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Research article

Addressing mathematics learning challenges through concept-based instruction: A study in Limpopo Province, South Africa

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Abstract: Continuous poor performance of learners in mathematics motivated the study reported in this paper. The purpose of the study was to investigate the challenges that concept-based instruction could address in trying to improve learners' performance in mathematics by equipping them with conceptual understanding. The study adopted a qualitative case study design approach that involved an interpretivist paradigm. Tests, questionnaires and semi-structured interviews were the data sources of this inquiry. Constructivism theoretically underpinned this study in a bid to bring up the importance of creating knowledge for oneself through linking new information to prior knowledge. The study involved 35 learners who were purposefully selected from a township school in Limpopo Province, South Africa. All the 35 learners wrote the test twice and completed a questionnaire. Six learners were selected for interviews for clarification of how they had arrived at their solutions and provision of more information. The study revealed the following mathematics learning challenges: poor mathematics background; too many rules and long steps involved; boredom and attitude; educator's pace versus learners' pace; and lack of variety of activities to reduce boredom. It was concluded that concept-based instruction has the potential to address challenges encountered by learners in learning mathematics.

Keywords: concept, conceptual understanding, procedural understanding, concept-based instruction, constructivism

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1 Introduction and background

Mathematics is a subject that is regarded as pivotal to a learner's progress in life, especially with careers in science, technology and engineering. That is the reason why in most countries it is a compulsory subject in their education systems. However, the extent to which mathematics is mandatory and the level to which it is studied varies by country (Keller et al., 2022). For instance, in South Africa, mathematics is mandatory up to Grade 9 level, thereafter each learner chooses between mathematics, mathematical literacy or technical mathematics, guided by their career aspirations or academic goals (Mahlangu, 2021; Fair and Scott, 2021). Mathematics equips learners with a uniquely powerful set of tools for logical reasoning, problem-solving and ability to think in abstract ways (Andamon & Tan,

2018). Mathematical understandings influence decision-making in all areas of life consciously or unconsciously, making it essential for personal spheres. Mathematics is crucial in most fields of human endeavour, be it private, social or civil. Mathematics is also a gateway to most scientific and technological fields.

Despite the role played by mathematics, most learners across the globe face persistent challenges in this subject, which is frequently reflected in poor academic achievements and low self-esteem (Filippello et al., 2020; Metsapelto et al., 2020). Taking into consideration, South Africa, learners consistently perform below international benchmark standards in mathematics assessments such as the Trends in International Mathematics and Science Study (Reddy at al., 2022). These problems are mainly based on conceptual understanding (Chinn, 2020; Novriani & Surya, 2017). Learners who lack conceptual understanding are at a higher risk of developing errors and misconceptions (Yang & Sianturi, 2021; Assem et al., 2023). For example, when learners incorrectly generalise rules, they fail to distinguish between increasing and deceasing functions due to shallow comprehension.

To avoid these errors and misconceptions, concepts need to be built carefully. The development of concepts is both challenging and crucial, as it directly impacts learners' ability to select, attend to, organise and integrate information (Chew & Cerbin, 2021). Traditional teaching approaches exacerbate learners' challenges in mathematics by focussing on transmission of factual knowledge, rules and skills that lack a deep understanding of the underlying concepts in procedural skills often revolving around rote memorisation of rules and procedures, with the educator taking centre stage while learners passively receive information. In such situations, learners struggle to apply their knowledge to solve problems in real-world contexts or make connections between mathematical concepts.

The challenges associated with mathematics are largely seen as coming from the cognitive demands of the subject itself (Chinn, 2020). Moreover, learners lack conceptual understanding. Concepts need to be introduced using approaches that give learners a chance to grasp them well to avoid misconceptions and address learning challenges. The teacher has to use teaching and learning approaches that bring conceptual understanding in learners. Not every method can be used to develop learners' conceptual understanding (Brown & Palincsar, 2018; Korn, 2014). The development of conceptual understanding needs teaching and learning approaches like concept-based instruction that have the power to enhance concept building.

Recognising the significance of conceptual understanding in the teaching and learning of mathematics, this study explores the use of concept-based instruction to address mathematics learning challenges. By addressing learners' challenges through concept-based instruction, this study sought to contribute to the ongoing efforts to enhance mathematics education and promote a deeper understanding of mathematical concepts among learners. Understanding the specific challenges that concept-based instruction can address will also provide valuable insights for educators, curriculum developers and

policymakers in improving instructional practices and fostering mathematical proficiency among learners. The following research questions guided this study:

- What challenges do learners encounter in the learning of mathematics and how do these impact the teaching process being utilised?
- How can concept-based instruction address learners' challenges in mathematics, and improve their understanding of mathematical concepts?

2 Theoretical framework

Mathematics education plays a crucial role in developing students' mathematical proficiency and problem-solving skills (Jacinto & Carreira, 2023; Rahman & Hassan, 2017). To enhance mathematical learning outcomes, researchers and educators explore various instructional approaches and theories. One prominent theoretical framework that has gained significant attention in mathematics education is constructivism (Durmus & Karakirik, 2006; Thompson, 2020; Zain et al., 2012). Constructivism learning theory was adopted by this study to provide a foundation for addressing mathematics learning challenges through concept-based instruction.

