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The Cognitive Complexity of Technical Sciences: An Analysis Using the Depth-of-Knowledge Level Scheme

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Abstract. This study examines the content complexity of Technical Sciences through the Depth-of-Knowledge (DOK) Level Scheme to provide a nuanced understanding of how cognitive demands influence student learning and instructional strategies. Using a quantitative research design and a systematic content analysis approach, the study evaluates the DOK levels embedded in Technical Sciences curricula, instructional resources, and assessment tools. The research focuses on categorizing Technical Sciences topics across the four DOK levels: recall and reproduction, skills and concepts, strategic thinking, and extended thinking. Data were collected from educational materials across various contexts and analysed to identify patterns in content complexity. The findings reveal a heterogeneous distribution of DOK levels, with some topics requiring higher-order thinking skills while others emphasize foundational knowledge. Significant discrepancies in the application of DOK levels across educational contexts were observed, underscoring the need for a consistent framework in curriculum design. The study highlights the implications for educators and curriculum developers, emphasizing the importance of integrating higher DOK levels into instructional practices to foster learners' critical thinking, problem-solving abilities, and deeper conceptual understanding. Recommendations include adopting DOK-aligned teaching strategies in Technical Sciences and conducting further research to explore the relationship between content complexity and student achievement. By addressing these gaps, the study contributes to ongoing efforts to enhance educational outcomes and promote a more rigorous and relevant Technical Sciences curriculum.

Keywords: Bloom's taxonomy; cognitive level; content complexity; depth-of-knowledge level scheme; technical sciences

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1. Introduction

The Depth-of-Knowledge (DOK) framework, introduced by Webb (1999), provides a tool for categorizing the cognitive complexity of curriculum content, instructional tasks, and assessment practices. Unlike other models, such as Bloom's Taxonomy, the DOK framework focuses on the depth of understanding required to successfully complete a task, encompassing four distinct levels: Recall and Reproduction (Level 1), Skills and Concepts (Level 2), Strategic Thinking (Level 3), and Extended Thinking (Level 4). These levels serve as a lens for evaluating the alignment between curriculum expectations, classroom instruction, and assessment practices, particularly in disciplines such as Science and Mathematics.

The growing emphasis on fostering critical thinking and problem-solving skills in science education has highlighted the importance of exposing learners to tasks requiring higher-order cognitive engagement (Fontno & Williams, 2019). International assessments, such as the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA), have consistently demonstrated the positive impact of incorporating high-complexity tasks on student achievement. In the South African context, the Curriculum and Assessment Policy Statement (CAPS) emphasizes the development of these skills (Department of Basic Education, 2011), yet there is limited research on the extent to which Technical Sciences curricula, instructional resources, and assessments align with these cognitive demands.

Existing studies on DOK application in education have primarily focused on general alignment between content standards and assessment practices, with limited attention to specific subjects such as Technical Sciences. For example, Zhao et al. (2023) explored assessment alignment strategies but did not delve into the unique complexities of Technical Sciences. Moreover, recent studies have called for a closer examination of content complexity frameworks, such as DOK, to ensure they address the cognitive requirements of increasingly specialized and technical subjects (Alonzo & Gearhart, 2020; Fontno & Williams, 2019).

This study addresses these gaps by applying the DOK framework to evaluate the alignment between CAPS performance statements and grade 11 Technical Sciences examinations. Specifically, it seeks to identify the distribution of DOK levels in curriculum documents, instructional materials, and assessments, providing insights into how well they support learners' critical thinking and problem-solving abilities. By exploring these dimensions, the research aims to inform curriculum developers and educators about strategies for integrating higher DOK levels into Technical Sciences instruction. Through this investigation, the study contributes to the broader discourse on content complexity in science education, offering a nuanced understanding of the cognitive demands of Technical Sciences. It also underscores the potential of the DOK framework to enhance alignment between curriculum goals and assessment practices, ultimately promoting educational equity and improved learning outcomes.

2. Background to the Study

Student performance in science has become a critical concern globally, with far-reaching implications that extend beyond education into economic development. Effective science teaching and learning focus on fostering scientific thinking both individually and collectively (Nsengimana et al., 2020). This approach recognizes that learners bring prior knowledge to lessons, which can be refined into scientifically accurate concepts through strategies such as cognitive conflict. Effective science education depends on the active engagement of both learners and teachers, grounded in relevant scientific concepts. One strategy to facilitate this process is the "Think-Write-Share" approach, proposed by Nsengimana et al. (2020), which encourages learners to think critically, write down their ideas, and share them with peers or instructors. Implementing this strategy across Sub-Saharan Africa aims to improve student performance in science, as teachers are encouraged to move from simple problem-solving to tackling more complex, open-ended challenges that promote discussion and critical thinking (Hassan et al., 2022).

International assessments, such as the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA), provide opportunities for comparing student performance across countries (OECD, 2018). South Africa, as part of the BRICS (Brazil, Russia, India, China, and South Africa) group, is recognized as one of the world's significant economies. South Africa's trade structure and the skill composition of its labour force are more aligned with middle-income countries (Kuehn, 2019). Technical and Vocational Education and Training (TVET) play a pivotal role in equipping the workforce with skills essential for sustainable economic development (Varma & Malik, 2024). Meeting labour market needs through education enhances employability and fosters a skilled workforce (Kuehn, 2019). The introduction of Technical Sciences in South African schools aims to address this educational need and improve the lives of its citizens (Department of Basic Education, 2014).

Research across Sub-Saharan Africa highlights a persistent issue of low-quality teaching and learning in science, often attributed to stagnant teaching practices (Nsengimana et al., 2020). In South Africa, this may result from the transition from the National Curriculum Statement (NCS) to the CAPS. Many teachers still rely heavily on traditional lecture methods, despite recent efforts to integrate smart boards into classrooms, particularly in Gauteng (Schwerdt & Wuppermann, 2011). However, gaps remain between the intended and implemented curricula for Technical Sciences, which necessitates the enhancement of both pre-service and in-service training programs (Pallikkara et al., 2022). Establishing institutional communities of practice and "laboratories" within schools would provide opportunities for science teachers to collaborate, share strategies, and address common challenges (Nsengimana et al., 2020).

Another crucial aspect in these countries is the incorporation of tasks with high content complexity, emphasized in frameworks like Bloom's taxonomy, which categorizes cognitive tasks from simple to complex. The original Bloom's taxonomy included six major categories: Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation (Krathwohl, 2002). The revised Bloom's taxonomy has shifted from a strictly hierarchical model to a more dimensional framework, allowing teachers to enhance assessments and engage learners in higher-order thinking skills (Lourdusamy et al., 2022).

Understanding content complexity is vital when designing student tasks and crafting effective instructional experiences. DOK level content complexity scheme provides a valuable framework for analysing the alignment between educational assessments and expected learning outcomes (Webb, 1999). By leveraging this scheme, teachers can ensure that their instructional practices adequately challenge learners and promote deeper scientific understanding.

