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RESEARCH PAPER

Development and Validation of Physics Achievement Test (PAT) to measure Conceptual Understanding of 9th Grade Students

[1]Shahzad Ahmad Shahzad* [2]Dr. Syed Shafqat Ali Shah

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

***Corresponding Author** sashahzad7861@gmail.com

ABSTRACT

Conceptual understanding is related with connected and operational network of thoughts. The main objective of the study was the development and validation of a Physics Achievement Test (PAT) to measure the conceptual understanding of 9th Graders. PAT was comprised of MCQs based test on first three levels of Bloom's Taxonomy. First step was content selection & its alignment with Student Learning Outcomes (SLOs). In Second step, Content validity was ensured through Content Validity Ratio (CVI) and Content Validity Index (CVI). Third step was specification of marks. In fourth step, PAT was pilot tested on 376, 9th grade science students. In fifth step, different quality statistics like Difficulty Index, Discrimination Power and Reliability were also computed. Initially, there were 84 items while final test was reduced to 75 items. Consequently, the results affirmed that PAT has adequate verifications of being valid and reliable to measure the conceptual understanding of 9th Graders.

Keywords: Conceptual Understanding, Development, Physics Achievement Test, Validation

Introduction

Science education is of great significance for the development of a country. Developing countries are facing different problems like corruption, political instability, weak economic condition, alarming law and order situation, poor agriculture system, pathetic attitude of teachers and substandard teaching methods. To resolve all the problems, teachers should prepare themselves to change their methodology towards teaching learning process (Kola, 2013). Physics is one of the most significant fields of knowledge, but different studies reveal that teaching physics through traditional method of teaching is not contributing in developing conceptual understanding of complex ideas among secondary students effectively (Rehmani, 2003). Although, students manage to get high grades in Board of Intermediate and Secondary Education examinations through rote learning yet their poor conceptual understanding unveils in entry/ admission tests of different professional institutions. Aftab et al. (2014) points out that students manage to achieve better grades through rote memorization of different concepts. This approach leads towards complete destruction of thinking, creativity, problem solving and reasoning. Conceptual Understanding is an incorporated and operational grip of concepts and understanding. Learners with conceptual understanding identify knowledge much greater than separate pieces of information and approaches (Kilpatrick, J., Swafford, J., & Findell, B., 2001).

Researchers have been trying to develop most excellent methods to assess Conceptual Understanding of learners (Guerreiro, Barker, & Johnson, 2022). The foremost focus of this study was to design a tool to assess Conceptual Understanding of 9th grade students in the subject of physics. The researchers designed and validated an instrument to measure Conceptual Understanding the of 9th grade students and used this test to assess the Conceptual Understanding of 9th grade students.

Literature Review

David (2014) points out that the term conceptual understanding is frequently used in teaching of physics. This phrase does not have any fixed meaning rather it is a multifaceted term. He calls it as quantitative reasoning as well as qualitative reasoning.

The assisting characteristics were purposeful learning actions, recalling, and misunderstanding. The outcomes of study conducted by Mills (2016) confirm that conceptual understanding is a procedure. In this procedure, information and facts are communicated to the learners. When they practised these facts, knowledge and understanding, they may construct significant connections and arrangement between different chunks of information. Then, they transfer these organized information between theory and exercise.

Dimensions of Conceptual Understanding

Mills (2016) also explored different important aspects of the conceptual understanding. The recognized aspects of Conceptual Understanding were

1) Procedural and Factual information
2) Connections
3) Transfer of knowledge
4) Meta-cognition

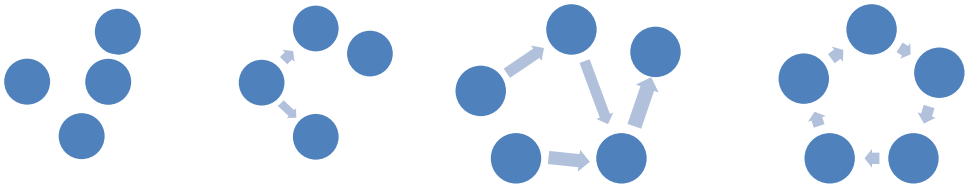

Figure 1: Aspects of Conceptual Understanding

Factual and procedural information:

The initial stage in the procedure of conceptual understanding is the acquiring of facts and information about process. Literature identifies that learners should have a solid base of fact and figures for achieving the insight of conceptual understanding (Ross & Wilson, 2012). Although this set of information makes the foundations, but does not promise the occurrence of conceptual understanding (Mills2016).

