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Construction and Standardization of Achievement Test in Mathematics for Prospective Elementary Teachers

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Abstract

Achievement tests are widely used for measuring learners' attainment in a specific subject area. Assessment of teachers' content knowledge can be measured through achievement tests based on the curriculum, including content for a particular level of education. This article deals with the construction and standardization of Achievement Test in Mathematics based on Diploma in Elementary Education curriculum for prospective teachers at the elementary level. It is based on Bloom's taxonomy levels of cognitive domain: Remembering, Understanding, Applying, and Skill-based. The study employed an instrumental research design and used purposive sampling for selection of the institution. The final semester of D.El.Ed. trainees of District Institute of Education & Training, Aizawl, Mizoram, 120 in number, were chosen to administer the test. Out of 51 preliminary draft items, 13 items were rejected, and 38 items were accepted. After selecting the 38 items, the reliability of the items was determined by using the split-half method. The investigator selected the D.El.Ed. trainees of DIET, Lunglei, Mizoram, to determine the reliability of the test. The reliability of the whole test was calculated to be 0.92. Based on the expert's judgment, it was determined that the test is valid and reliable for assessing the proficiency of the prospective teachers in mathematics. The study fills a significant gap in the availability of standardized mathematics achievement tests for prospective elementary teachers in Mizoram. The developed tool may be effectively used by teacher education institutions and researchers to assess mathematical proficiency and identify areas requiring academic support among D.El.Ed. trainees.

Keywords: Achievement, Mathematics, Achievement test in Mathematics, Mathematical Proficiency, Prospective Elementary Teachers, D.El.Ed. trainees

Introduction

Mathematics is a core subject in school education that contributes prominently to the development of logical reasoning, analytical thinking and problem-solving abilities among learners (National Council of Educational Research and Training [NCERT], 2005; Ministry of Human Resource Development [MHRD], 2020). ^[23, 19] As per the National Education Policy 2020. "Mathematics and mathematical thinking will be essential for India's future and India's leadership role in the numerous upcoming fields and professions that will involve artificial intelligence, machine learning, data science, etc." (MHRD, 2020). ^[19] Mathematics knowledge acquired through effective teaching of mathematical concepts at each stage (Ibrahim *et al.*, 2025). ^[15] The learning of mathematical concepts at the middle stage of school education is crucial as it lays the foundation for the secondary stage, which further leads students to choose their streams for higher education and contribute to research and development. Mathematics is the most vital subject due to its utilitarian and disciplinary value (NCERT, 2012), ^[24] yet most students lose their interest in mathematics after the elementary level (NCERT, 2005) ^[23] and study it only up to high school due to its consideration as a compulsory subject at that level of education. There are multiple interconnected factors responsible for this trend, including student-related issues such as low confidence, fear of failure, and negative past experiences (Finlayson, 2014;

Denhere, 2015),^[13, 9] teacher-related factors like ineffective teaching methods and teachers' own math anxiety also contribute significantly (Beilock & Maloney, 2015; Wani, 2020).^[5, 33] Family support, parental math anxiety, and societal stereotypes further shape students' attitudes toward mathematics (Dowker *et al.*, 2016; Sule, 2017).^[10, 29] Environmental pressures such as overcrowded classrooms, high-stakes assessments, and cognitive factors like learning disabilities and working memory overload also intensify negative attitudes towards mathematics (Ramirez *et al.*, 2018; Ablian & Parangat, 2022).^[27, 1]

Teachers at the elementary level are recruited to teach all school subjects irrespective of their stream at the higher secondary level of education; therefore, the level of mathematical understanding among prospective teachers may vary, and some of them may have anxiety towards mathematics. Teachers' own math anxiety can be reduced only if they have mastery of the mathematical content which they are supposed to teach at the particular level of education. Teachers' content knowledge, along with pedagogical knowledge, contributes a lot to developing interest among the students (Walia, 2022).^[32] It is important that elementary teachers possess adequate knowledge and understanding of mathematical concepts to develop interest among the students. The teachers for the elementary level are trained in the District Institute of Educational Training (DIET) for Diploma in Elementary Education (D.El.Ed.). This teacher education program aims to prepare prospective teachers with the necessary content and pedagogical knowledge required for effective teaching of each subject. Assessment of their content knowledge along with their pedagogical knowledge is equally important to take required measures. The level of mathematical achievement among prospective teachers often varies, and it should be assessed in a systematic and scientific manner.

