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Analyzing trends and suggested instructional strategies for Geometry education: Insights from Uganda Certificate of Education-Mathematics Examinations, 2016-2022

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ABSTRACT

Geometry education plays a pivotal role in fostering analytical, spatial, and problem-solving skills among students. Nonetheless, there is still a problem with how well geometry training in Ugandan schools accomplishes these objectives and this is evident in the Uganda Certificate of Education (UCE) examinations. To close this gap, a comprehensive examination of data taken from Uganda National Examinations Board (UNEB) reports covering the years 2016 to 2022 was carried out; with an emphasis on candidates' performance, the study looks at common geometric ideas, pinpoints areas of weakness for candidates, and assesses response quality. This study's content analysis reveals notable variations in the quality of responses to various mathematics areas, with geometry consistently having the largest percentage of poor responses. Interestingly, in most areas, attempt levels positively correlate with response quality; but, in the case of geometry, this correlation reverses, suggesting that learners in this domain confront different problems. These problems include using geometric principles for problem-solving, combining algebraic and geometric concepts, and spatial visualization. The study advocates for using technology, active and problem-based learning; as these approaches provide opportunities for experiential learning, and conceptual knowledge reinforcement to learners. All this will support ongoing attempts to enhance mathematics education, particularly in the field of geometry, within the Ugandan context.

Keywords: Geometry Education, Instructional Strategies, examination challenges, geometry concepts, UNEB

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INTRODUCTION AND BACKGROUND

Geometry education, which focuses on the study of shapes, spatial connections, and properties, is a crucial component of mathematics education. It is central to developing learners' ability to reason logically and spatially, and to solve problems (Mifetu, 2023). It incorporates topics such as circles, measurements, angles, coordinate geometry, transformation geometry, trigonometric geometry, bearings, constructions, and applied geometry (NCDC, 2019). This branch of mathematics holds significant educational importance, as many objects and phenomena in our environment are composed of geometric shapes, and effective utilization of these objects hinges upon understanding their interrelationships (Serin, 2018). For example, Serin's study highlights the pivotal role of geometry in mathematics education, emphasizing its capacity to cultivate critical thinking and problem-solving skills among learners. It is not only foundational for understanding topics like algebra, calculus, and graphs within mathematics but also finds practical applications in real-life contexts, scientific pursuits, and artistic endeavors (Serin, 2018).

Effective instructional strategies in geometry are those that promote meaningful learning and assist learners' mental understanding of geometric concepts. It has been demonstrated that employing manipulatives and visualizations to assist students in visualizing and investigating geometric concepts such as interactive diagrams and geometric shapes enhances their comprehension of spatial relationships (Wahab et al., 2016). Another strategy is problem-based learning (PBL), which involves students in real-world issues that call for geometric concepts and solutions techniques. This approach promotes critical thinking and real-world application (Jones, 2002; Mifetu, 2023; Susilawati et al., 2017). By offering visual aids and interactive feedback, technology integration such as dynamic geometry software and interactive apps enhances student engagement and facilitates the study of difficult geometry concepts. Lastly, formative evaluation is emphasized as a vital strategy for tracking student development, spotting misunderstandings, and customizing instructional approaches to match each student's unique learning needs (Malatjie & Machaba, 2019; Mosia et al., 2023; Mthethwa et al., 2020; Sunzuma, 2023).

Analyzing learners' examination-related issues to develop instructional strategies in geometry is critical for optimizing students' learning results. Through the analysis of examination data, teachers can pinpoint the typical difficulties and recurrent misconceptions that students face when working on particular geometric themes or assignments. Teachers can create focused interventions and instructional strategies that specifically address these challenges with the help of this knowledge, which is crucial for instructional planning (Hill & Tyson, 2009; Reeve et al., 2019). Differentiated instruction, which offers individualized support to improve student engagement and create a supportive learning environment, can be implemented by tailoring instruction to the requirements of students based on examination data (Lavania & Nor, 2020).

Exams are a major source of difficulty for students, especially in disciplines like geometry where a strong grasp of abstract concepts and spatial reasoning are necessary (Murphy et al., 2023). These difficulties can be caused by several facets, such as misunderstandings about important geometric concepts, trouble applying algebraic principles to geometric issues, and trouble picturing geometric relationships. For example, Salifu conducted a study to explore the geometric concepts perceived as challenging by pre-service teachers in a Ghanaian college and identified likely causes for these difficulties (Salifu et al., 2020). Luneta (2015) focused on analyzing the errors made by students when attempting coordinate-geometry problems in South Africa's final grade 12 examinations. The perceived difficult nature of geometry could have a bearing on learners' ability to respond to examination questions related to geometry. The current study analyzed the specific challenges faced by learners during mathematics assessments, focusing on geometry-related questions and proposed strategies to address these challenges.

Like Luneta, Mosia and associates examined the types of mistakes students make when answering problems involving Euclidean geometry, concentrating on the angle at the center theorem and its applications. This study made several recommendations, one of which was that educators evaluate students' proficiency in geometric reasoning and use that knowledge in lesson designs and teaching resources (Mosia et al., 2023). Despite this recommendation, several educators including those in Uganda have not focused on the evaluation of how their learners engage with examination questions, they only focus on the final grade without looking into the nature of responses and the complexity of different concepts of the examination to guide instruction, this unexplored gap was the basis of the current study.

Evidence from countries like South Africa where keen interest has been given to student examination scripts from the annual assessments indicates positive progress in the instructional strategies; some of which include making geometry instruction a top priority to give students the tools they need to successfully remember, integrate, and apply geometric ideas in pertinent contexts (Dhlamini et al., 2019). Similar studies have been conducted in Sri Lanka, for example, the research conducted by Silmi and colleagues illuminates the significant obstacles that Grade 11 students of Sri Lanka face when acquiring geometric knowledge and suggests workable solutions to these problems (Juman Abdeen et al., 2022). These studies emphasize the importance of understanding the difficulties learners face when dealing with different concepts during examinations with the hope of using the results to identify appropriate strategies to confront the existing obstacles. In support of this, Naidoo and Kapofu emphasize that pedagogical approaches should be tailored to alleviate these obstacles, suggesting a pivotal role for educators in fostering a positive learning environment conducive to improved mathematical outcomes among students (Naidoo & Kapofu, 2020).

