# A review of the final and supplementary Grade 12 Physics examinations from 2014 to 2018 based on a modified Bloom's taxonomy.

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**Abstract**. The South African National Department of Basic Education (DBE) has associated the poor pass rate in the National Senior Certificate (NSC) Physical Sciences to the learners' lack of practical work and the inability to solve problems by integrating their knowledge from different topics in Physical Sciences. Given that the Curriculum and Assessment Policy Statement (CAPS) is central to the planning, organising and teaching of Physical Sciences, the poor performance in the Grade 12 Physical Sciences: Physics (P1) may be due to a disjointed alignment between the CAPS and the P1. A purposive sampling procedure included the CAPS Grades 10–12 Physical Sciences document; the Physical Sciences Examination Guidelines Grade 12 documents and the final and supplementary P1 examinations for the period starting November 2014 to March 2018. A summative content analysis research technique was conducted using the Surveys of Enacted Curriculum (SEC) research method. The SEC method employed the use of the four topics of Physics and the four non-hierarchical levels of cognitive demand as described in the modified version of Bloom's taxonomy. The results of this study indicated that the CAPS had a higher proportion of recall based content than the P1, the CAPS, and the P1 had approximately equal proportions of comprehension based content, the CAPS had a lower proportion of application and analysis based content than the P1, and the CAPS, as well as the P1, did not contain any synthesis and evaluation based content. In terms of Bloom's taxonomy, the CAPS may be classified as promoting lower order thinking skills, and the P1 may be classified as promoting higher order thinking skills.

## 1. Introduction

In the 1950s, Benjamin Bloom created a scheme of classification that categorised the levels of reasoning skills required by learners [1]. This taxonomy created a scheme of classification that categorised the levels of reasoning skills (cognitive demand) required by learners. The purpose of Bloom's taxonomy was to develop a system of codification that could be used by educators to design a hierarchical organisation of learning outcomes. Bloom's taxonomy has six cognitive demand levels (CDL), which are knowledge, comprehension, application, analysis, synthesis, and evaluation. Figure 1, adapted from Krathwohl [2] illustrates the cognitive levels in Bloom's taxonomy.

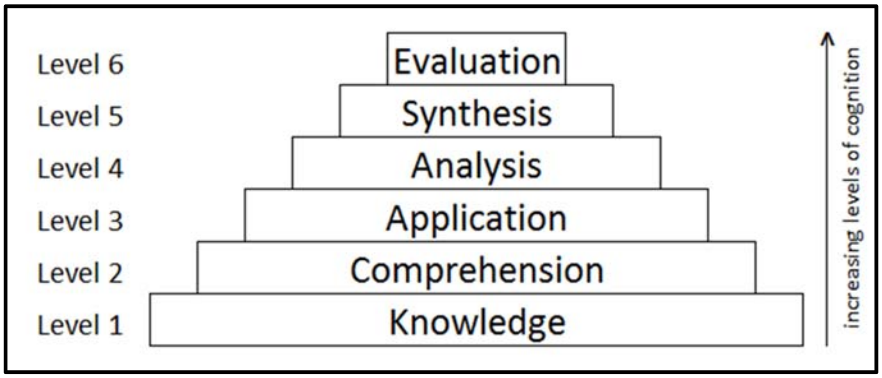


**Figure 1**. Cognitive demand levels in Bloom's taxonomy.

Wilson [3] defined the six levels of Bloom's taxonomy of the cognitive domain. In the knowledge level, a learner achieves information retrieval either by recognition or recall. In the comprehension level, a leaner assimilates new information by some form of communication. In the application level, a leaner applies gained knowledge to new conditions. In the analysis level, a learner detects relationships between the content and the source. In the synthesis level, a leaner creates new educational structures to assist in active communication. In the evaluation level, a leaner makes decisions about the significance of the knowledge gained.

