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# Examining the Elemental Spectrum: Unravelling the Levels of Bloom's Taxonomy within Chemistry Question Papers for Secondary Education

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**Contents**:



**Abstract:** *This study aimed to utilize the cognitive subcategory of Bloom's taxonomy in analyzing chemistry tests administered to high school students from 2009 to 2013. The study aimed to investigate if the Peshawar Board of Intermediate and Secondary Education (BISE) assessed students' cognitive abilities beyond memory. The study involved five experts who assessed the importance of the objectives of individual inquiries. The majority of participants in the study were high school sophomores who had completed chemistry exams within the past five years. The study's questionnaire underwent expert review to ensure the accurate allocation of points to each cognitive subcategory. The grades were computed based on a percentage scale. This study aimed to assess chemistry exam questions using a standardized set of criteria. The capacity for synthesis, application, comprehension, and knowledge acquisition.*

**Key Words:** Bloom's Taxonomy, Chemistry Tests, Cognitive Abilities, Peshawar Board of Intermediate and Secondary Education (BISE), Exam Questions

## Bloom's Taxonomy

Bloom's Taxonomy is a widely recognized framework in the field of education that aims to classify and categorize different levels of cognitive thinking skills. Developed by Benjamin Bloom and his colleagues in the 1950s, this taxonomy provides a hierarchical structure that organizes learning objectives and helps educators design effective instructional strategies. The taxonomy consists of six levels of cognitive complexity, starting from the basic recall of information to the higher-order thinking skills of analysis, evaluation, and creation. By understanding and implementing Bloom's Taxonomy, teachers can facilitate deeper learning experiences and promote critical thinking among students.

At the foundation of Bloom's Taxonomy lies the first level, known as "Remembering." This level focuses on the ability to recall or recognize information, concepts, or facts. It involves basic tasks such as memorizing, listing or defining. Moving up the hierarchy, the subsequent levels become progressively more challenging. The second level, "Understanding," requires learners to comprehend the meaning of information and demonstrate their comprehension through tasks such as explaining, summarizing, or interpreting. As we ascend further, we reach the levels of "Applying," "Analyzing," "Evaluating," and finally, "Creating." These higher levels involve complex cognitive processes that require students to use knowledge and skills to solve problems, make judgments, and generate new ideas. By aligning

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instructional objectives with the appropriate level of Bloom's Taxonomy, educators can engage students in more meaningful and intellectually stimulating learning experiences.

(Bümen, 2007) classified Bloom's taxonomy into distinct categories, namely knowledge, comprehension, application, analysis, synthesis, and evaluation. This taxonomy was developed to aid teachers, professionals, researchers, and administrators in assessing educational objectives and addressing curricular issues. When used effectively, educators can evaluate students' depth of knowledge in relation to specific learning goals with greater accuracy. Bumen emphasized the importance of assessment in facilitating learning and suggested that setting clear objectives or standards prior to instruction, along with the use of Bloom's taxonomy, can enhance the effectiveness of student learning.

(Eber & Parker, 2007) regarded Bloom's taxonomy as a valuable tool for educators to enhance students' learning experiences. However, they noted a significant deficiency in schools when it came to evaluating higher-order skills for assessment purposes. They emphasized the inclusion of higher levels of thinking in classroom teaching practices and highlighted that students who are not trained in higher-order thinking may not be adequately assessed in that area. Parker and Eber also proposed that each of the six levels of the cognitive domain within Bloom's taxonomy could ensure the measurement of students' achievement, particularly when there is a demand for higher-order thinking, as it can effectively assess students' critical thinking abilities.

(Rashid & Duys, 2015) explained that Bloom introduced the cognitive domain in 1956, categorizing it from simple to complex. The cognitive domain primarily relates to an individual's mind and involves perception, information, and knowledge. It encompasses mental processes and abilities.