Following Naidoo and Kapofu's study, studies on the effectiveness of some instructional strategies for geometry have been carried out. For example, Mifetu conducted a study examining the effectiveness of the activity-based teaching method in addressing these difficulties and improving students' performance in circle geometry. The study revealed that students encountered various obstacles when solving circle problems and that the active method facilitated their ability to tackle complex questions requiring the application of multiple circle theorems. Mifetu recommends the consistent use of the activity-based teaching method by mathematics educators to enhance the teaching and learning of circle geometry (Mifetu, 2023). Silmi Juman and Colleagues stressed that by promoting active participation and interaction, educators can create dynamic learning environments that cater to diverse learners' needs and promote deeper conceptual understanding (Juman Abdeen et al., 2022).

The difficulties students face in examinations offer important insights into the particular area in which they struggle and the misconceptions they hold regarding geometric concepts. By identifying and analyzing the specific difficulties that students face on assessments, educators can develop targeted lesson plans that address these areas of weakness (Krämer et al., 2021; Tai et al., 2023).

In Uganda, examinations are essential for evaluating students' proficiency in a range of subjects, including mathematics. The Uganda National Examinations Board (UNEB) administers the Uganda Certificate of Education (UCE) exams, which constitute a significant turning point in Ugandan students' academic careers. Within each subject, these exams usually cover a broad range of topics intended to assess students' comprehension, aptitude for solving problems, and application of ideas in practical settings. The outcomes of these tests have a big impact on how far students can go academically and what possibilities they will have later in life, including getting into college or a job. Examining the difficulties that students encounter throughout these tests offers important insights into areas that need focused instructional support and intervention to improve learning outcomes and raise the standard of education in Uganda as a whole.

As one of the several examinations under UCE, Mathematics examination serves as a key assessment tool for evaluating students' proficiency in geometry and other mathematical concepts for senior four students (16-18 years). However, despite its significance, geometry assessment dynamics, and trends remain underexplored, hindering efforts to address challenges and improve instructional strategies (Aguhayon et al., 2023; Namukasa et al., 2010; Sher et al., 2023).

This study addressed this gap by conducting an analytical examination of challenges faced by students in UCE Mathematics examinations focusing on geometry, trends, and instructional implications. Data extracted from UNEB reports spanning over six years were analyzed to establish trends and optimize instructional strategies for geometry education (UNEB, 2017, 2018, 2019, 2020, 2021, 2023). It sought to understand candidates’ behaviors, such as attempt patterns and response quality, as well as the frequency and distribution of geometry-related questions compared to other topics. Additionally, the study examined prevalent geometry concepts and associated challenges faced by candidates. It also examined recommended strategies outlined in UNEB reports to enhance learners' geometry reasoning levels and gave recommendations for improving geometry education and instructional strategies for mathematics teachers.

THEORETICAL UNDERPINNING

The theory that guided this study is the Cognitive Load Theory (CLT); proposed by Sweller, van Merrienboer, and Paas (1998). It highlights how limited cognitive resources, especially working memory capacity, are during the learning process. According to CLT, learners can only process new information using a limited amount of cognitive resources. Excessive use of educational materials or tasks can result in cognitive overload, which impairs the ability to learn effectively (Sweller et al., 1998).

The term "intrinsic cognitive load" describes the innate complexity involved in picking up particular ideas or skills. For instance, because geometry is spatial and abstract, learning its fundamentals requires a significant cognitive burden. Cognitive load that is not directly related to learning is known as *extraneous cognitive load*. It is brought on by how tasks and instructional materials are presented or designed. Geometry problems that are intricate or badly organized can add to the unnecessary cognitive burden. Germane Cognitive Load is the productive cognitive load that aids in the formation of mental schemas, or cognitive structures, which in turn aids in learning. Understanding and retention are improved when cognitive resources are directed toward arranging and integrating incoming knowledge (Bobis et al., 1993; Gupta & Zheng, 2020). In geometry education, germane cognitive load involves engaging students in meaningful activities that promote deep understanding and retention of geometric principles, emphasizing the importance of fostering active learning and problem-solving skills to enhance geometry proficiency (Paas & van Merriënboer, 2020). CLT provides insightful information that can be used to optimize instructional design and efficiently regulate cognitive load in educational settings, its strategies include breaking down difficult tasks into simpler ones, giving clear guidance through examples or scaffolding, minimizing unnecessary cognitive load by improving instructional materials, and encouraging the development of schemas through meaningful practice and repetition (Gupta & Zheng, 2020; Reeve et al., 2019). According to Paas & van Merriënboer (2020), when applied to geometry education, CLT can guide the development of instructional strategies that help students visualize geometric relationships, strengthen their spatial reasoning abilities, and successfully integrate algebraic and geometric concepts. To optimize learning, educators should focus on reducing extraneous cognitive load by using clear, effective teaching strategies and materials.

PROBLEM STATEMENT

Despite ongoing efforts to enhance mathematics education, persistent challenges continued to hinder the comprehension and application of geometry concepts among candidates taking the Uganda Certificate of Education (UCE) examinations. In an ideal educational scenario, geometry instruction would effectively nurture the required geometry skills, leading to proficient performance in assessments. The annual reports released by the Uganda National Examinations Board (UNEB) consistently highlighted prevalent weaknesses and areas needing improvement in geometry education. Yet a comprehensive analysis of these reports to discern underlying trends and instructional implications was lacking (UNEB, 2016, 2017, 2018, 2019, 2020, 2021, 2023).. This study aimed to bridge this gap by investigating trends in geometry assessments and their instructional implications as revealed in UNEB annual reports spanning six years. This will provide valuable insights that can inform targeted interventions and enhance geometry education strategies to align with the ideal outcomes.

Research Objectives

The study was guided by three objectives:

- To examine how question attempt levels and topic specificity influence candidates' quality of responses in UCE Examinations.
- To explore the prevalence of Geometry concepts, learners' challenges, and perceived importance in UCE Examinations over different years and topics.
- To evaluate the Feasibility and Effectiveness of Recommended Strategies within the reports on the work of candidates to Enhance Geometry Education.

Significance of the Study

The relevance of this study lies in its potential to inform curriculum development, instructional design, and teacher training initiatives aimed at enhancing geometry education. By identifying key areas of improvement and instructional implications, the findings of this study contribute to the refinement of geometry assessment practices and the promotion of effective teaching and learning strategies in Ugandan secondary schools and elsewhere applicable.