Achievement tests are widely used for measuring learners' attainment in a specific subject area. An achievement test is a test designed to measure knowledge, understanding and skills in a specific subject or a group of subjects (Chourasia *et al.*, 2020).^[8] Any test that measures the attainments or accomplishments of an individual after a period of training or learning is called an achievement test (Downie, 1961).^[11] In the assessment of mathematics learning, a developed test that could measure an individual's knowledge or skills after a period of training on mathematical instruction is known as an achievement test in mathematics (Rani & Anisha, 2017; Ibrahim *et al.*, 2025).^[28, 15] Gronlund (1972) highlighted that achievement tests should be carefully aligned with instructional objectives and should include items representing different levels of the cognitive domain of learning.^[14] Ebel (1965) stressed that well-constructed tests must ensure appropriate content coverage and balanced item difficulty in order to produce reliable and valid results.^[12]

The present study was conducted in Mizoram, a northeastern state of India. There are eight DIETs across eleven districts. There is a specialization paper called 'Pedagogy of Mathematics' prescribed by the Mizoram Board of School Education (MBSE) in D.El.Ed. course, which has content on mathematical concepts up to the middle stage and pedagogical practices such as methods, strategies, skills, use of teaching learning resources, etc., as well. A standardized test is needed to assess the content and pedagogical knowledge of prospective teachers at the elementary level in all DIETs.

Rationale of The Study

A number of studies have been conducted on the construction and standardization of achievement tests in mathematics, emphasizing systematic procedure and statistical rigor. For instance, Walia & Walia (2016),^[31] Chourasia *et al.*,^[8] Chakravarthi & Padmanaban (2020),^[7] Baruah & Gogoi (2022),^[4] developed and standardized achievement tests in mathematics for eighth-grade students by following the required steps. Further, Rani & Anisha (2017),^[28] Kunwar (2018),^[18] Kumar (2019)^[17] and Afemikhe & Imasuen (2025)^[2] developed the achievement tests in mathematics for secondary school students, and found that their final test demonstrated acceptable levels of reliability and validity. Kunwar (2018) developed the test to assess the cognitive level of students in tenth-grade mathematics,^[18] whilst Rani and Anisha (2017) developed a test for ninth-grade students, specifically focused on Geometrical content in mathematics.^[28] Moreover, Prabakaran and Saravanakumar (2020) developed the test for assessing 'Set language' in mathematics of higher secondary school students,^[26] while Ibrahim *et al.* (2025) developed a standardized mathematics achievement test for measuring higher secondary school students' learning outcomes.^[15] The objective of the test construction is dependent on the content and level of education.

Review of the related literature revealed that several standardized achievement tests in mathematics for different levels of school education are available, which were developed to achieve one of the objectives of their research work; therefore, the content of the test is specific and may not be generalized to other research investigations. Although several achievement tests in mathematics have been developed for school students at different educational levels, very limited attention has been given to the assessment of mathematical proficiency among prospective elementary teachers. Moreover, there are no standardized tools specifically designed for prospective elementary teachers to assess their proficiency in mathematical concepts based on the D.El.Ed curriculum prescribed by MBSE for the context of Mizoram. This test will be helpful to assess their level of understanding and to identify areas requiring improvement. Hence, the present study attempts to address this gap by constructing and standardizing a valid and reliable Achievement Test in Mathematics (ATM) for prospective elementary teachers.

Objectives of The Study

The study was conducted with the following objectives;

1. To construct an Achievement Test in Mathematics based on D.El.Ed. Curriculum of MBSE for prospective elementary teachers.
2. To standardize the Achievement Test in Mathematics based on the D.El.Ed. Curriculum of MBSE for prospective elementary teachers.

Research Methodology

Method of the Study

The study employed an instrumentation research design, which was considered suitable because the research focused on developing a valid and reliable achievement test in mathematics to assess the levels of cognitive domain of the prospective teachers at the elementary level. According to Nworgu, instrumentation research design refers to a type of

research aimed at developing and validating the effectiveness of an instrument used to measure a specific behavior or construct.

