

The 2-PL model was used to determine the characteristics of a good test item. The test items that fit the 2PL model were re-analyzed to determine their properties. According to the 2-PL model, the requirements for a good item are based on the discriminatory power (ai) and level of difficulty (bi) of each item. Discriminating power is regarded to be good if it is between 0 and 2. Additionally, a good difficulty index should range between -2 and +2 (Widarjono, 2015). This study found the discriminant index and the difficulties index of 73 questions (Appendix 2). These findings indicate that all items have a high discriminatory power index (ai), while 63 test items have a good difficulty level (bi) and ten items have a low difficulty level (bi). Although the 10 items showed a high discrimination index, they had a low difficulty level. Therefore, the ten items (A29, A30, B14, A27, A33, B25, A28, A17, A25, and B19) were revised.

The analysis of the multiple-choice test parameters was then continued with the analysis of the HOTS essay questions. The essay questions were analyzed using the R-Program. The results of the parameter analysis of the essay questions are shown as follows.

Table 2. The Results of Parameter Analysis on the HOTS Essay Questions

Item	Discriminatory Power		Difficulty Level				Conclusion
	a	Remarks	b	b2	b mean	Remarks	
A26	7.717	Poor	-0.981	-0.130	-0.555	Good	Revised
A8	0.07	Good	-0.851	-0.434	-0.642	Good	Accepted
A46	1.402	Good	-0.865	1.871	0.503	Good	Accepted
A15	0.173	Good	-0.260	-	-0.260	Good	Accepted

As shown in Table 5, item A26 has a low discrimination index of 7.717. Nevertheless, items A8, A46, and A15 have high discriminatory indices. All essay items have a reasonable difficulty index. Based on these findings, item A26 has a low discriminatory index but a high difficulty index; hence, item A26 must be amended and items A8, A46, and A15 were accepted.

g) Information Function and Standard error of measurement (IF SEM &)

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The test information function is equal to the sum of the test item functions. The relationship between the test information function and the standard error of measurement (SEM) is inverse, with a higher test information function indicating a smaller measurement error and vice versa. Figure 6 illustrates the IF and SEM curves.

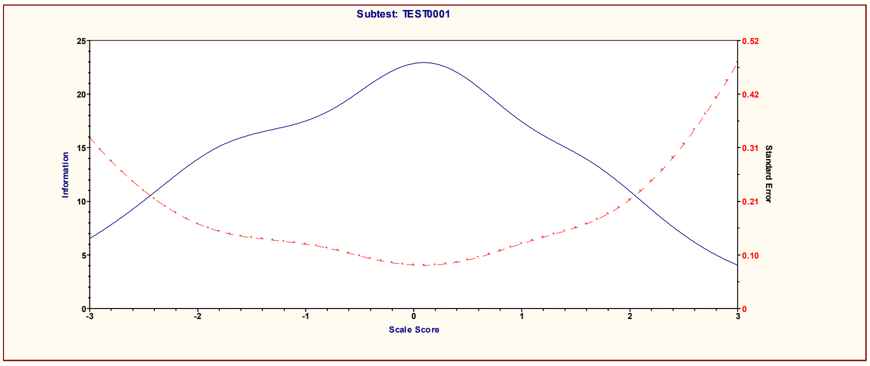

Figure 4. IF & SEM Curves

The analysis of the 2-Parameter Logistics (2-PL) model using BILOG-MG yields discriminating power (ai) and item difficulty level (bi), which were then utilized to determine the information function value for each HOTS test item. The test information value was calculated by adding the information functions of each item. The maximum test information function is found in ability = 0.1, with a value of 23.2 and a measurement error of 0.7. Additionally, Figure 6 illustrates that the HOTS test instrument covers the interval's lower and higher bounds. The interval's lower and upper bounds are the ability scores at which the graphs of the information function and standard error of measurement overlap. Based on the intersection line, it was determined that the HOTS test established in this study is appropriate for assessing higher order thinking skills in students with an ability (θ) of -2.85 to 2.15.

Discussion

Higher order thinking skills (HOTS) are higher-level cognitive abilities, not only memorization. HOTS entail a number of mental processes, including analyzing, evaluating, and producing, all of which are embedded in the problem-solving process. According to (Lewy, 2011), any ability that requires analysis, evaluation, and production is classified as a higher order thinking skill. Bloom's Taxonomy is the most frequently accepted hierarchical arrangement of HOTS in the field of education, as it examines the levels of thinking from knowledge to evaluation (Ramos et al., 2013). However, the new paradigm of educational research frequently references Marzano's Taxonomy, which includes comparing, classifying, inductive reasoning, deductive reasoning, error analysis, construction support, perspective analysis, abstracting, decision making, investigation, problem solving, experimental inquiry, and invention (Heong et al., 2011, 2016; Marzano, 1993; Marzano & Kendall, 2006).

According to the Marzano's Taxonomy, higher order thinking skills (HOTS) enable the development of student learning outcomes (SLO), class activities, and learning performance (Dubas & Toledo, 2016; Toledo & Dubas, 2016). Students that possess higher order thinking skills are capable of learning, improving their performance, and overcoming their weaknesses (Yee et al., 2011). Students who received thinking skills training improved their reading comprehension and academic performance. This demonstrates the critical nature of thinking skills in resolving learning challenges, stimulating competitive thinking, creating intellectuals, and avoiding cognitive errors (Heong et al., 2011). Higher order thinking skills are classified according to level of cognition (cognitive capacity). The most often used classification of thinking abilities is Bloom's Taxonomy or its modification, which includes the following: 1) remembering, 2) comprehending, 3) applying, 4) analyzing, 5) evaluating, and 6) creating (C. A. Anderson & Krathwohl, 2014; L. W. Anderson et al., 2000). Numerous scholars classify HOTS into three categories: analysis, evaluation, and creation.

Marzano defines knowledge as "information, mental procedures, and psychomotor procedures." Following that, the domain is separated into six hierarchical cognitive processes: retrieval, comprehension, analysis, knowledge utilization, metacognition, and self-system thinking. Marzano defines HOTS as the following: comparing, classifying, inductive reasoning, deductive reasoning, error analysis, construction support, perspective analysis, abstracting, decision-making, investigation, problem-solving, experimental inquiry, and invention (Heong et al., 2011, 2016; Marzano, 1993; Marzano & Kendall, 2006).

Along with Bloom, Anderson, and Marzano, Webb (2002) provides stages of thinking that are commonly employed in standard measurement in many nations. This thinking stage consists of four levels, namely 1) recall and reproduction, 2) skills and concepts, 3) strategic thinking, and 4) extended thinking. The SOLO (Structure of Observed Learning Outcomes) Taxonomy is another cognitive taxonomy that is commonly used in Australia, New Zealand, Canada, and the United Kingdom. SOLO is a hierarchical taxonomy of cognitive abilities that focuses on distinct elements and their relationships. This hierarchy is divided into five levels: pre-structural, unistructural, multi-structural, relational, and extended abstract. Brookhart (2010) constructs HOTS indicators using

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slices from all four taxonomies. According to Brookhart (2010), HOTS consist of logical ability and reasoning, analysis, evaluation, and creation, problem solving, judgment, and creativity and creative thinking. However, this study used a taxonomy that is tailored to the demands of future primary school science instructors

Conclusion

This study developed 77 questions, 73 multiple choice questions and four essay questions, all of which were determined to be valid in terms of content and constructs. The content validity test, calculated using the average Aiken V index, produced V = 0.879, indicating that the HOTS test is highly valid. Cronbach's Alpha coefficient for 77 items is 0.907 based on the construct validity test. The analysis of the multiple-choice items and essay questions revealed that the 2PL model was the most appropriate form of IRT model for analyzing the test items. Each HOTS test item has a discriminatory power index (ai) in the good category. However, in terms of difficulty level index (bi), there were 63 items in good category and 10 items in bad category. As a result, the ten test items needed to be altered. The 10 items had a high discriminatory index but a low level of difficulty. Items that needed to be revised included A29, A30, B14, A27, A33, B25, A28, A17, A25, and B19. Item A26 in the essay question section showed a low discrimination index, but a high difficulty level. Therefore, item A26 was revised, but items A8, A46, and A15 were accepted. All the test questions generated in this study are appropriate for assessing the higher order thinking skills of students with ability (θ) ranging from -2.85 to 2.15.

Suggestion

This study recommends further research to be able to promote HOTS through a learning approach. This aims to increase the HOTS of students throughout Indonesia.

Limitation

This research is limited only to the development of Physics Science test instruments. This is based on a pre-research needs analysis. Development in other fields is recommended.

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Notifications

HASIL REVIEW

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[PEGEGOG] Editor Decision

2021-12-05 03:44 PM

Dear Ika Maryani, Zuhdan Kun Prasetyo, Insih Wilujeng, Siwi Purwanti (Author):

We have reached a decision regarding your submission to Pegem Journal of Education and Instruction, "Higher-order Thinking Test of Science for College Students Using Multidimensional Item Response Theory Analysis".

Our decision is: **Minor Revisions Required**

Reviewer A:
Recommendation: Revisions Required

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1) Does the title reflect the content of the study?

Yes, acceptable.

Please, write your suggestions about the **Title**, if any, into the following field.

2) Does the abstract summarize the essential information in the study?

Yes, acceptable.

Please, write your suggestions about the **Abstract**, if any, into the following field.

The abstract has many mistakes especially wrong capitalization.

3) Does the introduction section adequately explain the problems the study address and the framework of the study? Are the importance and the contribution/implications of the study clearly stated?