Limitations of the Study

While the retrospective nature of the study limits direct intervention possibilities, it provides an opportunity to glean valuable insights from existing documentation, highlighting areas for potential future interventions and educational enhancements beyond the scope of UNEB reports.

METHODOLOGY

The study adopted an interpretivism paradigm and qualitative data analysis techniques to delve into the meanings and interpretations within UNEB reports. The interpretivism paradigm is well-suited for this study because it allows for a comprehensive understanding of the subjective and contextual factors that influence the interpretation of geometry challenges and recommendations within the UNEB reports (Creswell & Creswell, 2018b; Guba & Lincoln, 2005). Data were sourced exclusively from UNEB reports spanning six years (2016-2022), focusing on 34 mathematics examinations with a total of 204 question items. The study utilizes a retrospective research design to analyze historical data and uncover longitudinal patterns in geometry assessment dynamics and trends (Merriam & Tisdell, 2015). The primary analysis method employed is qualitative content analysis, with some quantitative analysis on the quality of responses (categorized as 1-High quality, 2-Low quality) and the level of attempts (categorized as 1-Most Attempted, 2-Least Attempted) for the different questions, this was to complement the qualitative findings and enhance the depth of analysis (Shava et al., 2021). Integrating quantitative data enriches the study's comprehensiveness by providing numerical support and offering a more robust exploration of geometry education dynamics within the UNEB context (Asenahabi, 2019; Baker, 2018; Creswell & Creswell, 2018a, 2018b; Kanika, 2015; Merriam & Tisdell, 2015; Novikov & Novikov, 2013; Shava et al., 2021; Stadtländer, 2009). Adherence to ethical guidelines was prioritized throughout the study to ensure responsible data handling and research conduct, thereby safeguarding the confidentiality and integrity of the data obtained from UNEB reports (Rana, 2020).

RESULTS AND DISCUSSION

Exploring the influence of question attempt levels and topic specificity on response quality and weaknesses in UCE Examinations

This subsection presents candidate engagement (level of attempts) and response quality in UCE exams, with an emphasis on geometry. It includes analysis from tables on response quality and attempt levels across mathematics topics, as well as a regression model correlating attempt levels and topic specificity with response quality, aiming to predict candidate performance patterns.

Quality of examination responses for different question items across different topics of Mathematics

Table 1 provides a breakdown of response quality for various topics in mathematics examinations. It categorizes responses as either "High quality" or "Low quality" and presents the total number of question items for each topic together with the corresponding percentages.

Table 1: Showing the distribution of response quality (high quality, low quality) per topic

	Response Quality		
Topic	**High quality**	**Low quality**	**Total**
Algebra	13(65%)	7(35%)	20 (10%)
Business mathematics	8(67%)	4(33%)	12(6%)
Functions	19(70%)	8(30%)	27(13%)
Geometry-Related	18(35%)	34(65%)	52(25%)
Inequalities and regions	2(50%)	2(50%)	4(2%)
Kinematics	2(25%)	6(75%)	8(4%)
Linear Programming	0(00%)	6(100%)	6(3%)
Matrices	12(100%)	0(00%)	12(6%)
Number Concepts	7(33%)	14(67%)	21(10%)
Probability	5(63%)	3(38%)	8(4%)
Sets	6(55%)	5(45%)	11(5%)
Statistics	9(90%)	1(10%)	10(5%)
Vectors	3(23%)	10(77%)	13(6%)
Total	**104(51%)**	**100(49%)**	**204(100%)**

Table 1 shows that the majority of responses (13 in number i.e., 65%) in the algebraic domain were rated as excellent quality, demonstrating a thorough comprehension and mastery of the subject. Comparably, a sizable percentage (67%) of excellent responses were found in the field of business mathematics, demonstrating proficiency in this domain. Functions performed very well, with 70% of responses classified as high quality, indicating a solid understanding of ideas relevant to functions. However, for the Geometry-Related questions, just 35% of the responses were classified as high quality while 65% were classified as low quality, suggesting that learners were having difficulty with this subject. Responses to questions from topics like linear programming and kinematics were mostly of low quality, indicating that the learners were either unfamiliar with or found these topics to be challenging. Students demonstrated excellent ability and comprehension in matrices, with every response to the question on this topic being classified as high quality (100%).

In general, while this study shows excellent candidate performance Algebra, Business Mathematics, Functions, and Matrices, candidates found geometry-related kinematics and linear programming challenging. This finding echoes previous studies that highlighted persistent challenges faced by learners in mastering geometric concepts (Juman Abdeen et al., 2022; Salifu et al., 2020). Salifu's study, for instance, identified specific difficult geometry concepts, including circles, congruent triangles, and trigonometry, all of which are reflected in the distribution of low-quality responses observed in this examination. Ngirishi and Bansilal (2019), also found similar results showing that learners have difficulties with problems involving definitions of geometry terms, interpretation of properties and shapes, class inclusion, and changing semiotic inclusions.

Educators and policymakers will do well to prioritize geometry education and allocate adequate resources to enhance instructional practices and support in this area. Implementing innovative teaching methods, such as hands-on activities, visual aids, and technology integration, can enhance students' engagement and understanding of geometric concepts. Additionally, fostering a supportive learning environment that encourages exploration, inquiry, and perseverance in geometry-related problem-solving can empower students to overcome challenges and succeed in mastering geometric concepts (Mifetu, 2023).

Attempt levels for examination question items across different topics of Mathematics

Table 2 displays the distribution of attempt levels for examination questions across different mathematics topics. It categorizes the questions as "Most Common" and "Least Common," indicating the popularity of questions.