Connections

Incorporating the fresh ideas and enhancing conceptual education by means of concept diagrams, schematic block diagram and flowcharts improve the insight learning and increase conceptual understanding (Ritchart, Turner, & Hadar, 2009). With the development of factual information, learners start to organize them in a sequence. With the increase in information, these bonds and connections start becoming more powerful and strong and hence level of conceptual understanding increases (Mills, 2016).

Transfer of knowledge

Transfer of information and construction of connections looks quite similar but both of them are dissimilar aspects of conceptual understanding. Without establishing connections, this is not possible to transmit and convey information. Anyhow, facts and figures can be transmitted on the basis of past knowledge but such transfer of knowledge helps the learners to make new connections and hence enhances conceptual understanding (Mills, 2016).

Meta-cognition

Novice learners merely concentrate on focus on apparent knowledge that is contrary to development of connections and transmission of information required for meta-cognition (Kelly and Colby, 2003). Metacognition is an understanding that someone possesses about his/ her thinking and applies the planning to lead and reconsider idea (Gredler, 2008). While Mills (2016) defines Metacognition is the knowledge of how learners understand, arrange and construct their knowledge. Arranging information and understanding in a logical sequence enhances the conceptual understanding.

Factors affecting Dimensions of Conceptual Understanding

There are three factors affecting the dimensions of conceptual understanding, either passively or in a negatively. They are purposeful knowledge actions, retention or recalling and Misunderstanding.

Purposeful knowledge activities

The achievement of conceptual understanding was supported by the including purposeful knowledge activities. A large number of research studies explain how conceptual understanding is attained by use of purposeful knowledge activities. Such activities occur through interaction with community and dynamic educational culture. Various instructional strategies have been mentioned in the literature like jigsaw, brainstorming, cooperative learning, concept building and analogies (Beyer, 2011)

Retention or recalling

A few research studies discourage retention or rote memorizations (Spier-Dance et al., 2005) as well as some studies appreciate it. The retention or rote learning can decrease the student's capability to concentrate in depth about a topic. Anyhow, in a few subjects like mathematics, retention or rote learning of facts is necessary for conceptual understanding (Ross & Wilson, 2012). Learning facts by heart was considered to be a barrier in understanding. Anyhow, in a few studies, retention or rote learning was found essential for conceptual understanding. Students depend on retention while making connections between facts, transferring and organization of knowledge.

Misunderstanding

The expression Misunderstanding deals with the mistake of student's thoughts. Misunderstanding proves to be an obstacle in the way of conceptual understanding by stopping absorption of knowledge and adjustment of information (Milligan & Wood, 2010). Error is point for learning (Van & Conroy,2009). Conceptual understanding deals with organizing and interpreting information based on previous knowledge and reconstruction of misunderstanding. Purifying information by dealing with misunderstanding helps learners to correct their thinking. Recognizing and correcting misunderstanding help learners to attain conceptual understanding.

Conceptual Understanding & Examination System in Pakistan

In Pakistan, the biggest hindrance in development of conceptual understanding among students is the examination system of the country. The students try to attain high grades in Board of intermediate and secondary education and other exams through rote learning. Rote Learning is a great barrier to conceptual understanding (Rittle-Johnson & Star, 2007). In this practice, students just try to meet the needs of examination by learning the lesson by heart. They just memorize facts and figure. They do not bother to make connection between facts, organizing the information and transmission of knowledge for conceptual understanding (Mills, 2016)

Conceptual Understanding and Bloom's Taxonomy

Reichenbach (2001), has pointed out different stages of cognitive domain of Benjamin Bloom. It is described that Conceptual Understanding of occurs in following six stages