Yes, but needs minor revision.

Please, write your suggestions about the **Introduction**, if any, into the following field.

The introduction has many mistakes especially wrong capitalization and wrong acronyms

4) Are research questions and/or hypotheses in line with the focus of the study?

Yes, but needs minor revision.

Please, write your suggestions about the **Research Questions** or H**ypotheses** , if any, into the following field.

No research questions are presented

5) Are the method and technique(s) employed appropriate for the study?

Yes, but needs minor revision.

Please, write your suggestions about the **Method** or **Technique**, if any, into the following field.

Methods needs further elaboration

6) Is the sample or the participants pertinent to the study?

Yes, but needs minor revision.

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Higher-order Thinking Test of Science for College Students Using Multidimensional Item Response Theory Analysis

HASIL REVISI

Abstract

The purpose of this study was to construct a higher-order thinking test of science for pre-service elementary school teachers. The test was created using the ADDIE model. The analysis stage was carried out by identifying the needs and baseline of higher-order thinking skills of students from the department of primary School Teacher education in Yogyakarta. The design stage involved the creation of test blueprints and questions cards. The development stage involved validating the test's content and construct validity. The content validity test was conducted using the Delphi technique with seven validators, whilst the construct validity test was conducted using item response theory and EFA. This study developed 77 questions, 73 multiple choice questions, and four essay questions, all of which were determined to be valid in terms of content and constructions. The HOTS test's content validity test resulted in a V-value of 0.879 (valid with high criteria) based on the average Aiken's V index. Meanwhile, reliability analysis using the Cronbach's Alpha coefficient revealed a score of 0.907 for the 77 test items based on the construct validity test. The discriminatory index (di) classified all items as good, whereas the difficulty index (bi) classified 63 items as good and 10 as poor. The ten items were revised, despite their high index of difference. All of the test questions are appropriate for students whose ability score (θ) ranged from -2.85 to 2.15.

Keywords: *Higher-order thinking, Science, Test, ADDIE*

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Introduction

The twenty-first century, with its ultramodern qualities, enables upheaval in several spheres of life, as well as a rapid renewal process that necessitates community preparation. The readiness of the educational environment is one of the absolutes. Education must be standardized to meet the needs of the twenty-first century. Teachers in the twenty-first century will encounter much more problems than in the previous centuries (Andriani, 2010). Teachers are confronted with a far more varied student population, more complicated and demanding subject matter, a higher quality of learning, and increased expectations for students' higher thinking abilities (Darling-Hammond, 2006). This represents a significant challenge for Institutions of Personnel Education in terms of developing teacher candidates who possess these competencies. LPTK graduates must possess strong critical thinking skills to aid in the school-based learning process. In LPTK, the stages of student learning correspond to those of adult learners (andragogy). At this level, students exhibit eight critical qualities of learning: 1) they are self-directed, 2) they are practical and goal-oriented, 3) they are more resistant to change due to their lack of openness, and 4) they learn more slowly and hence require integrative knowledge, 5) they value personal experience as a source of learning, 6) they are highly motivated, 7) they take on multiple responsibilities, and 8) they have high expectations (Pappas, 2013).

Science education is one of the critical lessons that aspiring elementary school teachers at the Department of Primary School Teacher Education must know. Numerous PSTE study programs have a hierarchical structure for science courses based on their study materials and depths. In general, all science courses are designed to provide PSTE students with pedagogical and content knowledge (PCK). As a result, pre-service primary school teachers are competent to create and develop science instruction independently or in conjunction with other subjects. The characteristics of science learning are complex and need advanced analytical and critical thinking abilities, posing a variety of difficulties for students who have not mastered them. Among them include misconceptions about science (Faizah, 2016), learning difficulty in science (Maryani et al., 2018), and poor learning outcomes in science. Another issue that PSTE students face is the overwhelming amount of study materials that must be memorized. In this department, elementary school students must study five core subjects and additional competency support courses. These students are required to master the principle of each learning model and develop it as innovative learning in elementary schools. This objective can be met if pre-service teachers possess strong critical thinking skills and the ability to adjust to changing circumstances. This capability is encapsulated in numerous studies on 21st-century skills.

Numerous education organizations and experts have researched 21st-century skills. The Assessment & Teaching of 21st Century Skills (ATC21S) classifies 21st-century skills into four areas, one of which is a manner of thinking (Suto, 2013). Not only rich countries are monitoring the issue of 21st-century skills; Indonesia is also participating in the study. Critical thinking, problem-solving, communication, and collaboration skills are all necessary for the twenty-first century (Trisdiono, 2013). Cognitive processes establish an individual's foundation when confronted with life's issues. A cognitive process is divided into various stages, including remembering, comprehending, applying, analyzing, making a judgment, and decision making. These elements of thinking are then referred to as Higher Order Thinking Skills (HOTS)

Higher Order Thinking Skills (HOTS) assess thinking abilities that go beyond recall and memorization to include features of analysis, synthesis, and evaluation. HOTS are cognitive abilities that result in higher-level thinking (Alice Thomas & Glenda Thorne, 2009). Higher-level thinking is intended to be more than the regurgitation of information. Higher Order Thinking Skills are critical for adult learners, particularly in developing scientific concepts and applying them in everyday life, including in all university courses. In a nutshell, HOTS teach individuals how to analyze, synthesize, and evaluate (Alice Thomas & Glenda Thorne, 2009).

Research on pupils' cognitive abilities has been conducted in Indonesia. One of them demonstrates that elementary school students in Semarang, Indonesia, lack critical thinking skills. The learning process is stymied by evaluation objectives that focus only on lower-order thinking skills. Additionally, pupils' ability to categorize induced thinking is moderate. Students' capacity to deduce, analyze errors, develop an analytical perspective, make decisions, gain experience, and solve problems is rated as low (Fajriyah & Agustini, 2018). *The low thinking abilities of elementary school pupils in Indonesia are a result of a variety of circumstances, including the continuing emphasis on developing low-level thinking abilities* (Surya et al., 2018)*. Most teachers continue to struggle with teaching and familiarizing their students with higher-order thinking. This is due to a teacher shortage of information about how to plan and administer HOTS instruction* (Kuntarto et al., 2019)*. Similar circumstances exist for elementary school teacher candidates (pre-service teachers). According to studies* (Gradini et al., 2018; Wiyoko & Aprizan, 2020)*, the proportion of pre-service elementary school teachers who fall into the LOTS category is greater than the proportion of pre-service elementary school teachers who fall into the HOTS category.*

Many studies have developed higher-order thinking skills (HOTS) tests of science; however, they mostly refer to Bloom's Taxonomy (Abdullah et al., 2015; Atmojo et al., 2017; Utomo et al., n.d.; Zulfiani et al., 2020), Few have examined the HOTS features of alternative theories that better fit the needs of 21st-century learning. With regards to this issue, we believe it is critical to construct a higher-order thinking skills (HOTS) test of science that relates to a variety of cognition/taxonomy theories that are tailored to the 21st century's issues.

Method

2.1 Research design

This Research and Development (R and D) study employed the ADDIE development method, which consisted of the following stages: analysis, design, Develop, Implement, and Evaluate (Branch, 2010). The research design is presented in Figure 1.

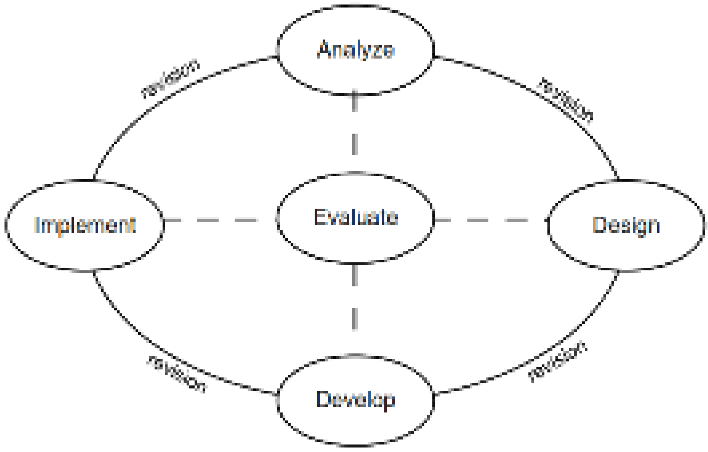

Figure 1. The ADDIE R&D Design (Branch, 2010)

As illustrated in Figure 1, the ADDIE development design comprises five interdependent stages. At the Analyze stage, needs analysis for HOTS-based test development and problem analysis was performed. At the design stage, the product design and prototype were generated. At the development stage, product revision, content validity test, and construct validity test were carried out to ensure the validity of the final product. The implementation stage was responsible for the overall product implementation process. At each level, the product can be revised, and the process and results of product deployment can be evaluated.

2.2 Participant

The samples have been taken randomly on elementary school teacher education students in Yogyakarta. Seven experts evaluated the content of the product under development, and 268 students participated in the construct validity test.

2.2 Data Collection Tools

. The HOTS test was divided down into six indicators, namely logic and reasoning, analysis, evaluation, and creation, problem-solving, and judgment. Each indicator was developed into 7-10 questions to produce 77 questions. Content validity was assessed using a questionnaire while construct validity was measured using the developed questions.

2.2 Data Analysis

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The content validity test was conducted using the Delphi technique. The results of the validity test were analyzed using Aiken's V, whilst the construct validity test findings were evaluated using item response theory.

