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Teachers' Experiences in Using Universal Design for Learning in Primary Mathematics Classrooms: Professed Benefits

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Abstract: The study explored the potential benefits of using the Universal Design for Learning (UDL) guidelines in primary mathematics classrooms. The multiple case study reported in this paper, grounded in social constructivism theory, focused on five under-resourced rural primary schools in the Free State Province, South Africa. A homogeneous purposive sampling method was used to select five mathematics teachers, one from each school. Data was generated through lesson observations, focus group discussions, and document analysis, with inductive content analysis employed to analyse the data. UDL guideline version 2.2 was used to interpret the data and provide explicit examples of UDL practices. The major pedagogical benefits of UDL, as indicated by the study's findings, included enhanced understanding and processing of content, offering learners multiple ways to access and engage with mathematical concepts, providing flexible teaching, and catering to a diverse learner population. Thus, the study's findings suggest that teachers should be strategic and intentional in using UDL to strengthen learning.

Keywords: Approach, primary mathematics, rural schools, universal design, Learning.

1. Introduction

Various researchers define Universal Design for Learning (UDL) as a flexible teaching framework that promotes inclusivity, accessibility, and diverse instructional strategies designed to meet the varied needs of all students (Dalton, 2017). Recent studies have expanded on this concept, highlighting UDL's potential to enhance learner autonomy and engagement through multiple methods of representation, expression, and interaction (Lee & Garcia, 2020; Kim, Rodriguez, & Lee, 2020). These contemporary perspectives emphasise that UDL is not just a collection of teaching techniques but a comprehensive strategy for curriculum development that addresses learner diversity and removes barriers to learning. Ultimately, this approach fosters a more equitable and responsive educational environment.

UDL is a framework that simplifies instructional design and makes content accessible to all learners (Baybayon, 2021). It is often used to support the planning and implementation of inclusive approaches (Garrad & Nolan, 2023). It further assists in guiding teachers to meet the educational needs of increasingly diverse learners in schools (Barteaux,2014). The UDL framework encompasses three principles underpinned by brain-based learning theories, research-based best practices, and instructional technologies (Sewell, Kennet, & Pugh, 2022). These principles offer meaningful applications that enable learning to occur and succeed for all learners (Pisha & Coyne, 2002; Rose & Meyer, 2002). The three UDL principles are multiple means of representation (MMR), multiple means of action and expression (MMAE), and multiple means of engagement (MME) (Centre for Applied Special Technology [CAST], 2011).

According to the UDL Guidelines, version 2.2, MMR aligns with the brain's recognition networks, which deal with the "*what*" of learning, encompassing perception, language and symbols, and comprehension. MMAE corresponds with the strategic brain networks that address the "how" of learning, involving physical action, communication, and executive function. Furthermore, MME

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aligns with the affective brain networks that focus on the "why" of learning, including recruiting interest, effort and persistence, and self-regulation (CAST, 2018b). The UDL principles constitute guidelines that promote inclusive, flexible, and accessible teaching, thus making it possible to achieve the goal of inclusive education, namely, "*no child left behind*" (Almumen, 2020). Appendix A (Figure 1) illustrates the three brain networks that depict how learning takes place.

The significance of this study lies in its contribution to ongoing discussions about the application of Universal Design for Learning (UDL) in mathematics, a field often regarded as "challenging" due to its abstract concepts and symbolic notation (Meyer, Rose, & Gordon, 2014). Historically, mathematics education has faced obstacles that can hinder students' engagement and understanding, particularly in diverse and underfunded settings (Rao, Ok, & Bryant, 2014). This has resulted in a perception of mathematics as a particularly difficult subject, leading to student disengagement and unequal learning outcomes (Lee & Garcia, 2020). Recent discussions have highlighted the transformative potential of UDL in reshaping mathematics instruction by providing flexible strategies that address the diverse needs of learners. Research indicates that applying UDL principles—through various methods of representation, engagement, and expression—can effectively reduce comprehension barriers and increase student involvement (Smith & Johnson, 2020; Kim, Rodriguez, & Lee, 2020). This study examines the firsthand experiences of primary mathematics teachers in resource-limited settings, providing timely empirical evidence that flexible and inclusive teaching approaches not only improve classroom dynamics but also have the potential for long-term, systemic advancements in educational practices. Ultimately, the findings contribute to ongoing discussions about educational reform and emphasise UDL's capacity to transform mathematics education in equitable and sustainable ways.

1.1 Literature review

1.1.1 The relevance of UDL in mathematics education

Recent research (Iyamuremye, Ndayambaje & Muwonge, 2021; Mpiti & Wambu, 2023; Aguhayon, Tingson & Pentang, 2023) indicates that the continued reliance on traditional teaching methods in mathematics classrooms significantly contributes to students' underperformance in the subject. Tsimane (2020) regards these methods as ineffective since they promote rote learning, which limits learners' conceptual understanding (Viennot, 2008). Traditional teaching practices further impede deep learning of mathematical concepts and often result in poor development of learners' reasoning skills (Umugiraneza et al., 2017). The traditional methods predominantly used in mathematics teaching disregard the fact that learners have diverse needs, which is a core emphasis of learner diversity as an issue worth addressing in educational practices (Possi & Milinga, 2017). UDL thus serves as an effective practice model for guiding inclusive and accessible teaching that works well for all learners, regardless of the different characteristics they bring to the classroom (Moleko, 2018).