Bloom's taxonomy is a hierarchical classification tool based on the presumption that learning is a sequential process, and the hierarchy presents a simple view of how learners understand information. The hierarchy further assumes that the levels in the hierarchy correspond to levels of thinking in which the higher levels of the taxonomy corresponds to higher order thinking skills, which are inherently more difficult than lower order thinking skills [4]. To overcome this flaw of the taxonomy, educators of Physical Science must promote learners to participate in higher order thinking tasks, starting at a low level of difficulty and increasing the level of difficulty by the learner's aptitude. The hierarchical taxonomy implies that learners are expected to understand concepts without requiring them to perform tasks involved in higher levels of the taxonomy, such as interpret, distinguish, relate, or question [4]. The hierarchical taxonomy leads to the argument that the learning of definitions in the exact words as described in the curriculum does not develop an understanding of the concepts in Physical Science.

Krathwohl [2] presented a revision to Bloom's taxonomy, which was verb based rather than noun based as it was in the original taxonomy. Figure 2, adapted from Krathwohl [2] and illustrated the two-dimensional nature of Bloom's revised taxonomy, the first being the cognitive dimension and the second being the knowledge dimension. There are six cognitive dimensions are remember, understand, apply, analyse, evaluate, and create. The four knowledge dimensions are factual, conceptual, procedural, and metacognitive.

| | Cognitive Dimension | | | | | |
|---|---|---|---|---|---|---|
| Knowledge Dimension | 1.Remember | 2. Understand | 3. Apply | 4. Analyze | 5. Evaluate | 6. Create |
| A. Factual knowledge | | | | | | |
| B. Conceptual knowledge | | | | | | |
| C. Procedural knowledge | | | | | | |
| D. Metacognitive knowledge | | | | | | |

**Figure 2**. Bloom's revised taxonomy.

The problem with the verb based taxonomy is a misconception that each verb explicitly describes the thinking involved in performing a task. An example of this is evident in the evaluate level of the taxonomy, being a level on its own implies that there are no evaluative components linked to any other level, which is not the situation [4]. The misconception that each level of the taxonomy is independent of each other is a flaw of Bloom's revised taxonomy.

The 2017 Grade 12 examination guidelines [5] uses a modified version of Bloom's revised taxonomy that comprises four cognitive levels. The four cognitive levels of the modified taxonomy are the recall, comprehension, application and analysis, and synthesis and evaluation levels. The application and analysis cognitive level is a combination of level three and level four of the original taxonomy. Likewise, the synthesis and evaluation cognitive level is a combination of level five and level six of the original taxonomy. Figure 3 illustrates a three-dimensional version of the modified taxonomy as used in this study. Unlike Bloom's original and revised taxonomies, the modified taxonomy is not hierarchical. The linear nature of the modified taxonomy is evident as a learner may be able to apply a principle (level 3) without having any degree of comprehension in it (level 2). Also, all the cognitive levels are in contact will every other cognitive level, illustrating the interdependence between them.

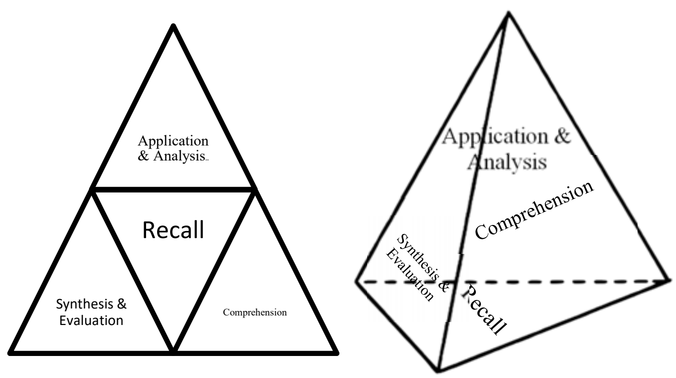


**Figure 3**. Cognitive demand levels in Bloom's modified taxonomy.

## 2. Literature review

Bloom's revised taxonomy is a framework that provides teachers with a tool to develop learning programs which meet learning objectives. The revised taxonomy enhances a teachers' understanding of the academic procedure, and a result of this teachers recognise complex cognitive development and how lower-level skills build into higher-order reasoning. Educational program demands are complex, and Bloom's taxonomy used as a framework can break these demands down into accessible chunks which can be utilised to guide daily lesson plans. Bloom's taxonomy can further be used as a checklist to ensure the proper analysis of the method of knowledge delivery (instruction); the method of evaluation (assessment) incorporates into proper lesson plans (curriculum). The instruction, assessment, and curriculum are the components of the education system and needs to be organised around a specific goal to be well-aligned.