Constructivism is a learner-centred theory that emphasises the active role of learners in constructing their knowledge and understanding of concepts (Watling & Ginsburg, 2019; Yasmin et al., 2017; Omoniyi, 2016). The theory posits that learners actively engage with the content, drawn upon their prior knowledge and construct meaning based on their experiences and interactions with the environment (Clark, 2018; Nugroho, 2017). By taking an active role in their learning process, students develop a deeper conceptual understanding of mathematical ideas.

Numerous scholars such Kaufman (2018) and Thompson (2020) have highlighted how constructivism facilitates learners' building of conceptual understanding in mathematics. They emphasise that constructivist approaches allow learners to make connections between mathematical concepts, explore multiple strategies and develop problem-solving skills. Cevikbas and Kaiser (2020) and Sawson (2020) further suggest that constructivism promotes intellectual growth, enabling learners to connect the dots and see the bigger picture of the content covered in class.

While constructivist learning theory has revealed valuable insights in mathematics education, it has its own short falls. From critics, the constructivist approach sometimes lack the structure needed for learners who lack foundational knowledge or when learning topics requiring procedural knowledge. In such cases, learners get confused and frustrated when required to construct knowledge without guidance. Furthermore, the constructivist approach can be demanding, requiring more time and effort from educators to come up with effective learning experiences.

However, recognising the limitations of constructivist learning theory does not dismiss its potential value of integrating approaches but rather focuses attention on

operationalising constructivism to address learning challenges. Future research could check how other frameworks like metacognition and scaffolding might enrich the constructivist learning theory. For the purpose of this study, constructivism offers a robust foundation for addressing mathematics learning challenges through concept-based instruction.

3 Literature review

There has been a plethora of research on the teaching and learning of mathematics. The studies bring out many views including the challenges encountered by learners in learning mathematics. Chand et al. (2021), Makhubele and Luneta (2014), Rameli (2016), Taley and Ndamenenu (2022) investigated learners' difficulties in mathematics. Their findings mostly pointed traditional teaching and learning approaches as the root causes of the challenges encountered by learners. However, there is limited research on addressing mathematics learning challenges. Despite the fact that these studies effectively identify issues, they provide limited if not no solutions for addressing learning challenges in a manner that facilitates deeper understanding of concepts. This signals the need to explore effective instructional methods.

Scholars like Ala-Mutka (2011), Godino (1996) and Widyastuti et al. (2020) emphasise the importance of conceptual understanding in mathematics education. Yurekli et al. (2020), Semilarski et al. (2019), Rittle-Johnson and Schneider (2015) define conceptual understanding as the knowledge of abstract ideas in mathematics. They argue that conceptual understanding enables learners to think critically, make connections between mathematical ideas and apply their knowledge to solve complex problems. Kenedi et al. (2019), Ojaleye and Awofala (2018) further emphasise that conceptual understanding involves understanding the underlying structure of mathematics and the relationships and interconnections of ideas that give meaning to mathematical procedures. This conceptual understanding can only be attained through teaching and learning approaches like concept-based instruction. The perspectives highlight the value of concept-based instruction as a pedagogical approach that prioritises meaningful learning over rote learning.

Various researchers have explored the effectiveness of concept-based instruction in mathematics learning. The researchers were comparing performance of learners from classes taught using concept based versus procedural classes. Some of the researchers are Al-Qatawneh (2012), Borji (2019), Chappell and Killpatrick (2003), Ghazali and Zakaria (2011), Ntow and Hissan (2021) and Owusu (2015). All the findings from their studies consistently depict that learners taught using concept-based approaches perform better than the ones taught using procedural approaches. Brussow et al. (2019) further emphasise that concept-based instruction fosters meaningful learning experiences by encouraging learners to explore mathematical ideas in depth. Unlike procedural methods, concept-based instruction prioritises understanding the relationships between

mathematical ideas, hence leading to improved retention and critical thinking (Ross & Myers, 2017).

3.1 Concept-based instruction and its effectiveness

Concept-based instruction is a teaching and learning approach that was proposed by Hilda Taba in the early 1960s with the opinion that learners should construct their own knowledge through organising and categorising information. Furthermore, concept-based instruction brings learners understanding and meaningful learning and improves their thinking skills (Erickson, 2012; Saez et al., 2019). Ross and Myers (2017) view concept-based instruction as a method that fosters connections and encourages learners to think at more elevated levels thereby bringing high retention levels. Skemp (1976), Giddens (2019) and Higgins and Reid (2017) buttress that concept-based instruction enables learners to understand how and why each of the ideas and relationships work the way they do. Concept-based instruction equips learners with the ability to identify how things are the same and also how they differ. With concept-based instruction learners make sense of facts, link, and apply them in a variety of situations.

3.2 Concept-based instruction and constructivism

By employing constructivism as a theoretical framework and implementing concept-based instruction as a teaching and learning approach, educators can create effective learning environments that promote conceptual understanding in mathematics education. Adak (2017) and Mutsvangwa (2016) highlight the value of constructivism in enhancing learners' conceptual understanding, as it encourages active cognitive processes and inquiry-based learning. The constructivist approach aligns with the demands of the 21st-century world, where students need to develop critical thinking, problem-solving skills, and the ability to apply mathematical knowledge in real-life situations.

The reviewed literature demonstrates the significance of constructivism and concept-based instruction in mathematics education. Concept-based instruction, grounded in constructivism, focuses on developing learners' conceptual understanding by prioritizing the exploration of mathematical ideas and relationships. By adopting constructivist approaches and implementing concept-based instruction, educators can create meaningful learning experiences that enhance learners' mathematical proficiency, critical thinking skills, and problem-solving abilities. The integration of constructivism and concept-based instruction provides a robust framework for promoting effective mathematics teaching and learning.