1.1.2 The common challenges in primary mathematics classrooms that UDL aims to address

The poor performance of primary learners in mathematics is a cause for concern in South Africa and globally (Mabena et al., 2021). As such, primary mathematics teachers have a vital role to play in ensuring that mathematics teaching becomes effective. As the first individuals to engage with learners, these teachers are responsible for laying a solid foundation and ensuring that learners are fully prepared for subsequent higher grades. Hence, Machaba (2017) stresses the importance of developing learners' foundational skills in mathematics through the proper selection and utilisation of content. According to Naude and Meier (2014), effective mathematics learning occurs when learners' curiosity inspires them to test their mathematical ideas in real life. To foster curiosity in learners, teachers need to employ specific tailored strategies (Pluck & Johnson, 2011). However, tailoring appropriate teaching strategies to develop such curiosity seems to be a "*mission impossible,*" as most teachers lack the pedagogical knowledge necessary to teach mathematical concepts effectively (Agyei et al., 2024). Taylor (2021) argues that, in certain instances, the assessment processes used by universities, particularly regarding lecturer evaluations, may result in the certification of student teachers who have not fully demonstrated the necessary competencies to teach mathematics effectively in South African primary schools. This poses serious challenges and makes it almost impossible for teachers to build a strong foundation that enables learners to cope with mathematics in higher grades. Consequently, we later observe learners dropping mathematics, opting for mathematical literacy, and sometimes abandoning it completely in secondary school.

Ball (1990b) maintains that knowing the subject matter is insufficient to teach it. Thus, beyond the content knowledge that teachers possess, they also need to harness pedagogical knowledge to teach the content effectively. Therefore, there is a need for a framework that will provide teachers with guidelines for the effective teaching of mathematics in primary schools. This framework should empower teachers with teaching guidelines and strategies for designing accessible and inclusive instruction to accommodate a diverse learner population. Hence, the UDL framework is deemed relevant for guiding the effective teaching of mathematics, as it encompasses the guidelines that promote flexible teaching, inclusivity, and accessibility (Moleko & Mosimege, 2021). This framework needs to be employed by primary teachers, as they are the first individuals to engage with the learners. They therefore have a significant responsibility to build a solid foundation and ensure that learners understand the mathematical concepts that later become prerequisites for learning topics in higher grades. Teaching mathematics in primary school using the UDL framework will offer several benefits, including guiding flexible and effective instruction and addressing diverse learning styles and difficulties in understanding abstract concepts.

1.1.3 Universal design for learning implementation in mathematics

There is extensive literature on implementing UDL in mathematics classrooms (Thomas et al., 2015; Lambert, 2020; Fovet, 2020; Root, Cox, Saunders & Gilley, 2020; Lohmann, Hovey & Gauvreau, 2018). This body of literature demonstrates how UDL can be applied to guide mathematics teaching and the associated benefits. The subsequent sections summarise the work that has been done in the field of mathematics in relation to UDL.

The implementation of UDL has been found to be effective in enhancing the mathematical problem-solving skills of learners with extensive support needs (ESN) (Root, Cox, Saunders & Gilley, 2020). Moleko's (2022) study illustrates the positive effects of applying a universal design for learning to guide the accessible, flexible, and inclusive teaching of geometry, maximising learning outcomes. UDL also serves as an effective educational framework for teaching learners in diverse classrooms, including multilingual mathematics settings (Moleko, 2018). Its application provides an instructional planning process that inspires classroom teachers to purposefully embed suitable accommodations and integrate multiple entry points into "cognitively demanding tasks to promote reasoning and problem-solving while meeting the needs of students with a broad range of interests and skills" (Buchheister et al., 2017, p. 8).

In an endeavour to enhance the application of assessments in mathematics through UDL, Nieminen (2022) found a universal design for assessment framework to be promising in a mathematics context, where assessment often does not enable students with disabilities to participate fully due to inaccessible practices. The study further identified UDL/UDA as useful in promoting partnership, diversity, and dialogue in mathematics assessment. The UDL principles can be employed to create classrooms that include students with disabilities in meaningful mathematics learning. Additionally, it aids teachers in providing access through multiple means of engagement, representation, and strategic action (Lambert, 2017). Although there is evidence regarding the application of UDL in mathematics, there appears to be a dearth of research reporting on the claimed pedagogical benefits of UDL in teaching mathematics at the primary school level, which is the gap this study intends to address.

1.2 Theoretical framework

This research is based on Social Constructivism Theory (SCT) as its theoretical foundation. A theoretical framework serves as a lens derived from established theories that guide every phase of the research process, from formulating research questions to interpreting data (Creswell, 2013; Miles & Huberman, 1994). It outlines the essential rationale for the study, ensuring that the investigation is anchored in a well-defined body of knowledge. Social Constructivism Theory (SCT) originates from the pioneering work of Lev Vygotsky (1978), who emphasised that learning is fundamentally a social activity. Vygotsky's concepts were later expanded by theorists such as Bruner (1996), who highlighted the role of culture, language, and social interactions in shaping cognitive development. These foundational contributions have established SCT as a crucial framework for understanding how individuals construct knowledge through social and cultural interactions. SCT posits that knowledge is actively constructed through engagement with others and is significantly influenced by the cultural and contextual environment in which these interactions occur (Vygotsky, 1978; Bruner, 1996). Rather than viewing knowledge as a fixed entity transmitted from the teacher to the learner, SCT emphasises that learning is a fluid, collaboratively built process. This perspective is particularly relevant for understanding how teachers develop and refine their practices when implementing Universal Design for Learning (UDL) in mathematics education. SCT is grounded in three primary principles:

- Co-construction of Knowledge: This principle asserts that learning is not an individual endeavour; instead, it emerges from dialogue, collaboration, and shared experiences (Vygotsky, 1978).
- Zone of Proximal Development (ZPD): This concept suggests that effective learning occurs when individuals receive support from more knowledgeable peers, allowing them to progress beyond their current abilities (Vygotsky, 1978).
- Contextual and Cultural Mediation: This principle indicates that cognitive development is deeply rooted in the cultural, social, and historical context in which learning occurs (Bruner, 1996).

In the context of this study, these principles imply that teachers' experiences with UDL are shaped by their interactions with colleagues, students, and the broader educational environment. The socially constructed nature of knowledge means that the specific contexts of their classrooms influence the perceived benefits of UD as experienced and expressed by teachers. For example, the collaborative elements inherent in UDL align with SCT's focus on social interaction as a catalyst for learning. This alignment makes SCT a suitable theoretical framework for understanding how teachers navigate, adapt to, and benefit from UDL practices.