An aligned education system implies that while the components each have their objectives, their interaction with each other must benefit the system as a whole [6]. Mhlolo & Venkat [7] explained that in aligned education systems, the components work independently to achieve individual objectives while also working as a group to achieve the goals of the system. Alignment within an education system is the degree to which the components are in agreement with each other [8]. Webb [9] stipulated that the alignment between the assessment component and the curriculum component is the degree to which they guide the learner to learn what they need to know.

Conventional analysis tools that measure the alignment between the curriculum and the assessment are sequential development, expert review, and content analysis. Sequential development analysis involves using the curriculum to develop each item of the assessment; this process results in "alignment by design" [10, p. 171]. The Expert review analysis involves the judgement of experts (subject experts, administrators, educators, parents or members of the public) that are conversant in the field of the content covered in the curriculum [11]. The expert review analysis requires an item by item review of each topic of the curriculum by the experts. Content analysis requires a subject domain and cognitive demand classification of the curriculum and assessment content [12]. The three frequently used methodologies that employ content analysis as a tool, is the Webb alignment method, the Achieve alignment method, and the Surveys of Enacted Curriculum (SEC) method.

The Webb alignment method investigates the dimensions of understanding which are, content focus, articulation across grades and ages, equity and fairness, pedagogical implications, and system applicability [9]. Each dimension comprises alignment criteria that were the outcome of US national and state alignment studies [9]. The content focus dimension comprises six alignment criteria which are categorical concurrence, depth of knowledge consistency, the range of knowledge correspondence, the structure of knowledge comparability, the balance of representation, and dispositional concurrence [9]. The articulation across grades and ages dimension includes two alignment criteria, which are cognitive soundness and increasing growth in knowledge during students' schooling [9]. The equity and fairness dimension incorporates the social construct of the education system [9]. The pedagogical implications dimension includes two alignment criteria, which are the engaging of students and effective classroom procedures as well as the use of materials, tools, and technology [9]. The system applicability dimension comprises the everyday application of systems within education [9].

The Achieve alignment method occurs in two steps; the first step involves confirmation of a test blueprint, a determination of the content and performance centrality, the evaluation of sources of challenge and the determination of cognitive demand levels [13]. The second step involves a complete evaluation of items matched to a central standard regarding the overall level of challenge, balance, and range [13]. The Achieve alignment method comprises five alignment criteria are content centrality, performance centrality, level of challenge, level of balance, and level of range.

The SEC alignment method classifies the content topic and cognitive demand level of the curriculum and the assessment. The matching of topics between the curriculum and the assessment is the categorical concurrence. The relative emphasis of the topic coverage between the curriculum and the assessment is the balance of representation. The relative emphasis of the cognitive demand between the curriculum and the assessment is the cognitive complexity. The SEC alignment method provides four alignment measures, which are the categorical coherence, balance of representation, cognitive complexity, and Porter's alignment index.

Porter's alignment index (AI) between the curriculum and the assessment is calculated using Porter's alignment equation. The AI ranges between zero to one with an AI of zero, indicating no alignment and an AI of one indicating perfect alignment [14]. The AI calculation requires two, dimensionally equal matrices (matrix X and matrix Y). One matrix represents the proportional data of the curriculum, and the other matrix represents the proportional data of the examination. The term $\sum_{i=1}^{n}|(X_i - Y_i)|$ in Porter's equation, represents the cell by cell non-intersects between the two matrices: the total difference of proportional data between the curriculum and the examination [15].

$$AI = 1 - \frac{\sum_{i=1}^{n}|(X_i - Y_i)|}{2}$$

$n$ refers to the total number of entries in each matrix;

$i$ refers to an integer from 1 to n;

$X_i$ refers to the $i^{th}$ cell of matrix X;

$Y_i$ refers to the $i^{th}$ cell of matrix Y;

$|(X_i - Y_i)|$ refers to the absolute difference between corresponding cells in each matrix;

$\sum_{i=1}^{n}|(X_i - Y_i)|$ refers to the sum of all the absolute differences matrix.