3. Literature Review

3.1 Different Levels of DOK

Webb's (1999) DOK framework provides a detailed and systematic way to assess content complexity within educational tasks. Unlike other educational taxonomies, such as Bloom's Taxonomy or Marzano's Dimensions of Thinking, DOK is specifically task-oriented and subject-specific. It categorizes cognitive demand into four distinct levels, each reflecting an increasing complexity in the type of knowledge and cognitive engagement required for a given task. In the context of Technical Sciences, these levels help educators design tasks that progressively challenge students and encourage deeper learning. Below, each of the DOK levels is discussed in relation to its relevance to the field of Technical Sciences.

3.1.1 *DOK Level 1: Recall and Reproduction*

DOK Level 1 focuses on the recall and reproduction of basic facts, definitions, and procedures. This level involves tasks that require minimal cognitive effort as students are asked to retrieve information that has been previously learned. In Technical Sciences, tasks at this level might include identifying components of a hydraulic system, recalling key principles of mechanics, or performing simple measurements. While these tasks are foundational to learning, they do not require higher-level thinking or complex problem-solving. They serve as the building blocks upon which more complex tasks are developed, helping students establish a solid understanding of core concepts and terminology.

3.1.2 *DOK Level 2: Skills and Concepts*

At DOK Level 2, learners are required to apply their knowledge and skills in more sophisticated ways. Tasks at this level often involve multi-step procedures and require students to make decisions based on their understanding of concepts and principles. In Technical Sciences, this might involve classifying mechanical systems, interpreting experimental data, or explaining the relationship between different components in a machine. Students must go beyond simple recall and engage with content at a deeper level, making connections between concepts and applying their skills to solve problems. This level fosters the ability to use learned knowledge in practical, real-world situations, preparing students for more complex cognitive challenges.

3.1.3 *DOK Level 3: Strategic Thinking*
DOK Level 3 emphasizes higher order thinking skills, including critical reasoning and problem-solving. At this level, students must engage in strategic thinking, where they analyse and synthesize information to address complex questions or problems. In Technical Sciences, tasks might involve designing experiments to test the efficiency of mechanical systems, justifying decisions based on evidence, or proposing solutions to problems that require consideration of multiple factors. These tasks necessitate a higher level of abstract thought, as students must not only apply their knowledge but also evaluate alternatives, make reasoned arguments, and use evidence to support their decisions. DOK Level 3 tasks encourage students to think critically and strategically, preparing them for real-world challenges that require nuanced problem-solving abilities.

3.1.4 *DOK Level 4: Extended Thinking*
DOK Level 4 represents the highest level of cognitive demand and involves extended thinking across disciplines. Tasks at this level require students to synthesize and apply knowledge from various areas, often involving long-term projects, detailed planning, and the integration of multiple concepts. In Technical Sciences, an example might be designing a multi-disciplinary project that incorporates principles of Mechanics, Electricity, and Materials. This could involve extensive data analysis, experimentation, and the formulation of solutions to complex problems. At this level, students must demonstrate a deep understanding of the subject matter, integrating diverse ideas, and applying them in creative and practical ways. DOK Level 4 tasks encourage students to think innovatively, solve complex problems, and develop solutions that are both comprehensive and sophisticated.

In summary, Webb's (1999) DOK framework offers a structured approach to understanding and assessing the cognitive demand of tasks within the Technical Sciences curriculum. By moving from basic recall to complex problem-solving and interdisciplinary synthesis, the framework ensures that students are challenged at each stage of their learning. Through carefully designed tasks at each DOK level, educators can foster a deeper, more integrated understanding of technical concepts and help students develop the critical thinking and problem-solving skills necessary for success in their field.

3.2 Empirical Insights into DOK in STEM Education

The DOK framework, introduced by Webb (1999), has emerged as a valuable tool for enhancing teaching and learning in Science, Technology, Engineering and Mathematics (STEM) education. By categorizing tasks into four levels of cognitive demand, the DOK framework encourages educators to design activities that foster critical thinking, deepen understanding, and prepare learners to address real-world complexities. These levels range from basic recall of facts (Level 1) to extended thinking that requires synthesizing information across disciplines (Level 4).

The application of DOK levels in STEM education has shown promise in fostering higher-order thinking skills among learners. Empirical studies demonstrate that instructional tasks aligned with higher DOK levels (Levels 3 and 4) significantly enhance cognitive engagement and encourage learners to think analytically, evaluate evidence, and solve problems in innovative ways. For instance, Nsengimana et al. (2020) found that integrating DOK into science curricula led to improved learner performance, particularly in inquiry-based activities that require students to formulate hypotheses, analyse data, and draw evidence-based conclusions. Such tasks not only promote mastery of content knowledge but also cultivate 21st-century skills such as critical thinking, collaboration, and creativity—essential competencies in STEM fields.

Another strength of the DOK framework lies in its ability to align instructional tasks with curriculum goals and real-world applications (Masharipova, 2024). By leveraging DOK levels, educators can create learning experiences that reflect the complexity and interconnectivity of STEM disciplines. For example, a Level 4 task in physics might involve designing and testing a renewable energy prototype, requiring learners to integrate knowledge from physics, engineering, and environmental science. This approach ensures that students not only acquire theoretical knowledge but also understand its practical implications in addressing global challenges, such as climate change and sustainable development.

Despite its potential, the effective implementation of DOK in STEM education is not without challenges. Teacher preparedness is a critical factor, as designing and delivering DOK-aligned tasks often require a deep understanding of the framework and its application in diverse classroom contexts (Allee & Castner, 2025). Many teachers lack adequate professional development opportunities to build this expertise, resulting in tasks that remain focused on lower DOK levels, such as rote memorization and basic comprehension (Zindi, 2024). Moreover, curriculum alignment poses another challenge, as existing STEM curricula may not always support the integration of higher DOK levels, particularly in under-resourced schools where access to advanced instructional materials and technology is limited (Joseph & Nwankwo, 2024).

The integration of DOK levels into STEM education offers a powerful mechanism for fostering critical thinking, promoting cognitive engagement, and aligning learning experiences with real-world complexities (Ammar et al., 2024). While the potential benefits are evident, addressing challenges related to teacher preparedness and curriculum alignment is essential for maximizing the impact of DOK-based instruction (Lumapenet et al., 2023). Future research and professional development initiatives should focus on equipping teachers with the skills and resources needed to implement the framework effectively, thereby ensuring that STEM education continues to empower learners with the knowledge and competencies required for success in an increasingly complex world.