To analyse the qualitative data collected in this study, the UDL guideline version 2.2 (see Table 1) is used as an analytical framework to organise UDL practices. When examined through the lens of SCT, the guideline emphasises how UDL fosters various pathways for interaction, engagement, and expression. This integration reinforces that teachers' experiences with UDL are not solely technical or procedural; they are also based on social interactions and context-specific practices. As a result, SCT offers the conceptual framework needed to understand the intricate, socially mediated benefits of UDL in primary mathematics classrooms. APPENDIX B (Table 1) represents the UDL guideline version 2.2 [principles and the brain networks].

1.3 Problem statement

The study reported in this article aimed to explore the experiences of rural primary mathematics teachers regarding the application of Universal Design for Learning (UDL) principles in their classroom lessons. Despite ongoing recommendations and advocacy for using UDL as a strategy to achieve the primary goal of inclusive teaching and learning, little empirical data demonstrates the practical benefits of implementing UDL principles as reported by the teachers, particularly in rural primary schools. Therefore, this study sought to identify and report on the benefits of applying UDL as expressed by the rural primary mathematics teachers who participated in this research, with a primary focus on how their UDL-informed teaching impacted student learning, engagement, and outcomes. Exploring the teachers' experiences and accounts of implementing UDL principles provides valuable insights into the efficacy of UDL, which is essential for influencing future policy reviews to promote effective mathematical teaching practices that benefit all learners. Based on this, the study sought to answer the following research question:

- What advantages does Universal Design for Learning (UDL) offer in teaching mathematics in primary schools?

2. Research Methodology

This study adopts a qualitative research approach using a multiple case study research design to explore and understand the potential benefits of using Universal Design for Learning (UDL) guidelines in the primary mathematics classroom. Qualitative research aims to describe or explore human experiences and perspectives (Kyngäs, 2020). Multiple case study research is a qualitative methodology that allows researchers to contrast individual cases, which represent a diversity of qualities and extremes, to create depth and understand a broad phenomenon without losing the individuality of each case study (Baxter & Jack, 2008; Thomas, 2011; Adams et al., 2022). In this study, the multiple case study approach facilitated an in-depth examination of each case while enabling cross-case analysis to identify common themes and patterns. The study was conducted in five rural primary schools in the Free State Province, South Africa. These schools were specifically chosen due to their under-resourced status, which presents unique challenges and opportunities for implementing UDL. A homogeneous, purposive sampling technique was employed to select the participants, ensuring that the sample comprised mathematics teachers from each of the five schools. This approach was used to gather insights from teachers with similar characteristics and teaching environments, thus providing a coherent understanding of the phenomenon under study.

The study employed three primary data collection methods: lesson observations, focus group discussions, and document analysis, to comprehensively understand the teachers' experiences. Classroom observation has played a role in documenting classroom practices to improve teaching and learning outcomes (Ndihokubwayo Uwamahoro & Ndayambaje, 2021). In this study, observations of mathematics lessons were conducted to capture the real-time implementation of UDL principles. Observational data provided insights into the teaching strategies used and the interactions between teachers and students. Focus group discussions were held with the five participating teachers to further explore their experiences, perceptions, and the benefits of using UDL in their classrooms. Focus group discussions are frequently used as a qualitative approach to gain an in-depth understanding of social issues (Nyumba et al., 2018). The focus group discussions in this study allowed participants to share diverse perspectives on the phenomenon under investigation.

Document analysis involved examining relevant documents, such as lesson plans, teaching materials, and assessment records, to triangulate the data obtained from observations and focus group discussions. Document analysis requires examining and interpreting data to elicit meaning, gain understanding, and develop empirical knowledge (Bowen, 2009; Corbin & Strauss, 2008; Rapley, 2007). Document analysis in this study helped identify evidence of UDL principles in planning and pedagogical practices. The data collected from observations, focus group discussions, and document analysis were analysed using inductive content analysis. The data were examined according to the six steps of Braun and Clarke's (2006) thematic analysis approach. Universal Design for Learning (UDL) guideline version 2.2 was used as an analytical framework to make sense of the data and explicitly exemplify the UDL principles in practice. This framework facilitated the identification of specific strategies and practices aligned with UDL principles, enabling a structured and systematic analysis. To ensure the study's trustworthiness, the use of multiple data collection methods (observations, focus group discussions, and document analysis) helped triangulate the findings and enhance the credibility of the results.

2.1 Ethical consideration

The study adhered to ethical guidelines throughout its implementation. Approval was obtained from the University Ethics Committee to ensure compliance with both institutional and national regulations. Participants provided informed consent by receiving detailed information sheets and signing written agreements. This process ensured that they fully understood the study's aims, methods, risks, and benefits, with participation being entirely voluntary and allowing them to withdraw at any time. To maintain confidentiality, data were anonymised using pseudonyms and stored securely. A purposive sampling method was used to select mathematics teachers from under-resourced rural schools respectfully. Classroom observations, focus group discussions, and document analysis were conducted with minimal interference and in a sensitive manner, preserving the privacy and dignity of all participants. In conclusion, ethical management of data and transparent reporting practices were upheld to protect the contributions of participants and provide rich, contextual insights into the benefits of Universal Design for Learning in primary education.

3. Presentation of Data

The successive sections present the findings and discussions. Four themes that illustrate the pedagogical benefits of UDL, as expressed by the participants, are highlighted and examined in these sections.

3.1 Theme 1: Enhanced understanding and processing of content

UDL-based strategies help make content easy for learners to process and understand (Darling-Hammond & Baratz-Snowden, 2007). This was evidenced by some of the teachers' remarks during the focus group discussions, as well as highlighted during the observation sessions.