The Webb alignment method and the Achieve alignment method are used predominantly to gain greater insight into the subject coverage comparisons, while the SEC alignment method is used to gain an understanding of both, the subject content and the cognitive demand between the curriculum and the assessment [16]. This study used the SEC alignment method to determine the alignment between the CAPS and the P1. This study used the SEC alignment method rather than the Webb alignment method or the Achieve alignment method as it provides a quantitative measure of alignment by an understanding of the cognitive demand between the CAPS and the P1 based on one subject (Physical Sciences: Physics) in one grade (Grade 12), in the absence of any performance data.

Studies to evaluate the alignment between the curriculum and the assessment for Grade 12 Physics or equivalent have been conducted for New York, China, and Singapore [17], for the Guangdong, Hainan, Ningxia and Shandong Provinces in China [18], and for South Africa [16]. Table 1 shows the AI calculated by each of these studies.

**Table 1.** Global curriculum assessment alignment studies for Grade 12 Physics (or equivalent).

| Author | Location of study | AI |
|---|---|---|
| Liu, Zhang, Fulmer, Kim & Yuan [17] | New York State<br>Jiangsu Province China<br>Singapore | 0.80<br>0.67<br>0.67 |
| Guo, Xing, Xu & Zheng [18] | Guangdong Province China<br>Hainan Province China<br>Ningxia Province China<br>Shandong Province China | 0.38<br>0.30<br>0.25<br>0.27 |
| Edwards [16] | South Africa | 0.80 |

*Note*. AI, alignment index.

New York had a significant alignment between the curriculum and the examination while China and Singapore did not In the study by [17]. The reasons provided for the low alignment in China and Singapore was a shift towards higher order thinking skills in the examination that was not in the curriculum. A shift towards higher thinking cognitive skills in the examination could be the case for the alignment between the CAPS and the P1. The alignment indices for the Chinese provinces ranged between 0.27 and 0.38, which represented a low alignment between the curriculum and the examination. The reason provided for the lack of alignment was the introduction of a new curriculum [18]. A change of curriculum from NCS to CAPS in 2014, could be the case for the lack of alignment between the CAPS and the P1 November 2014.

The study based on South Africa was the first to quantify the alignment between the curriculum and the examination for Physical Sciences in the South African context [16]. The study included an analysis of the NCS curriculum, the Grade 12 Physical Sciences: Physics (P1) and NSC Grade 12 Physical Sciences: Chemistry (P2). This study analysed three examinations: P1 and P2 Exemplar 2008, P1 and P2 November 2008, and P1 and P2 November 2009. An average AI of 0.7830 for the alignment of the NCS and P1 was calculated [16]. Similar to the study in the Chinese provinces [18], this study also claimed that a low AI is not necessarily harmful if it is due to the examination questions containing a higher cognitive demand than the curriculum prescribes [16].

## 3. Theoretical framework

Bloom's taxonomy of learning objectives frames this study [1]. The breadth of the CAPS referred to the four Physics topics (PST) of the Grade 12 Physical Sciences: Physics. The depth of the CAPS referred to the degree of cognitive complexity of the content, concepts, and skills of the CAPS.

The Physics topics used in this study was adapted from the 2017 Physical Sciences Examination Guidelines Senior Certificate Grade 12 [5]. The four Physics topics were: Mechanics (PST1); Waves, Sound, and Light (PST2); Electricity and Magnetism (PST3); and Optical Phenomena (PST4).

Recall is the first cognitive demand level (CDL) and was coded CDL1. In CDL1, knowledge is acquired as disconnected facts by the method of rote learning [19]. A learner must be able to remember, recall, and restate facts and information [20] with relative ease. CDL1 assessment questions test the learners' ability to recall, recognise, reproduce, or execute basic physics knowledge related to the question [21]. CDL1 assessment questions required a correct answer without incurring a significant error. Thus an understanding of how the procedure works is not required [21]. Examples of P1 examination questions based on CDL1 are: Name the instrument used to measure potential difference; state Newton's law of universal gravitation; and define inertia.