Table 2: Showing the number of attempt levels (most common, least common) for the examination question items across different topics of Mathematic

	Questions-Attempt level		
Topics	**Most common**	**Least Common**	**Total**
Algebra	17(85%)	3(15%)	20(10%)
Business mathematics	11(92%)	1(4%)	12(13%)
Functions	26(96%)	1(4%)	27(13%)
Geometry-Related	30(58%)	22(42%)	52(25%)
Inequalities and regions	3(75%)	1(25%)	4(2%)
Kinematics	3(38%)	5(63%)	8(4%)
Linear Programming	0(00%)	6(100%)	6(3%)
Matrices	12(100%)	0(00%)	12(6%)
Number Concepts	14(67%)	7(33%)	21(10%)
Probability	7(88%)	1(13%)	8(4%)
Sets	10(91%)	1(9%)	11(5%)
Statistics	9(90%)	1(10%)	10(5%)
Vectors	6(46%)	7(54%)	13(6)
Total	**148 (73%)**	**56(27%)**	**204**

The analysis of the data regarding attempt levels across different mathematical topics and questions (Table 2) sheds light on the distribution of the most common and least common levels of attempts by learners. In Algebra, the majority of questions (17 in number, equivalent to 85%) fell into the most common category, indicating a high degree of engagement with these questions, while only 15% of questions were categorized as least common. Similarly, Business Mathematics displayed a strong preference for the most common attempt level, with 92% of questions classified as most common compared to only 4% for the least common attempt level. Functions also exhibited a notable trend, with 96% of questions falling into the most common category. Topics such as Linear Programming had all questions categorized as least common, indicating a general lack of familiarity or difficulty among learners in this area. Conversely, Matrices showed all questions categorized as most common, reflecting a strong understanding and readiness for this topic.

When attempt levels for questions about geometry are examined, an interesting pattern emerges. Even while the majority of questions (58%) were classified as most common, indicating considerable engagement and knowledge of the concepts therein, a sizable portion (42%) moved into the least frequent group. This suggests a significant variation in the way learners approach Geometry-related questions, with a significant percentage encountering challenges (Juman Abdeen et al., 2022). The fair distribution draws attention to the complexity and range of understanding levels in this area of mathematics, highlighting the need for targeted support and individualized instruction to increase learners' understanding and confidence while tackling geometry-related questions. This aligns with Naidoo and Kapofu's emphasis on addressing negative perceptions of learning geometry among students to enhance engagement and performance (Naidoo & Kapofu, 2020).

Educators should ensure that geometry-related topics receive adequate attention in the curriculum and that students are well-prepared to tackle geometry questions in examinations. The high prevalence of geometry-related topics highlights the need for targeted support and resources to address any challenges students may face in mastering geometry concepts. Professional development for mathematics teachers should include strategies for effectively teaching geometry and identifying and addressing students' difficulties in this area.

Logistic Regression Model to examine the predictors of Quality Responses in UCE examinations

Logistic regression analyses explored predictors of quality responses in UCE exams (2016-2022) by UNEB. Attempt Level and Topic (including geometry) were predictors. The model showed a Nagelkerke R Square of 0.290, indicating 29.0% variance explained, highlighting multifaceted influences on assessment outcomes beyond content.

The logistic regression equation for predicting the log odds of achieving high-quality responses is presented as follows:

$$logit(HighQuality) = -3.283 + 2.583 \times Attempt\ Level + 0.010 \times Topic$$

The coefficient for Attempt Level ($B = 2.583, p < 0.001$) suggests a significant positive association between higher Attempt Levels and the likelihood of achieving high-quality responses, translating to 13.241 (Odds Ratio=$e^B = e^{2.583} \approx 13.241$) times higher odds with each unit increase in Attempt Level. However, the coefficient for Topic ($B = 0.010, p = 0.820$) indicates that Topic choice does not significantly influence quality response after controlling for Attempt Level, suggesting that other factors play a more substantial role. These results emphasize the critical role of Attempt Level, reflecting persistence and effort, in predicting quality responses across diverse UCE examination topics. Students engaging in multiple attempts demonstrate significantly higher odds of achieving high-quality responses, highlighting the importance of active learning strategies irrespective of the subject matter.

Turning specifically to the logistic regression analysis for geometry, the model with a Nagelkerke R Square of approximately 19.6% reveals insights into factors influencing response quality in geometry-related assessments. The logistic regression equation for geometry predicts the log odds of achieving high-quality responses as:

$$logit(High\ Quality) = 0.636 - 1.846 \times Attempt\ Level$$

The negative coefficient for Attempt Level (B = -1.846, p = 0.010) indicates that higher Attempt Levels are associated with decreased odds of achieving high-quality responses in geometry. Each unit increase in Attempt Level results in an 84.2% (Percentage Change =$(1 - e^B) \times 100\% = (1 - e^{-1.846}) \times 100\% \approx 82.4\%$) decrease in the odds of producing a high-quality response. These findings highlight challenges faced by candidates with higher Attempt Levels in understanding and applying geometric concepts effectively. Targeted interventions and support strategies are essential to address difficulties associated with increased Attempt Levels and improve performance in geometry assessments.

This observation aligns with previous studies that have highlighted specific challenges faced by learners in geometry, such as conceptual misunderstandings and procedural errors (Luneta, 2015; Mosia et al., 2023). The discrepancy between expected and actual levels of geometric understanding among students (Luneta, 2015) suggests that instructional practices may need to be reevaluated to better support students' learning of geometric concepts. Addressing procedural errors and conceptual misunderstandings through targeted interventions, such as activity-based teaching methods (Mifetu, 2023), could mitigate the negative impact of higher Attempt Levels on response quality in geometry assessments.

The intrinsic cognitive load, which refers to the inherent complexity of learning materials or tasks, is evident in the study findings. Geometry-related questions in UCE examinations impose a significant intrinsic cognitive load due to the complexity of geometric concepts, spatial reasoning requirements, and problem-solving strategies. The higher prevalence of low-quality responses in geometry questions compared to other topics underscores the intrinsic difficulty the learners face in mastering these concepts, aligning with CLT's emphasis on managing intrinsic cognitive load (Sweller et al., 1998).

Geometry concept, challenges, and perceived importance in UCE examinations.

Prevalence of Geometry-related challenges in Geometry assessments.

The distinct difficulties presented by specific geometry questions in various examination sets and years are highlighted in this section; for example, 2019/P2/Q17 indicate that the problem was encountered in the 2019 examination set, paper 2, and question 17. The difficulties were thematically analyzed, and four major themes emerged: Difficulty in spatial visualization and interpretation, struggle with integrating algebraic manipulation and geometric concepts, application difficulties of geometric principles, conceptual understanding and misconceptions. Each of these themes is illustrated below.