Findings

This study was successful in creating 77 HOTS test items, which included 73 multiple-choice questions and four essay questions. Validator feedback on the HOTS-based test instrument under development was just as valuable as input on other products. The validators checked the adequacy of learning achievement-learning indicators-question indicators-and items more thoroughly. The usage of analogies and experimental data was re-examined considering their logical consistency under specific settings. The editorial questions, the stimulus, the form of several items from multiple choice to description, as well as the response possibilities for multiple-choice questions, have all been altered significantly. The following summarizes the validators' input.

a) Writing
b) For test-item indicators, use the KKO analyzed from books written by Marzano or Anderson dan Krathwoll.
c) Input for the test items
    i. The HOTS instrument should be re-examined to determine whether the posed questions are rational. For instance, question number one says "when throwing a baseball from a distance of 7 meters, can the bounce travel as far as 10 meters with the power of an ordinary person?"
    ii. Question No. 2 is similarly less specific in terms of the ABCD points' position. Are these dots consecutive or non-sequential? Answers are frequently skewed. The solution to Problem No. 6 is ambiguous: the applicable laws are Newton's III and Pascal's laws, but Pascal's laws do not include mechanics.
    iii. The illustration is unclear, as in point No. 4 regarding the top of the hill. Problems can trap students because they believe that what is anticipated is the absence of frictional force, and hence refuse to consider alternative explanations for the correct answer.

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iv. Certain questions, particularly those regarding "creation", should be transformed into essay questions.

Following modifications to the HOTS instrument, it was reviewed using an assessment sheet. The HOTS instrument was evaluated on ten dimensions, including a) the items' suitability for learning outcomes; b) the items' suitability for the HOTS indicators; c) the items' suitability for the question indicator; d) the stimulus' novelty (encouraging students to read); e) the stimulus' quality (contextual and implies the answer to the question); f) the suitability of the item with the material being learned; g) the ability to measure HOTS in aspects of logic, reasoning, analysis, evaluation, creation, problem-solving, and judgment; h) clarity of the formulation of the questions; i) clarity and arrangement of answer choices on multiple-choice questions (homogeneous) and j) use of language. Additionally, the HOTS instrument makes use of the Likert scale. The instrument's content validity test indicated that the average Aiken V index produced V = 0.879 (highly valid). As a result of expert validation, the HOTS instrument was determined to be valid and was used in the next stage, namely the construct validity test.

The Results of the Construct Validity Test on the HOTS Instrument

a) Test of Unidimensionality Assumption

The criterion for meeting this assumption is that each test item evaluates only one ability. The assumption can be tested using factor analysis, which generates KMO, eigenvalues, explainable variance, and factor components. SPSS 24 was used to conduct the exploratory factor analysis. The following summarizes the findings of the factor analysis.

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.830
Bartlett's Test of Sphericity	Approx. Chi-Square	6260.265
	df	2926

Sig.	.000

The outcome of factor analysis indicates that the KMO value is 0.830 or greater than 0.50, indicating that the sample size utilized in this trial is adequate. Additionally, the Bartlett test's chi-square value is 6260.265 with 2926 degrees of freedom and a p-value greater than 0.01. Intercorrelation between variables was determined using the KMO-MSA test (Widarjono, 2015). If the matrix has a KMO value greater than 0.5, it can be factored in.

A test is considered unidimensional if it is demonstrated to measure only one dominant dimension, namely homogenous ability (Widarjono, 2015). The number of factors created can be determined by the presence of eigenvalues greater than one, which is the indicator factor (Widarjono, 2015). Factor analysis (Appendix 1) identified 27 components with an eigenvalue greater than one. This indicated that the 73 HOTS test items comprise 13 factors. The analysis results indicated that factor 1 is the dominant factor due to its eigenvalue of 12.931, which is greater than the others or the most dominant, implying that the HOTS test is unidimensional.

Statistical analysis also indicated an eigenvalue of 12.931, where the result is more than 2 times the eigenvalue of the second factor with a percentage of the variance of 16.79%. Cumulatively, the percentage of the 27 factors is 65.546, suggesting that 65.546% is explained by the 27 existing components. The cumulative percentage of 65.546% has fulfilled the minimal condition for the cumulative value of taking the proper number of variables, which is 50% (Widarjono, 2015). Evidence of cumulative percentage values corroborates the notion that the HOTS test instrument is believed to be unidimensional.

Dimensions recorded in data can be proven in the scree plot findings, specifically the number of steeps. The number of steps shows the number of dimensions/factors, while the slope of the change in eigenvalues does not indicate the presence of dimensions (Widarjono, 2015). Therefore, unidimensionality can also be shown from the ensuing scree plot. The test is deemed to be unidimensional when components 1 and 2 in the scree plot have a high enough distance (Furr & Bacharach, 2008).

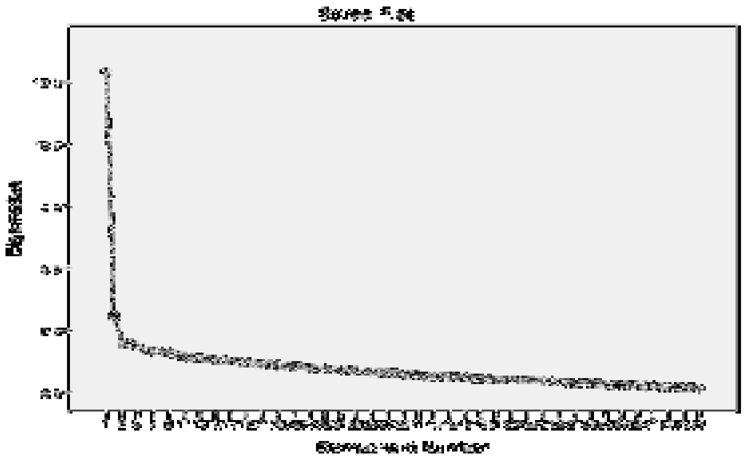

Figure 2. Scree plot of the Exploratory Factor Analysis Results

According to the scree plot in Figure 2, component 1 is located far away from component 2, whereas component 2 is located quite close to component 3 and other components. Additionally, as illustrated in Figure 2, the eigenvalues begin to slope with the third component. This demonstrates a single dominant factor and that other factors contribute significantly to the variance explained. The unidimensional analysis results corroborate the assertion of (Widarjono, 2015) that this HOTS test evaluates at least two components, with the first factor serving as the dominant factor. The scree plot in Figure 2 demonstrates that the HOTS test currently under development is unidimensional.

b) Test of Local Independence Assumption

One of the conditions for IRT analysis is the assumption of local independence. This assumption test is used to determine whether students' abilities are independent of the test questions, which means that their responses to one item do not affect their responses to subsequent items. The unidimensionality of the student response data to the test automatically establishes the local independence assumption test (Widarjono, 2015). The local independence assumption, on the other hand, can be demonstrated using a covariance matrix based on the ability of pupils categorized into many groups. If the correlation between the capability intervals is modest or close to zero, this assumption is fulfilled. Thus, a covariance value near zero satisfies the local independence assumption. Table 1 contains the covariance matrix.

Table 1. Covariance Matrix of Students' Higher Order Thinking Skills (HOTS)

	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10
K1	0,0726									
K2	0,0227	0,0132								
K3	0,0130	0,0066	0,0036							
K4	0,0250	0,0090	0,0052	0,0098						
K5	0,0077	0,0036	0,0020	0,0031	0,0012					
K6	0,0062	0,0024	0,0014	0,0023	0,0008	0,0006				
K7	0,0233	0,0089	0,0050	0,0089	0,0029	0,0022	0,0083			
K8	0,0092	0,0044	0,0023	0,0034	0,0013	0,0009	0,0033	0,0016		
K9	0,0312	0,0124	0,0070	0,0122	0,0040	0,0030	0,0113	0,0046	0,0156	
K10	0,0813	0,0555	0,0251	0,0300	0,0129	0,0095	0,0327	0,0163	0,0442	0,7280

Table 1 presents the variance-covariance matrix values for several groups of students' skills. The analysis reveals that the covariance variation across groups of students' ability intervals that form a diagonal line is negligible if not nil. As there is no association between the two variables, the assumption of local independence is satisfied.

c) Test of Parameter Invariance Assumption

The third requirement is parameter invariance. Parameter invariance shows that the test items are independent of the distribution of the students' ability parameter and vice versa, that students' ability parameter is independent of the test items. Students' abilities will not change because of working on a package of questions with distinct item parameters, and the item parameters will remain constant regardless of which group of students is assessed. There are two types of parameter invariance. The first type is item parameter invariance, and the second type is ability parameter invariance. The invariance of the item parameter can be determined by dividing the sample (218 students) into two even and odd groups. The estimated grain parameters for each sample are then plotted and associated using a scree plot. If the correlation is positive and significant, the assumption of item parameter invariance is satisfied (Widarjono, 2015). Figure 3 illustrates the estimation results for the invariance of the item parameters.

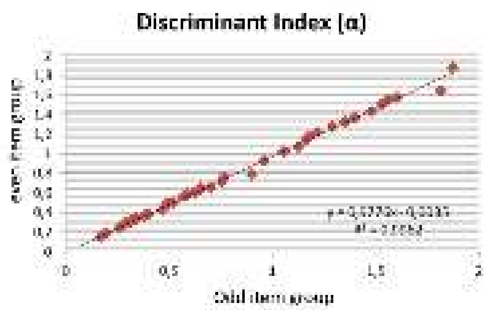

Figure 3. Scree plot of the parameter invariance of the HOTS test's discriminatory power

The scree plot in Figure 3 depicts the estimation of item parameter invariance for item discriminating power after students worked on odd and even questions. As illustrated in Figure 3, the estimated values are spread out and reasonably close to the linear line. The discriminatory power has a strong correlation with the student's response to the odd and even test items (0.9962). The scree plot and correlation analysis indicate that the discriminating power of the test items is invariant. The separation of two groups of test takers, odd and even, was also incorporated in the item parameter analysis for difficulty level. Microsoft Excel was used to conduct the analysis. Figure 4 depicts the correlation between the findings of the analysis.