Sampling

There are eight DIETs in Mizoram that offer courses such as Bachelor of Education, and Diploma in Elementary Education. All the D.El.Ed. students studying in the eight DIETs of Mizoram were considered the population of the study. Aizawl is the capital of Mizoram and the first district where DIET was established; therefore, DIET, Aizawl, was selected purposively to collect the data. There were 120 students enrolled in the course, who were selected as the sample of the study.

Test Construction Process

It comprises steps such as defining objectives, preparing items, their analysis, and the organization of selected items systematically. Further determining the validity, establishment of reliability, and norms are important steps under standardization. The steps are presented below;

Defining the Objectives of the Test

In order to ensure a balanced assessment of different levels of learning, the present achievement test was developed with reference to Bloom's Taxonomy of educational objectives. Originally proposed by Benjamin Bloom in 1956 (Bloom, 1956) [6], and later revised by Lorin Anderson and David Krathwohl in 2001, this framework classifies cognitive processes into hierarchical levels such as remembering, understanding, applying, analyzing, evaluating, and creating, progressing from lower-order to higher-order thinking skills (Anderson *et al.*, 2001) [3]. The taxonomy was used as a guiding framework in the present study to distribute test items across different cognitive levels, thereby ensuring that the test measures not only basic recall of knowledge but also deeper understanding and application of mathematical concepts. The test was developed on the basis of the levels of objectives: Remembering, Understanding, Applying, and Skill-based in the subject 'Pedagogy of Mathematics' under the final semester of D.El.Ed. Remembering and Understanding are considered the lower levels of achievement, whilst Applying and Skill-based are higher levels.

Planning and Writing of the Test Items

Initially, the investigators analyzed the syllabus of the paper 'Pedagogy of Mathematics' prescribed by the MBSE for fourth-semester students and identified the topics mentioned for the content knowledge of core mathematical concepts. Three units, consisting of Arithmetic, Algebra, Statistics, Linear equations, and Geometry, were selected to frame the items of the test.

Reviewing and Editing of the Test Items

A pool of 51 items was shown to the experts from schools and higher education. Five DIET lecturers, five faculty members from the Department of Education, Mizoram

University, and two from the Institute of Advanced Studies in Education and ten working middle school mathematics teachers within the Aizawl district were consulted for reviewing and editing the items of the test along with the answer key. Some of the items were reworded, modified, and corrected according to their suggestions. Corrections were made with regard to styles of questions, language and figures. After editing and reviewing, all the items were included for try-out. A total of 51 items was chosen from four areas of mathematics, assessing four levels of the cognitive domain. A total of 100 marks was allocated to them. The weightage to each level and content is presented in Figures 1 and 2.

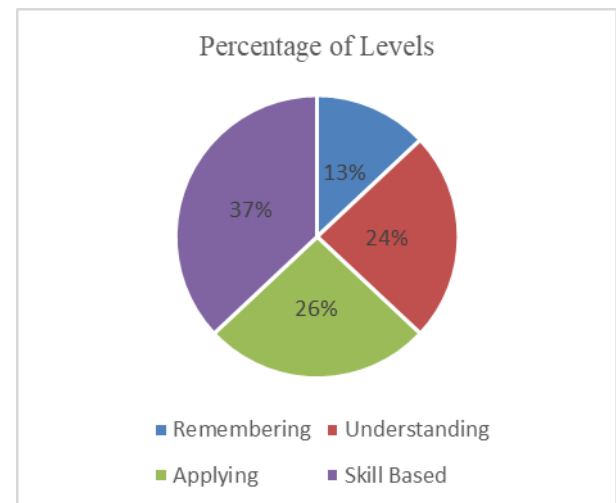


Fig 1: Weightage for different levels of Cognitive Domain in Preliminary Draft of ATM