Comprehension is the second cognitive demand level and was coded CDL2. In CDL2, the ability of learners to understand concepts in physics by integrating, identifying, and categorising characteristics of the assessment question [21]. Shao [22] referred to this understanding of assessment questions as the testing of procedures without any connections. Assessment questions based on CDL2 also involved the construction of an exact picture of the knowledge or a procedure needed to solve problems in physics [23]. Examples of P1 questions based on CDL2: Distinguish between the dependent and independent variables; use the graph and read off the velocity at t = 5 seconds, and classify the collision as elastic or inelastic.

Application and analysis is the third cognitive demand level and was coded CDL3. In CDL3, learners may have to modify known information in a manner suiting the requirements of the questions to solve problems within new situations. Assessment questions based on CDL3 involves the learner identifying relationships between the physics problem components and the categories of physics problems [21]. Assessment questions based on CDL3 tests the ability of learners to apply physics knowledge in solving problems and analyse concepts in physics. CDL3 based assessment questions include application as well as analysis type assessment questions. In CDL3 application type assessment questions, the learner applies knowledge and skills both in situations familiar and new and in CDL3 analysis type assessment questions, the learner makes a careful assessment of the question to obtain an answer [21]. Examples of P1 assessment questions based on CDL3: Calculate the final velocity of the trolley; draw a fully labelled free-body force diagram of the object; from given the displacement-time graph, sketch a corresponding velocity-time graph.

The fourth level of Bloom's modified taxonomy is synthesis and evaluation, which was coded CDL4. Assessment questions based on CDL4 involves the learner having the ability to utilise physics knowledge and not only be able to select but also explain the selection between two or more alternatives [21]. The learner must have the ability to solve problems by performing tasks, which may not be familiar or may require a complex solution, engaging a higher level of thinking and not just an application of conceptual or procedural knowledge.

## 4. Methodology

Document analysis is the most frequently used methodology to analyse the components (curriculum, assessment, and instruction) of an education system. Conventional methods of analysis include the Webb method [9], the Achieve method [24] and the SEC method [15]. The Webb method and the Achieve method provides for a better understanding of subject coverage comparisons. If an understanding of the content and cognitive levels are required, then the SEC method is most applicable [16]. Since an understanding of cognitive demand between the curriculum and the examination of one subject (Physical Sciences) in one grade (Grade 12) in the absence of any performance data was required, the SEC method was the most applicable. In this study, the alignment between the CAPS and the P1 required a quantitative measure of alignment, which was provided by integrating Porter's alignment tool with the SEC method. The sample of the study included the CAPS Grade 12 Physical Sciences document, four examinations guidelines Grade 12 Physical Sciences (Guidelines) from 2014 to 2017, four final Grade 12 Physical Sciences: Physics (P1) November examinations from 2014 to 2017, and four supplementary Grade 12 Physical Sciences: Physics (P1) March examinations from 2015 to 2018.

This study classified each item of the CAPS Physical Sciences: Physics, Guidelines, and the P1s according to the Physics topic and cognitive demand level. The classification process produced a CAPS Physical Sciences: Physics frequency matrix, Guidelines frequency matrix, and a P1 frequency matrix each having physics topics in the rows and cognitive demand in the columns. The CAPS Physical Sciences: Physics frequency matrix was added to the Guidelines frequency matrix to produce a CAPS frequency matrix. A cell wise division of each entry in the CAPS and P1 frequency matrices by the corresponding frequency matrix total produced the CAPS and P1 ratio matrices. The absolute difference between each entry in the CAPS ratio matrix and the corresponding entry of the P1 ratio matrix produced the absolute differences matrix. The matrix total of the CAPS – P1 absolute differences matrix was used in Porter's alignment equation to obtain Porter's alignment index.

Rater-effects affected the reliability of the document analysis. The consistency and the dependability of the document analysis were verified by computing an interrater reliability coefficient. This study used Cohen's kappa as a reliability test to calculate the interrater reliability coefficient. The overall kappa interrater reliability coefficient for the coding of the CAPS and the P1 was 0.88 which is higher than the 0.70 interrater reliability index reported by Porter [15] and which according to Coleman [25] is "almost perfect" reliability. This study adopted a list of verbs as described by Stanny [26] as the coding scheme. The coding method used substantive coding of items in instances of absent verbs.

