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The Effects of Educators' Mathematics Pedagogical Content Knowledge on The Mentoring of Grade 12 Students Using Problem-Based Learning

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ABSTRACT
This study investigated the effects of educators' mathematics pedagogical content knowledge on the mentoring of Grade 12 students using problem-based learning in two selected secondary schools in the Amajuba district in KwaZulu-Natal. The study collected qualitative data from four participating mathematics educators through the semi-structured interview questions that were presented to them. The data were analysed thematically according to the various sub-structures within Shulman's theoretical framework. The investigation suggests that educators who are well versed in mathematics pedagogical content knowledge, are masters of Grade 12 mathematics content, which enables them to use various teaching methodologies to design and implement lessons to successfully overcome students' difficulties. To achieve this, educators need additional information, like the curriculum's scope, educational objectives, and adequate teaching resources. Furthermore, the participants contend that mastery of content and delivery entails knowing the curriculum and their students' various age-appropriate learning difficulties; for effective lesson delivery. Moreover, the learning of mathematics needs to be student-centred, with an emphasis on group work, for the mutual and collaborative building of new knowledge on existing knowledge, under the educator's guidance. The study's findings also showed that Grade 12 Mathematics content is abstract therefore, subject educators should facilitate learning through a more concretised approach using realistic scenarios that appeal to the cognitive structures of individual students. Based on the findings, the study suggests that problem-based learning is the preferred instructional approach to teaching and learning Grade 12 mathematics and educators require development in their professional and content capacity in the use thereof.

KEYWORDS
Mathematics pedagogical content knowledge; problem-based learning; specialised mathematical knowledge; content knowledge; scaffolding knowledge.

INTRODUCTION

International scholars avow that mathematics pedagogical content knowledge (MPCK), or the "how" of teaching mathematics, is paramount in enhancing students' knowledge to improve their problem-solving skills in Mathematics (Bature & Atweh, 2020, Moh'd et al., 2021). On the same note, scholars from Rwanda, Burundi, Kenya, and the Republic of South Africa (RSA) suggest that educators' lack of MPCK may result in ineffective teaching and learning. These scholars further suggest that educators who lack MPCK have insufficient knowledge to teach students how to solve problems in Grade 12 mathematics (Moh'd et al., 2021). For effective learning, Grade 12 educators must employ communicative pedagogical practices or MPCK to teach content (Idris & Madugu, 2020; Klang et al., 2021). However, students learn mathematics using the problem-based learning (PBL) approach is the most effective learning strategy for improving students' problem-solving skills and performance in mathematics (Miller & Krajcik, 2019).

PBL is a student-focused learning strategy where students critically present creative ideas and communicate mathematically with peers (Koh & Chapman, 2019). PBL can help Grade 12 mathematics students solve problem-type questions and improve students' mathematics performance (Miller & Krajcik, 2019). In addition, educators with higher MPCK who use student-centred teaching strategies can successfully facilitate students' learning of new knowledge through scaffolding (Makofane & Maile, 2019).

Mathematics educators must be competent in content and use innovative instructional strategies to bring out students' critical learning and problem-solving skills for effective learning (Makofane & Maile, 2019). Therefore, mathematics educators must be proficient in content-based and student-centred teaching, or MPCK, for effective mathematics teaching and learning (Lee et al., 2018).

PBL is an effective model for learning and producing gains in Grade 12 mathematics (Makofane & Maile, 2019). The constructive learning of Grade 12 mathematics depends on the educators' MPCK, affecting students' mastering of the Grade 12 mathematics content (Shulman, 1987). In other words, the educators' MPCK can influence the quality of mathematics learning and its outcomes because educators disseminate content knowledge to students and are responsible for effective learning (Ko et al., 2016).

Mathematics students who use PBL to master the content often build new knowledge and develop higher-order thinking skills and inquiry abilities (Shulman, 1987). In other words, Grade 12 mathematics students, are collectively involved in a series of learning projects involving scientifically solving problems (Shulman, 1986). More specifically, the learning activities allow students to construct meaningful knowledge, skills, and attitudes in mathematics and simultaneously develop cooperative relationships under the guidance of the subject educator.

Educators with a good command of MPCK lead a favourable learning and teaching outcome for mathematics students in a high school. Mathematics educators know what learning

challenges different students experience according to their various learning barriers; will favour these students in their lesson demonstration, to ensure students gainfully acquire the theoretical content (Lee et al., 2018). Therefore, PBL is an effective learning strategy that can influence students' mathematics learning in Grade 12 (Ramli et al., 2020).