> ***Teacher 4:*** *…Some are able to understand the fraction concepts when I explain them. However, some find it very challenging. That is why I first use the concept of sharing, which they are used to. They are always asked to share items with their friends and at home, and when I teach them something like that, they are able to follow. Thereafter, I show them how a fraction is written numerically. I find the strategy very effective.*
> ***Teacher 2:*** *…I give them the activities that allow them to discover the concept independently. I give them the counters to work with, and tell them what to do, and then ask them to give me the answer...*
> ***Teacher 5:*** *…It is important to explain the numerator and the denominator. It makes it easy for them to know how to write the fraction correctly.*

Teacher 4's comment indicates that learners differ in how they assimilate and comprehend content. As such, the teacher devises strategies that reinforce understanding. To help learners easily process and understand the material, the teacher uses a mathematical example that learners can relate to. According to Teacher 4, teaching learners using relatable scenarios helps them grasp the content, hence the phrase "they are able to follow." It is only when the learners "are able to follow" (meaning, understand) that she introduces them to the numerical representation of the concept (fraction). According to UDL guideline version 2.2, using scenarios that learners can relate to helps optimise significance, value, and authenticity, enabling learners to access mathematical concepts (CAST, 2018). The practice of utilising mathematical concepts that learners encounter daily makes it easier for them to understand these ideas (Anderson, 2007). Besides promoting comprehension, this practice develops learners' awareness of the applicability of the concepts they use in mathematics classrooms outside the classroom. Thus, this practice optimises the relevance, value, and authenticity of the concept of fractions in this context. According to Da (2023), applying real-life situations in teaching mathematics makes the learning experience more meaningful and enhances learners' confidence and appreciation of mathematics.

To enhance understanding and processing of the fraction concept, Teacher 2 designs activities that actively engage the learners in the learning process. The teacher does this to ensure that the learners discover the concepts independently. Teacher 2's teaching style aligns with this approach, as she actively involves the learners in the activities. Thus, she employs counters as a different form of representation to facilitate understanding of the fraction concept. According to the UDL guideline version 2.2, using different formats to represent content enables learners to recognise and grasp the material (CAST, 2018). Furthermore, this UDL practice heightens learners' access to mathematical concepts. Adegboyega et al. (2023) endorse this practice, noting that it captures learners' interest and assists them in envisaging what they are doing, thereby explaining abstract concepts that are often difficult to understand.

Enhancing the understanding of mathematical concepts requires teachers to explain the specific mathematical key terms used. Teacher 5's statement, "…It is important to explain the numerator and the denominator. It makes it easy for them to know how to write the fraction correctly," confirms this. Addressing mathematical key terms reinforces understanding of the mathematical concepts and enhances knowledge of writing and representing them (in this context, the representation and writing of fractions). According to the UDL guideline version 2.2, teaching mathematical key terms is essential for promoting the understanding of mathematical concepts and supporting learning (CAST, 2018).

According to Seethaler, Fuchs, Star, and Bryant (2011), teaching learners mathematical vocabulary and different representations significantly contributes to developing mathematical proficiency and conceptual understanding. Van der Walt (2009) supports teaching mathematical vocabulary to aid learners in understanding mathematical concepts, which is why a certain amount of time must be devoted to teaching vocabulary (Riccomini et al., 2015). The extracts above illustrate UDL practices that enhance understanding and content processing. Using relatable mathematical examples, employing manipulatives to represent the fraction concept, and explaining the key terms involved in fractions all contribute to a deeper understanding and processing of this concept.

3.2 Theme 2: Affording learners multiple ways to access and engage with mathematical concepts

Multiple representations allow learners to access and engage with mathematical concepts (Kozma, 2020). The use of multiple representations was observed during the class, where the learners were introduced to several models for representing the fraction ¾ (see APPENDIX C - Figure 2).

Figure 1 shows the area model, bar/length model, and set model that was used to help learners understand and represent the fraction ¾. Mainali (2021) encourages the use of different representations, several of which encompass the same concept or a similar mathematical structure. These representations assist learners in grasping the common properties and enable them to extract the intended concepts. This aligns with Teacher 1, who believes that variety in teaching methods not only creates a more engaging learning environment but also promotes equity by meeting the diverse learning needs of all students.

> ***Teacher 1:*** *You know, when you use the different teaching methods and represent content in different ways, it does not only help make the session interesting, but these methods also accommodate the diverse learning styles.*

According to the UDL guideline version 2.2, customising content display improves access to mathematical content (CAST, 2018). Distrik et al. (2021) support the UDL practice of using multiple representations, as it helps clarify the concept and enables learners to build an abstraction that allows for deeper understanding.

The use of multiple representations was further exemplified by Teacher 3 in her lesson on the concept of fractions. During the focus group discussion, Teacher 3 indicated that she uses a hand-made fraction board (see Figure 2) to help learners understand this concept. From Teacher 3's reflection, it emerged that the fraction board helped clarify the concept. According to the UDL guideline version 2.2, using the fraction board addresses the abstraction of the concept, which often results from explaining the concept without utilising resources that aid in clarifying it. The board also enhances the perception of the concept and provides an alternative method for easily navigating it.

Using the fraction board (see APPENDIX D – Figure 3) further assisted the teacher in successfully incorporating the teaching of vocabulary, addressing relationships between concepts, and guiding information processing and visualisation. The lesson extract below evidences the above:

Extract 1:

Teacher 3: *…look at row number one. The green row. In there, we have one box, and call it a whole, and we represent the whole numerically as one or one over one. Do understand?*
Class: Yes, Teacher!
Teacher 3: *Now, in row number two, we have two boxes. Meaning that if we cut the box in row number one, we get two rows. This, therefore, means that in order to have whole, we have to add the two halves. Do you understand this class?*
Class: Yes, Teacher!
Teacher 3: *Let us look at row number 3. What do you see there?*
Learner 2: *One over four and one over four combined gives us one over two. Eeehh… over four plus one over four plus one over four-plus another one over 4 is equal to one.*
Teacher 3: *Wonderful Teacher 5! ...Four quarters (one over four) added together give whole, that is one. Two quarters added together gives us one half; that is one over two.*

Through the fraction board, Teacher 3 managed to demonstrate the relationship between fractions. For instance, Teacher 3 used coloured boxes (see Figure 2) to represent the fractions and their relationships. The first green box in row 1 represents a whole, which she referred to as one (1). Row 2 is divided into two equal blue parts, representing two halves. This form of representation made the concepts clear to the learners, as evidenced by the response provided by Learner 2. The learner's response shows that the board made it easy to see the relationship between rows 1 (fraction box number 1), 2 (fraction box number 2), and 3 (fraction box number 3). According to the fraction board, we must add two halves to have one whole. To obtain a half, we must add two quarters. According to the UDL guideline version 2.2, the teacher's practice of using the fraction board helps guide information processing and visualisation, thus making it easier for learners to recognise the pattern (CAST, 2018). This practice makes content perceptible and comprehensible (Burgstahler, 2009).