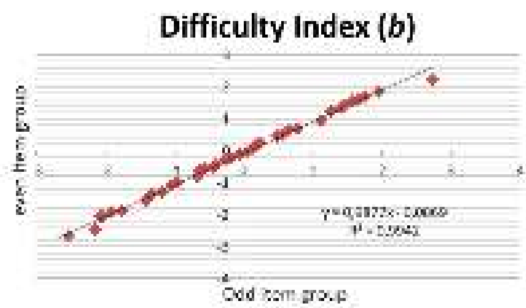

Figure 2. Scree plot of the Parameter Invariance of HOTS Test Difficulty Level

The scree plot of the estimated invariance of items in terms of difficulty level after students worked on odd and even questions is shown in Figure 4. As illustrated in Figure 4, the estimated values are dispersed and somewhat close to the linear line. The correlation coefficient between the difficulty of the questions and the responses of students to odd and

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even items is 0.9942 (high). Figures 3 and 4 indicate that the estimation of the item parameters' invariance in terms of discriminatory power and difficulty level is satisfactory. After splitting the odd and even subtest groups, the invariance of the students' ability parameter can be examined. The estimated ability parameter for each sample was plotted and associated using a scree plot. If the correlation is significant and positive, the assumption of invariance of the student's ability parameters is satisfied (Widarjono, 2015). In general, students' capacity to work on the test is estimated as scattered (Figure 5).

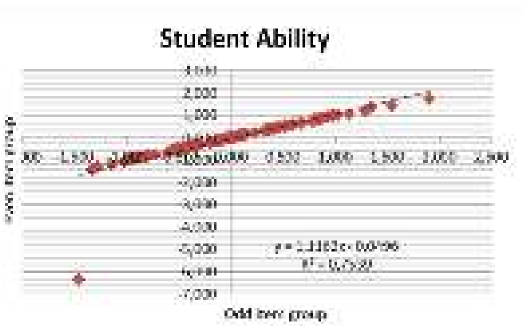

Figure 3. Scree plot of the Parameter Invariance of Students' Ability

The scree plot in Figure 5 depicts the estimated invariance of students' ability following an analysis of the abilities of even and odd-numbered students. Additionally, the scree plot findings show why the estimated values are quite close to a straight line with a correlation coefficient of 0.7539 (very high). In conclusion, the ability parameter invariance assumption has been satisfied.

d) Estimation of Reliability

The reliability coefficient of an instrument indicates the degree of confidence in the error-free findings of measurement (the greater the reliability coefficient, the more accurate the measurements). In this study, reliability was estimated using the SPSS 24 program. The Cronbach's Alpha coefficient for 77 items was 0.907 based on confirmed data. According to Mahrens and Lehman, while there is no universal agreement, it is usually believed that the test used to make individual student placement decisions must have a minimum reliability coefficient of 0.85 (Mehrens & Lehmann, 1991). According to the findings of this study and the experts' view, the reliability of the test developed in this study meets the criteria for a reliable test.

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e) Model Fit

The three assumptions for the IRT analysis had been well fulfilled so that the HOTS multiple-choice test was examined for model fit. Seventy-three items were produced. The model fit test for 1-PL, 2-PL, or 3-PL was performed by comparing X^2. The probability value for each test item must fulfill $p > 0.05$. The model fit analysis results summarized in Appendix 1 indicate that the 2-PL model is the best appropriate for the HOTS test instrument. In comparison to the 1-PL or 3-PL models, the 2-PL model accommodates the majority of the HOTS test's multiple-choice items. Since the study requires a 2-PL model, the parameters to examine are the discriminatory power (a) and the difficulty level (b) of each test item. Items that do not match the criteria for a "good item" are omitted from the final product.

After examining the model fit on the -choice test, the HOTS test's four essay items were analyzed. For essay questions, the model fit criteria are identical to those for multiple-choice questions. The essay questions, on the other hand, were examined using the R package MIRT program. This was done because the essay questions were scored as polytomous, which prevented them from being examined using the BILOG-MG tool. TABLE 3 summarizes the model fit analysis of the HOTS test essay questions.

Table 3. Model Fit Test on HOTS Essay Questions

Item	X^2				Remarks
	Statistics	df	RMSEA	P-Value	
A26	0.581	4	0.000	0.965	Fit
A8	3.771	5	0.000	0.583	Fit
A36	7.614	3	0.076	0.055	Fit
A15	4.749	4	0.026	0.314	Fit

According to TABLE 3, all test items fit the 2-PL model applied. The examination of the multiple-choice items and essay questions reveals that the 2-PL model is the best fit for the HOTS test items. The parameters measured in both types of questions are the same, namely discriminatory power (a) and degree of difficulty (b) of each test item.

f) Parameter of Time Item

The 2-PL model was used to determine the characteristics of a good test item. The test items that fit the 2PL model were re-analyzed to determine their properties. According to the 2-PL model, the requirements for a good item are based on the discriminatory power (ai) and level of difficulty (bi) of each item. Discriminating power is regarded to be good if it is between 0 and 2. Additionally, a good difficulty index should range between -2 and +2 (Widarjono, 2015). This study found the discriminant index and the difficulties index of 73 questions (Appendix 2). These findings indicate that all items have a high discriminatory power index (ai), while 63 test items have a good difficulty level (bi) and ten items have a low difficulty level (bi). Although the 10 items showed a high discrimination index, they had a low difficulty level. Therefore, the ten items (A29, A30, B14, A27, A33, B25, A28, A17, A25, and B19) were revised.

The analysis of the multiple-choice test parameters was then continued with the analysis of the HOTS essay questions. The essay questions were analyzed using the R-Program. The results of the parameter analysis of the essay questions are shown as follows.

Table 2. The Results of Parameter Analysis on the HOTS Essay Questions

Item	Discriminatory Power		Difficulty Level				Conclusion
	a	Remarks	b	b2	b mean	Remarks	
A26	7.717	Poor	-0.981	-0.130	-0.555	Good	Revised
A8	0.07	Good	-0.851	-0.434	-0.642	Good	Accepted
A46	1.402	Good	-0.865	1.871	0.503	Good	Accepted
A15	0.173	Good	-0.260	-	-0.260	Good	Accepted

As shown in Table 5, item A26 has a low discrimination index of 7.717. Nevertheless, items A8, A46, and A15 have high discriminatory indices. All essay items have a reasonable difficulty index. Based on these findings, item A26 has a low discriminatory index but a high difficulty index; hence, item A26 must be amended and items A8, A46, and A15 were accepted.

g) Information Function and Standard error of measurement (IF SEM &)

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The test information function is equal to the sum of the test item functions. The relationship between the test information function and the standard error of measurement (SEM) is inverse, with a higher test information function indicating a smaller measurement error and vice versa. Figure 6 illustrates the IF and SEM curves.

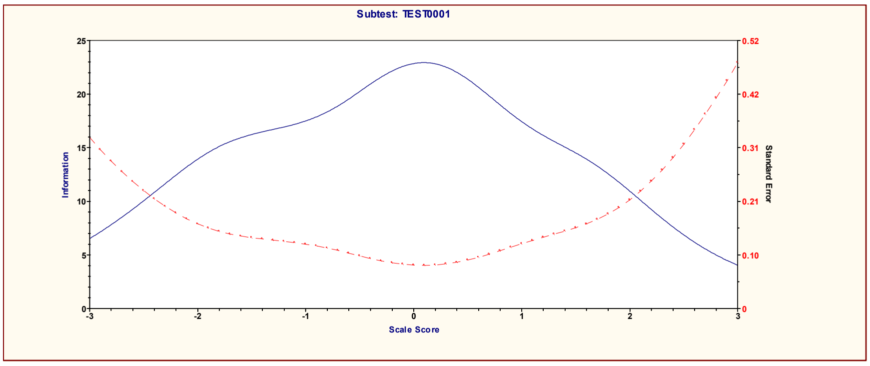

Figure 4. IF & SEM Curves

The analysis of the 2-Parameter Logistics (2-PL) model using BILOG-MG yields discriminating power (ai) and item difficulty level (bi), which were then utilized to determine the information function value for each HOTS test item. The test information value was calculated by adding the information functions of each item. The maximum test information function is found in ability = 0.1, with a value of 23.2 and a measurement error of 0.7. Additionally, Figure 6 illustrates that the HOTS test instrument covers the interval's lower and higher bounds. The interval's lower and upper bounds are the ability scores at which the graphs of the information function and standard error of measurement overlap. Based on the intersection line, it was determined that the HOTS test established in this study is appropriate for assessing higher-order thinking skills in students with an ability (θ) of -2.85 to 2.15.