South Africa's (Grade 12) mathematics students' performance is poor (Oosthuizen, 2021). Students cannot analyse and evaluate problem-based questions because they lack proficiency in Grade 12 mathematics (Badie, 2016). In most cases, this may be attributed to Grade 12 mathematics students being taught by educators who lack teaching methodology and content mastery, use educator-centred learning activities, and consequently, students become passive, leading to underperformance in problem-based questions at the NSC level (Braun et al., 2016). In other words, students' poor performance may be attributed to educators' lack of MPCK (Lee et al., 2018). The impact of MPCK in teaching and learning Grade 12 mathematics using PBL shows that students may critically assimilate the content in small groups (Makofane & Maile, 2019).

Grade 12 mathematics students' performance depends on how effectively PBL is used as a teaching and learning strategy (Lee et al., 2018). How can this be achieved? The educator's comprehension of what challenges different Grade 12 mathematics students experience in learning can be accommodated in the lesson presentation to facilitate learning (Lee et al., 2018). More importantly, the educators' MPCK will assist in implementing appropriate PBL strategies tailored to meet the learning needs of Grade 12 students to gain mathematical understanding and improve performance. The study is important because the researchers envisage that the investigation will produce insight into the practical implementation of PBL and improve students' performance in Grade 12 mathematics. Based on the above, the study examines the effects of educators' MPCK on the mentoring of Grade 12 students using PBL among two selected secondary schools in Newcastle in Kwa-Zulu Natal.

The complication behind the low performance levels of Grade 12 students in mathematics for the National Senior Certificate (NSC) for 2019, 2020, and 2021 is that most students do not have independent or creative thoughts and cannot manage analytical, evaluative, and problem-solving questions, contributing to the low pass rates for the mentioned years. This problem may be emanating from students being taught by mathematics educators with low knowledge of the subject content matter and low pedagogy (DBE, 2021). Therefore, mathematics educators who lack effective teaching and learning strategies may not be content-equipped to teach mathematics concepts successfully. Therefore, the study scrutinises the effects of educators' MPCK on the mentoring of Grade 12 students using PBL and how the quality of the educators' PBL impacts the standard of passes at the NSC level.

Improving learning outcomes in Grade 12 mathematics depends on the educators' ability to transfer the content to students to ensure effective learning and blended with the educators' MPCK. Some scholars postulate that educators with suitable levels of MPCK can ensure effective learning and teaching take place when they know their Grade 12 students, manipulate learning

instruction to their demands, and anticipate misconceptions in their present content knowledge banks (Ko et al., 2016).

Studies on PBL (Badie, 2016; Burrough et al., 2016) and MPCK (Bature & Atweh, 2020; Guerriero, 2017) exist, however, studies focusing on the effects of educators' MPCK on the mentoring of Grade 12 students using PBL in a South African context are scarce. Against the backdrop, the study aimed to investigate the phenomenon under review amongst two selected secondary schools in Newcastle in Kwa-Zulu Natal.

LITERATURE REVIEW

Much impact on the teaching and learning of Grade 12 mathematics is associated with identifying the educators' specific knowledge and competencies or the "how" to teach Mathematics for students' understanding (Bature & Atweh, 2020). Mathematics education is demanding for an educator because it involves teaching complex mathematical content (Makofane & Maile, 2019). Mathematics educators are the mediators of the content knowledge in the classroom and ensure effective teaching (Ko et al., 2016). Adequate content knowledge (CK) and MPCK can influence students' performance in mathematics (Koh & Chapman, 2019). Effective teaching and learning require educators to have a strong command of the subject content and transfer it to the students using various teaching skills like child-centred instructional strategies or PBL, in a disciplined and safe environment (Kar, 2017).

Ineffective instructional strategies have resulted in Grade 12 students being unable to analyse and evaluate problem-based questions for mathematics in the NSC 2019, 2020, and 2021 (DBE, 2021). This may be due to students being mentored by educators with insufficient MPCK (Lee et al., 2018). Therefore, there is a need for instructional approaches to promote effective learning of Grade 12 mathematics under the guidance of competent educators (Jameson et al., 2023; Klang et al., 2021).

The MPCK of educators in teaching the subject matter is crucial for effective learning and positive outcomes in secondary school mathematics (Bature & Atweh, 2020). Elsewhere, educators with a robust knowledge of mathematical content can overcome students' learning difficulties, build solid relationships with students in teaching-learning, and improve academic performance (Aidoo et al., 2016). Based on these views, the researchers are also of the opinion that Grade 12 mathematics educators should be masters of the content and have the professional capacity to teach it to students of diverse learning needs.