The fraction board further assisted the teacher in demonstrating the various representations of the fraction concept, such as ½ and a box cut into two equal parts. This form of representation facilitated communication of the key ideas related to the fraction concept (e.g. ½ represents "two equal parts of the whole"). While teaching the fraction concept with the fraction board, the teacher also addressed vocabulary that is used not only outside the classroom but also in mathematics, particularly in this context, namely, half and quarter. According to Reynders (2014), it is important to address these terms to clear any confusion that might arise, as they are not solely used in mathematics. The UDL guideline version 2.2 also endorses this practice. Thus, teachers need to eliminate learning barriers and minimise threats and distractions to help learners gain access to mathematical concepts (CAST, 2018).

The practices depicted above indicate UDL's potential benefit in providing learners with multiple ways to access and engage with mathematical concepts.

3.3 Theme 3: Providing flexible teaching

Flexible teaching is essential and beneficial because it allows teachers to meet the learners' needs and interests (Murawski & Hughes, 2009). Teachers whose teaching is flexible make it easy for learners to follow precisely what they are trying to teach them. During the focus group discussion, teachers reflected on some of the UDL teaching strategies they use to teach fractions. They reflected as follows:

> ***Teacher 1:*** *"Sometimes I bring a pizza to the class. It helps to make demonstrations. Learners understand quicker when we do demonstrations in class.*
> ***Teacher 4:*** *To introduce a different voice in my class, I sometimes use videos. I find them appealing.*
> ***Teacher 3:*** *I let them draw the pizza and use their drawings as models for teaching fractions.*

Using demonstrations in class to teach the concept of fractions seemed to be a preferred method. According to Teacher 1, demonstrations help learners quickly comprehend and grasp the concepts. According to UDL guideline version 2.2, customising content display heightens perception, making it easier for learners to understand the material. Teacher 3, on the other hand, due to a lack of resources, guided learners in constructing and replicating a pizza instead of bringing an actual pizza to class. According to UDL guideline version 2.2, this type of practice, in which the teacher uses multiple composition and construction tools, assists in making content comprehensible and in building a strong foundation for understanding. Mpalami and Moleko (2022) support this UDL practice, as it makes mathematics content accessible.

Using videos (see APPENDIX E – Figure 4) was also mentioned as one of the teaching strategies that teachers found appealing to learners. The nature of the videos, which allows for rewinding and watching at one's own pace, seems to contribute positively to learning. According to Teacher 4, videos provide teachers with various strategies that can be used to present the content in a manner that helps learners understand. Using videos offers the flexibility to teach in a way that serves the learners' interests. According to UDL guideline version 2.2, engaging learners' interests through videos optimises access to mathematical concepts. Yadav et al. (2011) assert that videos can convey intricate information more effectively than text, allowing for visual demonstrations and a more effective tone and emotion.

Using real-life scenarios (see APPENDIX F – Figure 5) also helps to bring the flexibility required to make teaching enjoyable and meaningful. Teaching real-life applications or relating mathematical concepts to real life provides learners with meaning and context for their learning (Uyen et al., 2021). The application of real life in mathematics can assist learners in making connections between mathematics and everyday life (Moleko & Mosimege, 2021). According to UDL version 2.2, this form of practice optimises value, relevance, and authenticity.

Theme 4: Catering to a diverse learner population

One of the benefits of UDL, mentioned during the focus group discussion and observed in some of the activities provided to learners during the lessons, is that UDL helps teachers cater to a diverse learner population. During one of the focus group discussions, a teacher remarked:

> ***Teacher 1:*** *You know, when you use the different teaching methods and represent content in different ways, it does not only help make the session interesting, but these methods also accommodate the diverse learning styles.*

According to Teacher 1, using different teaching methods and representing the content in various formats (see APPENDIX G – Figure 6) made her lessons vibrant and interesting. Furthermore, representing content in diverse ways helped address different learning styles, thus accommodating all learners. Multiple representations provide learners with full immersion in mathematics, enabling them to achieve a comprehensive conceptual view that fosters a mathematical mindset (Dey, 2019). This, in turn, promotes flexibility in mathematics and effective problem-solving (Nurrahmawati et al., 2020). The practice of representing concepts in multiple ways to accommodate varying learning styles was also observed during Teacher 5's lesson, particularly in one of the activities she assigned to the learners, as depicted in Figure 5. According to Distrik et al. (2021, p. 7), "multiple representation is more effective in improving concept understanding compared to traditional mode."

4. Discussion of Findings

The discussion explores the benefits of integrating Universal Design for Learning (UDL) in elementary school mathematics classrooms, drawing insights from teachers' experiences. It focuses on four key aspects: enhanced understanding and processing of content, diverse approaches to engaging with mathematical concepts, flexible teaching methods, and catering to the requirements of a varied group of students. UDL's adaptability is a key feature, allowing teachers to tailor their methods to the specific needs of their students, thereby ensuring a more effective and engaging learning experience.

Implementing UDL-based techniques significantly improved learners' comprehension and processing of mathematical material. UDL emphasises the importance of presenting information in various ways to help learners grasp complex concepts. Providing multiple means of representation is a fundamental aspect of this approach. Teachers involved in the study noted that UDL strategies enhanced the accessibility and comprehensibility of the content, which is consistent with Darling-Hammond and Baratz-Snowden's (2007) argument that UDL strategies facilitate content processing for learners. This was evidenced through discussions in focus groups and classroom observations. Teachers shared their use of visual aids, manipulatives, and real-life examples to elucidate mathematical concepts. For instance, using concrete examples, such as pizzas, to explain fractions provided a tangible context, enabling students to relate abstract concepts to familiar objects. This aligns with UDL's principle of providing multiple means of representation to enhance cognitive processing and understanding for learners (Almeqdad, Alodat, Alquraan, Mohaidat & Al-Makhzoomy, 2023).