Difficulty in spatial visualization and interpretation

This problem includes difficulties accurately perceiving and comprehending geometric figures and shapes. Issues with finding angles in three-dimensional diagrams (2016/P2/Q10), deciphering the geometric qualities of cones and cylinders (2019/P2/Q07, 2020/P2/Q04), and recognizing planes in geometric figures (2019/P2/Q17) were mentioned among the difficulties that learners encounter. This result is consistent with Wahab and associates' discovery that students struggle with spatial visualizations (Wahab et al., 2016). The development of spatial visualization skills can be greatly aided by utilizing students' prior mathematical knowledge and adapting teaching strategies to meet a variety of learning styles (Susilawati et al., 2017).

Struggle with integrating algebraic manipulation and geometric concepts

According to the reports, candidates have difficulty combining geometric and algebraic principles when solving problems. Applying trigonometric ratios and Pythagoras' theorem in geometric contexts might be challenging (2018/P2/Q17, 2019/P1/Q16), which emphasizes the need for students to have a thorough understanding of mathematical ideas. When faced with geometry problems involving algebraic manipulation, learners who are struggling can evaluate their understanding by experimenting with manipulatives. For instance, this procedure might help people see connections and changes which could result in more useful problem-solving techniques (Tjandra, 2023).

Application difficulties of geometric principles

This challenge is concerned with the precise application of geometric concepts to problem-solving. It was observed that candidates struggle to recognize angles and geometric attributes within figures (2017/P2/Q17, 2022/P2/Q17) and to determine the curved surface area of geometric solids (2016/P2/Q17, 2020/P2/Q04). The analysis of the literature brought to light the ongoing difficulties that students encounter while trying to comprehend and apply geometric principles. It has been determined that learners struggle most with concepts like congruent triangles, circles and circle theorems, trigonometry, and coordinate geometry (Salifu et al., 2020).

Conceptual understanding and misconceptions

It was mentioned that candidates had trouble grasping concepts and had misconceptions about geometry. Concerns include misunderstandings of geometric concepts (2016/P1/Q04, 2017/P1/Q05) and the relationship between surface area and volume (2018/P2/Q09, 2022/P2/Q06), underscoring the significance of clearing out underlying assumptions. Challenges related to conceptual understanding and misconceptions in geometry are echoed in Luneta's study on errors in geometric transformations (Luneta, 2015). Recommendations for targeted interventions align with Mosia et al.'s emphasis on assessing learners' levels of geometric reasoning for effective instructional planning (Mosia et al., 2023). Also, the study supports the notion of relevant cognitive load within CLT. Relevant cognitive load pertains to the cognitive effort devoted to meaningful learning activities that facilitate information processing and integration into long-term memory. The recommendations from the study emphasize strategies to enhance relevant cognitive load in geometry education, such as implementing innovative teaching approaches, strengthening spatial visualization skills, integrating algebraic manipulation with geometry, and reinforcing conceptual understanding (Sweller et al., 1998). The identified challenges underscore the importance of targeted instructional strategies to enhance students' proficiency in geometry.

Geometry concept prevalence and perceived importance in UCE examinations.

This subsection presents prevalent geometry concepts and the distribution of geometry-related questions in UCE examinations. Table 3 illustrates assessed mathematical concepts.

Table 3: Showing mathematical concepts assessed across years (2016 to 2022)

Year	Mathematical Concepts Assessed
2016	Substituting equations, solving equations, determining domains and ranges, integers, pie-charts, translations*, L.C.M., sample space, determinants, gradients, trigonometry, simultaneous equations, matrices, area, mean, median, functions, reflections, inequalities, percentages, Venn diagrams, gradients of lines, surds, coordinates, vectors, taxation, Pythagoras Theorem, 3-Dimensional Geometry, linear kinematics, mixed fractions, linear scale factor, units conversion, papygrams, composite functions, currency exchange, hire purchase, modulus, vector ratios.
2017	Factorization, simultaneous equations, statistics, operations, plane geometry, matrices, linear inequalities, Pythagoras’ theorem, probability, rotation transformation, graphical solution of quadratic equations, matrices addition and multiplication, changing subjects in formulas, geometrical construction, probability tree diagrams, matrices transformation, linear programming, business mathematics, sets, graphs, and coordinates, mensuration in three-dimensional geometry, rationalizing denominators, functions, coordinate geometry, ratios, vectors, BODMAS, map scales, sets and logic, kinematics, papygrams, collinearity of points using vectors, exchange rates, three-dimensional geometry (cuboid).

Year	Mathematical Concepts Assessed
2018	Substitution and evaluation, inequalities, matrices, mean, factors and squares, quadratic equations, the similarity of figures, reflection, probability, waves, transformation, simultaneous equations, matrices and transformations, construction, scale drawing, simultaneous equations using matrix method, linear programming, recurring decimals, coordinates and parallel lines, three-dimensional geometry and mensuration, sets and complements, graphs and equations, laws of logarithms and indices, business mathematics, relations and mappings, surface area of a cube, vector geometry, functions, sets and logic, kinematics, annual taxable income, variation, vectors, three-dimensional geometry calculations.
2019	Logarithms and indices, sets and Venn diagrams, graphs and equations, fractions and recurring decimals, coordinates and geometry, algebraic expressions and equations, angles in circles, simultaneous equations, cumulative frequency and Ogive, matrix multiplication, time intervals and equations, matrices and determinants, bearings and measurements, probability and trees, trigonometrical ratios and curves, matrix transformation and coordinates, linear programming, numerical concepts, functions and mappings, three-dimensional geometry, vectors and magnitude, business mathematics and compound interest, volume and surface area calculations, collinear points and position vectors, joint variation equations, sets and logic, velocity-time graphs, composite functions and inverses, taxation and net income calculations.
2020	Consecutive odd numbers, simultaneous equations, trigonometric ratios, mean for grouped data, laws of indices, quadratic equations, matrix multiplication, angles in circles, area scale factor, histograms and mode estimation, bearings and measurements, formulas and standard form, matrices, and profit calculations, table completion and curve drawing, probability and independent events, geometric transformations, linear programming, logarithms and prime factors, functions and mappings, kinematics and equations, 3-dimensional geometry, business mathematics and commission, numerical evaluation, sets and intersections, gradients and equations of lines, vectors and displacement, angles in pyramids, volume and area ratios, Venn diagrams and

Year	Mathematical Concepts Assessed
	probability, volume calculations and unit conversion, compound interest and tax calculations, inverse functions, graph plotting and symmetry, vector routes and equations.
2022	Linear equations and LCM, matrix inversion, algebraic expressions and factorization, properties of polygons, vectors, and transformations, mean for ungrouped data, inequalities, pie charts in problem-solving, bearings, laws of indices and quadratic equations, matrices and operations, the geometry of circles, speed, time, and distance, simultaneous equations, transformation matrices, linear programming and inequalities, ratio and proportion, sets and Venn diagrams, gradients and linear equations, function substitution and inverse, surds and rationalization, volume calculations, coordinate geometry, vector operations, currency conversion, scale factor equations, powers and indices, probability and set notation, hire purchase calculations, vector ratios and diagrams, geometry of pyramids.