Constructivism encourages learners to build on prior knowledge through exploration and inquiry, making it well suited for developing conceptual understanding. However, critics argue that the constructivists' views lack the structure necessary for learners possessing weaker foundational knowledge. This critic highlights the need to balance

constructivists teaching and learning methods with structured guidance to make sure all learners benefit.

3.3 Literature gap

Compelling evidence of the benefits of concept-based instruction and constructivism approach has been provided by the reviewed studies. However, there are missing clarifications on some issues. Most of the studies compared performance outcomes, lacking practical challenges of implementing these methods in diverse educational contexts particularly in under-resourced educational settings. Moreover, while proponents emphasise the value of conceptual understanding, limited studies critically examined how such approaches address persistent learning challenges or whether they adequately prepare learners for procedural demands. By addressing these gaps, this study seeks to contribute to a more nuanced understanding of how concept-based instruction underpinned by constructivism can mitigate mathematics learning challenges.

4 Methodology

The methodology employed in this study aimed to address the challenges that can be mitigated through concept-based instruction in the teaching and learning of mathematics. To achieve this, a qualitative research that used a case study design was employed to uncover learners' challenges in learning mathematics. The researchers adopted an interpretivist paradigm seeking understanding from participants' experiences and perspectives. The generic qualitative inquiry explored learners' reports of their subjective opinions, attitudes, beliefs, and reflections on their experiences in learning mathematics.

The research was conducted at one of the township schools in Limpopo Province, South Africa. Data were collected from an existing Grade 11 class of 35 learners that had been previously formed as part of the school academic structure. One mathematics teacher also took part in the study. Tests, questionnaires and semi-structured interviews were used as data sources for this study. All the 35 participants wrote two tests, completed the questionnaire and received instruction from a concept-based approach for three weeks. Only six of the participants were interviewed based on the solutions they had provided in the two tests. This selective sampling allowed a deeper exploration of learners' conceptual understanding and the nuances of their experiences in learning.

At the beginning, a test was written for pre-assessment as a way of determining participants' level of concepts and rewritten after three weeks of intervention to assess levels of understanding and ascertain changes brought about by concept-based instruction. This repeated pre-test, post-test design strengthened the study by allowing direct comparisons of learners' conceptual understanding before and after intervention.

After the administration of the second test, a questionnaire that consisted of closed and open-ended questions was administered to each of the 35 participants to give

participants a chance to dish out their opinions, suggestions and express their feelings about concept-based instruction.

Lastly, there were interviews with 6 participants to make a follow-up on learners' conceptual understanding. The semi-structured interviews provided allowance for probing questions, enabling the researchers to identify inconsistencies and validate participants' responses as a representative example to explore learners' challenges in understanding mathematical concepts.

The researchers employed triangulation by combining multiple data collection methods. This approach involved questionnaires and interviews to provide a comprehensive understanding of the participants' challenges, perceptions and opinions about the teaching and learning of mathematics. Triangulation strengthens the validity of the findings by corroborating the results across different data sources. Ethical considerations were also considered to ensure the protection of participants' rights and well-being. Informed consent was obtained from the participants and their guardians, ensuring their voluntary participation. Measures were implemented to safeguard participant anonymity and confidentiality, such as assigning unique identifiers to maintain privacy in data analysis and reporting.

While the sample size of 35 appears small, it aligns with the case study approach, focussing on in depth exploration within a specific context rather than wide generalisability. The purposeful sampling ensured the inclusion of participants in the township school setting which provides insights into challenges and opportunities for concept-based instruction in similar contexts.

By acknowledging the limitations of the sample size and the reliance on self-reported data, the study emphasises its focus on depth over breadth, with findings offering valuable insights into the specific educational context of a township school in South Africa. Though the results may not be broadly generalizable, they provide a basis for future research to build on and test the findings in larger and more diverse populations.

Furthermore, to address the potential of self-reported data bias in questionnaires and interviews, the study incorporated observations on learners' participation during intervention lessons. This provided more context and verification of self-reported insights

5 Data analysis and presentation of results

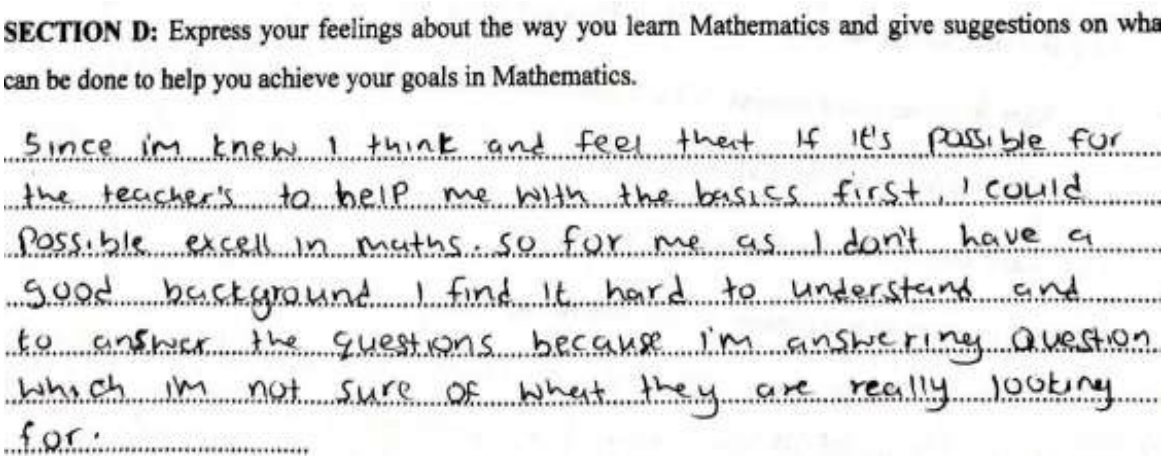
The study covered the mathematics topic of functions. Though the research targeted this topic, the findings aimed to contribute to addressing broad mathematics learning challenges. Learners were asked to explain the challenges they experienced specifically with functions aligning with the study's goals of investigating concept-based instruction as a teaching approach. Findings from participants' emotions, attitudes and feelings that were aired through the questionnaire and interviews were used to evaluate the challenges faced by learners when learning mathematics.