## 5. Results

Table 2 shows the results of the Physics topic (PST) and cognitive demand level (CDL) classification of the CAPS. Table 3 shows the PST and CDL classification of the P1. From the data of Table 2 and Table 3, the PST absolute difference between the CAPS and the P1 was 32.7 percent. The measure of the relative emphasis of Physics topic coverage was, therefore (100 – 32.7) 63.7 percent. From the data of Table 2 and Table 3, the CDL absolute difference between the CAPS and the P1 is 20.4 percent resulting in a cognitive demand coverage of (100 – 20.4) 79.6 percent.

**Table 2**. CAPS (2014 – 2017) topic and cognitive classification.

| | Recall | Comprehension | Application & Analysis | Synthesis & Evaluation | Total (%) |
|---|---|---|---|---|---|
| Mechanics | 225 | 130 | 299 | 0 | 58 |
| Waves, Sound & Light | 16 | 20 | 12 | 0 | 4 |
| Electricity & Magnetism | 108 | 64 | 165 | 0 | 30 |
| Optical Phenomena | 32 | 42 | 8 | 0 | 7 |
| Total (%) | 34 | 23 | 43 | 0 | 100 |

**Table 3**. P1 (2014 – 2017) topic and cognitive classification.

| | Recall | Comprehension | Application & Analysis | Synthesis & Evaluation | Total (%) |
|---|---|---|---|---|---|
| Mechanics | 32 | 39 | 109 | 0 | 42 |
| Waves, Sound & Light | 17 | 13 | 14 | 0 | 10 |
| Electricity & Magnetism | 35 | 40 | 81 | 0 | 36 |
| Optical Phenomena | 18 | 11 | 20 | 0 | 11 |
| Total (%) | 24 | 24 | 52 | 0 | 100 |

The term $\sum_{i=1}^{n}|(X_i - Y_i)|$ in Table 4 is equal to the CAPS – P1 absolute differences matrix total. This value is substituted into Porter's alignment equation to calculate the alignment index.

**Table 4**. Alignment index between CAPS and P1 (2014 – 2018)

| Examination | $\sum_{i=1}^{n}|(X_i - Y_i)|$ | AI |
|---|---|---|
| November 2014 | 0.5420 | 0.7969 |
| March 2015 | 0.4956 | 0.8107 |
| November 2015 | 0.4296 | 0.7200 |
| March 2016 | 0.5762 | 0.7119 |
| November 2016 | 0.4296 | 0.7852 |
| March 2017 | 0.4821 | 0.7590 |
| November 2017 | 0.4327 | 0.7837 |
| March 2018 | 0.4536 | 0.7732 |
| Average | | 0.7676 |

## 6. Discussion of results

Table 4 shows the lowest AI (0.7119) occurred between the CAPS and the March 2016 P1 and the highest AI (0.8107) occurred between the CAPS and the November 2015 P1. The average AI between the CAPS and the final P1s (0.7715) was higher than the average AI between the CAPS and the supplementary P1s (0.7637)

Regarding Blooms' taxonomy, the data of Table 4 shows that firstly, the CAPS (34 percent) has a higher CDL1 (recall) than the P1 (24 percent). The CAPS contains recall information such as definitions and concepts, which the P1 does not directly test to the same degree. Decreasing the definitions and concepts within the CAPS is one method of increasing the alignment between the CAPS and the P1. The CAPS need only refer to these definitions and concepts in the prescribed textbooks. Secondly, CDL2 (comprehension) of the CAPS (23 percent) and the P1 (24 percent) are approximately equal. Thirdly, CDL3 (application and analysis) of the CAPS (43 percent) is lower than the CDL3 of the P1 (52 percent). The CAPS does not contain enough references to the application and analysis type questions in the P1. The CAPS does not reflect the application and analysis based questions of the P1.

Further, the P1 tests the ability of learners to analyse problems and apply solutions to these problems, not testing learner's knowledge on the understanding of concepts. Fourthly, the is no synthesis and evaluation in the CAPS and the P1, which was also the result found by Mothlabane [27]. An analysis of the data showed that the CAPS promoted lower order thinking skills, while the P1 promoted higher order thinking skills [28], and is the source of the misalignment between the CAPS and the P1.

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