Discussion

Higher-order thinking skills (HOTS) are higher-level cognitive abilities, not only memorization. HOTS entail several mental processes, including analyzing, evaluating, and producing, all of which are embedded in the problem-solving process. According to (Lewy, 2011), any ability that requires analysis, evaluation, and production is classified as a higher-order thinking skill. Bloom's Taxonomy is the most frequently accepted hierarchical arrangement of HOTS in the field of education, as it examines the levels of thinking from knowledge to evaluation (Ramos et al., 2013). However, the new paradigm of educational research frequently references Marzano's Taxonomy, which includes comparing, classifying, inductive reasoning, deductive reasoning, error analysis, construction support, perspective analysis, abstracting, decision making, investigation, problem-solving, experimental inquiry, and invention (Heong et al., 2011, 2016; Marzano, 1993; Marzano & Kendall, 2006).

According to Marzano's Taxonomy, higher-order thinking skills (HOTS) enable the development of student learning outcomes (SLO), class activities, and learning performance (Dubas & Toledo, 2016; Toledo & Dubas, 2016). Students that possess higher-order thinking skills are capable of learning, improving their performance, and overcoming their weaknesses (Yee et al., 2011). Students who received thinking skills training improved their reading comprehension and academic performance. This demonstrates the critical nature of thinking skills in resolving learning challenges, stimulating competitive thinking, creating intellectuals, and avoiding cognitive errors (Heong et al., 2011). Higher-order thinking skills are classified according to a level of cognition (cognitive capacity). The most often used classification of thinking abilities is Bloom's Taxonomy or its modification, which includes the following: 1) remembering, 2) comprehending, 3) applying, 4) analyzing, 5) evaluating, and 6) creating (C. A. Anderson & Krathwohl, 2014; L. W. Anderson et al., 2000). Numerous scholars classify HOTS into three categories: analysis, evaluation, and creation.

Marzano defines knowledge as "information, mental procedures, and psychomotor procedures." Following that, the domain is separated into six hierarchical cognitive processes: retrieval, comprehension, analysis, knowledge utilization, metacognition, and self-system thinking. Marzano defines HOTS as the following: comparing, classifying, inductive reasoning, deductive reasoning, error analysis, construction support, perspective analysis, abstracting, decision-making, investigation, problem-solving, experimental inquiry, and invention (Heong et al., 2011, 2016; Marzano, 1993; Marzano & Kendall, 2006).

Along with Bloom, Anderson, and Marzano, Webb (2002) provides stages of thinking that are commonly employed in standard measurement in many nations. This thinking stage consists of four levels, namely 1) recall and reproduction, 2) skills and concepts, 3) strategic thinking, and 4) extended thinking. The SOLO (Structure of Observed Learning Outcomes) Taxonomy is another cognitive taxonomy that is commonly used in Australia, New Zealand, Canada, and the United Kingdom. SOLO is a hierarchical taxonomy of cognitive abilities that focuses on distinct elements and their relationships. This hierarchy is divided into five levels: pre-structural, uni structural, multi-structural, relational, and extended abstract. Brookhart (2010) constructs HOTS indicators using slices from all four taxonomies. According to Brookhart (2010), HOTS consist of logical ability and reasoning, analysis, evaluation, and creation, problem-solving, judgment, and creativity, and creative thinking. However, this study used a taxonomy that is tailored to the demands of future primary school science instructors

Conclusion

This study developed 77 questions, 73 multiple choice questions, and four essay questions, all of which were determined to be valid in terms of content and constructs. The content validity test, calculated using the average Aiken V index, produced V = 0.879, indicating that the HOTS test is highly valid. Cronbach's Alpha coefficient for 77 items is 0.907 based on the construct validity test. The analysis of the multiple-choice items and essay questions revealed that the 2PL model was the most appropriate form of IRT model for analyzing the test items. Each HOTS test item has a discriminatory power index (ai) in the good category. However, in terms of difficulty level index (bi), there were 63 items in the good category and 10 items in the bad category. As a result, the ten test items needed to be altered. The 10 items had a high discriminatory index but a low level of difficulty. Items that needed to be revised included A29, A30, B14, A27, A33, B25, A28, A17, A25, and B19. Item A26 in the essay question section showed a low discrimination index, but a high difficulty level. Therefore, item A26 was revised, but items A8, A46, and A15 were accepted. All the test questions generated in this study are appropriate for assessing the higher-order thinking skills of students with the ability (θ) ranging from -2.85 to 2.15.

Suggestion

This study recommends further research to be able to promote HOTS through a learning approach. This aims to increase the HOTS of students throughout Indonesia.

Limitation

This research is limited only to the development of Physics Science test instruments. This is based on a pre-research needs analysis. Development in other fields is recommended.

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Title Page

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Higher-order Thinking Test of Science for College Students Using Multidimensional Item Response Theory Analysis

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Higher-order Thinking Test of Science for College Students Using Multidimensional Item Response Theory Analysis

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Abstract

The purpose of this study was to construct a higher-order thinking test of science for pre-service elementary school teachers. The test was created using the ADDIE model. The analysis stage was carried out by identifying the needs and baseline of higher-order thinking skills of students from the department of primary School Teacher education in Yogyakarta. The design stage involved the creation of test blueprints and questions cards. The development stage involved validating the test's content and construct validity. The content validity test was conducted using the Delphi technique with seven validators, whilst the construct validity test was conducted using item response theory and EFA. This study developed 77 questions, 73 multiple choice questions, and four essay questions, all of which were determined to be valid in terms of content and constructions. The HOTS test's content validity test resulted in a V-value of 0.879 (valid with high criteria) based on the average Aiken's V index. Meanwhile, reliability analysis using the Cronbach's Alpha coefficient revealed a score of 0.907 for the 77 test items based on the construct validity test. The discriminatory index (di) classified all items as good, whereas the difficulty index (bi) classified 63 items as good and 10 as poor. The ten items were revised, despite their high index of difference. All of the test questions are appropriate for students whose ability score (θ) ranged from -2.85 to 2.15.

Keywords: *Higher-order thinking, Science, Test, ADDIE*

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Introduction

The twenty-first century, with its ultramodern qualities, enables upheaval in several spheres of life, as well as a rapid renewal process that necessitates community preparation. The readiness of the educational environment is one of the absolutes. Education must be standardized to meet the needs of the twenty-first century. Teachers in the twenty-first century will encounter much more problems than in the previous centuries (Andriani, 2010). Teachers are confronted with a far more varied student population, more complicated and demanding subject matter, a higher quality of learning, and increased expectations for students' higher thinking abilities (Darling-Hammond, 2006). This represents a significant challenge for Institutions of Personnel Education in terms of developing teacher candidates who possess these competencies. LPTK graduates must possess strong critical thinking skills to aid in the school-based learning process. In LPTK, the stages of student learning correspond to those of adult learners (andragogy). At this level, students exhibit eight critical qualities of learning: 1) they are self-directed, 2) they are practical and goal-oriented, 3) they are more resistant to change due to their lack of openness, and 4) they learn more slowly and hence require integrative knowledge, 5) they value personal experience as a source of learning, 6) they are highly motivated, 7) they take on multiple responsibilities, and 8) they have high expectations (Pappas, 2013).

Science education is one of the critical lessons that aspiring elementary school teachers at the Department of Primary School Teacher Education must know. Numerous PSTE study programs have a hierarchical structure for science courses based on their study materials and depths. In general, all science courses are designed to provide PSTE students with pedagogical and content knowledge (PCK). As a result, pre-service primary school teachers are competent to create and develop science instruction independently or in conjunction with other subjects. The characteristics of science learning are complex and need advanced analytical and critical thinking abilities, posing a variety of difficulties for students who have not mastered them. Among them include misconceptions about science (Faizah, 2016), learning difficulty in science (Maryani et al., 2018), and poor learning outcomes in science. Another issue that PSTE students face is the overwhelming amount of study materials that must be memorized. In this department, elementary school students must study five core subjects and additional competency support courses. These students are required to master the principle of each learning model and develop it as innovative learning in elementary schools. This objective can be met if pre-service teachers possess strong critical thinking skills and the ability to adjust to changing circumstances. This capability is encapsulated in numerous studies on 21st-century skills.

Numerous education organizations and experts have researched 21st-century skills. The Assessment & Teaching of 21st Century Skills (ATC21S) classifies 21st-century skills into four areas, one of which is a manner of thinking (Suto, 2013). Not only rich countries are monitoring the issue of 21st-century skills; Indonesia is also participating in the study. Critical thinking, problem-solving, communication, and collaboration skills are all necessary for the twenty-first century (Trisdiono, 2013). Cognitive processes establish an individual's foundation when confronted with life's issues. A cognitive process is divided into various stages, including remembering, comprehending, applying, analyzing, making a judgment, and decision making. These elements of thinking are then referred to as Higher Order Thinking Skills (HOTS)

Higher Order Thinking Skills (HOTS) assess thinking abilities that go beyond recall and memorization to include features of analysis, synthesis, and evaluation. HOTS are cognitive abilities that result in higher-level thinking (Alice Thomas & Glenda Thorne, 2009). Higher-level thinking is intended to be more than the regurgitation of information. Higher Order Thinking Skills are critical for adult learners, particularly in developing scientific concepts and applying them in everyday life, including in all university courses. In a nutshell, HOTS teach individuals how to analyze, synthesize, and evaluate (Alice Thomas & Glenda Thorne, 2009).