Categories through careful analysis of learners' responses in the tests, questionnaires and interviews were identified with the extraction of common themes and recurring issues. The themes were then grouped into the following categories: poor mathematics background, too many rules and long steps involved, boredom and attitude, failure to cope with other learners' pace and lack of variety of activities to reduce boredom. The thematic categorisation was based on learners' subjective experiences and reflections on their challenges in the learning of mathematics.

5.1 Poor mathematics background

The main characteristic of conceptual understanding, according to Kleine (2019), is the rich network of connecting pieces of information. The development of conceptual understanding is achieved by constructing relationships between pieces of information that are stored in memory or between an existing piece of knowledge and newly learnt information (Gutknecht & Wibral, 2021). In simple terms, for the development of conceptual understanding to occur, there is a need to establish connections between new knowledge and existing knowledge. Ornstein et al. (2018) stressed that relationships between knowledge cannot be built if prior knowledge does not exist. Responding to the questionnaire, one of the participants had this to say:

Excerpt 1. Learner responses on attitudes and feelings about learning mathematics


SECTION D: Express your feelings about the way you learn Mathematics and give suggestions on wha can be done to help you achieve your goals in Mathematics.

Since im knew I think and feel that if it's possible for the teacher's to help me with the basics first, I could possible excell in maths. so for me as I don't have a good background I find it hard to understand and to answer the questions because I'm answering question which im not sure of what they are really looking for.

The participant was worried about his lack of prior knowledge. Learning and learner achievement are greatly influenced by prior knowledge (Achmetli et al., 2019; Simonsmeier et al., 2018; Yang et al., 2018). In their studies, Buehl (2023) and Isaqjon (2022) discovered that prior knowledge contributed much to the learning of mathematics. This depicts that even when functions were taught, there was a need for learners to have a background of algebra and graphs for them to link to the new knowledge. Participants in the current study expressed their worries concerning lack of preliminary background. Here are some of the participants' interview responses as part of their challenges

Table 1. Interview responses

L1: *It is difficult for me to master concepts of mathematics in Grade 11 because I lack sufficient background of mathematics which are taught in Grade 8 and 10.*
L2: *The sad part and the embarrassing facts are that I even fail to do the basic things in mathematics that some Grade 8 and 9 learners can do.*

The concerns from participants indicate that learners themselves can see that lacking mathematical background affects them in grasping new concepts. The most worrying factor is that most of these learners are demotivated by their poor background because they will not understand the basic concepts in the lesson while those with the background will be able to quickly grasp and understand. It makes them feel bad and, in most cases, hesitant to participate during discussions.

In an attempt to get further substantiation on the efficacy of concept-based instruction in the learning and teaching of mathematics, learners' proffered views, reactions and solutions which were aired through questionnaires and interviews were taken into cognisance. In the excerpts L represents learner and T represents teacher.

Some of the responses from questionnaires were as follows:

Table 2. Interview responses

L1: *My background in mathematics is poor and makes me struggle, but I am happy I improved in the second test.*
L2: *The teacher explains but I do not understand easily because of my poor mathematics background.*
L3: *At first I had a lot of challenges in the topic of which most of them were due to my poor background that gave me problems to understand with others.*
L4: *It's not good to memorise maths. One must understand basics well.*
L5: *I could answer some of the questions using some of the things I already knew about functions. Good background helps.*
L6: *Poor mathematical background hinders us learners to do well in mathematics.*

The participants were very much worried about their poor mathematics background. They indicated that lack of background foundation hinders one from grasping newly taught material.

The other responses from interviews were vivid testament to the usefulness of prior knowledge in the learning. The following responses are a testimony of importance of strong mathematical background.

Table 3. Interview responses

L3: *I managed to pull through because the way we learnt made it possible to apply what I already knew.*
L4: *We need good teachers from lower grades so that we start and finish well. The way we learnt this time is what we should have been doing all the time.*

The learners' responses suggest that for better comprehension of concepts, it is essential to understand the basics in mathematics. The participants realised that some of the problems they were facing were created by lack of basic concepts which could make it easy for one to perform mathematics tasks successfully.

Lack of background knowledge in learning resulted in poor connection between concepts while good background made it easy for learners to build their knowledge. Hence, there is need to find ways of equipping learners with a strong mathematical background to do away with the obstructions. Concept-based instruction is a teaching and learning approach that can help learners gain strong background in mathematics. The teaching and learning approach can then allow learners to identify patterns in concepts and be in a position to make connections to other concepts and topics relating with other subjects.