Gaining knowledge

The knowledge can be described as some information about some particular issue, event or field. In initial stage students gather information regarding new skills, concepts and approaches. This stage is named as gaining knowledge. This stage has following salient feature;

a) Completion of various assignments by recalling already gained information

b) Identification of the requisite knowledge

c) Arrangement data into a series

d) Relationship of primary data for advance procedure

e) Discovery of innovative ideas and knowledge

f) Defining of various terms operationally

g) Extracting important and significant knowledge from unprocessed information

Comprehension

Comprehension can be described as understanding of information or facts by receiving new information and arranging previous knowledge in a sequence. This stage is characterized by the following features

a) Explanation of in depth knowledge

b) Discourse on a particular idea

c) Extraction of inference on the base of acquired knowledge

d) Capability to express information into different settings

e) Reorganization of accessible knowledge according to the context

f) Description the theme of information into valuable form

g) Explanation of data to get rational connection

Application

This stage is concerned with the practical use of a concept or an idea in a new situation or context. With the help of gained knowledge, students make its use in some new or novel situation to solve the matter in real life problems. This stage is characterized with following prominent feature;

a) Exhibition of acquired knowledge in actual life situations

b) Use of gained understanding into genuine context

c) Display of gained knowledge into different settings

Analyze

Analyze refers to the breakdown of complex concepts or themes into different factors and chunks of information for better understanding of connections and relationships between different parts of concept. Different aspects associated with analyze stage are given below;

a) Distinguishing of central and surface concepts from the given knowledge

b) Difference between apparent statements and theoretical concepts.

c) Classification of gathered knowledge

d) Formation of similarities and differences among existing data

Synthesis

Synthesis can be described as the procedure of combining different dispersed concepts to create some novel knowledge. The given actions are included in synthesis stage;

a) Construction of novel ideas, opinions and then develop them in various perspectives

b) Capability to change or alteration into an innovative theory

c) Display of new methods to find the solution of on hand problem

Evaluation

The final stage is evaluation. It deals with the capability to examine the connection among existing evidences and output in evaluation phase. In this phase following characteristic are supposed;

a) Decision making

b) Rejection

c) appraise

d) importance

e) Critic

f) Evaluate

Development of Physics Achievement Test (PAT)

The researchers developed a multiple choice questions based test on the basis of first three levels of Bloom's Taxonomy i.e. Knowledge Level, Comprehension Level and Application Level.

Content and Alignment of Physics Achievement Test (PAT) with SLO's

Physics Achievement Test (PAT) was based on SLOs for 9th Grade. The test items contained concepts of 9th Grades Physics. To develop the test, 9th grade Physics of Punjab Text Book Board Lahore, being the recommended book was selected for developing the test. Physics Achievement Test (PAT) was developed by keeping in view the SLO's of National Curriculum for Physics 2006. Initially test was comprised of 84 items. Then after pilot testing, subject experts' opinion and item analysis, final Physics Achievement Test (PAT) was consisted of 75 items.

Table of Specification

Bloom Taxonomy suggests "knowledge level", "comprehension level" and "application level", the three basic levels of cognitive domain of learning. So the Bloom's Taxonomy was kept in mind while constructing Physics Achievement Test (PAT).

Table 2
Specification of marks

Sr. No	Learning Level	No. of Items	Item No.	Percentage
1	"Knowledge Level"	25	1, 4, 10, 11, 12, 35, 39, 46, 47, 48, 50, 55, 56, 63, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75	33%
2	"Comprehension Level"	26	2, 3, 17, 18, 22, 23, 26, 27, 28, 29, 30, 31,32, 33, 34, 43, 44, 45, 53, 54, 58, 59, 60, 61, 62, 64	35%
3	"Application Level"	24	5, 6, 7, 8, 9, 13, 14, 15, 16, 19, 20, 21, 24, 25, 36, 37, 38, 40, 41, 42, 49, 51, 52, 57	32%

Tables indicates that approximately equal percentage of marks was given to each category of the cognitive domain. i.e. marks allocation for knowledge level was 33%, marks allocation for comprehension level 35% and marks allocation for 32% for application level

Validity of Physics Achievement Test (PAT)

There is no significance of an instrument without validation. Face validity deals with relatedness, clearness, sensibleness and transparency of the items (Oluwatayo, 2012. Face Validity can be ensured by assessment of subject specialists, assigning proper weightage to Student learning outcomes and subject matter (Engellant et al., 2016).

Content validity is very much necessary in an attainment tests. It deals with degree to what assessment assesses a representative model of the subject material (Mohamad et al., 2015). It can be ensured through CVR and CVI founded on reviews by the experts (Engellant et al., 2016).