3.3 Defining Technical Sciences

Technical Sciences bridges the theoretical and practical aspects of STEM education, specifically tailored to Mechanical, Electrical, and Civil Technology fields. Unlike Physical Sciences, which emphasize theoretical understanding, Technical Sciences integrate practical applications, fostering skills relevant to real-world engineering challenges (Moloi & Motlhabane, 2023). Key Knowledge Areas in Technical Sciences:

- Matter and Materials: Foundational knowledge on properties of materials.
- Mechanics: Core concepts such as forces, motion, and energy.
- Electricity and Magnetism: Application of electrical principles.
- Heat and Thermodynamics: Understanding energy transformations.

Mechanics, the focus of this study, represents the most substantial portion of the Technical Sciences curriculum, progressively advancing in complexity from Grade 10 to Grade 12. The practical assessment tasks (PATs) in Technical Sciences play a pivotal role in contextualizing theoretical concepts. However, learners often struggle with the theoretical content due to its perceived lack of relevance to practical applications (Department of Basic Education, 2014).

4. Conceptual Framework

The conceptual framework for this study merges Webb's (1999) DOK framework with the Technical Sciences Mechanics curriculum, providing a structured approach to enhance both the teaching and learning experience in Mechanics. This framework focuses on three key aspects that address the alignment of curriculum goals, the application of theory to practice, and the promotion of cognitive complexity in student learning.

4.1 Alignment of DOK Levels with Curriculum Goals

A fundamental aspect of this study is the alignment between DOK levels and the specific knowledge areas within the Mechanics curriculum. Webb's (1999) DOK framework categorizes tasks based on cognitive complexity, ranging from basic recall and application to higher-order critical thinking and problem-solving. In this context, the study ensures that each component of the curriculum is mapped to an appropriate DOK level, thereby guaranteeing that instructional tasks reflect the cognitive demands outlined in the curriculum. This alignment is crucial because it ensures that learners engage with content at an appropriate level of difficulty, which is essential for mastering complex concepts in Mechanics.

4.2 Bridging Theory and Practice

The second key component of the framework is the connection between theoretical knowledge and practical application. By integrating DOK levels with practical tasks, particularly in PATs, the framework supports students in applying the theoretical knowledge they have acquired to real-world scenarios. This is essential in Technical Sciences, where students need to not only understand theoretical principles but also apply them to solve practical problems. By ensuring that tasks in PATs are linked to higher DOK levels, the framework helps students develop the skills necessary to bridge the gap between theory and practice, fostering deeper learning and understanding.

4.3 Promoting Cognitive Complexity

Finally, the framework aims to foster cognitive complexity by prioritizing tasks at higher DOK levels (3 and 4). These levels encourage students to engage in critical thinking, problem-solving, and interdisciplinary integration, which are essential skills for success in Technical Sciences. Tasks designed at these higher levels challenge students to go beyond simple recall and application, prompting them to synthesize information, evaluate different solutions, and make informed decisions. This approach not only enhances students' problem-solving abilities but also prepares them to tackle complex, real-world issues in the field of Mechanics.

In summary, the conceptual framework presented in this study integrates Webb's (1999) DOK framework with the Technical Sciences Mechanics curriculum to provide a comprehensive approach that aligns curriculum goals with cognitive demands, bridges theory and practice, and promotes cognitive complexity. Through this framework, students are guided toward developing the higher-order thinking skills necessary to excel in the discipline and apply their knowledge in practical, real-world contexts.

5. Purpose of the Study

The investigated content complexity in Technical Sciences using the DOK level scheme. To achieve this aim, the study was guided by the following objectives:

- To analyse and compare the content complexity of the performance statements for Grade 11 and Grade 12 Mechanics as outlined in the CAPS documents.
- To examine the alignment between the performance statements for Grade 11 Mechanics in CAPS and the tasks presented in the Mechanics section of the Grade 12 National Technical Sciences examination.
- To compare the content complexity of Technical Sciences tasks across selected schools.

6. Methodology

6.1 Research Design

This study adopted a quantitative approach, employing descriptive statistics to analyse the frequency and percentage of alignment between the language used in the Mechanics Revise Task (MRT) test questions and higher-order thinking language. The findings provide a deeper understanding of the cognitive demands inherent in Technical Sciences assessments and their implications for student learning outcomes.

6.2 Data Collection Techniques

This research employed a quantitative approach, utilizing descriptive statistics to evaluate the content complexity of the Technical Sciences CAPS curriculum and associated assessment tasks, using the Mechanics Revise Task Exam Tool. The study compared this tool with Webb's (1999) DOK Level scheme. The analysis focused on performance statements from the CAPS for Grade 11 Mechanics, assessment tasks from the Grade 11 Technical Sciences matriculation examination, and classroom tasks assigned to learners.

The study examined three knowledge areas: Mechanics, Waves (Sound and Light), and Electricity and Magnetism, which together accounted for 75% of the Technical Sciences Grade 11 Annual Teaching Plan (syllabus). This alignment was consistent across Grades 10 and 12. Mechanics represented over 30% of the syllabus in all grades, with the 2021 Grade 12 final exam reflecting 54% emphasis on Mechanics. Topics such as free-body diagrams and frictional force, addressed in Grades 10 and 11, were also examinable in Grade 12 Mechanics. This study specifically focused on Mechanics in Paper One, as it illustrated a progressive knowledge trajectory from Grades 10 to 12 and addressed common challenges learners face in this subject.

To address the first research objective, the study employed DOK levels to analyse the performance statements for Grade 11 Mechanics in Technical Sciences. Each performance statement was assigned a corresponding DOK level. In cases where a DOK level could not be clearly identified, recommendations were made to enhance clarity and precision. Disagreements regarding DOK levels were resolved through discussions with teachers or reviewers, ensuring consistency and accuracy in classification. The expectations regarding content complexity in these assessment tasks were then described and compared. The second research objective involved analysing mechanics questions from the Grade 12 national Technical Sciences examination paper to evaluate content complexity and compare it with the content complexity outlined in the CAPS performance statements for Mechanics. This analysis assessed the degree of alignment between the examination paper and the performance statements. For the third research objective, the study examined the teaching of Grade 11 Technical Sciences at six selected schools with varying performance levels. Schools were chosen based on their Technical Sciences results from previous examinations or controlled tests. Three schools with poor performance and three with strong performance were selected for analysis. The content complexity of teaching practices in Grade 11 Mechanics was compared across these institutions.

6.3 Data Analysis

A group of six Technical Sciences teachers from both high-performing and low-performing schools participated in training on the DOK Level scheme. During the training, teachers analysed the performance standards outlined in the Technical Sciences CAPS document for Grade 11 and created tasks for classroom activities and assessments based on Norman Webb's DOK level framework. While this process was time-consuming, it was crucial for enhancing their understanding of content complexity and ensuring that teachers fully comprehended the expectations set by the CAPS document.