MPCK refers to mathematics educators' understanding of students' age-related difficulties in grasping and overcoming content. Similarly, MPCK can be considered as the mathematics educators’ knowledge used to teach the content, using various teaching strategies, appropriate to the intellectual level of every child in the classroom (Lee et al., 2018). Furthermore, MPCK may also be defined as the concept that merges the educators' mathematics content knowledge (what to teach) and pedagogy (how to teach) specific to mathematics education.

MPCK is a distinguished body of knowledge a Grade 12 mathematics educator must possess, empowering the educator to create learning opportunities by using various skills and knowledge to facilitate mathematics learning amongst groups of students to make sense of it (Lee et al., 2018). Therefore, for this study, MPCK is regarded as the knowledge of teaching and learning mathematics, including but not limited to the curriculum's scope, educational objectives, and adequate teaching resources (Moh'd et al., 2021). In other words, MPCK is the resource mathematics educators need to employ in teaching so that instructional learning strategies like PBL can be implemented to successfully facilitate Grade 12 mathematics teaching and learning amongst students (Miller & Krajcik, 2019). However, students' inability to analyse and evaluate problem-based questions at the NSC level significantly results from educators' poor mathematics content knowledge and low professional content resulting in unproductive teaching and learning with lower achievement levels in Grade 12 mathematics (Guerriero, 2017).

As a result of this, there is now an urgency from the South African government to raise the levels of students' achievements at the NSC level. The National Development Plan (NDP) was conceptualised for building capabilities and enhancing the competencies of its state agencies, including educators' education, through compelling content and pedagogy support (South African Government, 2012). Furthermore, the NDP advocates that developing mathematics educators' content and pedagogy may improve Grade 12 students' skills and knowledge in problem-solving questions at the NSC level.

Mathematics educators should be competent in content and use innovative instructional strategies to bring out students' critical learning and problem-solving skills for effective teaching and learning (Ko et al., 2016; Makgakga, 2023). Therefore, mathematics educators need to be proficient in content-based and student-centred teaching, or MPCK, for effective teaching and learning of mathematics (Makofane & Maile, 2019). Thus, PBL is an effective model for constructive learning and producing gains in Grade 12 Mathematics (Guerriero, 2017).

PBL is an inquiry-based instructional learning strategy designed by educators for students to collaborate and acquire new knowledge through self-directed learning for life-size encounters, which can lead to achievement gains in mathematics (Aidoo et al., 2016). Mathematics students can actively pose questions and participate in investigative processes while learning new concepts and developing processing and thinking skills to transfer knowledge to their peers (Klang et al., 2021; Mosia & Matabane,2022).

PBL, as an effective instructional method, is focused on student-centeredness with educational activities complementary to the learning needs of various students (Shulman, 1987). Students studying mathematics using PBL demand that they are actively involved, take on challenging mathematical problems, make interdisciplinary connections, and communicate mathematically with real-life issues (Makondo & Makondo, 2020).

PBL is a practical pedagogical child-centred approach to expose Grade 12 mathematics students to real-life situations whereby they are now critical thinkers and creative solvers of

complex problems, and are self-motivated to learn and collaborate mathematically (Koh & Chapman, 2019). Building on this, some scholars postulate that Grade 12 students can achieve success in their performance by learning Mathematics through the PBL approach (Aidoo et al., 2016). Contrary to PBL, learning methods like question and answer, exposition, lecture method, work from the textbook, and educator demonstration encourage poor student performance levels (Makondo & Makondo, 2020). This leads to students being passive absorbers of the content handed down by the mathematics educator. This does not require students to actively assimilate and make sense of the content knowledge. Therefore, Grade 12 students, passively experiencing mathematics and driven by an educator-centred technique were not independent or creative in their learning and this possibly generated a cohort of mathematics students that had limited analytical, evaluative and problem-solving skills by the time they exited school (DBE, 2021). In other words, students' inability to analyse and evaluate problem-based questions significantly results from educators' weak subject content knowledge and low pedagogical content, leading to educators implementing educator-centered learning strategies in the classroom.

Overcoming these learning challenges and making sense of the new mathematics content, educators using their MPCK can successfully utilise PBL to teach mathematics to Grade 12 students so that they can acquire problem-solving skills by scaffolding content combined with group dialogue (Shulman, 1986). Effective mathematics learning can occur in a social classroom when the scaffolding of new knowledge is based on existing knowledge. In other words, students' grounding knowledge (intermediate and senior phase) in mathematics forms the foundation for Grade 12 students to learn Mathematics in their groups.