Mainly, Construct Validity deals with psychological meaningfulness of a scale. It differentiates one hidden variable from other one. It can be ensured through Item analysis (Taherdoost, 2016).

Criterion-related validity may be defined as the degree to what a test achievement is concerned to another achievement test (Aulia et al., 2014). It can be ensured though Discrimination Analysis (Engellant et al., 2016).

Content Validity of Physics Achievement Test (PAT)

Fourteen (14) subject Expert/ specialists of physics validated the Instruments for Physics achievement test (PAT). Content validity and face validity, was confirmed by assigning reasonable ratio of Student. CVR and CVI were determined. Table of values of CVR and CVI is given below.

Table 3
Item wise CVR values of Physics Achievement Test (PAT)

Item No.	Level of item	CVR	Decision
1	KNOWLEDGE	1.00	Select
2	COMPREHENSION	1.00	Select
3	COMPREHENSION	0.86	Select
4	KNOWLEDGE	1.00	Select
5	APPLICATION	1.00	Select
6	APPLICATION	1.00	Select
7	APPLICATION	0.86	Select
8	APPLICATION	1.00	Select
9	APPLICATION	1.00	Select
10	KNOWLEDGE	1.00	Select
11	KNOWLEDGE	1.00	Select
12	KNOWLEDGE	0.71	Select
13	APPLICATION	1.00	Select
14	APPLICATION	1.00	Select
15	APPLICATION	1.00	Select
16	APPLICATION	1.00	Select
17	COMPREHENSION	1.00	Select
18	COMPREHENSION	0.86	Select
19	APPLICATION	1.00	Select
20	APPLICATION	1.00	Select
21	APPLICATION	1.00	Select
22	COMPREHENSION	0.71	Select
23	COMPREHENSION	1.00	Select
24	APPLICATION	0.86	Select
25	APPLICATION	1.00	Select
26	COMPREHENSION	1.00	Select
27	COMPREHENSION	1.00	Select
28	COMPREHENSION	1.00	Select
29	COMPREHENSION	0.86	Select
30	COMPREHENSION	1.00	Select
31	COMPREHENSION	1.00	Select
32	COMPREHENSION	1.00	Select
33	COMPREHENSION	1.00	Select
34	COMPREHENSION	0.14	Reject
35	COMPREHENSION	1.00	Select
36	KNOWLEDGE	0.86	Select
37	APPLICATION	1.00	Select
38	COMPREHENSION	0.43	Reject
39	APPLICATION	1.00	Select
40	APPLICATION	1.00	Select

41	KNOWLEDGE	0.86	Select
42	APPLICATION	0.86	Select
43	APPLICATION	1.00	Select
44	APPLICATION	1.00	Select
45	COMPREHENSION	1.00	Select
46	COMPREHENSION	1.00	Select
47	COMPREHENSION	1.00	Select
48	KNOWLEDGE	1.00	Select
49	KNOWLEDGE	1.00	Select
50	KNOWLEDGE	0.71	Select
51	APPLICATION	1.00	Select
52	KNOWLEDGE	1.00	Select
53	APPLICATION	1.00	Select
54	APPLICATION	1.00	Select
55	COMPREHENSION	1.00	Select
56	COMPREHENSION	0.86	Select
57	KNOWLEDGE	1.00	Select
58	COMPREHENSION	0.43	Reject
59	KNOWLEDGE	1.00	Select
60	APPLICATION	1.00	Select
61	COMPREHENSION	1.00	Select
62	COMPREHENSION	1.00	Select
63	COMPREHENSION	1.00	Select
64	COMPREHENSION	1.00	Select
65	COMPREHENSION	0.14	Reject
66	COMPREHENSION	0.29	Reject
67	COMPREHENSION	1.00	Select
68	KNOWLEDGE	1.00	Select
69	COMPREHENSION	1.00	Select
70	KNOWLEDGE	0.86	Select
71	KNOWLEDGE	1.00	Select
72	KNOWLEDGE	1.00	Select
73	KNOWLEDGE	1.00	Select
74	KNOWLEDGE	1.00	Select
75	COMPREHENSION	0.29	Reject
76	KNOWLEDGE	0.14	Reject
77	KNOWLEDGE	1.00	Select
78	KNOWLEDGE	1.00	Select
79	KNOWLEDGE	0.86	Select
80	KNOWLEDGE	1.00	Select
81	KNOWLEDGE	1.00	Select
82	COMPREHENSION	0.43	Reject
83	KNOWLEDGE	1.00	Select
84	COMPREHENSION	0.14	Reject