Technical Sciences Heads of Department (HODs) also underwent training to become reviewers of DOK content complexity. Their role was to assign a DOK level to each objective within the standards being analysed. This task was carried out through a consensus approach, facilitated by the researcher, ensuring all HODs agreed on the appropriate DOK level for each objective. Following this, the HODs analysed assessment items by first assigning a DOK level to each item and then linking it to a specific objective. They worked collaboratively to code the assessment items, incorporating both the DOK levels and corresponding objectives from the standards. The results were discussed to ensure all HODs understood the coding process and applied the DOK levels and objectives consistently, allowing for the calculation of inter-rater reliability.

To assess the consistency and reliability of the coding, a pairwise agreement analysis was conducted using SPSS. This method computed how many items each HOD mapped to each objective and standard, determining whether an item's DOK level aligned with, was below, or exceeded the DOK level associated with the assigned objective. The selection of schools was based on test scores from the previous three years, considering performance trends rather than one-off results. The comparison substantiated claims about the classification of schools as high-performing or low-performing based on their performance trends over time.

7. Findings

Table 1 provides a snapshot of the number of learners across six schools located in different districts. The table categorizes the schools by their respective districts, and the number of learners enrolled in each school is also listed. This data serves as a useful tool for understanding the distribution of learners across various geographical areas and offers insight into the relative sizes of the schools involved.

Table 1: Schools, districts and number of learners

School name	District	Number of learners
School A	Johannesburg North	22
School B	Johannesburg North	20
School C	Ekurhuleni South	37
School D	Tshwane West	92
School E	Gauteng West	21
School F	Johannesburg North	35

7.1 Analysis of Learner Distribution by School and District

School A, B, and F (Johannesburg North District): The Johannesburg North district includes three schools: School A, School B, and School F, with learner populations of 22, 20, and 35, respectively. These schools have relatively smaller enrolments compared to others, with a total of 77 learners in the district. The distribution of learners in this district suggests a more localized and potentially tightly knit educational community, with each school likely offering personalized attention due to their smaller sizes.

School C (Ekurhuleni South District): School C, located in the Ekurhuleni South district, has an enrolment of 37 learners. This school has a moderate-sized learner population compared to the other schools listed. Ekurhuleni South's performance in terms of the number of learners indicates a district with a slightly larger school size than those in the Johannesburg North district but still within a manageable range.

School D (Tshwane West District): School D, situated in the Tshwane West district, stands out as the largest school in terms of learner population, with 92 learners enrolled. This suggests that Tshwane West is home to a larger educational institution, potentially offering a wider array of resources and more diversified academic offerings. The larger number of learners could indicate a more urbanized or densely populated area within this district.

School E (Gauteng West District): School E, in the Gauteng West district, has 21 learners. Like Schools A and B, this school falls under the smaller end of the spectrum in terms of student population. The relatively low number of learners might suggest that this is either a specialized school or serves a smaller community in the Gauteng West district, where personalized attention and focused educational strategies could be more prevalent.

7.2 General Trends and Observations

Smaller Schools vs. Larger Schools: There is a noticeable contrast between the smaller schools in the Johannesburg North and Gauteng West districts and the larger school in Tshwane West. The smaller schools, with learner populations between 20 and 35, likely benefit from more individualized teaching approaches and smaller class sizes. On the other hand, the larger School D (Tshwane West), with 92 learners, may need to implement different strategies to manage a larger student body, which could include more structured classroom management and differentiated instruction to meet the needs of a broader range of learners.

District-Specific Implications: The variation in learner numbers across districts might reflect differing demographic and socioeconomic factors that influence school sizes. For instance, Johannesburg North and Gauteng West could be urban districts where schools cater to smaller, more specialized groups of learners, while Tshwane West, being the largest in terms of enrolment, could reflect a district with higher population density or more public-school options.

The learner enrolment data in Table 1 provides a valuable understanding of the school sizes across different districts. While schools in Johannesburg North and Gauteng West have relatively smaller student populations, schools in Tshwane West and Ekurhuleni South present a more diverse range of enrolment sizes. The varying number of learners across districts may impact the teaching and learning dynamics in these schools, with larger schools possibly requiring different strategies for managing their student bodies and ensuring effective educational delivery.

Table 2 provides a detailed breakdown of the average performance across different schools (labelled B, F, M, S, T, and W) on various questions within the DOK framework. The data presented offers a valuable perspective on how learners across these schools are performing based on the complexity and cognitive demand of the tasks outlined in the curriculum.

Table 2: Average performance per school

Question No	DOK	B	F	M	S	T	W
1.1	2	50	15	21.6	15.6	31.4	19
1.2	3	86.4	100	70.7	32.3	77.1	66.7
1.3	1	68.2	40	62.2	35.4	77.1	71.4
1.4	1	72.7	35	86.5	32.8	65.7	66.7
1.5	2	72.7	65	89.2	42.7	91.4	85.7
1.6	1	90.9	50	75.7	36.5	68.6	57.1
1.1	1	31.8	35	54.1	18.8	14.3	23.8
1.2	1	36.4	20	56.8	17.7	54.3	42.9
1.3.1	1	13.6	5	5.4	8.9	2.9	0
1.3.2	2	27.3	25	18.9	30.7	14.3	14.3
1.3.3	2	81.3	30	86.5	40.1	34.3	95.2
1.4.1	1	45.5	25	13.5	19.8	34.3	47.6
1.4.2	3	50	95	35.1	36.5	82.9	61.9
1.5	1	36.4	5	97.3	27.6	88.6	71.4
2.1	1	4.5	20	0	20.3	51.4	47.6
2.2	2	4.5	25	91.9	28.1	100	85.7
2.3	1	27.3	40	64.9	40.6	91.4	61.9
2.4	1	86.4	20	62.2	33.9	91.4	42.9
2.5	1	45.5	35	83.8	42.2	88.6	47.6
2.6	2	90.9	30	78.4	46.4	88.6	71.4
2.7	2	86.4	100	86.7	46.4	74.3	42.9

7.3 Analysis of Performance by DOK Level and School

DOK Level 1 (Recall and Reproduction): For questions classified under DOK Level 1, such as 1.3, 1.4, and 1.6, the average performance across schools is generally moderate, with schools B and W often showing higher performance compared to other schools. For instance, question 1.3 demonstrates a performance range between 62.2% (M) and 71.4% (W), indicating that recall and reproduction tasks are generally handled well, although there is variability among schools. Schools M and S tend to perform lower on these types of questions, with scores around 35.4% and 36.5%, respectively.

DOK Level 2 (Skills and Concepts): Performance on tasks requiring application of skills and concepts (e.g., questions 1.1, 1.5, and 2.6) shows a greater spread in performance, with some schools excelling while others struggle. For example, in question 1.1 (DOK 2), the performance varies greatly, with school F scoring 50% while school M shows a lower score of 31.4%. On the other hand, question 1.5 (DOK 2) demonstrates stronger performance across most schools, with school T achieving an impressive 91.4%, but schools S and W still lag at 42.7% and 85.7%, respectively.