Source: Content analysis for assessment focus of each question item.

** The blue color highlights the mathematical concepts related to Geometry.*

From Table 3, every year's examination covered a broad spectrum of mathematical concepts, ranging from sophisticated geometric concepts and statistical applications to basic algebraic operations. To highlight real-world mathematical applications, 2017 saw a noticeable emphasis on geometry and problem-solving, with ideas like vectors, coordinates, and statistics. In the years that followed, algebra and geometry were systematically integrated, with an emphasis on more complex mathematical concepts by 2019 such as logarithms and matrix operations. Assessments in 2020 gave priority to problem-solving and practical applications, whereas the 2022 cycle focused on understanding fundamental mathematical ideas including vector operations and algebraic expressions. This tendency highlights the basic importance of geometry in assisting students in developing their critical thinking and spatial reasoning abilities,

In addition to geometry, the UCE exams heavily rely on algebraic concepts. Among the subjects that are frequently assessed are factorization, quadratic equations, matrices, and inequalities, highlighting the links between algebra and geometry in the broader field of mathematics. Algebra and Geometry are combined to emphasize the interconnection of many mathematical disciplines and the holistic approach to mathematical learning through topics like functions, coordinate geometry, and vector operations. While the frequency of certain topics varies throughout examination years such as sets and logic, logarithmic and index laws, linear programming, and other topics, this change is a reflection of shifting curricular emphasis and educational trends. These variations highlight how dynamic mathematics education is and force teachers to modify their lesson plans in response to shifting student needs and assessment frameworks.

However, geometry-related subjects have been examined in the Uganda Certificate of Education (UCE) for a long period, demonstrating geometry's ongoing significance in the mathematics curriculum. Exams cover fundamental subjects such as coordinates, reflections, transformations, three-dimensional geometry, Pythagoras' theorem, and properties of polygons each year. The results of the investigation show a clear trend in the frequency and importance of geometry-related ideas. Interestingly, geometry is a major theme every year; subjects like coordinates, reflections, transformations, 3-dimensional geometry, Pythagoras' Theorem, and polygonal characteristics are all often evaluated.

However, in contrast to other mathematical fields, a notable tendency can be seen in the more recent evaluations, especially in 2020 and 2022, of increase in the assessment of themes connected to geometry. This indicates that contemporary curriculum assessments have placed a conscious emphasis on geometric problem-solving abilities and spatial reasoning, reflecting the understanding that geometry is a fundamental component of mathematical competency and critical thinking. Concepts like logarithms, compound interest, taxation, matrices, and simultaneous equations are still assessed, but their rising tendency is not as strong as that of geometry-related topics, suggesting that geometric reasoning is still being prioritized in mathematics education. The continued popularity of geometry ideas emphasizes both their fundamental value in math education and their ongoing applicability in real-world situations

The literature strongly supports the notion that geometry holds a central and vital role within secondary school mathematics education in Uganda. It is considered a major branch of mathematics, integral to understanding and applying concepts across various mathematical disciplines and related subjects like physics and engineering, as outlined in the NCDC curriculum framework (NCDC, 2019). Also, the finding aligns with literature advocating for tailored pedagogical approaches to address geometry challenges (Juman Abdeen et al., 2022; Naidoo & Hajaree, 2021). The enduring importance of geometry underscores the need for innovative instructional strategies, such as activity-based learning methods and visual representations to enhance student engagement and comprehension (Luneta, 2015; Mifetu, 2023).

The trend of the number of mathematics questions set across different topics and years

Fascinating trends in question representation throughout time were found via trend analysis of UNEB questions on a variety of themes (Figure 1).

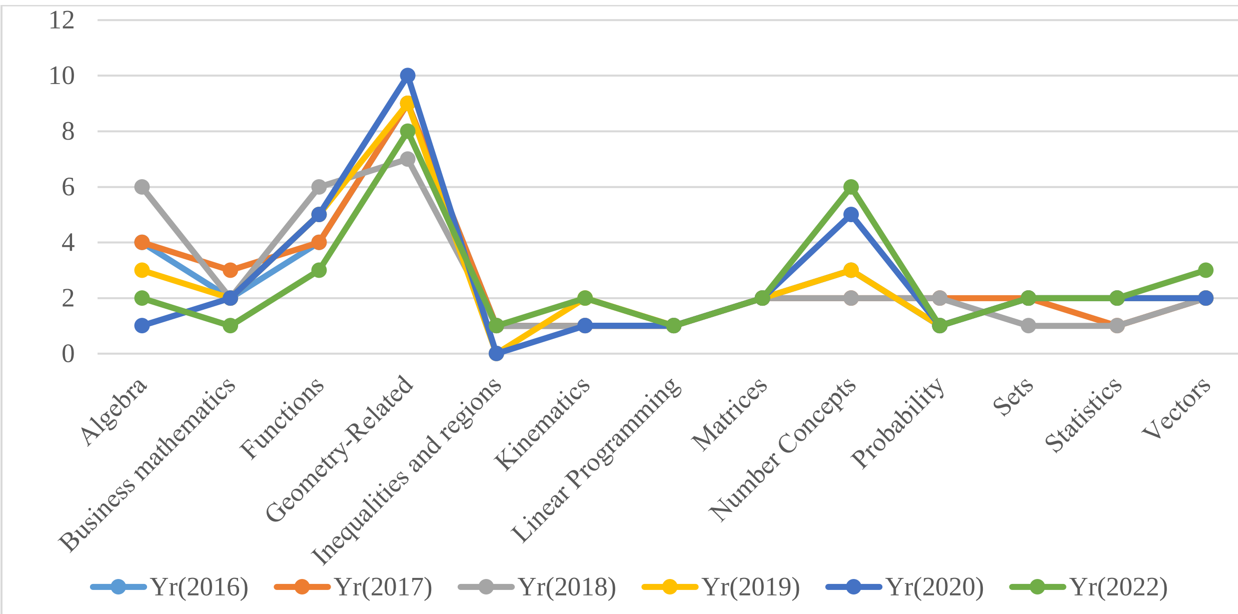

Figure 1: Showing the trend of number of mathematics questions set across topic and year

