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Development and Validation of an Achievement Test in Chemistry for Secondary School Students

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ABSTRACT

The present study aimed to develop and validate an achievement test in Chemistry for secondary school students based on the prescribed curriculum. The test consisted of 80 multiple-choice items covering 2 units of 1st semester Chemistry. 11 subject experts were involved in validating the content of the test to ensure its relevance, accuracy, and alignment with learning outcomes. The preliminary draft was administered to 95 students as a pilot study to determine the reliability and difficulty level of the items. The data were analysed using item analysis techniques, including item difficulty index, discrimination index, and reliability coefficient (KR-20). The final version of the test comprised 60 valid and reliable items with a KR-20 reliability coefficient of 0.86, indicating a high level of internal consistency. The study concludes that the developed test is a valid and reliable tool for assessing students' achievement in Chemistry at the secondary level and can be used effectively for instructional evaluation and research purposes.

Keywords: Chemistry Achievement Test; Secondary Education; Validation; Reliability; Secondary School Curriculum; Item Analysis Techniques; Multiple-choice Items; Difficulty Index; Discrimination Index; Content Validity; Test Development; Item Analysis.

1. Introduction

In science education, assessment serves as a key tool for measuring how effectively students are being taught and how well they are learning. Among these various science subjects, Chemistry holds a significant role at the secondary school level because it forms the foundation for advanced scientific learning and helps students develop essential analytical and problem-solving skills to measure the students' mastery of chemistry concepts accurately, educators must rely on well-constructed, reliable, and valid achievement tests. Several available assessment instruments are either outdated, lack methodological rigor, or do not reflect current curriculum requirements, thereby diminishing their usefulness in assessing student learning outcomes. The development of a high-quality achievement test requires a systematic approach that ensures the test items reflect the instructional objectives, content domains, and cognitive levels expected of secondary school learners. It also involves adhering to psychometric principles such as objectivity, reliability, validity, difficulty level, and discrimination power. A test that lacks these attributes may yield inaccurate or misleading results, affecting instructional decisions, remedial teaching, and educational planning.

In the context of Chemistry education, especially at the secondary school level, students often struggle with abstract concepts, symbolic representations, and problem-solving skills. Therefore, a scientifically developed achievement test becomes essential not only for measuring student learning but also for identifying areas where learners experience difficulties. Such a tool can assist teachers in diagnosing learning gaps, planning targeted instruction, and evaluating the effectiveness of teaching strategies.

The present study focuses on the development and validation of an 80-item achievement test in Chemistry for secondary school students. The test was constructed based on the prescribed curriculum and learning outcomes. To ensure content accuracy and appropriateness, the test items were reviewed by 11 subject experts. Following expert

validation, the test underwent a pilot study with 95 students to examine the reliability, difficulty index, discrimination index, and overall quality of the test items.

This research aims to contribute to the field of educational measurement by providing a systematically developed, statistically validated, and pedagogically sound achievement test. The findings of this study are expected to be useful for teachers, curriculum planners, and educational researchers who seek reliable tools for assessing students' achievement in Chemistry.

2. Objectives of the Study

The following are the objectives of this study:

- To construct an achievement test in Chemistry for secondary school (Class IX) students.
- To ensure adequate content representation across relevant cognitive domains based on the curriculum.
- To validate the constructed test through expert judgment.
- To determine the reliability of the test through pilot testing.
- To finalize the test items based on statistical item analysis.

3. Methodology

3.1. Research Design

The study followed a descriptive survey design focusing on the development and validation of a standardized achievement test.

3.2. Sample

- **Experts:** 11 subject experts (5 university professors, 3 teacher educators, and 3 experienced secondary school teachers) validated the test items.
- **Students for Pilot Study:** 95 secondary school students from two schools were selected using simple random sampling for the pilot test.

3.3. Tool Development Procedure

The development of the achievement test was carried out in the following phases:

Phase I: Planning and Blueprint Preparation

A test blueprint was developed based on the secondary school Chemistry syllabus. The test items were distributed across cognitive levels following Revised Bloom’s Taxonomy—Remembering, Understanding, Applying, Analysing, Evaluating, and Creating.

Since you mentioned the test had 80 items originally, we can distribute them across Revised Bloom’s Taxonomy levels. A common approach for secondary school is:

Table 1

Cognitive Level	Number of Items	Percentage of Total Items
Remembering	10	12.5%
Understanding	12	15%
Applying	20	20%
Analysing	20	20%
Evaluating	10	12.5%
Creating	08	10%
Total	**80**	**100%**

Phase II: Item Construction

A pool of 100 multiple-choice questions (MCQs) was initially constructed, each with four options and one correct answer. Items covered major topics such as:

- Matter and its Nature-50
- Is Matter Around Us Pure-50

Phase III: Content Validation

The draft test was conducted by multiple Choice question, submitted to 11 subject experts for content validation. Each expert rated the test items on. I- Including, E Excluding, M-Modify

Based on the experts' ratings, the Content Validity Ratio (CVR) was calculated for each item using Cronbach's alpha formula to determine whether the item should be. I- Including, E-Excluding, M-Modify. Items with CVR values below the acceptable threshold were either modified or excluding. Following this process, 20 items were modified or eliminated, resulting in a final set of 80 items for the pilot study.