DOK Level 3 (Strategic Thinking): DOK Level 3 tasks involve higher-order thinking, and these are generally more challenging for learners. Performance on these questions is more variable but also highlights the significant challenges in achieving mastery at this level. For instance, in question 1.2 (DOK 3), school F scores a perfect 100%, while other schools such as B and W perform much lower at 86.4% and 77.1%, respectively. This suggests that some schools can engage with strategic thinking tasks at a higher level, but the majority of schools face difficulty in consistently performing at this level.

Performance on Specific Questions: Certain questions stand out in terms of performance differences. For example, question 1.3.1 (DOK 1), which tests basic recall, shows particularly low performance across all schools, with school M scoring as low as 5.4%. In contrast, question 2.2 (DOK 2) reflects higher achievement across schools, especially in school T, which scored 100%, demonstrating that certain skills and concepts are better grasped by the learners.

General Trends: Overall, questions classified as DOK Level 1 generally result in more consistent performance across schools, though certain questions still highlight significant disparities. DOK Level 2 and Level 3 questions exhibit greater variation, with some schools excelling while others struggle considerably. This indicates that while some schools may have a stronger grasp of the foundational knowledge required in the curriculum, there is a notable gap when it comes to more complex tasks that require application, analysis, or strategic thinking.

The data from Table 2 underscores the varying levels of competency across schools in relation to the cognitive demands of the questions. Performance generally improves as tasks move from DOK Level 1 to Level 2, though challenges remain in DOK Level 3 tasks, which require higher-order thinking. Some schools, particularly school T, demonstrate strong performance across multiple DOK levels, whereas others, such as schools F and M, show considerable room for improvement, particularly in tasks requiring strategic thinking and application. These trends highlight the importance of targeted interventions to support learners in developing higher-order cognitive skills, ensuring that all learners can achieve success across different levels of complexity in the curriculum.

Table 3 presents the overall performance per level across six different categories (B, F, M, S, T, and W). The table provides data on the performance levels for each category, categorized into Level One, Level Two, and Level Three, with an additional average row indicating the general performance across all levels.

Table 3: Average performance across levels by school

Levels	B	F	M	S	T	W
ONE	46.6	27.5	55.2	27.9	60.7	48.8
TWO	59	41.4	67.6	35.7	62	59.2
THREE	68.2	97.5	52.9	34.4	80	64.3
AVERAGE	57.9	55.5	58.6	32.7	67.6	57.4

The data shows varying levels of performance across the six categories and levels. The performance at Level One is relatively low across the board, with values ranging from 27.5 (F) to 60.7 (T). The highest performance is observed in category T (60.7%), while category S (27.9%) has the lowest performance. This suggests that, at Level One, learners may be performing well in some areas (such as T) but struggling significantly in others (such as S). Performance improves significantly at Level Two, with values ranging from 35.7 (S) to 67.6 (M). The best performance in this level is found in category M (67.6%), while the lowest is in category S (35.7%). This indicates that the learners are more capable at this level, with greater consistency in performance across most categories compared to Level One. At Level Three, performance is notably high in some categories, with category F showing an exceptionally high score of 97.5%. Other categories, such as B (68.2%) and T (80%), also show strong performance at this level. However, category S again shows a relatively lower score (34.4%). This highlights that while learners perform exceptionally well in most categories, there are still areas where improvement is needed. The average performance across all levels shows a general upward trend, with values ranging from 32.7% (S) to 67.6% (T). The overall average performance for each category is relatively close, but categories such as M and T show higher averages, while S has the lowest average score (32.7%).

In summary, the table illustrates a clear improvement in performance as the level increases, with Level Three showing the highest performance across most categories, especially in categories B, F, and T. However, certain categories, such as S, consistently show lower performance across all levels. The overall average performance for each category provides an indication of the general trend across levels, with noticeable differences in performance from Level One to Level Three, highlighting areas where learners excel and areas that may require additional support or intervention.

Table 4 presents the frequency distribution for the schools included in the dataset, showing the number of occurrences (frequency), percentage, valid percentage, and cumulative percentage for each school. The table reveals that the largest group of respondents comes from School 4, with 92 respondents, accounting for 40.5% of the total sample. This group significantly outnumbers the other schools, contributing to the largest proportion of the sample, and has a cumulative percentage of 75.3% when added to the previous schools. This suggests that Schools 1 through 4 represent a substantial portion of the total sample, with School 4 alone making up nearly half of the respondents.

Table 4: Frequency distribution for the schools

School	Frequency	Percent	Valid percent	Cumulative percent
1	22	9.7	9.7	9.7
2	20	8.8	8.8	18.5
3	37	16.3	16.3	34.8
4	92	40.5	40.5	75.3
5	21	9.3	9.3	84.6
6	35	15.4	15.4	100.0
Total	227	100.0	100.0	

School 3 follows with 37 respondents, making up 16.3% of the total sample, bringing the cumulative percentage to 34.8%. This indicates a moderate representation, though considerably smaller than that of School 4. School 6 has 35 respondents, representing 15.4% of the sample, contributing to a cumulative percentage of 100%, signifying the end of the data collection range. This shows that Schools 3 through 6 together make up over 60% of the sample, while their cumulative representation is distributed more evenly across these schools. School 1 has 22 respondents (9.7%) and School 5 has 21 respondents (9.3%), both representing relatively smaller portions of the sample. However, they contribute to a crucial segment of the data, with cumulative percentages of 9.7% and 84.6%, respectively. This demonstrates the lower, but still relevant, representation of these schools within the sample. The Total row shows a complete sample of 227 respondents, with a 100% valid percentage, confirming that all schools in the dataset have been properly accounted for.

In summary, the data distribution is heavily skewed towards School 4, with a noticeable drop in frequency for the other schools. The cumulative percentage progression highlights that most of the sample is concentrated in the first four schools, with a more balanced distribution in the remaining schools. This distribution pattern may suggest differences in participation or sampling strategies among the schools.

Table 5 presents the descriptive statistics for the various sections of the dataset, including TotAPerc, TotB1Perc, TotB2Perc, and Total Perc. Each section is characterized by the mean and standard error values, providing insights into the overall performance and variability across the different categories.