5.2 Too many rules and long steps

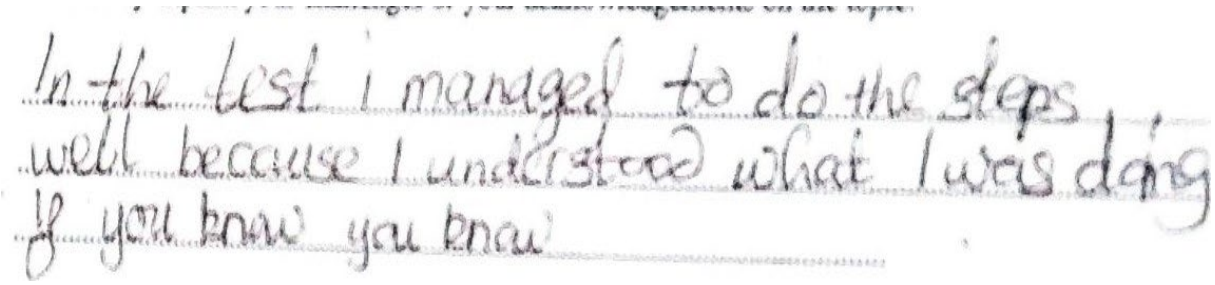
Another recurring challenge that emerged from the interviews was that of too many rules and long calculation steps involved in mathematics. The next excerpt indicates one interviewee's responses.

Table 4. Interview responses

T: *How do you rate yourself in maths?*
L5: *I am not good; I know.*
T: *But is maths a difficult subject?*
L5: *Yes, but the way we were taught recently made me to think that it is not difficult as such.*
T: *What do you think makes the subject to be difficult?*
L1: *It has too many rules to be followed. If one cram, s/he forgets them.*
T: *Is cramming bad?*
L2: *In Maths it's bad because one must know a lot of things and be able to link.*

These responses coincide with the results obtained by Demby (1997), Gunner (2020), Kieran (2007) and Meng et al. (2020), who posit that mathematics involves too much terminology and rules which offer little meaning to many learners. Mbewe (2013) argues that learners misuse previously learnt procedures and rules in situations where they are not applicable. Ncube (2016) and Watson (2007) lament that learners overgeneralise and misapply the mathematics rules because the subject involves too many rules. One learner's response indicates that if one knows what s/he is doing, then there is no need to worry about the steps. Therefore, learners should be equipped with conceptual understanding for them to sail through the steps easily. See one of the learners' response in the questionnaire.

Excerpt 2. Learner's acknowledgements



Too many rules, according to Ncube (2016), are not felt if a learner has conceptual understanding. Therefore, the reason for unfortunate encounters is lack of conceptual understanding. Learners need to be taught using teaching and learning approaches that help them gain retainable and applicable understanding. The concept-based instruction is a recommended approach that can address this challenge.

Some of the comments made by the participants in the interviews on the issue of too many rules and long steps involved in mathematics include:

Table 5. Interview responses

L3: *To be honest I feel that this is too much as they are many steps to reach to the answer.*
L4: *I wish there can be a short cut which is manageable to reach to the answer.*
L5: *I have discovered that I am failing to master the entire steps due to the fact that I have no knowledge of the other topics that are related to the current topic of algebraic functions.*

From the participants' responses, one can deduce that learners are afraid of questions which call for long calculations involving many rules and applications like when learners make use of the method of completing the square to determine the coordinates of a turning point. For weak learners, the steps are too many and confusing because of lack of conceptual understanding. The preceding responses suggest that mathematics learners are afraid of the calculation steps involved in the subject. In fact, it can be deduced that these learners lack conceptual understanding and want to make use of memorised procedural knowledge and they get lost along the way. A learner who has mastered the concepts can answer questions well even if the questions involve many steps to be followed because s/he knows the meaning and relevance of each step. This is because conceptual understanding allows linking and transferring of ideas (Erickson, 2012; Roling et al., 2019). This boils down to the need to use approaches that foster conceptual understanding in learners, of which concept-based instruction is one of them.

5.3 Boredom and attitude

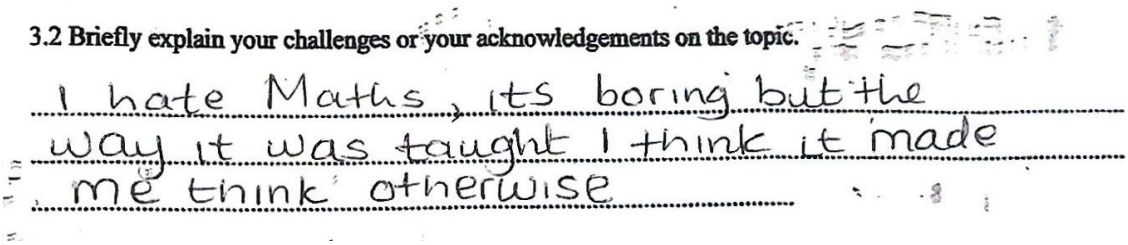
Another chronic challenge that emerged from interviews was that of boredom and attitude. The theme identified in this study is in line with the works of Mutodi and Ngirande (2014) which assert that students who struggle with mathematics perceive the amount of material in the subject to be overwhelming, therefore, making it difficult to absorb. It is alluded that most of the learners find mathematics boring, mostly irrelevant and unrewarding (Colgan, 2014; Kunwar et al., 2021). The following narrative indicates that some of the students have a negative attitude towards mathematics and this ultimately leads to boredom. The following responses from questionnaires bring out these attitudes towards mathematics:

Table 6. Interview responses

L1: *Boring, I hate maths. The teacher explained a lot of things at the same time.*
L2: *A lot of homework which I don't know is given. It's boring.*
L3: *Maths is not everyone's cup of coffee; it's difficult.*
L4: *Mathematics is just a boring subject and dreaded by most of the people; so, I also find all topics boring*

The responses from the participants indicate that mathematics gives learners a hard time in their history of learning. Mathematics is perceived as a boring subject. This attitude results in learners lacking interest and focus. The following extract also indicates learners' bad attitude towards mathematics.

