



**RESEARCH PAPER**

**Development and Validation of Higher Order Thinking Ability Test (HOTAT) in Biology for 10<sup>th</sup> Grade Students**

Ayesha Nazir <sup>\*1</sup> Dr. Mobeen-Ul-Islam <sup>2</sup>

1. Ph. D Scholar, Department of Education, University of Gujrat, Punjab, Pakistan
2. Assistant Professor Department of Education, University of Gujrat, Punjab, Pakistan

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**ABSTRACT**

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**\*Corresponding  
Author**

ayeshanazir51@gm  
ail.com

In our 21st century workplace, nations' need to acquire essential learning skills in a knowledge-based society. Idea generation is a thinking skill activity that requires a high degree of thinking and action. Higher Thinking (HOT) is one of the most desirable traits for educational and professional success in this era. Higher thinking helps students to excel in learning and living. This study focuses on the development and validation of higher order thinking abilities in the 10th grade biology test (HOTAT). This study consists of five steps (content selection, table specification, test validation, pilot testing, results and analysis, discussion and recommendations of test). Initially, 50 items are inductive and include expert-verified facial validity, content validity, construct validity, criteria validity, and item difficulty statistical results and discriminative analysis. Created using a deductive approach. Reliability analysis also confirmed the proper consistency of the equipment. After going through the validity and reliability process, a total of 30 items will remain as final items on this device. Learn all the details of item analysis, reliability analysis, and validation.

**Introduction**

Higher level thinking demands us to interpret raw data, analyze these facts conceptually, or manipulate that information by using of high level thinking abilities (Lee & La, 2017). So, an individual will be able utilize the new or prior knowledge to get a rational answer in new situation (Limbach & Barbara, 2009). Subsequently, creative thoughts can only be generated through high level thinking, instead of the low level thinking through the application of knowledge learned in daily lives (B. Limbach & Waugh, 2019).

Educationists stated HOTs into three categories

- HOTs in Terms to transfer

- HOTS in terms of critical thinking
- HOTS in terms of problem solving (B. Limbach & Waugh, 2019).

According to the different goals of teaching and learning transfer is the most central aspect of HOTS. Every teacher wants to retain their basic ideas in students' mind for a long time and every teacher also wishes to transfer individual knowledge to another learners. Retention demands remember or memories concepts and transfer requires to transfer their knowledge for the betterment of individual and society (Mirzaee & Maftoon, 2016). Whereas the critical thinking aspect defines: a conceptual, reasoned, and reflective thinking focused on decision making process which precedes the sense of making choices. According to (Nachiappan, Damahuri, Ganaprakasam, & Suffian, 2018), *critical thinking* is not only a thinking dimension but also it is an art of thinking, which comprises with a number of qualities like insightful thinking, inquiring, inspecting, perceiving and describing. In problem solving an individual decides how he/she reach his/her goal? In this process a student's give himself self-directions and he/she decided individually how he fulfills his goal. He/she must use his/her one or more higher-order thinking abilities to solve a problem (Nachiappan et al., 2018).

### Literature Review

Educationists suggested to the students to be equip with analytical, evaluative and critical thinking skills. According to (Corre, Lebee, Sab, Ferradi, & Cespedes, 8 February 2018) rise in labor efficiency depends on individual's quality of thinking, personal talent and creative ability (Corre et al., 8 February 2018). (Edwards, 2000) illustrated that creative and innovation are both such dynamic thinking keys that open new ways of innovation and development (Edwards, 2000). Management strategies of institutions depend on rapid technological change because digital media effects on the abilities of problem solving, motivation tactics, and finally taking decisions. According to (Heonga et al., 2012) states that individual idea are basic thinking element which can be consists on soft and hard elements (Heonga et al., 2012). Thoughts on all stages in one's mind is abstract in shape and it have the ability to visualize in our abilities and actions (Ismail & Tasir, April 2017). (Jerome, Lee, & Ting, 2017) classified these ideas generation as a higher order thinking skills (HOTS) it also demands very high level creative thinking correspondence with individual action (Jerome et al., 2017). It is very tough process to generate such ideas because a number of cognitive, chemical, biological and metacognitive processes did in mind (Khana & Masood, 2015) . But, this process became practical initiating by the gathering information, analyzing that information, evaluating it and at last to create new ideas (Khana & Masood, 2015).