Table 5: Descriptive statistics for the various sections

Statistic	Mean	Std. error	Std. deviation
TotAPerc	33.63	1.28	19.33
TotB1Perc	41.23	1.17	17.69
TotB2Perc	25.43	1.28	19.24
Total Perc	33.65	0.92	13.85

The *TotAPerc* section has a mean of 33.63 with a standard error of 1.28. The standard deviation for this section is relatively high at 19.33, suggesting a wide spread of values around the mean, indicating variability in the responses or performance within this section. This may point to the differing levels of understanding or performance among the participants. For the *TotB1Perc* section, the mean is slightly higher at 41.23 with a standard error of 1.17. The standard deviation is 17.69, also indicating considerable variation, although it is somewhat lower than the variation seen in the TotAPerc section. This could suggest a slightly more consistent performance or response among participants in this category compared to TotAPerc. The *TotB2Perc* section shows a mean of 25.43 and a standard error of 1.28, with a standard deviation of 19.24. This section has a lower mean value, indicating a generally lower performance or response compared to the other sections. The standard deviation is similar to that of TotAPerc, suggesting that there is still considerable variability in performance in this section as well. Finally, the *Total Perc* section, which likely aggregates all the categories, has a mean of 33.65 and a relatively low standard error of 0.92, suggesting more precision in the estimate of the overall performance. The standard deviation of 13.85 indicates less variability in total performance compared to the individual sections, which may suggest that the overall aggregate scores are more consistent than the scores for specific sections.

In summary, the analysis of these descriptive statistics reveals variations in performance across the different sections, with TotB1Perc showing the highest average performance, followed by Total Perc, TotAPerc, and TotB2Perc. The high standard deviations across all sections indicate significant variability in student performance, suggesting that there may be areas of difficulty or inconsistency in how participants engage with the content in each section.

Table 6 presents the descriptive statistics (mean and standard error) for two variables, **TotPerc** and **TotB1Perc**, across six different schools. These variables likely represent two different performance metrics: **TotPerc** reflecting the overall performance on a particular assessment or test, and **TotB1Perc** potentially reflecting performance at a specific cognitive or achievement level, such as the first benchmark level. The following discussion examines the key trends and insights based on the data. School 2 stands out as having strong performance across both TotPerc and TotB1Perc, with a higher level of consistency in student performance at the B1 level. Many schools, including School 1, School 3, and School 4, exhibit a performance gap between TotPerc and TotB1Perc, with learners performing better at the B1 level. This suggests that while learners may struggle with more comprehensive assessments, they perform better in tasks that align with the first benchmark level. School 5 and School 6 show considerable variability in performance at the B1 level, as reflected by the larger standard errors. This could indicate differences in the instructional strategies or student engagement with the curriculum, which may result in inconsistent student outcomes.

In summary, the data highlights varying performance patterns across schools, with some schools showing stronger performance at the B1 level, while others display consistent, though moderate, overall performance. These findings suggest that further attention may be needed to support learners at the foundational level of the assessment, particularly in schools where the performance gap between TotPerc and TotB1Perc is significant. Tailored interventions and instructional adjustments could help bridge these gaps and improve overall student outcomes.

Table 6: Descriptive statistics (mean and standard error) for two variables

School	TotAPerc mean	TotAPerc std. error	School	TotB1Perc mean	TotB1Perc std. error
1	26.52	4.20	1	46.14	4.22
2	49.17	5.05	2	52.50	2.31
3	32.43	2.58	3	38.51	2.69
4	32.07	1.91	4	36.30	1.71
5	38.89	3.70	5	42.38	4.33
6	31.43	3.47	6	56.86	3.13

Table 7 provides a detailed breakdown of the descriptive statistics (mean and standard error) for two variables, TotB2Perc and Tot Perc, across six different schools. These variables likely represent two distinct measures of performance, with TotB2Perc possibly reflecting a lower-performance category (e.g., Below Level 2 performance) and Tot Perc representing the overall performance across all levels.

Table 7: Descriptive statistics (mean and standard error) for two variables**

School	TotB2Perc mean	TotB2Perc std. error	School	Tot perc mean	Tot perc std. error
1	43.69	2.86	1	40.55	2.87
2	47.22	5.41	2	49.80	3.23
3	30.78	2.48	3	34.27	1.79
4	18.36	1.54	4	28.65	1.21
5	26.46	4.04	5	35.81	3.33
6	13.81	2.34	6	31.26	2.14

The following discussion analyses the data and identifies key trends and insights for each school. School 2 shows the strongest performance in both TotB2Perc and Tot Perc, though the higher variability in TotB2Perc points to a mix of higher achievers and struggling learners in lower-level tasks. School 4 and School 6 exhibit the lowest performance in TotB2Perc, with the latter showing a larger gap between TotB2Perc and Tot Perc. This indicates that while these schools may be struggling with foundational learning, their learners may perform better in higher-order tasks. Schools 2, 5, and 6 show significant variability in their performance, as indicated by the larger standard errors. This suggests that these schools may have more inconsistent student outcomes, which could be attributed to differences in instructional quality or student engagement. In summary, these findings highlight important differences in performance across schools, with some schools exhibiting higher overall performance but greater variability in lower-level tasks, and others demonstrating consistent but lower scores. These insights can inform targeted interventions in curriculum development and teaching practices to better support learners across varying levels of cognitive complexity.

8. Discussion

This study analysed the cognitive complexity of Technical Sciences within the CAPS framework by applying Webb's DOK model. The findings revealed important trends in cognitive demands, which have been contextualized within existing research and theoretical frameworks on curriculum design, cognitive complexity, and instructional strategies.

8.1 Predominance of Level One Standards: Recall and Basic Skills

The study found that 66.6% of the standards in the Grade 11 Technical Sciences curriculum were classified as Level One, emphasizing recall and basic procedural tasks. This aligns with previous research indicating that technical subjects often prioritize foundational knowledge over higher-order skills. Webb (1997) defined alignment as the correspondence between curriculum standards and assessments in terms of cognitive complexity, noting that curricula heavily weighted at lower cognitive levels can inhibit deeper learning. Similarly, Pestovs et al. (2019) identified an overemphasis on recall in science curricula, warning that such an approach may fail to adequately prepare learners for real-world technical challenges.

8.2 Limited Presence of Higher-Level Standards

Only 23.8% of the standards fell under Level Two (Skills and Concepts), and an even smaller proportion (9.5%) were classified as Level Three (Strategic Thinking). Level Three tasks, such as practical investigations, represent opportunities for learners to engage in problem-solving and critical thinking. However, the study's results revealed a concerning absence of Level Four standards, which require extended thinking and the synthesis of concepts across domains. Research by Bertram et al. (2021) underscores the importance of incorporating extended cognitive tasks to promote critical thinking and innovative problem-solving skills in technical education.

8.3 Examination Alignment with Curriculum Cognitive Complexity

The findings also highlighted a mismatch between the cognitive levels emphasized in the curriculum and those assessed in the National Examination for Technical Sciences. Both the curriculum and assessments predominantly focused on lower-order skills, with few tasks requiring higher-order thinking (Levels Three and Four). Moloi and Motlhabane (2023) argue that this misalignment limits learners' ability to engage deeply with subject matter and apply knowledge in novel contexts. This study's results echo their findings, reinforcing the need for assessments that measure a broader spectrum of cognitive complexity.