Excerpt 3. Learners' attitude towards mathematics


3.2 Briefly explain your challenges or your acknowledgements on the topic.

I hate Maths, its boring but the way it was taught I think it made me think otherwise

Participants indicated that they were bored by the subject. The problem with this kind of attitude towards the subject is that it becomes difficult for one to put effort in something which s/he finds boring. Furthermore, the general misconceptions about mathematics being difficult subject may cause anxiety that may mutate into a phobia, resulting in lack of interest in the subject. There are higher chances of these negative attitudes being instigated by lack of understanding because learners get motivated when they understand what they are learning. Consequently, it is important to find ways of helping learners to attain conceptual understanding so that they can find pleasure in learning the subject. Jesionkowska et al. (2020) and Nerantzi (2020) see active learning instructional

strategies as promoting conceptual understanding. This is because learners make sense of what happens during the process of teaching and learning. The concept-based instruction enhances active learning, therefore, worth recommending for effective teaching and learning of mathematics.

5.4 Failure to cope with other learners' pace in class

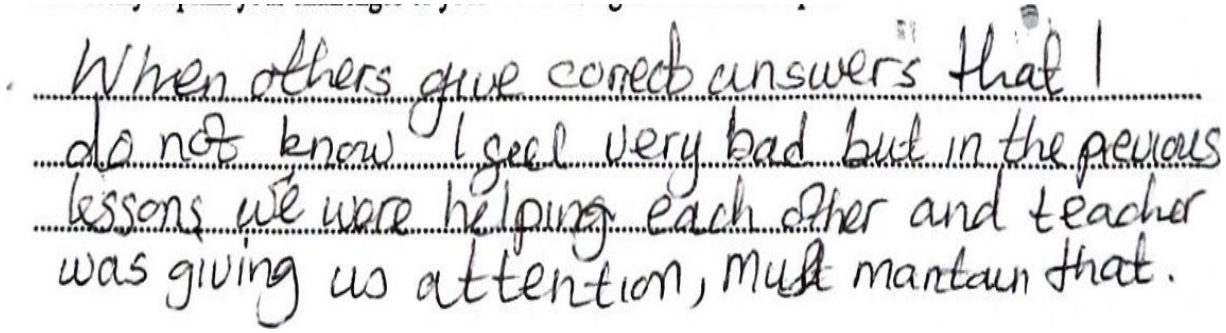
Learners who have difficulties in learning mathematics need help with the evaluation of the effectiveness of chosen solution strategies (Ozrecberoglu & Caganaga, 2018; Siagan et al., 2019). There is need for differentiation when teaching mathematics. To get a clear picture of this situation, there is a need to check challenges that were raised by the participants in the interviews.

Table 7. Interview responses

L5: *It feels bad if you do not know what other learners know in a class.*
L6: *I cannot ask if the others seem to know what I do not know.*
L1: *...did not find a chance to get someone to explain for me to understand.*

Dignath and Buttner (2018) and Martin and Evans (2018) recommend explicit instruction for learners who have difficulties in learning mathematics. This is a way of showing the need to have special teaching instructions for the less gifted learners so that they also grasp the concepts at their own pace. Learners do not understand what is being taught at the same time; so, they need to be treated differently. Some need faster paces of teaching while others need slow paces. One of the learners confirmed this in the questionnaire as shown in Figure 4.

Excerpt 4: Learners' challenges and acknowledgements.



The educator should be able to identify the needs of these learners and group them accordingly, then find suiting instructional practices for the different groups. Concept-based instruction is highly recommended as it gives both the educator and learners chances to determine the pace of the lesson. The educator then paces the lesson in such a

way that all learners get actively involved giving them a chance to understand conceptually. The pace of the lesson has to focus on conceptual understanding not on completing given tasks.

5.5 Lack of variety of activities to reduce boredom

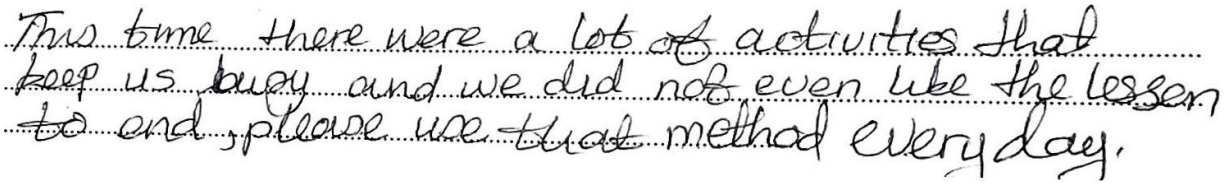
Educators should employ a variety of activities to facilitate learning to alleviate learners' engagement levels and confidence in the learning of mathematics (Attard, 2012; Iji et al., 2018;). Sullivan and McDonough (2007) suggest that teachers find ways of encouraging learner engagement and confidence in learning mathematics. This can be achieved by implementing meaningful activities embedded in real-life contexts (Balta, 2021; Kacerja, 2012). Taking into consideration these responses from the interview sessions:

Table 8. Interview responses

L3: *Our teachers must help us to develop concepts by giving us a lot of different activities.*
L4: *We need different activities in our mathematics lessons as in the last few days.*
L6: *I really enjoyed because there were a lot of activities involved.*

One can deduce that varying activities during lessons will help in capturing learners' interests. The figure below gives one of the participants' response in the questionnaire on acknowledgements of the intervention.