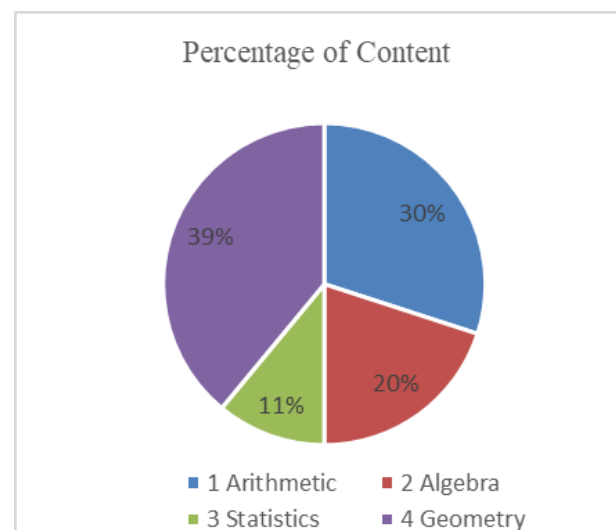


Fig 2: Weightage for different Content in Preliminary Draft of ATM

Four types of questions, viz., Multiple Choice, Very Short Answers, Short Answers and Long Answers were included in the test with different marking schemes.

Table 1: Types of Questions in Preliminary Draft of ATM

S. No.	Type of Questions	No. of Questions	Marks per Question	Total marks
1.	Multiple Choice (MCQs)	21	1	21
2.	Very Short Answer (VSA)	15	2	30
3.	Short Answer (SA)	11	3	33
4.	Long Answer (LA)	4	4	16
Total		51		100

Key of the test: The present ATM is a subjective type test; therefore, different scores were assigned to different types of questions. Table 1 indicates the scores assigned to each type of question. To ensure objectivity in scoring, an answer key and marking scheme were prepared in advance for all

subjective items included in the test.

Blue Print: Blue print considers the information regarding the contents and levels of the cognitive domain of the achievement test. Content-wise and level-wise distribution of items is presented in Table 2.

Table 2: Blue Print Achievement Test in Mathematics of Preliminary Draft)

Content Level	Remembering	Understanding	Applying	Skill Based	Total
Arithmetic	4	11	9	6	30
Algebra	2	8	0	10	20
Statistics	3	1	4	3	11
Geometry	4	4	13	18	39
Total Marks	13	24	26	37	100

Try Out

This step included two phases, i.e., small group try-out and final group try-out. For a small group try-out, six students of the fourth semester of D.El.Ed. from DIET, Aizawl were chosen to estimate the time taken to complete the test and first-hand information from the population about the difficulty level and language of the test items, if any. After the try-out, the investigator found that most of the students completed the test successfully within three hours, and no significant problem was observed during the test with respect to language. Then, the investigator kept the preliminary draft unchanged because the students finished answering the questions with no difficulty.

Final try-out was conducted at the end of April, because final year students of D.El.Ed. are supposed to cover the syllabus which is asked in the test. There was a total of 120 students who studied in the fourth semester of D.El.Ed. trainees (prospective elementary teachers). The test was administered on 108 prospective teachers, as 12 were absent at the time of the administration of the test. Notably, they received information about the test sixteen days in advance. The age group of students was between 19 and 28 years. Three hours were given and fixed for the duration of the test.

Administration of the Test

The test was administered in the Auditorium of DIET, Aizawl, collectively. Important information in relation to the administration of the test was announced clearly before administering the test. After that, test booklets were distributed among the students. The test booklets were collected after three hours. Students recorded their responses in the booklets. Items were scored in accordance with the answer key.

Item Analysis

Item analysis is a crucial step in the test development process. Tests can be upgraded by selecting, substituting, or revising the items. In terms of their content and their statistical properties, items can be analyzed qualitatively and quantitatively. Qualitative analysis focused on the considerations of face and content validity. Quantitative analysis principally takes in the measurement of item difficulty and item discrimination index. According to Kelly (1939), the discrimination index is best determined by comparing the upper and lower groups. Item difficulty is the indicator of the easy and difficulty level of an item. It is calculated by dividing the total number of respondents by the number of respondents who attempted the item correctly. The item difficulty and item discrimination index of each item are tabulated and presented in table 3. The range of acceptance of items for both criteria lies between 0.2 and 0.8 (Ebel, 1965).

The items' Difficulty Value (D.V.) and Discrimination Index (D.I.) were calculated using standard formulae.