Group discussions may allow students to build new ways of thinking, involving questioning their understandings, and verbalising and negotiating on different answers. To achieve this, Grade 12 students need the educator to understand students' current knowledge and produce meaningful learning by building new knowledge on their existing content (Idris & Madugu, 2020). Mathematics educators are now tasked with their new authority to mediate the learning experience to students or scaffold the theoretical concepts to students represented by real-life experiences (Awuah, 2018).

Mathematics educators as mediators of the content have a unified command of MPCK and this impacts students' mastery of the content since it influences students' learning and leads to improved learning outputs (Bature & Atweh, 2020). Elsewhere, educators who are less knowledgeable in mathematics content knowledge, have demonstrated a pattern of errors and are ineffective in teaching the content to students.

Ineffective teaching and learning of Grade 12 mathematics are mostly at the hands of mathematics educators who lack teaching methodology and content mastery. As a result of this, they use educator-centered learning activities; consequently, students become passive, leading to underperformance in problem-based questions that are featured in the NSC (Braun et al., 2016). Moreso, these educators trust in their educator-centred practices because they believe

they are the experts of knowledge, and therefore employ ineffective teaching strategies (Braun et al., 2016).

Effective mathematics educators' approach to teaching is now a mediator and no longer giving explicit instructions while students passively listen to the content delivered through the "chalk and talk" method. Moreso, the educator's MPCK allows the educator to successfully execute a meaningful lesson by offering a different approach to the delivery of the content in a less rigid environment. Mathematics mediators must present a rich and balanced lesson in the subject matter (Makofane & Maile, 20190). These scholars highlighted some of the following features of a mathematics lesson as adequate learning opportunities for students;

- Practical lessons cater for students of varying educational needs,
- Students are actively involved in teaching and learning-centered activities, and
- Mathematical tasks discuss a range of crucial mathematical content;

For educators to effectively present a wide range of mathematics content to Grade 12 students, they need to use instructional strategies like PBL and be good disseminators of the learning content to students. Mathematics educators use content and pedagogical knowledge to collectively plan and present their lessons for students to adequately learn (Moh'd et al., 2021). The critical instruction and the quality of the Grade 12 outputs given by the PBL educator are determined by the educators' command of content knowledge or their MPCK (Lee et al., 2018).

Research Questions

- How do educators' Mathematics Pedagogical Content Knowledge (MPCK) affect the learning of Grade 12 Mathematics using PBL?
- How would use PBL in the mentoring of Grade 12 Mathematics?
- What skills and knowledge do you think a Grade 12 Mathematics educator must have to implement PBL in the Mathematics classroom successfully?

THEORETICAL FRAMEWORK

This paper is underpinned by Shulman's (1987) MPCK theoretical framework. It is made up of seven theoretical sections of content knowledge that are found in a mathematics educator's cognitive growth; namely: (i) content knowledge to be taught; (ii) general pedagogical knowledge, this particularly unique form of knowledge fits into the broader assumptions and teaching strategies of classroom control and organization; (iii) knowledge of the curriculum, in particularly with regard to guidelines focused at tutoring specific content knowledge and bodies of knowledge at a specific level, together with the depth of knowledge cascaded, and complementary to the use of different teaching media available; (iv) pedagogical content knowledge, which is the educators body of knowledge encapsulated by the mathematics content and pedagogical practices, which is exclusively resides in the mathematics educators; (v) knowledge of students and their learning abilities; (vi) knowledge of instructional environments, from group work or classroom dynamics, understanding the cultural diversity

that resides in different students(vii); and, finally, the understanding of the goals aims, purposes and the importance of education, coupled with its past historical and metaphysical grounding.

The researchers used Shulman's theoretical framework to explore and comprehend the effects of educators' MPCK on the mentoring of Grade 12 students using PBL. These sub-categories provide a point of reference as to what constitutes the subject educators' content knowledge necessary for the successful teaching of the learning matter and the professional knowledge necessary for enacting mathematics lessons in Grade 12.

Amongst these sub-categories, MPCK is the most crucial sub-category for mathematics educators to possess, to ensure constructive tutoring of the subject matter (Shulman, 1986) betterfying PBL. The authors contend that PBL is a concept that allows the recognition of separate categories of content knowledge for teaching and learning allowing the synergy of content knowledge (concepts to be taught) with pedagogy (the understanding of how to teach the concepts).

In this setting, MPCK refers to how particular mathematics concepts and theories are manipulated to meet students' various learning needs. Therefore, MPCK consists of instructional learning strategies that are enacted by educators so mathematics concepts appeal to the unique learning natures of various students activating PBL. Also, MPCK focuses on the learning impediments (students' misunderstandings and misinterpretations) imposed on mathematics students and how educators can facilitate effective tutoring of the content (Ramli et al., 2020).