Excerpt 5. Learners' appreciation of variety of activities



The answer reveal that a variety of activities within concept-based instruction helped maintain learner engagement and boredom. If there is a variety of activities and one activity is not interesting, then the other one/s can be interesting. To add more to that, learners do not get bored when there is variation of activities. In the teaching and learning of algebraic functions, learners can draw graphs, interpret drawn graphs and also apply knowledge from other topics like algebraic equations and inequalities. Conceptual understanding can, therefore, be attained as among the activities, there are chances that at least one of them will enhance conceptual understanding.

6 Summary of the findings of the study

From the findings, lack of preliminary background was identified as one of the main challenges for learners in grasping new concepts, particularly in linking new and prior knowledge. Participants in this study expressed their worries concerning lack or poor mathematics background. In the questionnaires and in the interviews, hapless comprehension of concepts was linked to poor mathematics background. It was established that learners face a superfluity of multifaceted challenges which can be attributed to lack of a firm background in mathematical concepts. The majority of participants blamed their foundational backgrounds claiming that it was very weak. They indicated that they many a times fell short of basic concepts which they were supposed to have acquired right from their lower grades, making it extremely difficult for them to grasp new concepts. This lack of foundational knowledge disrupted ability to link new concepts with existing ones leading to poor retention of concepts. The main issue lies on equipping learners with conceptual understanding.

Participants consistently attributed their challenges to gaps in prior knowledge, emphasising the need for teaching and learning approaches that promote deep understanding of concepts. The findings of this study revealed that a strong mathematical foundation in learners which, according to Michael (2015), involves more than the rote application of procedural knowledge, could be established by employing teaching and learning approaches that allow learners to build a robust conceptual understanding. Though equipping learners with a strong mathematical background is pivotal, it is important not only to introduce concept-based instruction but to also engage learners in coming up with specific concepts and skills they feel lacking. Understanding learners' perceived gaps gives educators a chance to tailor instruction targeting on those areas thereby creating more effective and personalised learning experiences. This approach enhances elimination of barriers to learning by fostering deeper connections between new mathematical concepts and existing knowledge.

A critical insight from the study was the role of learners' negative attitudes toward mathematics, often resulting from an overload of terminology and rules offering little meaningful context. The study found that learners were demotivated by too many rules and long steps involved in solving mathematical problems. Guner (2020) and Meng et al. (2020) concur that mathematics has a plethora of terminology and rules encouraging procedural learning at the expense of conceptual grounding, leading to frustration and disengagement. These rules are misapplied if learners lack conceptual understanding. The concept-based approach with its focus on uncovering the reasoning behind the steps and connecting them to broader ideas, mitigates this issue by making learning more accessible and meaningful.

There was also the issue of learners getting bored by the subject. Kunwar et al. (2021) allude that mathematics is boring to most of the learners. According to Nett et al. (2010), boredom can be highly detrimental. In the findings of this study, it was discovered that the subject is considered boring by most of the learners. Mostly, learners hated the subject

because of poor performance. Lack of variety of activities was also another cause of boredom in the subject. The study established that mathematics, being a cumulative subject, makes it difficult for learners to gain new knowledge after failing to link it to prior knowledge and learners end up finding themselves disengaged and hating the subject. Boredom and disengagement were mainly linked to limited variation of classroom activities. Practical and engaging activities were found to enhance learner motivation and participant engagement, supporting the findings of Mazana et al. (2019), that a positive attitude towards mathematics is critical for effective learning.

Another significant finding was the mismatch between teaching strategies and learners' different abilities in mixed ability classrooms. Most of the participants indicated that it was false that mathematical concepts are indeed difficult to understand. Understanding of concepts was found to be partly affected by the way teachers taught learners of different abilities in the same class. Learners disclosed that the understanding of mathematics becomes burdensome if a teacher approaches the subject without matching the pace of the lesson to the level of learners' understanding. Differentiation which calls for tailored instruction was, therefore, established to be a better method of helping learners to grasp concepts which matches the views of Martin and Evans (2018). The concept-based instruction which provides a framework for implementing differentiation is highly recommended to focus on the individual construction of meaning, thus accommodating learners with varying proficiency levels.

It was established that lessons lack variation of activities of which if there is a variety, it improves learner engagement and then attitude. The study found out that it is extremely difficult to engage in a lesson where there is no variation of activities. According to Mazana et al. 2019), learning highly depends on engagement during lessons; hence, the need for teacher to prepare and implement a variety of activities that capture their interests. To prevent disengagement among learners, teaching and learning needs to involve practical and exciting activities. The concept-based instruction, with its variety of activities that encourages learner engagement, is, therefore, highly recommended.

Prior to being taught through concept-based approach, some learners did not understand functions. Their challenges were solved by the use of a different teaching and learning approach that targeted learners' acquisition of conceptual understanding. The concept-based instruction brought positive effects to the teaching and learning of mathematics, with learners constructing meaning based on their involvement during intervention. The implementation of the concept-based instruction with its properties of targeting learners on gaining conceptual understanding can address the challenges faced in the teaching and learning of mathematics. This reinforces the argument that equipping learners with conceptual understanding can address mathematics foundational gaps and enhance performance.