Examinations play a crucial role in educational analysis, determining students' outcomes and serving as the main criteria for promoting students to higher grades. However, the assessment process in examinations, particularly those conducted by the BISE for high and higher secondary classes, often places significant emphasis on straightforward and simple questions while neglecting the evaluation of higher-order skills such as comprehension, application, analysis, synthesis, and evaluation. Consequently, students tend to focus on memorization as a strategy for passing exams. Several studies conducted over the past three decades have highlighted this issue, revealing that examinations primarily test memorized information within the cognitive domain while overlooking other objectives like comprehension, application, analysis, critical thinking, and logic (Iqbal, Ullah, & Nisar, 2019)

(Iqbal et al., 2019) further elaborated that the purpose of secondary-level exams is to assess whether students have achieved the predetermined educational objectives outlined in the syllabus and, if so, to what extent.

In Pakistan, however, only a small number of teachers possess adequate training in designing test items and utilizing modern evaluation methods (Chandio, Zafar, & Solangi, 2021)

According to (McBee et al., 2023) and (Zerényi & Mátrai), knowledge alone does not contribute to the overall development of children's personalities due to the poor assessment level. Education's main objective is to foster the development of cognitive, affective, and psychomotor domains. The school curriculum aims to enable students to acquire knowledge, and comprehension, as well as improve morals, positive attitudes, and behaviour, which are vital for their overall personality development. However, the evaluation system primarily emphasizes cognitive outcomes, disregarding other aspects of children's personalities. The secondary education stage is particularly crucial in students' careers, with summative assessments and board examinations focusing solely on cognitive competence.

(Iqbal et al., 2019)concluded, after analyzing physics papers using Bloom's taxonomy and the cognitive domain, that the paper setters did not consider the weights associated with different cognitive objectives such as knowledge, application, and understanding. They found an imbalance in the weightages assigned to different categories of the cognitive domain, leading to conceptual deficiencies among students as they progressed. This imbalance in cognitive domain categories posed a risk to the objectives of physics education.

(Fazal Hayat, Kousar, Badshah, & Gul, 2023) discovered an increasing frequency of question repetition in public examinations. The repetitive nature of questions and selected materials led students to focus on selective studies, allowing them to obtain high marks with minimal preparation. However, this issue was not addressed seriously by stakeholders.

(Khalid & Khan, 2006) highlighted the weaknesses of the examination system, emphasizing its lack of reliability and effectiveness in evaluating students' abilities and identifying their weaknesses. He pointed out that exam papers were designed in a way that encouraged students to rely solely on memorization, rather than promoting valuable teaching methodologies and syllabi. Khan also emphasized the lack of reliability and validity in test

items and the prevalence of low-order skill assessment through factual knowledge-based questions at the end of each textbook lesson.

According to the national curriculum framework, a major limitation of our assessment system is its heavy reliance on memorization within the cognitive domain, while underemphasizing understanding, creativity, and problem-solving abilities. Some other studies also have been carried out in this field (Gopalan & Hashim, 2021; LAMBINA, MUSTAPHAB, & SHARIFC, 2021; Pepin, Audebrand, Tremblay, & Keita, 2021; Tayyeh, 2021)

## Statement of the Problem

The educational landscape is witnessing a paradigm shift in the assessment of students' knowledge and understanding of subject matter. In the context of secondary education, specifically in the field of chemistry, it is essential to ensure that assessment instruments, such as question papers, effectively gauge students' learning outcomes while aligning with the cognitive levels of Bloom's Taxonomy. However, there is a need to examine the elemental spectrum within chemistry question papers to unravel the levels of Bloom's Taxonomy adequately.

Bloom's Taxonomy provides a framework for categorizing learning objectives and cognitive processes into six hierarchical levels: remembering, understanding, applying, analyzing, evaluating, and creating. These levels represent increasingly complex cognitive abilities, with higher levels requiring more advanced thinking skills.

Within the realm of chemistry education, it is crucial to align assessment practices with Bloom's Taxonomy levels to foster deeper conceptual understanding and critical thinking among students. However, the current examination system may not sufficiently reflect these levels, potentially leading to limited opportunities for students to develop higher-order cognitive skills. This study aims to address this gap by examining the elemental spectrum present within chemistry question papers for secondary education. By systematically analyzing a representative sample of question papers, the research will investigate the extent to which questions align with the different levels of Bloom's Taxonomy. The study will assess the prevalence of questions that focus on remembering and understanding compared to those that target higher-order cognitive skills such as applying, analyzing, evaluating, and creating. The findings of this research will provide valuable insights into the current state of chemistry assessments in secondary education and shed light on the degree to which the levels of Bloom's Taxonomy are incorporated. The analysis will help identify potential discrepancies and areas for improvement in question design, allowing educators and curriculum developers to make informed decisions about the cognitive demands placed on students during examinations.