Research on pupils' cognitive abilities has been conducted in Indonesia. One of them demonstrates that elementary school students in Semarang, Indonesia, lack critical thinking skills. The learning process is stymied by evaluation objectives that focus only on lower-order thinking skills. Additionally, pupils' ability to categorize induced thinking is moderate. Students' capacity to deduce, analyze errors, develop an analytical perspective, make

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decisions, gain experience, and solve problems is rated as low (Fajriyah & Agustini, 2018). *The low thinking abilities of elementary school pupils in Indonesia are a result of a variety of circumstances, including the continuing emphasis on developing low-level thinking abilities* (Surya et al., 2018)*. Most teachers continue to struggle with teaching and familiarizing their students with higher-order thinking. This is due to a teacher shortage of information about how to plan and administer HOTS instruction* (Kuntarto et al., 2019)*. Similar circumstances exist for elementary school teacher candidates (pre-service teachers). According to studies* (Gradini et al., 2018; Wiyoko & Aprizan, 2020)*, the proportion of pre-service elementary school teachers who fall into the LOTS category is greater than the proportion of pre-service elementary school teachers who fall into the HOTS category.*

Many studies have developed higher-order thinking skills (HOTS) tests of science; however, they mostly refer to Bloom's Taxonomy (Abdullah et al., 2015; Atmojo et al., 2017; Utomo et al., n.d.; Zulfiani et al., 2020), Few have examined the HOTS features of alternative theories that better fit the needs of 21st-century learning. With regards to this issue, we believe it is critical to construct a higher-order thinking skills (HOTS) test of science that relates to a variety of cognition/taxonomy theories that are tailored to the 21st century's issues.

Method

2.1 Research design

This Research and Development (R and D) study employed the ADDIE development method, which consisted of the following stages: analysis, design, Develop, Implement, and Evaluate (Branch, 2010). The research design is presented in Figure 1.

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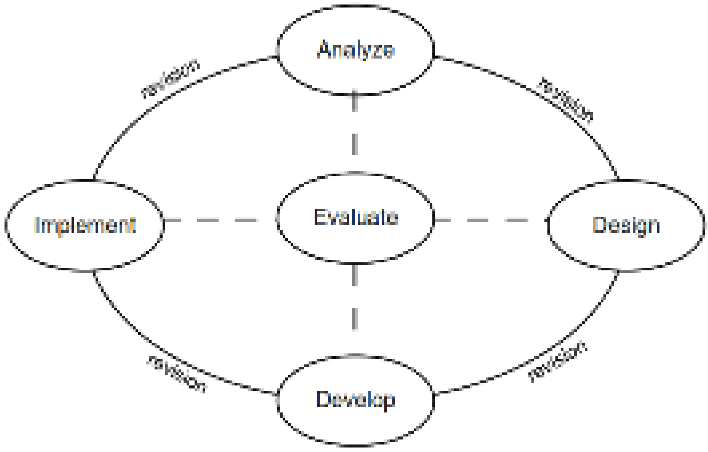

Figure 1. The ADDIE R&D Design (Branch, 2010)

As illustrated in Figure 1, the ADDIE development design comprises five interdependent stages. At the Analyze stage, needs analysis for HOTS-based test development and problem analysis was performed. At the design stage, the product design and prototype were generated. At the development stage, product revision, content validity test, and construct validity test were carried out to ensure the validity of the final product. The implementation stage was responsible for the overall product implementation process. At each level, the product can be revised, and the process and results of product deployment can be evaluated.

2.2 Participant

The samples have been taken randomly on elementary school teacher education students in Yogyakarta. Seven experts evaluated the content of the product under development, and 268 students participated in the construct validity test.

2.2 Data Collection Tools

. The HOTS test was divided down into six indicators, namely logic and reasoning, analysis, evaluation, and creation, problem-solving, and judgment. Each indicator was developed into 7-10 questions to produce 77 questions. Content validity was assessed using a questionnaire while construct validity was measured using the developed questions.

2.2 Data Analysis

The content validity test was conducted using the Delphi technique. The results of the validity test were analyzed using Aiken's V, whilst the construct validity test findings were evaluated using item response theory.

Findings

This study was successful in creating 77 HOTS test items, which included 73 multiple-choice questions and four essay questions. Validator feedback on the HOTS-based test instrument under development was just as valuable as input on other products. The validators checked the adequacy of learning achievement-learning indicators-question indicators-and items more thoroughly. The usage of analogies and experimental data was re-examined considering their logical consistency under specific settings. The editorial questions, the stimulus, the form of several items from multiple choice to description, as well as the response possibilities for multiple-choice questions, have all been altered significantly. The following summarizes the validators' input.

a) Writing
b) For test-item indicators, use the KKO analyzed from books written by Marzano or Anderson dan Krathwoll.
c) Input for the test items
    i. The HOTS instrument should be re-examined to determine whether the posed questions are rational. For instance, question number one says "when throwing a baseball from a distance of 7 meters, can the bounce travel as far as 10 meters with the power of an ordinary person?"
    ii. Question No. 2 is similarly less specific in terms of the ABCD points' position. Are these dots consecutive or non-sequential? Answers are frequently skewed. The solution to Problem No. 6 is ambiguous: the applicable laws are Newton's III and Pascal's laws, but Pascal's laws do not include mechanics.
    iii. The illustration is unclear, as in point No. 4 regarding the top of the hill. Problems can trap students because they believe that what is anticipated is the absence of frictional force, and hence refuse to consider alternative explanations for the correct answer.

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iv. Certain questions, particularly those regarding "creation", should be transformed into essay questions.

Following modifications to the HOTS instrument, it was reviewed using an assessment sheet. The HOTS instrument was evaluated on ten dimensions, including a) the items' suitability for learning outcomes; b) the items' suitability for the HOTS indicators; c) the items' suitability for the question indicator; d) the stimulus' novelty (encouraging students to read); e) the stimulus' quality (contextual and implies the answer to the question); f) the suitability of the item with the material being learned; g) the ability to measure HOTS in aspects of logic, reasoning, analysis, evaluation, creation, problem-solving, and judgment; h) clarity of the formulation of the questions; i) clarity and arrangement of answer choices on multiple-choice questions (homogeneous) and j) use of language. Additionally, the HOTS instrument makes use of the Likert scale. The instrument's content validity test indicated that the average Aiken V index produced V = 0.879 (highly valid). As a result of expert validation, the HOTS instrument was determined to be valid and was used in the next stage, namely the construct validity test.

The Results of the Construct Validity Test on the HOTS Instrument

a) Test of Unidimensionality Assumption

The criterion for meeting this assumption is that each test item evaluates only one ability. The assumption can be tested using factor analysis, which generates KMO, eigenvalues, explainable variance, and factor components. SPSS 24 was used to conduct the exploratory factor analysis. The following summarizes the findings of the factor analysis.

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.830
Bartlett's Test of Sphericity	Approx. Chi-Square	6260.265
	df	2926

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Sig.	.000

The outcome of factor analysis indicates that the KMO value is 0.830 or greater than 0.50, indicating that the sample size utilized in this trial is adequate. Additionally, the Bartlett test's chi-square value is 6260.265 with 2926 degrees of freedom and a p-value greater than 0.01. Intercorrelation between variables was determined using the KMO-MSA test (Widarjono, 2015). If the matrix has a KMO value greater than 0.5, it can be factored in.

A test is considered unidimensional if it is demonstrated to measure only one dominant dimension, namely homogenous ability (Widarjono, 2015). The number of factors created can be determined by the presence of eigenvalues greater than one, which is the indicator factor (Widarjono, 2015). Factor analysis (Appendix 1) identified 27 components with an eigenvalue greater than one. This indicated that the 73 HOTS test items comprise 13 factors. The analysis results indicated that factor 1 is the dominant factor due to its eigenvalue of 12.931, which is greater than the others or the most dominant, implying that the HOTS test is unidimensional.

Statistical analysis also indicated an eigenvalue of 12.931, where the result is more than 2 times the eigenvalue of the second factor with a percentage of the variance of 16.79%. Cumulatively, the percentage of the 27 factors is 65.546, suggesting that 65.546% is explained by the 27 existing components. The cumulative percentage of 65.546% has fulfilled the minimal condition for the cumulative value of taking the proper number of variables, which is 50% (Widarjono, 2015). Evidence of cumulative percentage values corroborates the notion that the HOTS test instrument is believed to be unidimensional.

Dimensions recorded in data can be proven in the scree plot findings, specifically the number of steeps. The number of steps shows the number of dimensions/factors, while the slope of the change in eigenvalues does not indicate the presence of dimensions (Widarjono, 2015). Therefore, unidimensionality can also be shown from the ensuing scree plot. The test is deemed to be unidimensional when components 1 and 2 in the scree plot have a high enough distance (Furr & Bacharach, 2008).