7 Practical implications

The study underscores the importance of concept-based instruction in transforming mathematics education. Teachers should prioritise strategies that build conceptual understanding, such as using a variety of classroom activities and tailoring lessons to learners' needs. Policy makers, school administrators and curriculum designers can also leverage these findings to advocate for teacher training programs that prioritise conceptual teaching methods with differentiation techniques. Training institutions should also integrate concept-based teaching methodologies into their programs to prepare educators for practical implementation into diverse contexts.

8 Recommendations of the study

This study explored and determined some of the challenges that learners face when learning mathematics and highlighted the potential of concept-based instruction to address these issues. Conceptualisation of this study was against the background of poor performance in mathematics. From the findings of this study and the preceding discussion, recommendations were proffered to different stakeholders for deliberation as presented in the next section.

- de-emphasise memorisation of learnt mathematical facts as concept-based teaching makes it easier to understand abstract facts as these are presented in real life situations, and incorporate visual aids, manipulatives and technology that help learners visualise relationship between concepts.
- strive to demonstrate connectivity of concepts under discussion to other topics as well as other subjects so that the topic is not viewed in isolation and without relevance to real life.
- avoid hurrying through a lesson and give learners time to solve mathematics problems and think for themselves in a process of self-exploration. The teacher should also guide learners to build concepts and apply them to real life examples so that knowledge develops and lodges in their mental faculties and use flexible groupwork activities for collaborative problem-solving.
- perform the role of a mediator or midwife in guiding learners to discover each new knowledge frontier by asking open-ended questions that encourage critical thinking and exploration, and provide formative feedback that emphasise reasoning.
- probe for associated meaning in learners as part of assessing the level of understanding by including 'why' and 'how' questions during and assessment for gauging learners' conceptual understanding and using diagnostic assessments before the introduction of new topics to identify gaps in foundational knowledge and implement remediation to address them.

- Encourage stakeholders beyond the classroom to reinforce concept-based learning by encouraging parents to support learning at home through activities demonstrating real world relevance.
- Address challenges in diverse classroom settings by using differentiation techniques, leveraging technology and providing professional development workshops for teachers.
- Anticipate limitations adapting to constraints as concept-based instruction may face challenges such as time constraints, limited resources or large class sizes. To address these, there is need to plan lessons with realistic time allocations, use low-cost readily available resources, and advocate for smaller class sizes or get assistant teachers to help with individualised attention.
- encourage this hands-on approach that is steeped in constructivism by engaging in practical and interactive activities through the use of real life examples and encouraging learners to present their solutions, explaining their reasoning to their peers.

Conclusions

This study had an important intention of addressing mathematics learning challenges by exploring the potential of concept-based instruction. The findings underscored that learners were facing a superfluity of multifaceted challenges which they attributed to weak foundational knowledge in mathematical concepts, difficulties with too many rules and long steps, boredom stemming from unengaging lessons, failure to copy with pace of their peers, negative attitude toward the subject, and lack of interesting class activities. These challenges highlight the need for teaching and learning approaches that prioritise conceptual understanding which equips learners with long lasting and transferrable knowledge.

The implementation of concept-based instruction in this study depicts ability to bring changes in mathematics education by helping learners to construct meaning through active engagement. In this case learners who had struggles with functions and misconceptions about core concepts previously learnt, were able to come up with clearer and improved retainable understanding from the intervention. These findings corroborate that a focus on conceptual understanding has the potential to reduce learners' reliance on rote learning and improve on problem-solving skills, fostering positive attitudes toward mathematics.

However, this study acknowledges limitations of its theoretical framework. The constructivist learning theory, while it is important in emphasising learner-centred learning, has its own shortcomings. Its assumptions of learners being intrinsically motivated and ready to engage in active meaning making does not always hold water, like in cases where classrooms have high levels of disengagement or varying abilities. Additionally, the constructivist approach may require training sessions, reduced class sizes, which may be a bit difficult in some of the educational contexts.

In conclusion, while challenges in mathematics education are multifaceted, this study demonstrates that implementing concept-based instruction can bring changes to teaching and learning. By focussing on conceptual understanding, educators can empower learners to overcome foundational gaps, engage meaningfully with the subject, and develop skills that extend beyond the classroom. This research lays a foundation for reimagining mathematics education as a more inclusive, engaging, and impactful discipline.

Research ethics

Author contributions

Ncube M was responsible for conceptualization, investigation, methodology, project administration, validation, visualization, formal analysis, writing the original draft preparation, and writing.
Luneta K did the data curation, funding acquisition, supervision, review and editing.

All authors have read and agreed to the published version of the manuscript.

Artificial intelligence

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Informed consent statement

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Data availability statement

The data to support this article is available and is with the corresponding author.

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Conflicts of Interest

The authors declare no conflicts of interest.

Appendix A. Inteview guide

Attitudes and feelings:

Is Mathematics easy or difficult for you? What makes it easy or difficult for you?

What do you prefer between coming up with your own solutions or being given the solutions by your teacher?

After learning algebraic functions for the second time did you find any changes as far as conceptual understanding is concerned?

What do you think led to the changes that you observed?

How was the teaching and learning approach used in teaching algebraic functions?

What are your suggestions on the teaching and learning of Mathematics?

Are there any additional comments that you would like to make?

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