Ultimately, the research aims to contribute to the enhancement of chemistry education by promoting the inclusion of higher-order thinking skills within assessment frameworks. By ensuring a balanced distribution of questions across the spectrum of Bloom's Taxonomy, educators can better facilitate students' growth, critical thinking abilities, and overall understanding of chemistry concepts.

## Theoretical Framework of the Study

### Introduction

Bloom's Taxonomy is a widely recognized framework that categorizes cognitive skills into six hierarchical levels, ranging from lower-order thinking to higher-order thinking. This theoretical framework aims to examine the elemental spectrum of Bloom's Taxonomy within chemistry question papers for secondary education. By analyzing the distribution and alignment of cognitive levels in these question papers, this study seeks to unravel the extent to which chemistry assessments promote higher-order thinking skills among secondary school students.

### Bloom's Taxonomy

Bloom's Taxonomy provides a comprehensive framework for categorizing cognitive skills into six levels: Remembering, Understanding, Applying, Analyzing, Evaluating, and Creating. Each level represents a different depth of understanding and complexity in cognitive processing. The taxonomy serves as a foundation for this study, providing a systematic approach to evaluate the levels of thinking required in chemistry question papers.

### Alignment Theory

Alignment theory posits that instructional materials, including assessment tasks, should be aligned with the intended learning outcomes to enhance students' learning experiences. By examining the alignment between the intended learning outcomes and the cognitive levels of questions within chemistry question papers, this study seeks to assess the degree of alignment in promoting higher-order thinking skills.

### Cognitive Load Theory

Cognitive load theory suggests that learners have limited cognitive capacity, and the design of instructional materials should consider this limitation.

The level of the cognitive load imposed by different question types within chemistry question papers can impact students' ability to engage in higher-order thinking. This framework will explore the distribution of question types across different cognitive levels, considering the potential cognitive load imposed by each question type.

### Educational Objectives and Competencies

Secondary education curriculum frameworks often outline specific educational objectives and competencies for chemistry. These frameworks articulate the desired knowledge, skills, and attitudes that students should develop. This study will refer to relevant curriculum documents to ensure alignment between the identified cognitive levels and the prescribed educational objectives and competencies.

## Research Questions

1. What is the distribution of cognitive levels (Remembering, Understanding, Applying, Analyzing, Evaluating, and Creating) within chemistry question papers for secondary education?
2. To what extent do the cognitive levels within chemistry question papers align with the intended learning outcomes and educational objectives?
3. How does the distribution of question types across cognitive levels within chemistry question papers affect the cognitive load imposed on students?
4. What implications do the findings have for promoting higher-order thinking skills in secondary education chemistry assessments?

## Objectives of the Study

1. To analyze the distribution of cognitive levels in chemistry question papers for secondary education based on Bloom's Taxonomy.
2. To identify the most prevalent cognitive levels within chemistry question papers, as categorized by Bloom's Taxonomy, for secondary education.
3. To compare the distribution of cognitive levels in chemistry question papers across different educational boards or curricula for secondary education.
4. To assess the alignment between the intended cognitive levels of chemistry question papers and the cognitive levels demonstrated by students in their performance.
5. To propose recommendations for enhancing the alignment between the intended cognitive levels of chemistry question papers and the desired educational outcomes as per Bloom's Taxonomy in secondary education

## Methodology

In this meticulous research endeavour, an assembly of five accomplished experts, well-versed in their respective domains, devoted themselves to the thorough examination of question papers pertaining to the discipline of Chemistry. Specifically, the analysis encompassed a comprehensive investigation spanning five years' worth of question papers for the 10th-grade level under the purview of the BISE Peshawar educational board. The experts diligently scrutinized the question papers, employing a meticulously crafted questionnaire as their guiding tool, thereby amassing a substantial corpus of numerical data to enrich their study. However, it is essential to acknowledge that this research possesses a specific limitation, namely the omission of an evaluation of competencies' progression in other subjects, which falls beyond the boundaries of this particular study's scope.