### **Higher Order Thinking through Bloom's Taxonomy**

The development of higher order thinking skills is the key for academics. Bloom's Taxonomy used as a base in teaching and learning for structuring learning outcomes from curriculum. The taxonomy is effective to assess knowledge (factual, conceptual, procedural, and metacognitive) and development of cognitive skills (remembering, understanding, applying, analyzing, evaluating and creating). Bloom's Taxonomy is the comprehensive and perfect addition for an effective teacher (Nava Nourdad, May 01, 2018). Bloom's Taxonomy is a framework in which a teachers can assess teaching learning process well and students can explore their hidden abilities (Teimourtash & Moghaddam, 2017).

- A) The *knowledge* level is illustrated as "recalling facts, terms, basic concepts and answers".
- B) The 2nd level is *comprehension* level includes on "organizing, comparing, translating, interpreting, giving descriptions, and stating main ideas".
- C) The next and third level is *application level of Bloom taxonomy*; problem solving is the core of this level.
- D) The fourth level is *analysis level of Bloom taxonomy*. Which is the start of higher order thinking? At this level learner see or observe the information in segments in accordance with their causes. At this stage students became able to observe facts from a whole concept and infer it on other situation.
- E) The fifth and 2nd higher level stage of the Bloom taxonomy is *synthesis*. *Synthesis* is combining scattered information and makes an idea or comprehensive concept. Theory formation is the example of this level.
- F) The final and top most step of higher order thinking process of Bloom taxonomy is *evaluation*. It is at the highpoint of the Bloom taxonomy; at this stage the learner begins to define their opinions and judgments in real sense. Learners are autonomous at this level (Krathwohl, 2002).

This original taxonomy was later revised by Anderson et al. (2001) to include: *remember, understand, apply, analyze, evaluate* and *create* (Anderson, 2001). Two sub categories are verified apparently, but not as conceptually as it seems. The first level in the original Bloom taxonomy, *knowledge*, is illustrated as *remember* it make it more workable. Basically, this revised taxonomy refers to a verbal domain to noun domain, due to the independent nature of noun. *Comprehension* is transformed to *understanding*

because of most of educationists use the term *understanding* instead of *comprehension*. *Analysis* at the same position with same meanings. Finally, *evaluation* changed with *synthesis* and *synthesis* is changed to *create* having last position. The reason behind this change is that the final level of taxonomy reflects a process and at the end outcome is given (Krathwohl, 2002)