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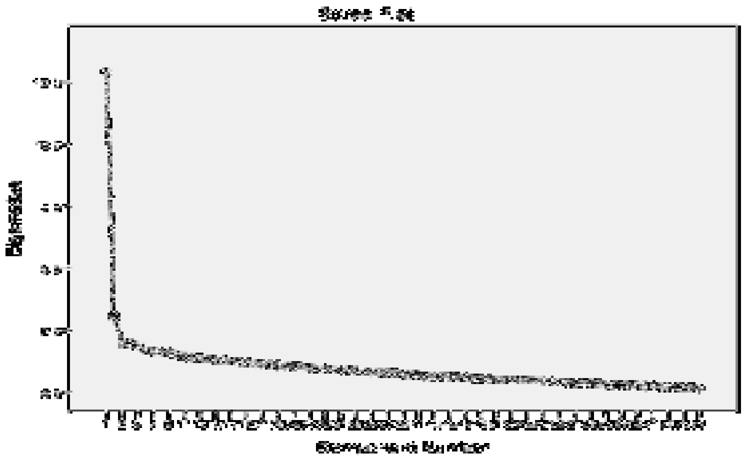

Figure 2. Scree plot of the Exploratory Factor Analysis Results

According to the scree plot in Figure 2, component 1 is located far away from component 2, whereas component 2 is located quite close to component 3 and other components. Additionally, as illustrated in Figure 2, the eigenvalues begin to slope with the third component. This demonstrates a single dominant factor and that other factors contribute significantly to the variance explained. The unidimensional analysis results corroborate the assertion of (Widarjono, 2015) that this HOTS test evaluates at least two components, with the first factor serving as the dominant factor. The scree plot in Figure 2 demonstrates that the HOTS test currently under development is unidimensional.

b) Test of Local Independence Assumption

One of the conditions for IRT analysis is the assumption of local independence. This assumption test is used to determine whether students' abilities are independent of the test questions, which means that their responses to one item do not affect their responses to subsequent items. The unidimensionality of the student response data to the test automatically establishes the local independence assumption test (Widarjono, 2015). The local independence assumption, on the other hand, can be demonstrated using a covariance matrix based on the ability of pupils categorized into many groups. If the correlation between the capability intervals is modest or close to zero, this assumption is fulfilled. Thus, a covariance value near zero satisfies the local independence assumption. Table 1 contains the covariance matrix.

Table 1. Covariance Matrix of Students' Higher Order Thinking Skills (HOTS)

	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10
K1	0,0726									
K2	0,0227	0,0132								
K3	0,0130	0,0066	0,0036							
K4	0,0250	0,0090	0,0052	0,0098						
K5	0,0077	0,0036	0,0020	0,0031	0,0012					
K6	0,0062	0,0024	0,0014	0,0023	0,0008	0,0006				
K7	0,0233	0,0089	0,0050	0,0089	0,0029	0,0022	0,0083			
K8	0,0092	0,0044	0,0023	0,0034	0,0013	0,0009	0,0033	0,0016		
K9	0,0312	0,0124	0,0070	0,0122	0,0040	0,0030	0,0113	0,0046	0,0156	
K10	0,0813	0,0555	0,0251	0,0300	0,0129	0,0095	0,0327	0,0163	0,0442	0,7280

Table 1 presents the variance-covariance matrix values for several groups of students' skills. The analysis reveals that the covariance variation across groups of students' ability intervals that form a diagonal line is negligible if not nil. As there is no association between the two variables, the assumption of local independence is satisfied.

c) Test of Parameter Invariance Assumption

The third requirement is parameter invariance. Parameter invariance shows that the test items are independent of the distribution of the students' ability parameter and vice versa, that students' ability parameter is independent of the test items. Students' abilities will not change because of working on a package of questions with distinct item parameters, and the item parameters will remain constant regardless of which group of students is assessed. There are two types of parameter invariance. The first type is item parameter invariance, and the second type is ability parameter invariance. The invariance of the item parameter can be determined by dividing the sample (218 students) into two even and odd groups. The estimated grain parameters for each sample are then plotted and associated using a scree plot. If the correlation is positive and significant, the assumption of item parameter invariance is satisfied (Widarjono, 2015). Figure 3 illustrates the estimation results for the invariance of the item parameters.

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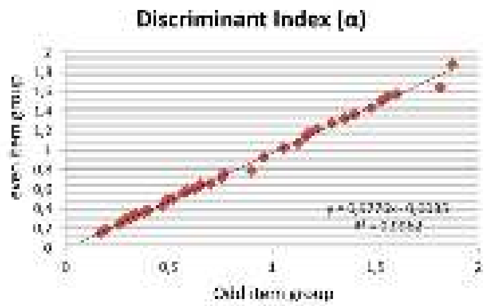

Figure 3. Scree plot of the parameter invariance of the HOTS test's discriminatory power

The scree plot in Figure 3 depicts the estimation of item parameter invariance for item discriminating power after students worked on odd and even questions. As illustrated in Figure 3, the estimated values are spread out and reasonably close to the linear line. The discriminatory power has a strong correlation with the student's response to the odd and even test items (0.9962). The scree plot and correlation analysis indicate that the discriminating power of the test items is invariant. The separation of two groups of test takers, odd and even, was also incorporated in the item parameter analysis for difficulty level. Microsoft Excel was used to conduct the analysis. Figure 4 depicts the correlation between the findings of the analysis.

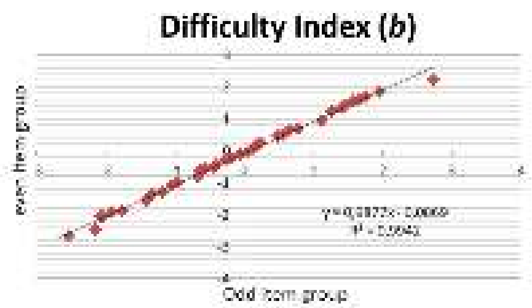

Figure 2. Scree plot of the Parameter Invariance of HOTS Test Difficulty Level

The scree plot of the estimated invariance of items in terms of difficulty level after students worked on odd and even questions is shown in Figure 4. As illustrated in Figure 4, the estimated values are dispersed and somewhat close to the linear line. The correlation coefficient between the difficulty of the questions and the responses of students to odd and

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even items is 0.9942 (high). Figures 3 and 4 indicate that the estimation of the item parameters' invariance in terms of discriminatory power and difficulty level is satisfactory.

After splitting the odd and even subtest groups, the invariance of the students' ability parameter can be examined. The estimated ability parameter for each sample was plotted and associated using a scree plot. If the correlation is significant and positive, the assumption of invariance of the student's ability parameters is satisfied (Widarjono, 2015). In general, students' capacity to work on the test is estimated as scattered (Figure 5).

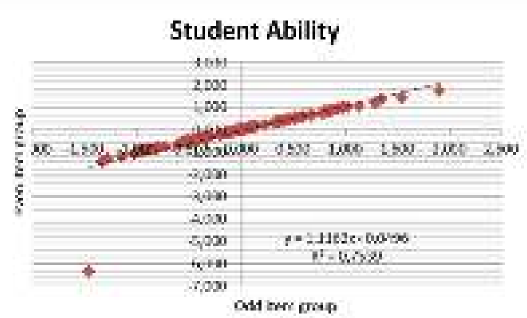

Figure 3. Scree plot of the Parameter Invariance of Students' Ability

The scree plot in Figure 5 depicts the estimated invariance of students' ability following an analysis of the abilities of even and odd-numbered students. Additionally, the scree plot findings show why the estimated values are quite close to a straight line with a correlation coefficient of 0.7539 (very high). In conclusion, the ability parameter invariance assumption has been satisfied.

d) Estimation of Reliability

The reliability coefficient of an instrument indicates the degree of confidence in the error-free findings of measurement (the greater the reliability coefficient, the more accurate the measurements). In this study, reliability was estimated using the SPSS 24 program. The Cronbach's Alpha coefficient for 77 items was 0.907 based on confirmed data. According to Mahrens and Lehman, while there is no universal agreement, it is usually believed that the test used to make individual student placement decisions must have a minimum reliability coefficient of 0.85 (Mehrens & Lehmann, 1991). According to the findings of this study and the experts' view, the reliability of the test developed in this study meets the criteria for a reliable test.

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e) Model Fit

The three assumptions for the IRT analysis had been well fulfilled so that the HOTS multiple-choice test was examined for model fit. Seventy-three items were produced. The model fit test for 1-PL, 2-PL, or 3-PL was performed by comparing X^2. The probability value for each test item must fulfill $p > 0.05$. The model fit analysis results summarized in Appendix 1 indicate that the 2-PL model is the best appropriate for the HOTS test instrument. In comparison to the 1-PL or 3-PL models, the 2-PL model accommodates the majority of the HOTS test's multiple-choice items. Since the study requires a 2-PL model, the parameters to examine are the discriminatory power (a) and the difficulty level (b) of each test item. Items that do not match the criteria for a "good item" are omitted from the final product.

After examining the model fit on the -choice test, the HOTS test's four essay items were analyzed. For essay questions, the model fit criteria are identical to those for multiple-choice questions. The essay questions, on the other hand, were examined using the R package MIRT program. This was done because the essay questions were scored as polytomous, which prevented them from being examined using the BILOG-MG tool. TABLE 3 summarizes the model fit analysis of the HOTS test essay questions.

Table 3. Model Fit Test on HOTS Essay Questions

Item	X^2				Remarks
	Statistics	df	RMSEA	P-Value	
A26	0.581	4	0.000	0.965	Fit
A8	3.771	5	0.000	0.583	Fit
A36	7.614	3	0.076	0.055	Fit
A15	4.749	4	0.026	0.314	Fit

According to TABLE 3, all test items fit the 2-PL model applied. The examination of the multiple-choice items and essay questions reveals that the 2-PL model is the best fit for the HOTS test items. The parameters measured in both types of questions are the same, namely discriminatory power (a) and degree of difficulty (b) of each test item.

f) Parameter of Time Item

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The 2-PL model was used to determine the characteristics of a good test item. The test items that fit the 2PL model were re-analyzed to determine their properties. According to the 2-PL model, the requirements for a good item are based on the discriminatory power (ai) and level of difficulty (bi) of each item. Discriminating power is regarded to be good if it is between 0 and 2. Additionally, a good difficulty index should range between -2 and +2 (Widarjono, 2015). This study found the discriminant index and the difficulties index of 73 questions (Appendix 2). These findings indicate that all items have a high discriminatory power index (ai), while 63 test items have a good difficulty level (bi) and ten items have a low difficulty level (bi). Although the 10 items showed a high discrimination index, they had a low difficulty level. Therefore, the ten items (A29, A30, B14, A27, A33, B25, A28, A17, A25, and B19) were revised.