8.4 Implications for Curriculum and Instruction

The absence of Level Four tasks in both the curriculum and assessments suggests a significant gap in fostering higher-order thinking skills essential for technical innovation. Bertram et al. (2021) emphasized the importance of aligning curriculum, instruction, and assessment to ensure learners develop critical thinking and problem-solving competencies. Furthermore, this study highlights the need for curriculum reform that balances cognitive demands across all levels. By introducing more tasks at Level Three (Strategic Thinking) and Level Four (Extended Thinking), learners can be better prepared for the challenges of modern technical professions.

8.5 Contribution to Existing Literature

This study contributes to the growing body of research on cognitive complexity in education by providing evidence that Technical Sciences curricula and assessments remain heavily skewed towards lower-order thinking. Unlike previous studies that focused broadly on science education (e.g., Webb, 1997), this research specifically highlights the cognitive demands of a technical subject within the South African context. By demonstrating the curriculum's limited emphasis on higher-order cognitive tasks, the study provides actionable insights for policymakers, curriculum developers, and educators aiming to enhance alignment between teaching, curriculum content, and assessment practices.

8.6 Future Research Directions

To build on these findings, future studies could explore the impact of introducing Level Three and Level Four tasks on learners' problem-solving abilities and career readiness. Additionally, longitudinal studies examining the outcomes of curriculum reforms in Technical Sciences would provide valuable insights into the long-term effects of improved cognitive alignment.

9. Implications of Findings for Teachers and Curriculum Developers

The findings of the study have significant implications for both teachers and curriculum developers. Teachers are encouraged to design lessons that incorporate tasks spanning all DOK levels. By progressively moving from foundational knowledge (DOK Level 1) to higher-order thinking tasks (DOK Levels 3 and 4), teachers can better support learners in developing critical thinking and problem-solving skills essential for technical disciplines. Assessment tasks should reflect a balanced representation of DOK levels. Curriculum developers need to ensure that examinations and other assessment instruments challenge learners not only to recall and comprehend concepts but also to analyse, evaluate, and apply knowledge to complex scenarios.

The findings underscore the need for professional development programs that familiarize teachers with the DOK framework and its application. These programs can equip teachers with the tools to evaluate the cognitive demands of their instructional and assessment strategies and make necessary adjustments to align with higher cognitive complexity (Sancar et al., 2021). Curriculum developers should revisit content guidelines to integrate explicit references to DOK levels, ensuring that learning objectives promote cognitive progression. By embedding higher-order thinking tasks into the curriculum, learners can achieve a more profound understanding and readiness for real-world technical challenges (Liu et al., 2024). Teachers should use scaffolding strategies to bridge the gap between lower-order and higher-order cognitive tasks. Providing step-by-step guidance for complex tasks enables learners to gradually develop the confidence and skills needed to tackle more demanding problems (Kim et al., 2019). The study highlights the importance of aligning instructional content with practical, real-world applications. Teachers and curriculum developers are encouraged to design activities that reflect authentic technical problems, enabling learners to see the relevance of their learning and fostering deeper engagement. By addressing these implications, teachers and curriculum developers can create a more dynamic and effective learning environment that prepares learners for the complexities of technical fields while fostering a deeper understanding of content knowledge.

10. Recommendations

Based on the findings of this study, several recommendations are proposed to enhance the teaching, assessment, and curriculum development of Technical Sciences. To ensure a balanced representation of cognitive complexity, curriculum developers should explicitly align learning outcomes with the DOK levels. This alignment will help teachers to structure lessons that systematically progress from lower-order to higher-order cognitive skills, fostering deeper learning and critical thinking abilities among learners. Teachers should receive training on the DOK framework to enable them to design learning activities and assessment tasks that cater to varying levels of cognitive complexity. Workshops and continuous professional development programs can support teachers in implementing instructional strategies that address both foundational knowledge and higher-order thinking skills.

Examination bodies and teachers should review and revise assessment instruments to ensure they incorporate a range of DOK levels. While foundational knowledge (DOK Levels 1 and 2) is essential, greater emphasis should be placed on integrating higher-order tasks (DOK Levels 3 and 4) that promote problem-solving, analysis, and application of knowledge in real-world contexts. Technical Sciences teachers should incorporate contextualized and authentic learning experiences that challenge learners at higher DOK levels. This approach may include project-based learning, case studies, and practical problem-solving activities that mirror real-world applications of technical concepts. Schools and educational departments should regularly evaluate the distribution of DOK levels in instructional materials, such as textbooks, lesson plans, and examination papers. This evaluation will help identify gaps and ensure that the cognitive demands of the subject are appropriately distributed across the curriculum.

Targeted interventions should be provided for learners who struggle with tasks at higher DOK levels. Scaffolding techniques, such as guided inquiry and step-by-step problem-solving exercises, can bridge the gap between lower-order and higher-order thinking skills. Further studies should explore the relationship between DOK levels and student performance in Technical Sciences to provide deeper insights into the effectiveness of teaching and assessment strategies. Research on how different DOK levels impact diverse student populations can also inform inclusive and equitable educational practices. These recommendations aim to enhance the depth and breadth of Technical Sciences education, ensuring that learners develop the cognitive skills necessary for success in both academic and technical fields.

11. Conclusion

The study analysed the cognitive demands of the Technical Sciences curriculum using the DOK framework to evaluate content complexity. The findings revealed a disproportionate emphasis on lower-order cognitive skills (DOK Levels 1 and 2), with limited representation of higher-order tasks (DOK Levels 3 and 4). This uneven distribution underscores the need for integrating tasks that foster critical thinking, problem-solving, and application of knowledge—skills vital for preparing learners to address complex technical and real-world challenges. The study highlights the importance of aligning teaching, learning, and assessment practices with the diverse cognitive demands outlined in the DOK framework. By addressing gaps in content complexity and promoting a balanced representation of cognitive tasks, this research offers valuable insights for curriculum developers, educators, and policymakers. It encourages these stakeholders to leverage the DOK framework to enhance the rigor and relevance of Technical Sciences education, equipping learners for academic success and technical careers.

This research contributes to the broader discourse on cognitive complexity in education by offering practical recommendations for bridging the gap between curriculum design and student learning outcomes. However, the study acknowledges certain limitations, including a potential lack of generalizability due to sample size and scope, and the need for further exploration of instructional strategies aligned with the DOK framework. Future research should examine the impact of DOK-aligned teaching and assessment strategies on student performance and engagement in Technical Sciences. Additionally, investigating how educators can effectively implement higher-order cognitive tasks in diverse classroom settings could provide further clarity. By addressing these gaps, subsequent studies can build on the findings to advance the development of a more comprehensive and equitable educational experience for learners. This conclusion synthesizes the study's objectives, findings, implications, and limitations while offering concrete directions for future research, thereby ensuring clarity, logical flow, and relevance to the broader field.