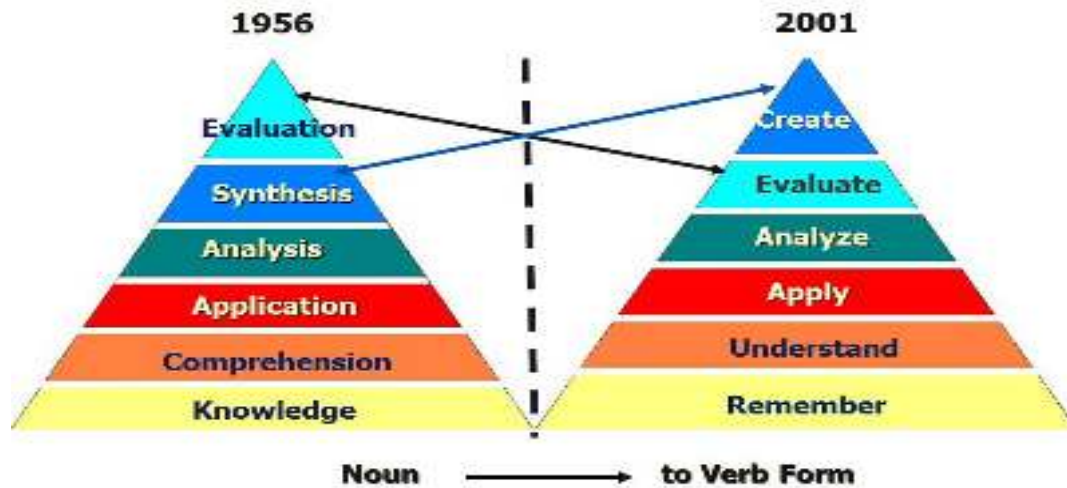


Figure-1: Revised Bloom Taxonomy

### Why Higher Order Thinking Skills Assess as Higher Order Thinking Abilities?

Teaching and assessment of HOTS on daily bases have a number of benefits in itself (Thamrin, Widodo, & Margana, 2019). This process is very helpful not only for teacher but also for student. Teacher can easily understand the changing took place in students' mind and behavior (Teimourtash & Moghaddam, 2017). Students can improve their thinking by analyzing, evaluation and finally creating or constructing new ideas (Tanujaya & Margono, 2017). Therefore they can improve their thinking (Alebaikan & Troudi, 2016). Learning through assignments and projects that needs high intellectual ability and massive critical work must improves student achievement (R. Singh, Singh, Mostafa, & Singh, 2018). These rises have also been observed in achievement tests, standardized test scores, annual grades, and research projects. (C. K. S. Singh, Singh, Singh, Mostafa, & Mohtar, 2018) reviewed studies based on Evidence from NAEP and TIMSS. He reported clear evidence from both the National Assessment of Educational Progress (NAEP) and the Trends in International Mathematics and Science Study (TIMSS) that, in mathematics and science, teaching stressing on intellectual reasoning have a significant relationship with higher scores than on rote learning in all grades (C. K. S. Singh et al., 2018). It is very complex task to decide how a researcher can measure higher-order thinking by a scoring scheme

supported by factual concepts. Scoring the quality of human thinking and reasoning is not a bed of roses (Angelo & Cross, 1993). For the purpose of summative assessment teacher must use graded tests and projects supported by a well-established scoring schemes. Some scoring schemes constituted on only surface features used for counting the number of correct answers by students' responses (Angelo & Cross, 1993; Kihzoza, Zlotnikova, & Bada, 2016). Teacher can mauled these scoring schemes to assess higher-order thinking that *reflect* the students thinking well. So, researcher decided to use multiple choice questions and restricted response essay questions to measure higher order thinking ability among 10<sup>th</sup> grade biology students.

### **Content and Method for Development of Higher Order Thinking Ability Test in Biology**

The content selected for the Higher Order Thinking Ability MCQs test was a curriculum provided by Punjab Text Book Board (2006) Pakistan, titled as Text Book of Biology 10th grade studied in all Punjab. This content is divided in 4 sections, 50% of all syllabus (2 Sections) were selected. 1st two sections were selected because research treatment were implemented at the start of year and follow the Academic Calendar. The content was further divided in to 6 units and 95 students learning outcomes which were constructed by the help of (Ministry of Education, 2006). The detail of each unit is presented in table 1.

**Table 1  
Content of Summary**

Sections	Description of Units	Student Learning Outcomes (SLOs)					
		Levels of Cognitive Domain					
		Total SLOs	Analyzing (A)	Evaluating (E)	Creating (C)	HOTs Related SLOs	Unit-wise
Life Processes	Gaseous Exchange	26	5	6	7	18	20%
	Homeostasis	30	2	3	5	10	10%
	Coordination and Control	44	10	11	4	25	24%
	Support and Movement	20	2	2	3	7	8%
Continuity in Life	Reproduction	34	4	9	6	19	20%
	In-Heritance	39	9	5	2	16	18%
		193	32	36	27	95	100%

### Table of Specification for Higher Order Thinking Ability Test

It is very difficult to decide how a researcher or teacher can measure higher-order thinking by a typical scoring scheme that supported by factual concepts. Scoring the level and quality of human thinking and reasoning is not a bed of roses.

That's why researcher made MCQs test to Measure higher order thinking domains Analyzing and Evaluating and one line short restricted response questions for Creating. For the purpose teacher must use graded tests supported by a well-established scoring schemes or table of specification. Thus, the below-mentioned table of specification (TOS) was incorporated for the development of the test, namely conceptual understanding in Higher Order Thinking Ability Test (HOTAT).