The number of algebra questions fluctuated, reaching a peak of six in 2018 but then falling in the years that followed, indicating that the examination syllabus had different priorities. Business mathematics showed a consistent representation in test material over the years, except for a modest decline in 2020 and 2022. Questions on Functions reached their zenith in 2018 and then started to dwindle, maybe due to changes in the priorities of the curriculum or the emphasis on assessments. The representation of themes linked to geometry was stable, with a peak observed in 2019. This indicates the continued significance of geometry concepts in assessments. After 2018, there was a decrease in the representation of Inequalities and Regions, indicating a possible change in curriculum or assessment goals. Moderate variability was seen in kinematics and vectors, which is indicative of shifts in the assessment's focus on these topics. Number concepts showed a discernible upward trend starting in 2018, indicating an increasing focus on basic numerical concepts. Over time, probability, sets, and statistics were consistently represented in examinations, suggesting that these fundamental mathematical topics were consistently given attention. It is evident from this trend that themes connected to geometry continue to be highly represented in comparison to other themes. This pattern reflects a persistent interest in and importance of geometry within the curriculum and evaluation criteria across time, underscoring the ongoing significance and attention put on geometry ideas in UNEB evaluations and the significance of geometry itself (NCDC, 2019).

Feasibility and effectiveness of recommended strategies from report on the work of candidate to enhance Geometry education.

The report on the work of candidates identified specific recommendations for addressing various challenges in geometry education. For instance, students' failure to calculate trigonometric values correctly (2019/P1/Q15) shows problem in trigonometrical understanding. To address this, UNEB recommended instructional strategies emphasizing the correct drawing of trigonometrical graphs and tables while using calculators and tables for calculations. This involves incorporating hands-on activities with calculators and graphical representations of trigonometric functions to enhance understanding. Another significant challenge identified centered on scale factors and geometry, where students exhibited an inadequate understanding of Area Scale Factor (ASF), Volume Scale Factor (VSF), and Linear Scale Factor (LSF) (2016/P2/Q05). UNEB suggested instructional strategies emphasizing computing and relating scale factor skills through problem-based learning (PBL) to engage students in real-world problems related to scale factors.

Spatial visualization also posed a challenge, with students having trouble in visualizing 3-dimensional diagrams (2016/P2/Q10). UNEB recommended instructional strategies that emphasize the use of models in teaching 3-dimensional Geometry, coupled with hands-on activities and physical models to aid spatial visualization. Similarly, challenges with geometry understanding included confusion with geometric formulas and concepts (2016/P2/Q17, 2020/P2/Q04). UNEB recommended using models to teach 3-dimensional Geometry and implementing technology tools for interactive learning; for instance, integrating dynamic geometry software such as GeoGebra, Geometer's Sketchpad, and practical demonstrations to enhance comprehension.

Volume concepts and unit conversion were also challenging for students to understand, leading to difficulty in applying these concepts (2017/P2/Q04, 2020/P2/Q13). UNEB recommended teaching methods that emphasize the practical application of volume concepts and unit conversion through real-world scenarios and problem-based learning. Practical geometry also posed challenges to students; trouble in determining lengths and angles in 3-dimensional figures (2017/P2/Q17, 2020/P2/Q10). UNEB recommended teaching 3-dimensional Geometry using models for practical understanding, supplemented by hands-on activities and physical models to aid the visualization of geometric relationships.

Learners also had trouble with mensuration skills and particularly their confusion with solid geometry formulas were identified as a challenge (2018/P2/Q03). UNEB recommended comprehensively teaching the mensuration of solids using models, manipulatives, and physical models to explore solid geometry. Additional challenges identified were with geometric theorems and properties which highlighted the difficulty candidates had in applying these concepts (2018/P2/Q17). UNEB recommended emphasizing the identification of geometric properties and practical applications through problem-solving scenarios and hands-on activities.

Visualization and practical application challenges were also identified, including student trouble with interpreting geometric language and figures (2019/P2/Q07, 2017/P2/Q17, and 2019/P2/Q17). UNEB recommended using nets and models for practical applications and integrating technology tools for interactive exploration. The recommended instructional strategy involves incorporating physical models, manipulatives, and dynamic geometry software to demonstrate geometric concepts effectively. Finally, challenges with concepts of similarity and enlargement were observed, with students failing to apply similarity concepts effectively (2018/P1/Q07). UNEB recommended providing more practice involving similarity and enlargement, supplemented by hands-on activities and visual aids to illustrate concepts. From the above UNEB recommendations, three overarching themes emerged from a thematic analysis of the qualitative data taken from the report on the candidates' work as explained below.

Spatial visualization enhancement

The recommendations stressed how crucial it is for learners to develop their spatial visualization abilities, especially when it comes to comprehending three-dimensional geometry. To help students correctly visualize and interpret geometric shapes, teachers were urged to employ models, hands-on activities, technology, and practical demonstrations. This strategy is in line with studies indicating that practical learning and visual aids improve students' understanding and memorization of mathematical ideas, particularly those on geometry and spatial reasoning (Kastens & Ishikawa, 2006b; Wahab et al., 2016).