Difficulty Value (D.V.) =

$$\frac{\text{No. of students with the correct answer}}{\text{Total no. students who attempted the questions}}$$

$$\text{Discrimination Index (D.I.)} = \frac{R_U - R_L}{N}$$

R_U = No. of correct responses of 27% of upper group students
 R_L = No. of correct responses of 27% of lower group students
 The upper- and lower-27 percent groups were selected for item analysis following Kelley's (1939) recommendation, as this method provides maximum differentiation between high and low achievers.

Table 3: Item Analysis of Preliminary Draft of ATM for Prospective Elementary Teachers

Item No.	D.V.	D.I.	Status	Item No.	D.V.	D.I.	Status
Item 1	0.91	0.09	Rejected	Item 27	0.70	0.35	Accepted
Item 2	0.74	0.35	Accepted	Item 28	0.80	0.15	Rejected
Item 3	0.87	0.18	Rejected	Item 29	0.60	0.35	Accepted
Item 4	0.73	0.32	Accepted	Item 30	0.70	0.24	Accepted
Item 5	0.71	0.00	Rejected	Item 31	0.70	0.32	Accepted
Item 6	0.69	0.35	Accepted	Item 32	0.70	0.47	Accepted
Item 7	0.89	0.00	Rejected	Item 33	0.70	0.53	Accepted
Item 8	0.72	0.32	Accepted	Item 34	0.40	0.59	Accepted
Item 9	0.74	0.38	Accepted	Item 35	0.50	0.62	Accepted
Item 10	0.70	0.32	Accepted	Item 36	0.10	0.15	Rejected
Item 11	0.90	0.00	Rejected	Item 37	0.40	0.76	Accepted
Item 12	0.84	0.03	Rejected	Item 38	0.40	0.68	Accepted
Item 13	0.71	0.32	Accepted	Item 39	0.40	0.76	Accepted
Item 14	0.73	0.35	Accepted	Item 40	0.30	0.24	Accepted
Item 15	0.74	0.32	Accepted	Item 41	0.30	0.62	Accepted
Item 16	0.88	0.00	Rejected	Item 42	0.20	0.35	Accepted
Item 17	0.90	0.06	Rejected	Item 43	0.30	0.79	Accepted
Item 18	0.75	0.35	Accepted	Item 44	0.20	0.68	Accepted
Item 19	0.73	0.44	Accepted	Item 45	0.30	0.76	Accepted
Item 20	0.82	0.00	Rejected	Item 46	0.30	0.71	Accepted
Item 21	0.69	0.32	Accepted	Item 47	0.20	0.53	Rejected
Item 22	0.70	0.38	Accepted	Item 48	0.30	0.79	Accepted
Item 23	0.72	0.24	Accepted	Item 49	0.10	0.32	Rejected
Item 24	0.74	0.32	Accepted	Item 50	0.20	0.56	Accepted
Item 25	0.80	0.20	Accepted	Item 51	0.20	0.26	Accepted
Item 26	0.72	0.35	Accepted				

Table 3 presents the D.V. and D.I. for each test item, which were calculated to determine their acceptance or rejection. Items selected for the final draft have difficulty values and discrimination indices ranging from 0.2 to 0.8. Thirteen items; item numbers 1, 3, 5, 7, 11, 12, 16, 17, 20, 28, 36, 47 and 49 were rejected, because they did not meet the requirements to be included in the final draft. Out of the 51 preliminary draft items, 13 items were rejected, and 38 items were accepted. Therefore, the final draft of the remaining 38 items was accepted and approved.

Final Draft of ATM

The items in the test were rearranged in the final draft in accordance with the content area sequences, weightage, marks and number of questions. The final draft has 38 items with a total score of 80 marks. Two and a half hours was the allotted time to finish the test. The following figures 3 and 4 show the weighting by level and content-wise.