**Table 2**  
**Table of Specification for Higher Order Thinking Ability Test**

Sections	Description of Units	Student Learning Outcomes (SLOs)				
		Levels of Cognitive Domain				Unit-wise Weightage
		Analyzing (A)	Evaluating (E)	Creating (C)	HOTs Related SLOs	
Life Processes	Gaseous Exchange	5	6	7	18	20%
	In HOTs Test	3	3	4	9	10%
	Homeostasis	2	3	5	10	10%
	In HOTs Test	1	2	2	5	5%
	Coordination and Control	10	11	4	25	24%
	In HOTs Test	5	6	4	15	14%
	Support and Movement	2	2	3	7	8%
	In HOTs Test	1	1	2	4	4%
Continuity in Life	Reproduction	4	9	6	19	20%
	In HOTs Test	2	5	3	10	10%
	In-Heritance	9	5	2	16	18%
	In HOTs Test	5	3	1	9	9%
Total	Total SLOs	32	36	27	95	100%
	Total in HOTs Test	16	13	11	50	50%

Figure-2 indicates that a similar proportion of marks are allocated for each unit of content.



Figure-2: Marks Allocated for Each Unit of Science

Figure-3, indicates that an almost similar proportion of marks were allocated to each level of the cognitive domain

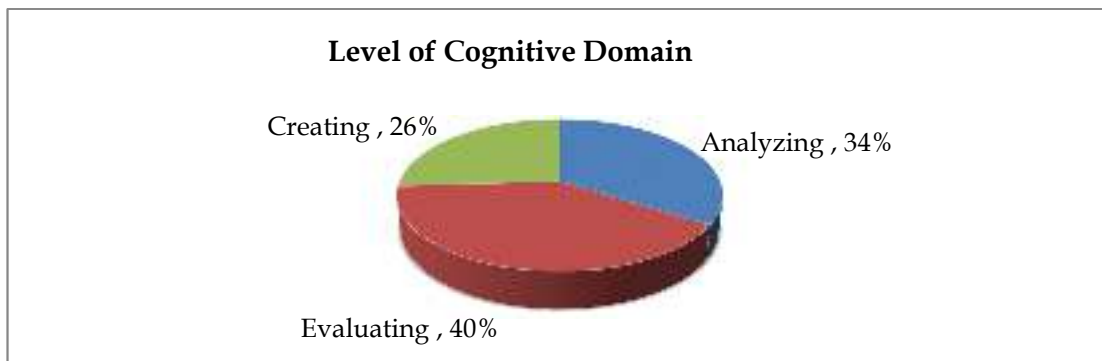


Figure-3: Marks Allocated for Each Level of Cognitive Domain

### Validity of Higher Order Thinking Ability Test

Primarily, fifty (50) items and the answer key were developed for the higher order thinking ability test (HOTAT) by the penal discussion of 3 subject specialists of Biology working in public sector schools. The items and the answer key of the

preliminary draft were discussed with the supervisor and peers for guidance, restructuring, and rectification. Almost twenty-five (25) tests (HOTAT) and the answer key in hard form were distributed among experts, and fifteen (15) sets of (HOTAT) were received back. Without ensuring the validity, a test gains nothing. Validity were ensured by following this pattern;

**Table 3**  
**Higher Order Thinking Ability Test’s Validity**

Types	Technique
Content Validity	CVR, CVI based on Review by Expert allocating appropriate weightage/percentage to SLOs and content
Face Validity	Review by Expert allocating appropriate weightage/percentage to SLOs and content
Construct Validity	Item Analysis
Criterion Validity	Predictive Discriminant Analysis

(Aulia & Sukirlan, 2014)

Therefore, construct validity was ensured by item analysis, and criterion predictive validity was ensured by discriminant analysis. Similarly, validity, including content validity and face validity, was ensured by allocating appropriate weightage/percentage to SLOs and content. Similarly, it was ensured after seeking the valuable opinion of Subject Matter Experts (SMEs). They provide their opinion on each item of the test in terms of “Essential”, “Necessary,” and “Un-necessary” item. Therefore, the Content Validity Ratio (CVR) and Content Validity Index (CVI) was calculated accordingly. Table 3. Indicates item-wise Content Validity Ratio (CVR) values of the items of conceptual understanding in higher order thinking ability (HOTAT). Content validity ratio (CVR) of the items all 50 items of conceptual understanding in higher order thinking ability (HOTAT) ranged from 0.57 to 0.86. Lawshe (1969) reported that the CVR value greater than 0.49 is acceptable for fifteen (15) panelists. Hence, 44 items were retained, and six (6) of the items was dropped from the higher order thinking ability (HOTAT). Similarly, Content Validity Index (CVI) value was computed to ensure the validity of the test. Its value remained 0.83, which was greater than 0.7, which is an acceptable value. This indicates that experts endorsed the validity, including content validity and face validity.