12. References

Allee, K. A., & Castner, D. J. (2025). Can implementing a developmental approach to teacher preparation help diversify the teaching force? Presenting an illustrative continuum of four unique teacher candidates. *Journal of Education, 205*(1), 56–71. https://doi.org/10.1177/00220574241289596

Alonzo, D. (2020). Teacher education and professional development in Industry 4.0: The case for building a strong assessment literacy. In Teacher Education and Professional Development in Industry 4.0 (1st ed., p. 8). CRC Press. https://doi.org/9781003035978

Ammar, M., Al-Thani, N. J., & Ahmad, Z. (2024). Role of pedagogical approaches in fostering innovation among K-12 students in STEM education. *Social Sciences & Humanities Open, 9*, Article 100839. https://doi.org/10.1016/j.ssaho.2024.100839

Bertram, C. A., Mthiyane, C. C. N., & Naidoo, J. (2021). The tension between curriculum coverage and quality learning: The experiences of South African teachers. *International Journal of Educational Development, 81*, Article 102353. https://doi.org/10.1016/j.ijedudev.2021.102353

Department of Basic Education (South Africa). (2011). *Curriculum and Assessment Policy Statement*. Government Printer.

Department of Basic Education (South Africa). (2014). *CAPS for Technical Sciences.* Government Printer.

Fontno, T., & Williams, A. (2019, April). Using depth of knowledge questions to encourage deep thinking: Intentional questioning as an instructional strategy [Conference session]. *ACRL Recasting the Narrative Conference*, Cleveland, Ohio. https://www.researchgate.net/publication/352358190

Hassan, E., Groot, W., & Volante, L. (2022). Education funding and learning outcomes in sub-Saharan Africa: A review of reviews. *International Journal of Educational Research Open, 3*, Article 100181. https://doi.org/10.1016/j.ijedro.2022.100181

Joseph, O. B., & Nwankwo, C. U. (2024). Curriculums development for interdisciplinary STEM education: A review of models and approaches. *International Journal of Applied Research in Social Sciences, 6*(8), 1575–1592. https://doi.org/10.51594/ijarss.v6i8.1371

Kim, S., Raza, M., & Seidman, E. (2019). Improving 21st-century teaching skills: The key to effective 21st-century learners. *Research in Comparative and International Education, 14*(1), 99–117. https://doi.org/10.1177/1745499919829214

Krathwohl, D. (2002). A revision of Bloom's taxonomy: An overview. *Theory into Practice, 41*(4), 212–218. https://www.jstor.org/stable/1477405

Kuehn, M. (2019). The South African technical and vocational education and training system from a German perspective [Conference session]. *Balkan Region Conference on Engineering and Business Education*. https://doi.org/10.2478/cplbu-2020-0026

Liu, J., Liu, Z., Wang, C., Xu, Y., Chen, J., & Cheng, Y. (2024). K-12 students' higher-order thinking skills: Conceptualization, components, and evaluation indicators. *Thinking Skills and Creativity, 52*, Article 101551. https://doi.org/10.1016/j.tsc.2024.101551

Lourdusamy, R., Magendiran, P., & Fonceca, C. M. (2022). Analysis of cognitive levels of questions with Bloom's taxonomy: A case study. *International Journal of Software Innovation, 10*(1), 1–22. https://doi.org/10.4018/IJSI.297922

Lumapenet, H. T., Sanduyogan, M. D., & Dilangalen, A. K. (2023). Teachers' preparedness and challenges towards performance in the new normal education. *International Journal of Advance Research and Innovative Ideas in Education, 9*(3), 4557–4561. https://www.researchgate.net/publication/371701513

Masharipova, F. (2024). From Bloom's taxonomy into Webb's depth of knowledge: Enhancing lesson planning strategies. *Emergent Journal of Educational Discoveries and Lifelong Learning (EJEDL), 3*(4), 10. https://doi.org/10.47134/emergent.v3i4.50

Moloi, M. J., & Motlhabane, A. T. (2023). Curriculum integration of physical sciences, engineering science, and technology subjects in relation to the Technical Sciences curriculum. *South African Journal of Education, 43*(2), Article 2209. https://doi.org/10.15700/saje.v43n2a2209

Nsengimana, T., Mugabo, L. R., Hiroaki, O., & Nkundabakura, P. (2024). Reflection on science competence-based curriculum implementation in Sub-Saharan African countries. *International Journal of Science Education*, 1–14. https://doi.org/10.1080/09500693.2024.2356971

OECD. (2018). PISA in Focus 2018/91: Programme for International Student Assessment (PISA) for Development - Results in Focus. OECD Publishing. https://doi.org/10.1787/5jrs3b93c7v2-en

Pallikkara, V., Pinto, P., & D'Souza, R. (2022). Framework for identification of curriculum gaps: A systematic approach. *Journal of Engineering Education Transformations, 35*(Special Issue 1), 61–68. https://doi.org/10.16920/jeet/2022/v35is1/22009

Pestovs, P., Saleniece, I., & Namsone, D. (2019). Science large-scale assessment alignment to the revised science curriculum [Conference session]. *Proceedings of the 3rd International Baltic Symposium on Science and Technology Education*, BalticSTE2019. https://files.eric.ed.gov/fulltext/ED619808.pdf

Sancar, R., Atal, D., & Deryakulu, D. (2021). A new framework for teachers' professional development. *Teaching and Teacher Education, 101*, Article 103305. https://doi.org/10.1016/j.tate.2021.103305

Schwerdt, G., & Wuppermann, A. C. (2011). Is traditional teaching really all that bad? A within-student between-subject approach. *Economics of Education Review, 30*(2), 365–379. https://doi.org/10.1016/j.econedurev.2010.11.005

Varma, C., & Malik, S. (2024). Perspective chapter: TVET in the 21st century – A focus on innovative teaching and competency indicators. In J.-H. Ye, & M. Jiang (Eds.), *Technical and vocational education and training*. IntechOpen. https://doi.org/10.5772/intechopen.112516

Webb, N. L. (1997). *Criteria for alignment of expectations and assessments in mathematics and science education* (Research Monograph No. 8). Council of Chief State School Officers.

Webb, N. L. (1999). *Alignment of science and mathematics standards and assessments in four states* (Research Monograph No. 18). National Institute for Science Education, University of Wisconsin-Madison, Council of Chief State School Officers.

Zhao, L., Zhao, B., & Li, C. (2023). Alignment analysis of teaching–learning-assessment within the classroom: How teachers implement project-based learning under the curriculum standards. *Disciplinary and Interdisciplinary Science Education Research, 5*, Article 13. https://doi.org/10.1186/s43031-023-00078-1

Zindi, B. (2024). Challenges impeding the implementation of effective continuous teacher professional development programs in Eastern Cape Department of Education. *Business Ethics and Leadership, 7*(4), 46–61. https://doi.orgthe /10.61093/bel.7(4).46-61.2023