The analysis of the multiple-choice test parameters was then continued with the analysis of the HOTS essay questions. The essay questions were analyzed using the R-Program. The results of the parameter analysis of the essay questions are shown as follows.

Table 2. The Results of Parameter Analysis on the HOTS Essay Questions

Item	Discriminatory Power		Difficulty Level				Conclusion
	a	Remarks	b	b2	b mean	Remarks	
A26	7.717	Poor	-0.981	-0.130	-0.555	Good	Revised
A8	0.07	Good	-0.851	-0.434	-0.642	Good	Accepted
A46	1.402	Good	-0.865	1.871	0.503	Good	Accepted
A15	0.173	Good	-0.260	-	-0.260	Good	Accepted

As shown in Table 5, item A26 has a low discrimination index of 7.717. Nevertheless, items A8, A46, and A15 have high discriminatory indices. All essay items have a reasonable difficulty index. Based on these findings, item A26 has a low discriminatory index but a high difficulty index; hence, item A26 must be amended and items A8, A46, and A15 were accepted.

g) Information Function and Standard error of measurement (IF SEM &)

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The test information function is equal to the sum of the test item functions. The relationship between the test information function and the standard error of measurement (SEM) is inverse, with a higher test information function indicating a smaller measurement error and vice versa. Figure 6 illustrates the IF and SEM curves.

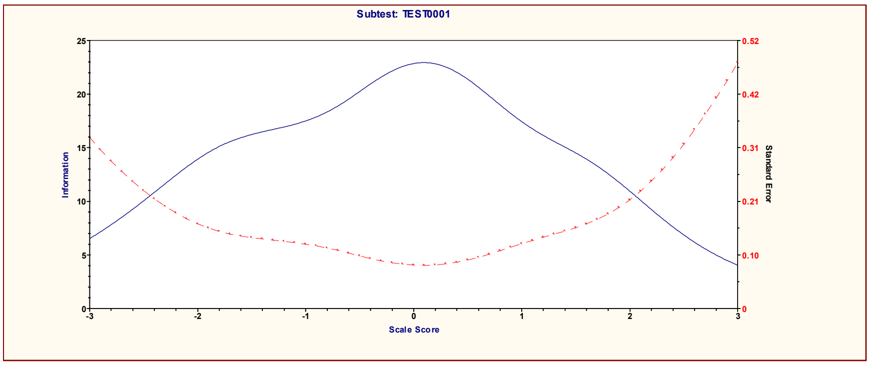

Figure 4. IF & SEM Curves

The analysis of the 2-Parameter Logistics (2-PL) model using BILOG-MG yields discriminating power (ai) and item difficulty level (bi), which were then utilized to determine the information function value for each HOTS test item. The test information value was calculated by adding the information functions of each item. The maximum test information function is found in ability = 0.1, with a value of 23.2 and a measurement error of 0.7. Additionally, Figure 6 illustrates that the HOTS test instrument covers the interval's lower and higher bounds. The interval's lower and upper bounds are the ability scores at which the graphs of the information function and standard error of measurement overlap. Based on the intersection line, it was determined that the HOTS test established in this study is appropriate for assessing higher-order thinking skills in students with an ability (θ) of -2.85 to 2.15.

Discussion

Higher-order thinking skills (HOTS) are higher-level cognitive abilities, not only memorization. HOTS entail several mental processes, including analyzing, evaluating, and producing, all of which are embedded in the problem-solving process. According to (Lewy, 2011), any ability that requires analysis, evaluation, and production is classified as a higher-order thinking skill. Bloom's Taxonomy is the most frequently accepted hierarchical arrangement of HOTS in the field of education, as it examines the levels of thinking from knowledge to evaluation (Ramos et al., 2013). However, the new paradigm of educational research frequently references Marzano's Taxonomy, which includes comparing, classifying, inductive reasoning, deductive reasoning, error analysis, construction support, perspective analysis, abstracting, decision making, investigation, problem-solving, experimental inquiry, and invention (Heong et al., 2011, 2016; Marzano, 1993; Marzano & Kendall, 2006).

According to Marzano's Taxonomy, higher-order thinking skills (HOTS) enable the development of student learning outcomes (SLO), class activities, and learning performance (Dubas & Toledo, 2016; Toledo & Dubas, 2016). Students that possess higher-order thinking skills are capable of learning, improving their performance, and overcoming their weaknesses (Yee et al., 2011). Students who received thinking skills training improved their reading comprehension and academic performance. This demonstrates the critical nature of thinking skills in resolving learning challenges, stimulating competitive thinking, creating intellectuals, and avoiding cognitive errors (Heong et al., 2011). Higher-order thinking skills are classified according to a level of cognition (cognitive capacity). The most often used classification of thinking abilities is Bloom's Taxonomy or its modification, which includes the following: 1) remembering, 2) comprehending, 3) applying, 4) analyzing, 5) evaluating, and 6) creating (C. A. Anderson & Krathwohl, 2014; L. W. Anderson et al., 2000). Numerous scholars classify HOTS into three categories: analysis, evaluation, and creation.

Marzano defines knowledge as "information, mental procedures, and psychomotor procedures." Following that, the domain is separated into six hierarchical cognitive processes: retrieval, comprehension, analysis, knowledge utilization, metacognition, and self-system thinking. Marzano defines HOTS as the following: comparing, classifying, inductive reasoning, deductive reasoning, error analysis, construction support, perspective analysis, abstracting, decision-making, investigation, problem-solving, experimental inquiry, and invention (Heong et al., 2011, 2016; Marzano, 1993; Marzano & Kendall, 2006).

Along with Bloom, Anderson, and Marzano, Webb (2002) provides stages of thinking that are commonly employed in standard measurement in many nations. This thinking stage consists of four levels, namely 1) recall and reproduction, 2) skills and concepts, 3) strategic thinking, and 4) extended thinking. The SOLO (Structure of Observed Learning Outcomes) Taxonomy is another cognitive taxonomy that is commonly used in Australia, New Zealand, Canada, and the United Kingdom. SOLO is a hierarchical taxonomy of cognitive abilities that focuses on distinct elements and their relationships. This hierarchy is divided into five levels: pre-structural, uni structural, multi-structural, relational, and extended abstract. Brookhart (2010) constructs HOTS indicators using

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slices from all four taxonomies. According to Brookhart (2010), HOTS consist of logical ability and reasoning, analysis, evaluation, and creation, problem-solving, judgment, and creativity, and creative thinking. However, this study used a taxonomy that is tailored to the demands of future primary school science instructors

Conclusion

This study developed 77 questions, 73 multiple choice questions, and four essay questions, all of which were determined to be valid in terms of content and constructs. The content validity test, calculated using the average Aiken V index, produced V = 0.879, indicating that the HOTS test is highly valid. Cronbach's Alpha coefficient for 77 items is 0.907 based on the construct validity test. The analysis of the multiple-choice items and essay questions revealed that the 2PL model was the most appropriate form of IRT model for analyzing the test items. Each HOTS test item has a discriminatory power index (ai) in the good category. However, in terms of difficulty level index (bi), there were 63 items in the good category and 10 items in the bad category. As a result, the ten test items needed to be altered. The 10 items had a high discriminatory index but a low level of difficulty. Items that needed to be revised included A29, A30, B14, A27, A33, B25, A28, A17, A25, and B19. Item A26 in the essay question section showed a low discrimination index, but a high difficulty level. Therefore, item A26 was revised, but items A8, A46, and A15 were accepted. All the test questions generated in this study are appropriate for assessing the higher-order thinking skills of students with the ability (θ) ranging from -2.85 to 2.15.

Suggestion

This study recommends further research to be able to promote HOTS through a learning approach. This aims to increase the HOTS of students throughout Indonesia.

Limitation

This research is limited only to the development of Physics Science test instruments. This is based on a pre-research needs analysis. Development in other fields is recommended.

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Higher-order thinking test of science for college students using multidimensional item response theory analysis

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Keywords: higher-order thinking skills, science, item response theory

Abstract

The purpose of this study was to construct a higher order thinking test of science for pre-service elementary school teachers. The test was created using the ADDIE model. The Analyze stage was carried out by identifying the needs and baseline of higher order thinking skills of students from the Department of Primary School Teacher Education in Yogyakarta. The Design stage involved the creation of test blueprints and question cards. The Develop stage involved validating the test's content and construct validity. The content validity test was conducted using the Delphi technique with seven validators, whilst the construct validity test was conducted using item response theory and EFA. This study developed 77 questions, 73 multiple choice questions and four essay questions, all of which were determined to be valid in terms of content and constructions. The HOTS test's content validity test resulted in a V-value of 0.879 (valid with high criteria) based on the average Aiken's V index. Meanwhile, reliability analysis using the Cronbach's Alpha coefficient revealed a score of 0.907 for the 77 test items based on the construct validity test. The discriminatory index (di) classified all items as good, whereas the difficulty index (bi) classified 63 items as good and 10 as poor. The ten items were revised, despite their high index of difference. All of the test questions are appropriate for students whose ability score (θ) ranged from -2.85 to 2.15.

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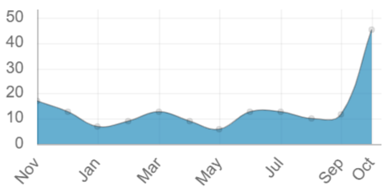

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