### **Pilot Testing of Higher Order Thinking Ability (HOTAT)**

The higher order thinking ability (HOTAT) comprising forty-four (44) items was pilot tested on 220, 10<sup>th</sup> grade students. The sample of the study was not included in the pilot testing. Different quality statistics like the level of difficulty (*p*), Discriminating Power (*D*), and Test Item Reliability (Aulia et al., 2014) of the higher order thinking ability (HOTAT) were computed by using M.S. Excel, 2013.

### **Item Analysis of Higher Order Thinking Ability Test (HOTAT)**

Different values like Point Biserial, Discriminating Index, Alpha, Standard Deviation, were computed by using M.S Excel 2013 software.

### **Results and Discussion**

Results of higher order thinking ability test was given below; Fourteen (14) items of the higher order thinking ability (HOTAT) remained below the acceptable value of quality items. Therefore, the item No. 2,3,9,13,16,17,25,29,30,36,38,40, and 43 were deleted/removed from the final higher order thinking ability (HOTAT).

Figure-5 represents the retention of items of higher order thinking ability (HOTAT) after the process of validity and reliability.

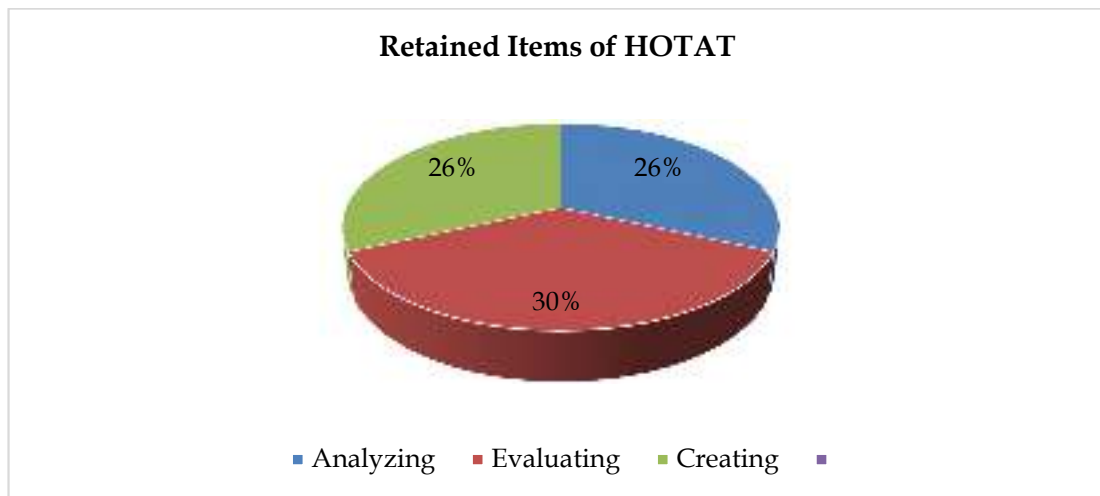
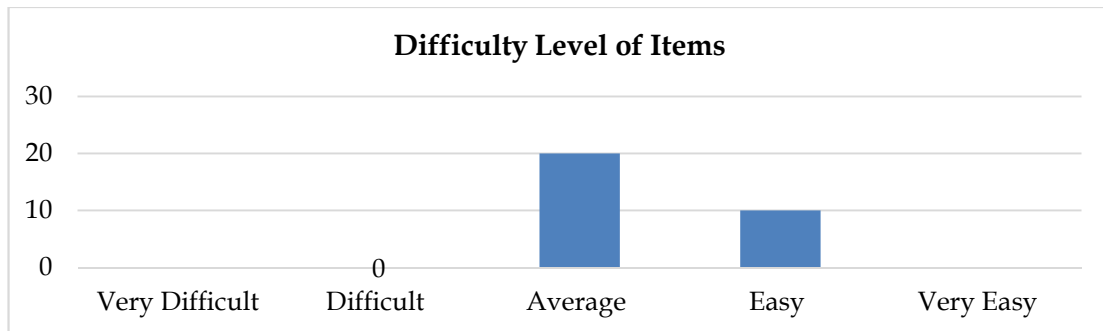


Figure-5: Retention of Items

Fourteen items (18%) were to be dropped. This indicates that 82% of items of the higher order thinking ability (HOTAT) were to be retained.