More than merely a teaching method, UDL fosters a strong sense of community in the classroom, where learners and teachers collaborate to create an inclusive learning environment, promoting a sense of connection and engagement among educators (Boothe, Lohmann, Donnell & Hall, 2018; Navaitienė & Stasiūnaitienė, 2021). According to the perspective of social constructivism, learning involves active and social processes. Learners build knowledge through interactions with their environment, peers, and instructors (Akpan, Igwe, Mpamah & Okoro, 2020; Hayden, Carrico, Ginn, Felber & Smith, 2021). The implementation of UDL strategies, as indicated by the educators in this research, facilitated such social interactions, thereby enhancing the accessibility and comprehensibility of mathematical content. Vygotsky (1978) emphasised the collaborative nature of knowledge construction in social settings. Learning is most effective within learners' "zone of proximal development" (ZPD) - the range between what learners can achieve independently and what they can accomplish with guidance and cooperation.

The findings reveal the adaptability of UDL, as it allows students to understand and engage with mathematical concepts in ways that suit their individual learning styles. According to Kozma (2020), using diverse models to deliver content enables students to interact with and comprehend mathematical concepts from different perspectives. This was observed in classrooms where teachers employed various models, such as drawings and physical objects, to teach fractions. Teachers' remarks, including the use of drawings and videos to explain fractions, highlight the effectiveness of providing a range of representations for mathematical concepts. For example, Teacher 3's method of having students draw pizzas and use those illustrations as models for learning fractions illustrates the UDL principle of offering multiple ways of engagement. This approach allows students to choose the representation that suits them best, ultimately improving their understanding and involvement with the content. Social constructivism is important because it offers learners various ways to access and interact with content, which is essential for creating collaborative learning environments (Akpan, Igwe, Mpamah & Okoro, 2020; Saleem, Kausar & Deeba, 2021).

According to Kozma (2020), using different representations, such as models, drawings, and physical objects, is important for helping learners develop their understanding of mathematical concepts. The study demonstrated that teachers utilised various representations to encourage learners' engagement with these concepts, promoting social learning through discussion, exploration, and negotiation of meaning. The findings emphasise the significance of adaptable instruction when teaching mathematics, especially when employing UDL strategies. As Murawski and Hughes (2009) described, adaptable instruction allows teachers to modify their approaches to meet their learners' diverse needs and preferences. The educators in this research highlighted various flexible methods, including videos, hands-on demonstrations, and real-world scenarios, to teach mathematical concepts such as fractions. For example, Teacher 1's technique of bringing a pizza to class for demonstrations represents a flexible approach that accommodates learners' different styles and preferences. Similarly, Teacher 4's use of videos introduces a dynamic element to the learning process, appealing to visual learners and offering an alternative mode of engagement. These instances align with the UDL principle of providing multiple ways of presenting and interacting with the material, ensuring that all learners can connect with the content meaningfully (Ismailov & Chiu, 2022; Sharma, Thakur, Kapoor & Singh, 2023). Social constructivism emphasises the importance of flexible instruction to meet learners' diverse needs, interests, and cultural backgrounds (Shah, 2019; Hamza & Hernandez de Hahn, 2012). In this study, teachers demonstrated flexibility by adjusting their methods to incorporate various Universal Design for Learning (UDL) strategies, such as videos, demonstrations, and real-world scenarios. This flexibility allowed students to engage with mathematical concepts more effectively, fostering an inclusive and supportive learning environment.

The findings suggest that Universal Design for Learning (UDL) helps teachers meet the needs of a wide range of learners by accommodating various learning styles and needs. UDL promotes inclusivity by encouraging educators to provide multiple ways of engagement, representation, and action/expression. This, in turn, addresses diverse learning preferences and abilities, fostering a sense of empathy and understanding among educators. This finding is supported by Priyadharsini and Mary (2024), who identify key principles of Universal Design for Learning as multiple means of representation. This principle involves presenting information and content in various ways to cater to the diverse needs of learners. It includes the use of multimedia, different text formats, visual aids, and other strategies to make content accessible to all learners. During a focus group discussion, Teacher 1 emphasised how employing different teaching methods and presenting content in various formats made lessons more engaging and lively.

The varied representations of content also enabled teachers to accommodate different learning styles, thereby creating a more inclusive learning environment. For example, during Teacher 5's lesson, multiple representations were used to ensure that all learners could connect with the material, regardless of their preferred learning style. This approach aligns with UDL by enabling all learners, including those with diverse learning needs, to access and process the material effectively (Navaitienė & Stasiūnaitienė, 2021). Social constructivism acknowledges that students come from varied backgrounds, experiences, and previous knowledge when learning. It stresses the importance of using teaching methods that can accommodate these discrepancies (Normoyle, 2023; Chen, Hong, Ye & Ho, 2022). The findings suggest that UDL techniques assist teachers in serving diverse learners by offering multiple avenues for accessing and interacting with the material. This method aligns with the social constructivist belief that knowledge depends on the context and that learners' social, cultural, and historical backgrounds significantly shape their learning experiences (Gamage, Dehideniya & Ekanayake, 2021; Marougkas, Troussas, Krouska & Sgouropoulou, 2023).

5. Conclusions and Recommendations

The study sought to explore the research question, "What advantages does Universal Design for Learning (UDL) offer in teaching mathematics in primary schools?" The findings demonstrate that UDL methods significantly enhance students' understanding of mathematical concepts and their engagement with the subject. Educators reported that using relatable mathematical scenarios, manipulatives, fraction boards, videos, and simulations clarified abstract concepts and provided various ways for students to access, process, and apply mathematical knowledge. However, the study's focus on a small, intentionally selected sample from five underserved rural primary schools in the Free State Province may limit the generalisability of the findings. In light of these results, it is recommended that teachers and education policymakers incorporate UDL strategies into curriculum design and teacher training to promote inclusive and effective mathematics instruction. Future research should aim for larger and more diverse samples, as well as longitudinal approaches, to investigate the long-term effects of UDL on teaching and learning across different educational settings.