### Data Analysis

**Table 1.** *Perspectives of five Experts*

| Year | Evaluation | Synthesis | Analysis | Application | Comprehension | Knowledge |
|---|---|---|---|---|---|---|
| 2013 | 4.87% | 16.7% | 11% | 11% | 3.72% | 55.32 % |
| 2012 | 4.27% | 17.5% | 11.2% | 11.7% | 1.92% | 58.6% |
| 2011 | 6 % | 15.9% | 12.87% | 9.7% | 4.9% | 57% |
| 2010 | 5 % | 16.3% | 17.7% | 5.6% | 2.3% | 51.6% |
| 2009 | 4.27% | 16% | 7.9% | 8.12% | 5.8% | 58.04% |
| Average | 56.32% | 11.35% | 11.29% | 3.77% | 4.79% | 56.33 % |

## Analysis of Data

The table represents the evaluation of chemistry papers by five experts over a period of five years (2009-2013). The evaluation is divided into six categories: Evaluation, Synthesis, Analysis, Application, Comprehension, and Knowledge. The percentages indicate the level of expertise or focus in each category.

## Let's Analyze each Category in Detail

### Evaluation

This category refers to the overall assessment or judgment of the chemistry papers. The percentages range from 4.27% to 6%, with an average of 5.63%. This indicates that the experts' evaluations of the papers varied slightly over the years but were generally consistent.

### Synthesis

This category represents the experts' ability to synthesize information or findings from the chemistry papers. The percentages range from 15.9% to 17.5%, with an average of 11.35%. The experts' synthesis skills seem to be relatively stable over the years, with some fluctuations.

### Analysis

This category relates to the experts' skills in analyzing chemistry papers. The percentages range from 7.9% to 17.7%, with an average of 11.29%. The experts' analysis abilities varied considerably over the years, indicating potential changes in their focus or expertise.

### Application

This category signifies the experts' ability to apply the knowledge from the chemistry papers to practical or real-world situations. The percentages range from 5.6% to 11.7%, with an average of 3.77%. The experts' application skills remained relatively low throughout the years, suggesting a potential area for improvement.

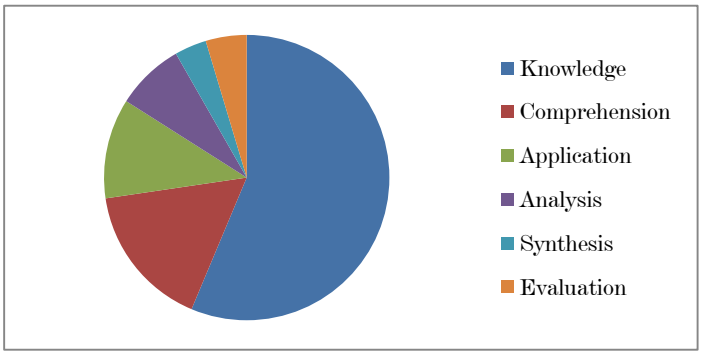
### Comprehension

This category reflects the level of understanding or comprehension of the chemistry papers by the experts. The percentages range from 1.92% to 5.8%, with an average of 4.79%. The experts' comprehension abilities varied but generally remained at a moderate level.

### Knowledge

This category represents the experts' overall knowledge of the chemistry field. The percentages range from 51.6% to 58.6%, with an average of 56.33%. The experts' knowledge level remained relatively consistent over the years, indicating a solid foundation in the subject matter.