Table 3 points out that the values CVR of the items of Physics Achievement Test (PAT)ranged from 0.14 to 0.86. Lawshe (1969) reported that the value of Content Validity Ratio more than 0.51 is suitable for fourteen (14) experts. Therefore, 75 items were selected, and only Nine (09) items were dropped from the Physics Achievement Test (PAT)**.** Similarly, value of CVI was calculated to confirm validity of PAT. It was found as .89 which is more than 0.7 that is a good enough value

Pilot testing of Physics Achievement Test (PAT)

Physics Achievement Test (PAT) consisting of 75 items, was pilot tested on 376, 9th grade students of district Gujranwala. Several statistical techniques like difficulty index, discriminating power and reliability of test items to ensure quality (Aulia et al., 2014) of Physics Achievement Test (PAT**)** were computed by using M.S. Excel, 2013

Item Analysis

Item analysis is a technique that tells us about the difficulty of the items. It also differentiates among dull and the brilliant students. In this study, items were analysed in the following three manners i.e. Difficulty Index, Discrimination Power and Test Item Reliability.

Difficulty Index

Difficulty Index =100 x (Sum of upper group score + Sum of lower group score)/Total No. Of students

Items whose difficulty index ranging from 0 – 0.099 (0% to 9%) are very hard. They need complete modification or replacement. Items whose difficulty ranging from 0.1 to 0.299 (10% to 30%) are difficult but are acceptable. Items whose difficulty index lies in range from 0.3 to 0.7 (30% to 70%) have good difficulty level. Items whose difficulty index ranging from 0.7 to 0.9 (70% to 90%) are easy. While, items whose difficulty index lies in range from 0.9 to 1.0 (90% to 100%) are very easy, they should be replace or revised completely (Aulia et al. (2014).

In this study, most of items are easy and moderate and a few like item no.18 & 31 were difficult with difficulty index of 0.28 and 0.25 respectively. Item no.1 is the easiest one with Difficulty index of 0.89. Detail of difficulty level of the item has been shown in the table

Table 4
Level of Difficulty of Items

Difficulty Level	No. of items
Very Difficult	0
Difficult	2
Average	64
Easy	10
Very Easy	0

Discrimination Power

Physics Achievement Test consisting of 75 items was administered on 376 science students of grade 9 in District Gujranwala in pilot testing, the researcher scored them and then ordered them according to their overall score with the help of Excel sheet, Then, the researcher took two groups, the Upper Group (top 188 scorers) and the Lower Group (188 low scorers), then, determined the sum of correct answers in both groups, then, calculated Discrimination Index of each item (Aulia et al., 2014).

Table 5
Standard Values of Discrimination Power for Quality of items

Statistics	Standard Range	Remarks about Item	Decision
Discriminating Power	-1 to 0	Poor Discriminator	requires complete modification/change
	0	No Discriminator	Requires change
	0 to 0.19	Acceptable quality Discriminator	Retain

	.2 to 0.34	good quality Discriminator	Retain
	Above than 0.35	Excellent Discriminator	Retain
Musa, Shaheen, Elmardi, & Ahmad (2018)			

If the difference between scores of both groups is greater, then item's power of discrimination will be greater and vice versa. Its value ranges from -1 to +1. If the value is near to +1, it indicates that item is a good discriminate of dull and the brilliant students

Table 6
Discrimination Power

Quality	No. of items
Poor	0
No	0
Acceptable	66
Good	9
Excellent	0

In present study, different values like sum of Top Scorers, Sum of Low Scorers, Discrimination Index and Difficulty Index were calculated as given in the table below

Table 7
Item wise statistics of Physics Achievement Test (PAT)