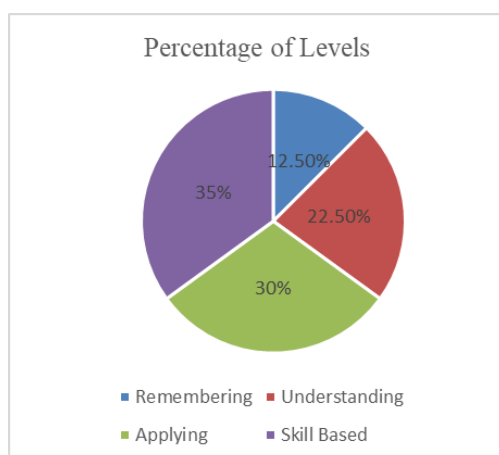


Fig 3:Weightage for different levels of Cognitive Domain in Final draft of ATM

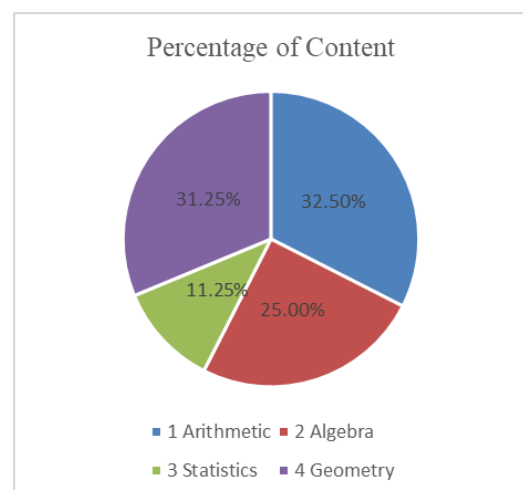


Fig 4: Weightage for different Content in Final draft of ATM

Standardization of The Test

The validity and reliability are the ultimate parameters of the standardization of the test's items so they are established.

Determination of Validity of the Test

Expert judgment was used to determine the content validity. To determine the test's content validity, investigators asked experts in the field of educational and mathematical research, as well as working middle school mathematics teachers, to examine the test items. As stated in "Planning and writing of the test items," step the investigators revised the test draft in response to their feedback.

Determination of Reliability of the Test

After selecting the 38 items, the reliability of the items was determined. The investigator selected the prospective teachers (D.El.Ed. trainees) of DIET, Lunglei, to assess the

reliability of the test. The final year trainees of D.El.Ed. at DIET, Lunglei, consist of 100 in number, and out of 100, 96 trainees participated in the test, because 4 trainees have dropped out.

The split-half method is one of the statistical methods used to determine the reliability of a test and to ensure internal consistency while minimizing administrative constraints. Following this method, the investigator divided the test into two equal halves, i.e., odd and even number items. The scores of each student were tabulated for each half separately. After that, the scores were correlated from both halves using a statistical method of Pearson's Correlation Coefficient, and the Spearman-Brown formula (Spearman, 1910) was applied to examine the reliability of the full test, as shown below:

The Spearman Brown Prophecy Formula is $R = 2r/1+r$

Where, r = Correlation coefficient

Pearson Coefficients of correlation of two halves (r)=0.85, therefore $R=0.92$

The calculated value of the reliability of the whole test is 0.92 which is positive and strong.

Based on the procedures followed and standards established for the mathematics achievement test, it was determined that the test was valid and reliable for assessing the proficiency of the prospective teachers at the elementary level.

Educational Implications

The standardized Achievement Test in Mathematics (ATM) can be used by teacher education institutions to evaluate the mathematical proficiency of prospective elementary teachers systematically. The tool may help educators to identify conceptual gaps among trainees and design remedial instructional strategies accordingly. It can also support researchers in conducting studies related to mathematics achievement, teacher competency, and mathematics anxiety in teacher education programs.

Conclusion

The present study successfully developed and standardized an Achievement Test in Mathematics (ATM) based on D.El.Ed. curriculum prescribed by MBSE for prospective elementary teachers. The test demonstrated satisfactory validity and high reliability, indicating its suitability for assessing mathematical achievement among D.El.Ed. trainees. The tool can assist teacher educators, institutions, and researchers in identifying the strengths and weaknesses of prospective elementary teachers in mathematical concepts and skills. Moreover, the test may contribute to improving mathematical teaching competencies at the elementary level by ensuring better assessment of teachers' content knowledge. Further studies may validate the test on larger and more diverse samples across different states and teacher education institutions.

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and validation of the Achievement Test in Mathematics. The authors also thankful to the authorities and students of DIET Aizawl and DIET Lunglei, Mizoram for their cooperation and participation in the study.

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