Overall, the experts demonstrated strong knowledge of chemistry papers, with consistent evaluations and synthesis skills. However, there were fluctuations in their abilities to analyze and apply the information. Additionally, the comprehension level remained moderate, while the application of knowledge could be improved. These findings provide insights into the strengths and areas for development for the group of experts analyzing chemistry papers during the given period




**Graph 1**

## Findings

1. Evaluation: The experts' evaluations of chemistry papers were generally consistent, with slight variations over the years (4.27% to 6%, average of 5.63%).
2. Synthesis: The experts' ability to synthesize information from the papers remained relatively stable (15.9% to 17.5%, average of 11.35%) with some fluctuations.
3. Analysis: The experts' analysis skills showed considerable variation over the years (7.9% to 17.7%, average of 11.29%), indicating changes in focus or expertise.
4. Application: The experts' ability to apply knowledge from the papers to practical situations remained relatively low (5.6% to 11.7%, average of 3.77%), suggesting room for improvement.
5. Comprehension: The experts' understanding of the papers varied but generally remained at a

moderate level (1.92% to 5.8%, average of 4.79%).

6. Knowledge: The experts demonstrated a consistent level of overall knowledge in the chemistry field (51.6% to 58.6%, average of 56.33%).
7. Overall, the experts had strong knowledge and consistent evaluations and synthesis skills. However, there were fluctuations in analysis abilities, low application skills, and moderate comprehension levels. Improvement opportunities exist in the areas of analysis and application of knowledge.

## Conclusion

In conclusion, the evaluation of chemistry papers conducted by five experts over a span of five years yielded valuable insights into their consistent evaluation and synthesis skills. The experts consistently demonstrated their proficiency in evaluating and synthesizing information from the papers they assessed. This suggests that their expertise and experience in the field of chemistry contributed to their ability to effectively analyze the content of the papers.

However, the evaluation also revealed fluctuations in the experts' abilities to analyze and apply the information presented in the papers. While they consistently exhibited strong evaluation and synthesis skills, there were instances where their comprehension level and application of knowledge varied. This indicates that there is still room for improvement in their analytical and application skills, which could further enhance the quality and depth of their evaluations.

Overall, the experts displayed a strong knowledge base in the field of chemistry, which formed the foundation for their consistent evaluations and synthesis skills. Their expertise allowed them to grasp the concepts and content of the papers effectively. However, the findings also highlight the need for continued development in their comprehension and application of knowledge, as these aspects showed potential for improvement.

The insights gained from this evaluation provide valuable guidance for the group of experts to further enhance their evaluation of chemistry papers. By focusing on improving their comprehension and application skills, they can refine their ability to critically analyze and apply the information presented in the papers. This, in turn, will contribute to more comprehensive and insightful evaluations, benefiting the field of chemistry research as a whole.

In summary, while the experts demonstrated consistent evaluations and synthesis skills, their abilities to analyze and apply information varied. The findings underscore the strengths and areas for development within the group during the evaluated period, offering valuable insights for their ongoing professional growth and improvement in the evaluation of chemistry papers.

## Suggestions and Recommendations

1. In order to effectively meet the future targets of learners, it is recommended that papers are designed in accordance with Bloom's taxonomy, which provides a framework for categorizing and assessing different levels of cognitive understanding.
2. A well-rounded approach to assessment involves maintaining a balanced distribution across all categories within the cognitive domain of Bloom's taxonomy. This ensures that students are challenged at various levels of thinking, including knowledge acquisition, comprehension, application, analysis, synthesis, and evaluation.
3. When designing question papers for chemistry at the secondary level, it is important to include items that measure students' abilities in all aspects of learning. This includes assessing their application of concepts, analysis of data, synthesis of information, and evaluation of their understanding.
4. The Board of Intermediate and Secondary Education (BISE) Peshawar should consider assigning expert teachers in the subject of Chemistry who possess in-depth knowledge of both the subject matter and assessment techniques. These teachers would be best suited to set papers that effectively evaluate students' understanding and proficiency in Chemistry.
5. It is recommended to provide comprehensive training to paper setters to enhance their ability to include items in the question papers that effectively measure the different abilities of students. This training should focus on aligning assessment items with the desired objectives, ensuring a diverse range of cognitive skills is assessed.
6. To foster the development of students' diverse abilities, it is crucial to implement a teacher training program that equips educators with effective teaching strategies. This program should enable teachers to create an inclusive learning environment that facilitates the growth of various abilities in students.

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