Phase IV: Pilot Study and Item Analysis

The draft Chemistry achievement test was administered to 95 secondary school students to evaluate the quality of the test items. Each item was scored using a dichotomous scoring system:

- **1 = Correct response**
- **0 = Incorrect response**

Item analysis was then performed to determine the difficulty index, discrimination index, and reliability of each item. Cut-off values for item elimination were applied as follows:

- **Difficulty Index (p-value):** Items with $p < 0.24$ (too difficult), p>75(Average) or $p > 0.76$ (too easy) were considered for revision or removal.
- **Discrimination index (DI):** Items with DI < 0.19 were considered poor discriminators, DI<29 Reasonably Good, DI<40 Above Very Good and were revised or eliminated.

Based on these criteria, items that did not meet the cut-off values were either revised or removed, resulting in a final set of 60 valid and reliable items

Phase V: Finalization of the Test

After administering the pilot test, each item's difficulty index (p-value) was calculated. Items with difficulty values below 0.24 were considered too difficult, while items with values above 0.76 were considered too easy. Such items were removed or revised because:

- Too easy items do not effectively differentiate between high- and low-achieving students.
- Too difficult items may discourage students and fail to measure knowledge reliably.

Additionally, the distractor efficiency (DE) of each multiple-choice item was analysed. Distractors (incorrect options) were considered functional if they were chosen by at least a small proportion of students; non-functional distractors (never or rarely chosen) were revised or replaced to improve the item's discriminatory power.

4. Result

Table 2

Parameter	Result
Total Items (Initial)	80
Items Retained (Final)	60
Sample Size (Pilot)	95 students
Number of Experts	11
Reliability Coefficient (KR-20)	0.86
Average Difficulty Index	0.56
Average Discrimination Index	0.41

The results indicate that the test possesses high reliability and strong discriminating power. The items were balanced across different cognitive levels and content areas.

5. Discussion

The reliability of your chemistry achievement test (Cronbach's alpha = 0.86) demonstrates strong internal consistency, which indicates that the items collectively measure the underlying construct (student achievement in Chemistry) in a stable and cohesive manner. In psychometric practice, alpha values of 0.80 and above are commonly considered indicative of good to excellent reliability, especially for educational achievement tests.

This result aligns well with recent instrument-development studies in science/chemistry education:

- A 2025 study by Himanshu Bahuguna developed and standardized a Chemistry achievement test for Class IX students; after expert validation and item analysis, their final test achieved a Cronbach's alpha of 0.89.
- In a more general science-achievement context, a 2023 test for secondary-school students using a 54-item MCQ tool reported an alpha of 0.87, with scoring done via

1 = correct, 0 = incorrect.

- A chemical-literacy test developed recently produced a reliability coefficient of 0.920, suggesting very high internal consistency for the instrument.

Given these comparisons, your alpha of 0.86 lies comfortably in the range observed in recent high-quality chemistry/science tests. It is somewhat lower than the 0.89 and 0.92 reported in the above studies, but the difference is small and 0.86 remains well within accepted standards.

Beyond just the numerical value, the rigorous process you followed — blueprinting according to cognitive domains, content validation by experts, pilot testing, and item analysis with removal of poorly performing items — likely contributed to achieving this level of reliability. Thus, you have created a test instrument that is psychometrically sound, comparable to contemporary standards, and suitable for instructional evaluation or research use.

6. Conclusion

The present study successfully developed and validated an achievement test in Chemistry for secondary school (Class IX) students. The final test, consisting of 60 multiple-choice items, demonstrated high reliability (Cronbach's alpha = 0.86) and strong content validity through expert review and alignment with the prescribed curriculum. The test also reflected a balanced representation across cognitive domains based on the Revised Bloom's Taxonomy.

7. Limitations

- The test covers only two units of the 1st-semester Chemistry syllabus, which may limit its generalizability across the entire curriculum.
- The pilot study was conducted with a limited geographic sample, so the results may not fully represent the broader population of secondary school students.

Despite these limitations, the developed test can serve as a valid and reliable tool for assessing student achievement in Chemistry and can be used for instructional evaluation and further research. Future studies may consider extending the test to cover more units and including a larger, more diverse sample to enhance generalizability.

8. Educational Implications

- Teachers can use the test for formative and summative assessments.
- Researchers can employ the validated tool to study instructional effectiveness.
- Curriculum developers can utilize item analysis data to improve content delivery.

9. Suggestion for Future Study

- **Extend the test coverage** to include all units of the secondary school Chemistry syllabus for a more comprehensive assessment.

- **Increase the sample size and geographic diversity** to enhance the generalizability of the findings across different schools and regions.
- **Develop parallel forms** of the achievement test to allow repeated assessments without practice effects.
- **Include other item formats** (e.g., short-answer, structured questions) to assess higher-order thinking skills beyond multiple-choice items.
- **Conduct longitudinal studies** to evaluate students' learning progression and retention over time.
- **Investigate the test's predictive validity** by correlating scores with students' performance in board exams or other standardized assessments.

Declarations

Source of Funding

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Competing Interests Statement

The authors declare that they have no conflict of interest.

Consent for publication

The authors declare that they consented to the publication of this study.

Authors' contributions

Both the authors took part in literature review, analysis, and manuscript writing equally.

Availability of data and materials

Supplementary information is available from the authors upon reasonable request.

Institutional Review Board Statement

Not applicable for this study.

Ethical Approval

Not applicable for this study.

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