6. Declarations

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List of Appendices

Appendix A: Brain networks

Figure 1. UDL and the learning brain. Wakefield, MA: Author. Retrieved from http://www.cast.org/products-services/resources/2018/udl-learning-brain-neuroscience (CAST, 2018b).

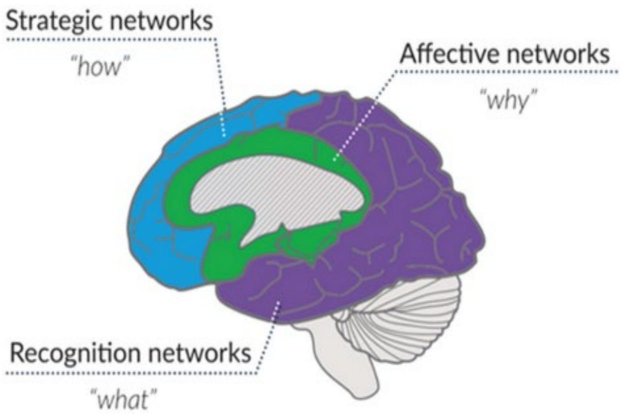


Figure 1: Brain Networks

Appendix B [Table 1]: UDL guideline version 2.2 [principles and the brain networks

	AFFECTIVE NETWORKS: The WHY of Learning	RECOGNITION NETWORKS: The WHAT of Learning	STRATEGIC NETWORKS: The HOW of Learning
	Provide multiple means of **Engagement** For purposeful, motivated learners, stimulate interest and motivation for learning	Provide multiple means of **Representation** For resourceful, knowledgeable learners, present information and content in different ways	Provide multiple means of **Action & Expression** For strategic, goal-directed learners, differentiate the ways that students can express what they know
Access	Provide options for **Recruiting Interest**	Provide options for **Perception**	Provide options for **Physical Action**
Build	Provide options for **Sustaining Effort & Persistence**	Provide options for **Language & Symbols**	Provide options for **Expression & Communication**
Internalize	Provide options for **Self Regulation**	Provide options for **Comprehension**	Provide options for **Executive Functions**
Goal	Purposeful & Motivated	Resourceful & Knowledgeable	Strategic & Goal Driven