Application-based learning for problem-solving

The recommendations suggest that helping students in understanding the connections between algebraic equations and geometric figures calls for the provision of real-world applications and multidisciplinary settings, i.e., that students should engage in hands-on experiments and real-world situations to develop a deeper understanding of geometric principles and their applications. Teachers can help their students become more adept at applying algebraic concepts to solve geometric problems by integrating mathematical concepts into a range of topic areas and real-world scenarios (Driscoll et al., 2017). As suggested by multiple prior research, this approach fosters a thorough knowledge of mathematics by emphasizing the relevance of abstract concepts in real-world contexts and creating interdisciplinary connections with other academic disciplines (Andika et al., 2020; Asli & Zsoldos-Marchis, 2021; Bal & Doğanay, 2022; Viro & Joutsenlahti, 2020). For instance, using technology, practical demonstrations, and hands-on activities to improve spatial visualization skills aligns with curriculum objectives and makes use of readily available resources that are frequently used in educational settings (Abdullah & Zakaria, 2013; Aboagye et al., 2021; Akhter & Usmani, 2018; Altıparmak & Gürcan, 2021; Ayuningtyas et al., 2019; Brijlall & Abakah, 2022; Çavuş & Deniz, 2022).

Conceptual understanding reinforcement

The recommendations emphasized how crucial it is to clear up misconceptions and reinforce basic geometric ideas. To help students get a deeper conceptual understanding of geometry, teachers are encouraged to implement targeted interventions, individualized support, and a variety of instructional methodologies. Furthermore, gives students more practice and guidance to assist them gain confidence in their ability to solve quadratic equations and carry out algebraic operations linked to geometry. Teachers can help students grasp fundamental geometric ideas and become proficient in using algebraic principles in geometric contexts by implementing these tactics (Alex & Mammen, 2018; Malatjie & Machaba, 2019; Mills, 2016).

These teaching strategies aim to boost students' interest and involvement in geometry classes by emphasizing experiential learning, real-world applications, and interdisciplinary approaches. The focus on reinforcing fundamental geometric concepts and dispelling myths aligns with known educational research, offering a promising path to enhance students' geometry proficiency (Xu et al., 2023). These strategies have been found to be effective in numerous research studies by Ishikawa & Newcombe (2021), and Kastens & Ishikawa (2006). The latter studies highlight the critical role of spatial visualization in understanding complex geometry concepts and emphasize the effectiveness of using tools like GeoGebra, augmented reality, and 3D printing to enhance these skills. Chivai et al. (2022) also validate the use of GeoGebra in improving students' spatial reasoning and engagement with cylindrical geometry through interactive and visual learning experiences and Sahronih et al. (2019) and Yew & Goh (2016) show how application-based learning, integrated with real-world scenarios, enhances problem-solving skills and makes abstract mathematical concepts more relatable. Similarly, Alex & Mammen (2018) confirm that Van Hiele's phased instruction effectively addresses misconceptions and strengthens conceptual understanding in geometry, demonstrating that these strategies collectively enhance student outcomes in geometry education.

To effectively implement these ideas, educational institutions need to budget for the provision of geometrical tools, instructional technology, interdisciplinary teaching materials, and for teacher professional development. By fostering a love of mathematics in students through the provision of engaging learning experiences and student-centered initiatives, schools may equip them with the critical problem-solving skills they need to excel academically and in real-world circumstances (Kastens & Ishikawa, 2006b; Xu et al., 2023).

For many students, geometry's intrinsic complexity often comes with the challenges of intrinsic cognitive load. However, depending on their past knowledge, learning preferences, and the instructional strategies employed to teach geometry, learners may encounter other difficulties. Furthermore, the disparities in response quality that have been noted between geometry topics and the frequency of poor-quality responses in specific geometric domains point to the impact of extraneous cognitive load brought on by how geometry-related questions are presented and evaluated. The study findings offer empirical evidence in favor of cognitive load theory in the context of teaching geometry, highlighting the significance of matching instructional approaches to cognitive load theories to improve student learning outcomes and experiences (Paas & van Merriënboer, 2020; Sweller, 2019; Sweller et al., 1998).

CONCLUSIONS AND RECOMMENDATIONS

The study has analyzed key aspects of geometry education in UCE examinations, focusing on question attempt levels, topic specificity, geometry concept frequency, and teaching method effectiveness. The study shows that in UCE exams, higher question attempt levels correlated with improved response quality, highlighting the influence of student effort. Various geometry themes exhibited differing response quality, emphasizing the need for targeted training and consideration of topic specificity in instructional interventions. The frequency of geometry topics in UCE exams emphasizes the ongoing significance of geometry instruction in mathematics education. However, the study identified substantial differences in response quality between geometry-related topics and other mathematical areas. This underscores the necessity for targeted interventions to enhance students' performance and comprehension in geometry.

Three strategies that this study focused on are spatial visualization enhancement, application-based learning for problem-solving, and conceptual understanding reinforcement. These strategies align with cognitive load theory (CLT), emphasizing controlled cognitive functions for efficient learning. The study highlights the complexity of geometry concepts, identifies factors contributing to cognitive load, and advocates for managing cognitive load to improve understanding.

The recommendations for improving geometry education can be categorized into three main areas: (1) addressing the current challenges in geometry education, (2) advocating for policy changes and resource allocation, and (3) suggesting areas for further research. To solve existing problems, it is crucial to prioritize geometry within the curriculum and allocate resources to support innovative teaching methods like hands-on activities and technology integration. Enhancing spatial visualization and conceptual understanding through practical demonstrations and targeted interventions is also essential. For policy advocacy, supporting professional development for educators and collaborating with curriculum developers to refine geometry frameworks and assessment practices are key. Advocating for sufficient resources and instructional materials will further support effective geometry instruction. Lastly, future research should explore interdisciplinary connections between algebra and geometry, assess collaborative learning approaches' effectiveness, and conduct longitudinal studies to evaluate the impact of implemented strategies and policy changes on student outcomes and attitudes toward geometry education. These recommendations aim to strengthen geometry education and promote student success in this critical area of mathematics.

DATA AVAILABILITY. The data used in this study was obtained from the reports on candidates' work published by UNEB and it can be requested through the official UNEB website (http://www.uneb.ac.ug). The specific data extracted from these reports is publicly available through the following link:

https://docs.google.com/spreadsheets/d/1iHK_mvOd_wk9htABeenmyhC7k8KgqkCmbI8LWHs45xk/edit?usp=sharing

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AUTHOR CONTRIBUTIONS: *Issa Ndungo* was responsible for the conceptualization, methodology, data collection, analysis, and writing of the draft paper.

Edwin Akugizibwe and *Sudi Balimuttajjo* provided supervision, guidance on research design and data analysis, and contributed to the review and editing of the manuscript.

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