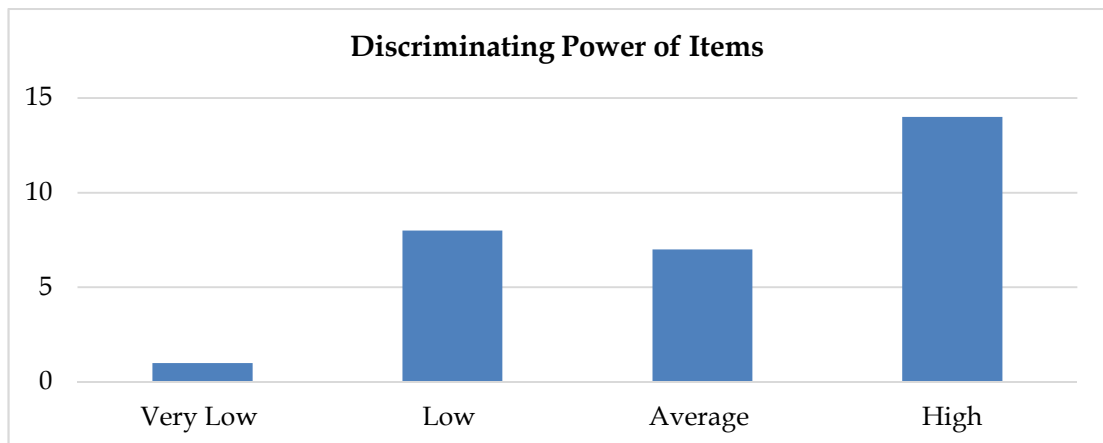
The difficulty level of each item of higher order thinking ability test (HOTAT) was established based on Prop. Correct values.



**Figure-6: Difficulty Level of Items**

Figure-6 represents that none of the items of the conceptual understanding in science test (CUST) was “very difficult”, “difficult”, and “very easy”. However, ten (10) items were “easy”, twenty (20) “average”.

**Discriminating Power of each item of higher order thinking ability test (HOTAT) was established based on Point Biserial values**



**Figure-7: Discriminating Power of Items**

Figure-7 indicates that one (1) items of the higher order thinking ability test have very low discriminating power. Whereas eight (08) items have low discriminating power, seven (07) average and fourteen (14) have high discriminating power. Thus, twenty-one (21) items were having average and high discriminating.

The quality of each item of conceptual understanding in higher order thinking ability test (HOTAT) was established based on the value of the Discrimination Index.



Figure-8: Quality of Items Based on Discrimination Index

Figure-8, represents the quality of items based on the Discrimination Index. 18% items of higher order thinking ability test were excellent, 1 % acceptable, 12% good and 0% were Poor items.

#### **Final Higher Order Thinking Ability Test (HOTAT)**

By adopting the above-cited, evidence-based review of test items, poor-performing items were dropped out from the higher order thinking ability test (HOTAT). Table 3.22 indicates that item No. 2, item No. 3, item No. 9, item No. 13, item No. 16, item No. 17, item No. 25 to item No. 29, item No. 30, item No. 36, item No. 38, item No. 40, item No. 41 and item No. 43 were dropped since they were below the acceptable value. Only thirty (30) Multiple Choice Questions (MCQs) remained fit to retain after item analysis. After removing the weak items, the reliability (Cronbach's alpha value) of the conceptual understanding in science test (CUST) on valid items was 0.826, which is higher than 0.7 (the Reliability value for tests suggested by Tavakol & Dennick, (2011). Thus, the higher order thinking ability test (HOTAT) was highly reliable. This test was finalized, and it was used as a pretest and posttest. Test Statistics of the Final the higher order thinking ability test (HOTAT) in the below-mentioned table indicates item-wise test statistics of the final the higher order thinking ability test (HOTAT) consisting of thirty (30) Multiple Choice Questions (MCQs).