Appendix C: Fraction model of representations

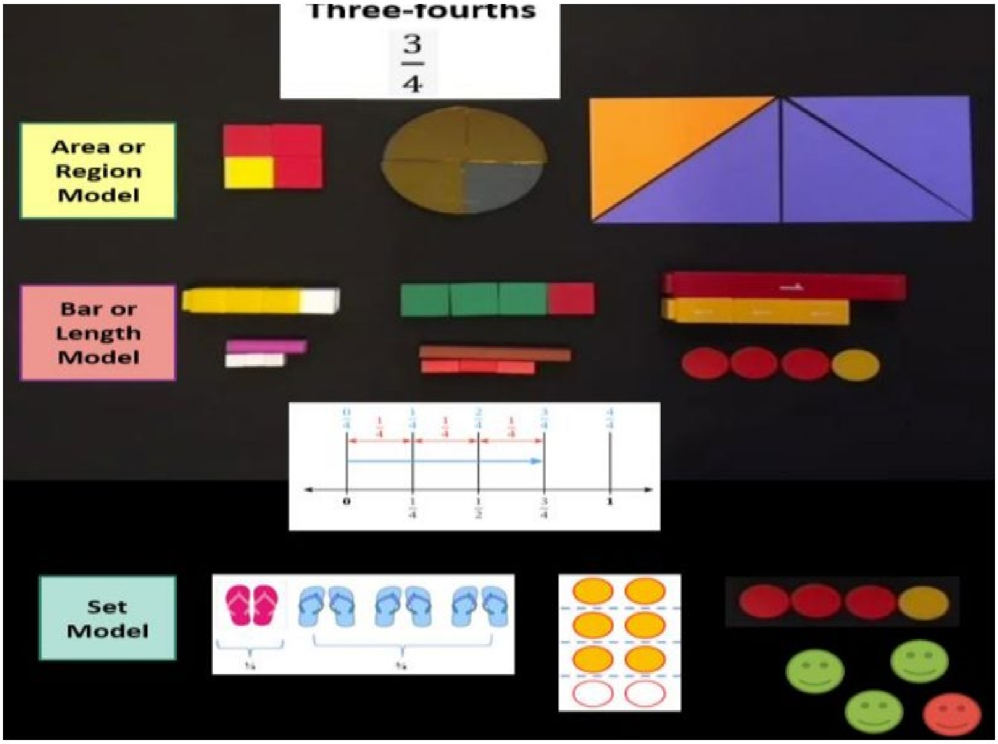


Figure 2: Fraction model of representations

Appendix D: Fraction Board

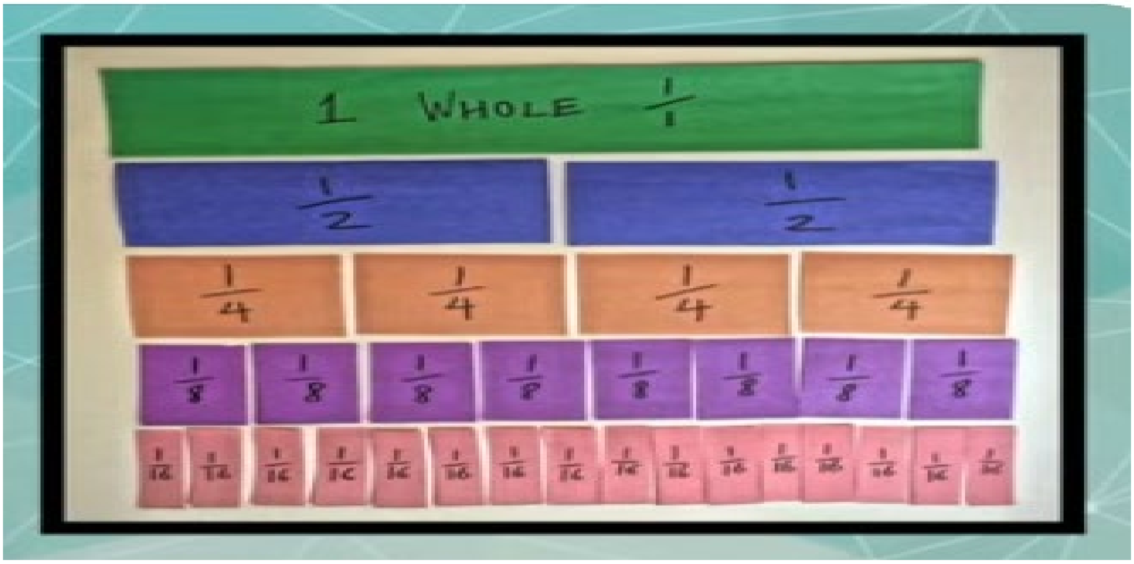


Figure 3: Fraction Board

Appendix E: Fraction representations using a video

Figure 4: Fraction representations using a video

Appendix F: Real-life scenario activity

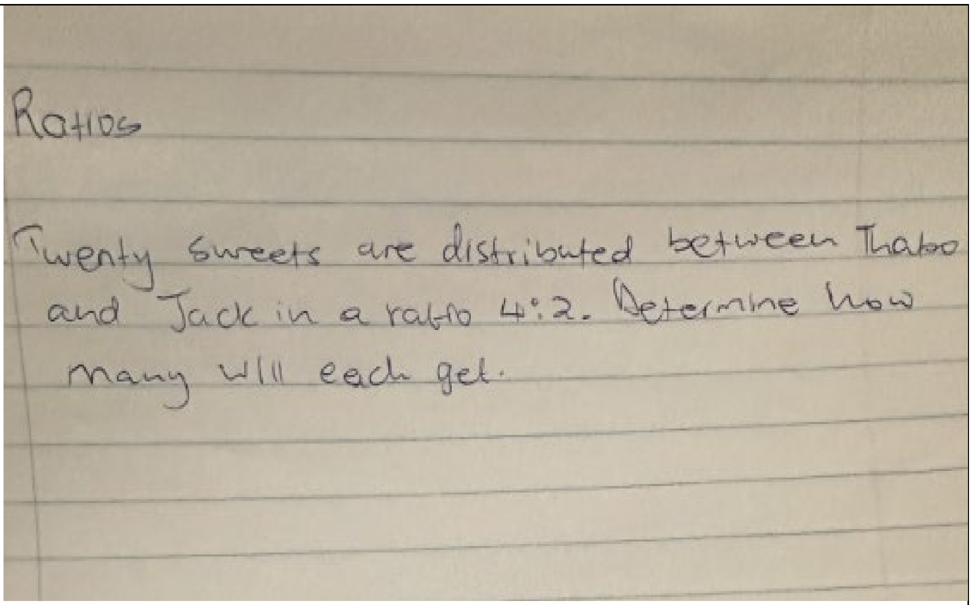
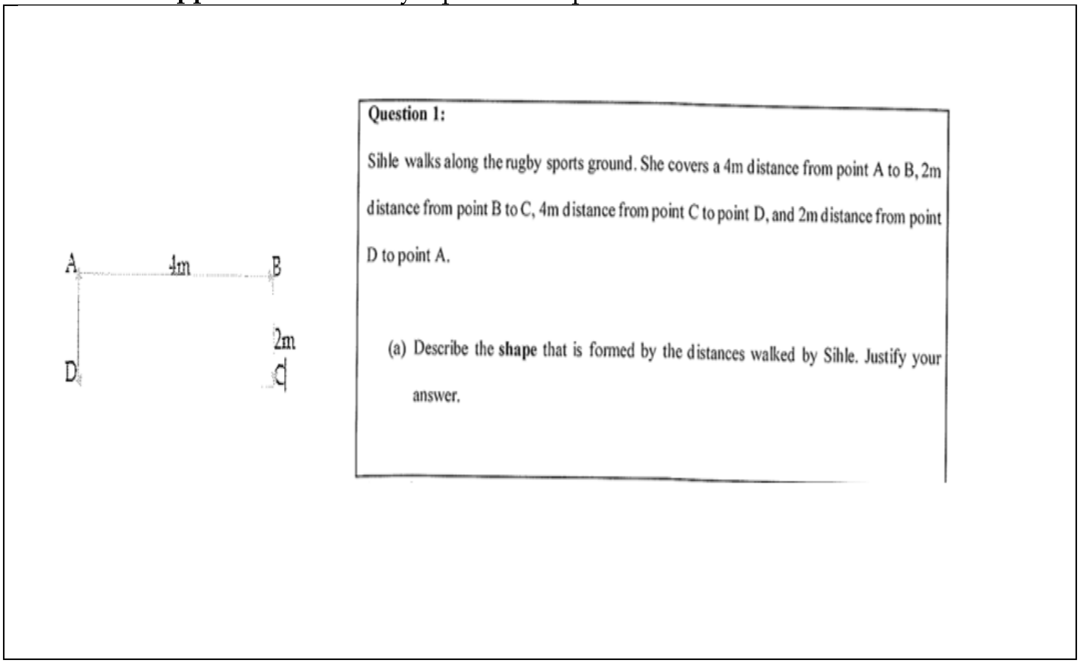


Figure 5: Real-life scenario activity

Appendix G: Activity – problem represented in different formats



Question 1:

Sihle walks along the rugby sports ground. She covers a 4m distance from point A to B, 2m distance from point B to C, 4m distance from point C to point D, and 2m distance from point D to point A.

(a) Describe the **shape** that is formed by the distances walked by Sihle. Justify your answer.

Figure 6: Activity – problem represented in different formats