Item No.	Discrimination Index	Difficulty Index	Decision
1	0.11	89	Retained
2	0.12	32	Retained
3	0.18	43	Retained
4	0.13	38	Retained
5	0.24	45	Retained
6	0.17	36	Retained
7	0.12	49	Retained
8	0.15	48	Retained
9	0.16	30	Retained
10	0.21	51	Retained
11	0.13	81	Retained
12	0.13	73	Retained
13	0.16	42	Retained
14	0.16	30	Retained
15	0.13	60	Retained
16	0.15	47	Retained
17	0.11	33	Retained
18	0.20	28	Retained
19	0.14	68	Retained
20	0.18	55	Retained
21	0.17	43	Retained
22	0.12	48	Retained
23	0.14	52	Retained
24	0.12	37	Retained
25	0.18	74	Retained
26	0.13	57	Retained
27	0.10	63	Retained

28	0.13	57	Retained
29	0.18	66	Retained
30	0.22	68	Retained
31	0.21	25	Retained
32	0.14	47	Retained
33	0.10	48	Retained
34	0.22	55	Retained
35	0.13	79	Retained
36	0.10	69	Retained
37	0.21	35	Retained
38	0.15	44	Retained
39	0.16	51	Retained
40	0.13	42	Retained
41	0.17	48	Retained
42	0.11	34	Retained
43	0.14	38	Retained
44	0.14	58	Retained
45	0.14	40	Retained
46	0.13	73	Retained
47	0.16	34	Retained
48	0.18	63	Retained
49	0.12	31	Retained
50	0.20	59	Retained
51	0.12	57	Retained
52	0.15	36	Retained
53	0.14	52	Retained
54	0.18	57	Retained
55	0.16	63	Retained
56	0.16	67	Retained
57	0.15	48	Retained
58	0.15	47	Retained
59	0.10	34	Retained
60	0.11	52	Retained
61	0.13	49	Retained
62	0.16	35	Retained
63	0.18	71	Retained
64	0.11	57	Retained
65	0.11	73	Retained
66	0.14	55	Retained
67	0.19	68	Retained
68	0.11	56	Retained
69	0.15	73	Retained
70	0.11	38	Retained
71	0.14	69	Retained
72	0.22	65	Retained
73	0.16	78	Retained
74	0.11	57	Retained
75	0.19	64	Retained

Reliability Coefficient (ρ_T) of Physics Achievement Test (PAT)

The value of alpha points out the category of reliability of a test that is, low Reliable, average reliable and high reliable test.

Table 8
Standard Values for Reliability

Statistics	Alpha (α) Value	Remarks	Decision
Test Item Reliability (ρ_T)	0 – 0.400	Low	Not adequate Reliable
	.401 – .700	Average	adequate Reliable
	.701 – 1.000	High	Excellent

Aulia et al. (2014)

The reliability of the physics achievement Test was determined through MS Excel software by using following formula.

$$\rho_T = \frac{k}{k-1}\left(1 - \frac{\sum_{i=1}^{k}\sigma_i^2}{\sigma_X^2}\right).$$

Where,

K = No. of Items = 75

$\Sigma\,\sigma^2$ = Sum of Item Variance = 17.09

σ^2_X = Variance of total Scores = 184.7377

ρ_T= KR21 reliability coefficient = 0.919

In this study, the value of KR21 reliability coefficient obtained Physics Achievement Test (PAT) was 0.919. According to Aulia et al. (2014), the value of 0.919 is considered excellent for reliability of a test.

Conclusion and Recommendations

The primary objective of this research study was to develop and validate a test to measure conceptual understanding of 9th grade students in Physics. On the basis of results and statistics, Content Validity Ratio, Content Validity Index, Item Analysis and Reliability, Physics Achievement Test (PAT) can measure conceptual Understanding of 9th grade students. The Content Validity Ratio for each of the item was calculated which was found greater than 0.50 except item no, 34, 38, 58, 65, 66, 75, 76, 82 and 84 which were excluded from the test. Most of items were easy and moderate and a few like item no.18 & 31 were difficult with difficulty index of 0.28 and 0.25 respectively. Item no.1 is the easiest one with Difficulty index of 0.89. Discriminating Power of most of the items lies between 0.10 and 0.24 that point out that items were acceptable and good discriminators. The value of KR21 reliability coefficient was 0.919 that also verified the reliability of Physics Achievement Test (PAT). From the results and finding of above statistics, it is concluded that Achievement Test (PAT) is reliable and valid and suitable for use for summative and formative test.

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