**Table 4**  
**Item wise statistics of Higher Order Thinking Ability Test (HOTAT)**

Item No.	Level of difficulty (p)	Disc. Index	Point Biser	Status of Items			Remarks
				Based on Prop. Correct	Based on Point Biser	Based on Disc. Index	
1	0.66	0.4	0.32	Average	High	Excellent	Retain
2	0.56	0.4	0.39	Average	High	Excellent	Retain
3	0.43	0.3	0.30	Average	Average	Good	Retain
4	0.50	0.4	0.34	Average	High	Good	Retain
5	0.63	0.4	0.30	Average	High	Good	Retain
6	0.5	0.5	0.30	Average	High	Good	Retain
7	0.66	0.5	0.30	Average	High	Good	Retain
8	0.60	0.6	0.32	Average	High	Good	Retain
9	0.73	0.5	0.36	Easy	High	Excellent	Retain
10	0.56	0.5	0.30	Average	High	Good	Retain
11	0.76	0.3	0.36	Easy	Average	Excellent	Retain
12	0.73	0.5	0.30	Easy	High	Good	Retain
13	0.86	0.3	0.36	Easy	Average	Excellent	Retain
14	0.8	0.2	0.35	Easy	Low	Excellent	Retain
15	0.46	0.2	0.40	Average	Low	Excellent	Retain
16	0.73	0.3	0.38	Easy	Average	Excellent	Retain
17	0.6	0.2	0.30	Average	Low	Good	Retain
18	0.73	0.1	0.35	Easy	Very Low	Excellent	Retain
19	0.53	0.2	0.36	Average	Low	Excellent	Retain
20	0.73	0.2	0.37	Easy	Low	Excellent	Retain
21	0.6	0.2	0.38	Average	Low	Excellent	Retain
22	0.43	0.3	0.30	Average	Average	Good	Retain
23	0.43	0.4	0.35	Average	High	Excellent	Retain
24	0.56	0.4	0.36	Average	High	Excellent	Retain
25	0.46	0.5	0.30	Average	High	Good	Retain
26	0.43	0.2	0.35	Average	Low	Excellent	Retain
27	0.83	0.3	0.38	Easy	Average	Excellent	Retain
28	0.86	0.3	0.36	Easy	Average	Excellent	Retain
29	0.46	0.2	0.35	Average	Low	Excellent	Retain
30	0.52	0.5	3.30	Average	High	Good	Retain

Table-4 represents the retained items (thirty (30) Multiple Choice Questions). item No. 1, item No. 4, item No. 6, item No. 7, item No. 10, item No. 11, item No. 12 to item No. 14, item No. 14, item No. 18, item No. 19, item No. 20, item No. 21 and item No. 22, item No. 23, item No. 26, item No. 27, item No. 28, item No. 31, item No. 32, item No. 33, item No. 34, item No. 37, item No. 39, item No. 42, item No. 44, item No.

45, item No. 48, item No. 49 and item No. 50 were retained in the higher order thinking ability test (HOTAT).

### **Conclusion**

All the test statistics indicated that the higher order thinking ability (HOTAT) worked well and fulfilled its primary purpose. Higher order thinking ability test can measure 10<sup>th</sup> grade biology students' higher order thinking abilities. Content validity index of each value was more than 0.7, which indicates that each item was statistically significant and able to use it in practical form. Estimated values of item difficulty ranged from 3.00 to 7.00 which indicates that items were not too easy nor too difficult and fulfil the criteria of item standardization. Discrimination index of items ranged in 0.20 to 0.1. Which indicates that items were good and excellent by the aspect of item discrimination. The reliability value was up to the stander which indicates that higher order thinking test was reliable.

### **Recommendations**

By the references of results and conclusions its recommended that this higher order thinking ability test was valid and reliable and ready to in formative and summative assessment purposes. This test also have the ability to measure higher order thinking ability of students which is necessary for conceptual understanding of students.

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