METHODS

The researchers used an exploratory qualitative study to examine the effects of educators' MPCK on the mentoring of Grade 12 students using PBL. A case study has been chosen as a preferred research design. For the site selection, the researchers used purposive sampling to select two secondary schools. The criteria used to identify the schools were one school consistently performing highly (above 80% average), and the other consistently underperforming (below 65% average) in the National Senior Certificate for 2019, 2020, and 2021 (DBE, 2021). The reader should in no circumstance take this criterion as a comparison between the two selected schools. Year-end district reports were used to identify the two secondary schools. For the participants selection, the researchers purposively selected two Mathematics educators from each school, who were teaching Grade 12 Mathematics in 2023. The educators selected were both rich in their comprehension, skills, encounters, and attitude because of their present teaching experience in Grade 12 Mathematics (Creswell & Creswell, 2018). For a complete investigation, it is important to show a brief résumé of the participants' biographic attributes of qualification, position held, and type of school. Table 1 below shows the educators' age, sex, years of teaching experience, and highest qualifications from the school that is consistently underperforming (below 65% average).

Table 1.

Biographical information of the participants from the school that is consistently underperforming (below 65% average).

Participants	Age	Sex	Teaching experience	Highest qualification	Position held	School
Educator 1	59	M	39 years	B.A Degree	PL1	Public
Educator 2	24	F	3 years	Unqualified	PL1	Public

It is clear from Table 1 that one of the Mathematics educators is qualified, with a B. A degree has 39 years of teaching experience while the second educator is unqualified with three years of teaching experience. Table 2 below shows the educators' age, sex, years of teaching experience, and highest qualifications from the school that is consistently performing highly (above 80% average).

Table 2.

Biographical information of the participants from the school that is consistently performing highly (above 80% average).

Participants	Age	Sex	Teaching experience	Highest qualification	Position held	School
Educator 3	36	M	15 years	B.A Degree	PL1	Public
Educator 4	44	F	20 years	B.A Degree	PL1	Public

It is clear from Table 2 that both Mathematics educators are qualified, with a B. A degree with 15 years of teaching experience while the second educator has 20 years of teaching experience.

The researchers used an interview protocol as a data collection instrument. This is a data-collection instrument that contains semi-structured interview questions that were posed to the participants individually (Creswell & Creswell, 2018). This was intended to earn the participants' opinions and experiences on the effects of their pedagogical content knowledge in learning and teaching of Grade 12 Mathematics using PBL.

Lastly, the researchers used documentary analysis (Creswell & Creswell, 2018). A scrutiny of the participants' lesson plans was used to conduct an analytical comparison between the data and various data collection techniques and offered a comprehensive understanding of the phenomenon under review.

Thematic data analysis was used to interpret the data gained from the participants and generate a code for each feedback. (Burrough et al., 2019). The codes were used to identify themes throughout the interview process to reach a repeated pattern of meaning. The themes were categorised according to the information gained from the participants' responses, as suggested by Braun and Clarke (2006). The categories were obtained from questions coded.

To ensure that the data interpretation was valid, the researchers employed the process

of crystallisation. This process entails the validating of data by using various modes of data collection methods and techniques (Creswell, 2016). The researchers chose to use the term “crystallisation” rather than “triangulation” in qualitative research because crystallisation provides us with an intensified, multiplexed comprehension of phenomena under review. According to Ellingston (2009), some of the principles of crystallisation include paying attention to the complex nature of explanations as well as thick and deep explanations of data and reflexivity.

Therefore, the interviews were audio recorded and thereafter, transcripts were generated. This enabled the researchers to capture thick and deep explanations of the participant's experiences of the phenomenon under review. Next, the researchers were reflexive or in other words acknowledged their roles in the research project. Reflexivity refers to the researcher's reflection on their role in the empirical review and their culture, background, and experiences that could influence the data interpretations and analysis (Creswell & Creswell, 2018). By exercising reflexivity in the data collection and interpretation process, the researchers could limit bias and their experiences having a disproportionate effect on the study's conclusions. Therefore, the researchers engaged reflexivity by making short notes about participants' statements and our feelings during the interview processes, compiling memos immediately after interviews, and continuously creating and improving their subjectivity declarations. PBL. Lastly, the researchers favoured documentary analysis which consisted of an analysis of their lesson plans. This was done to augment the other data collection techniques and to triangulate the results of the data gained. Therefore, the findings of the data and the different perspectives shared by the participants by generating detailed explanations or thick descriptions forms of the data collection and analysis process (Ellingson, 2009).

RESULTS AND DISCUSSION

The responses given by the mathematics educators during the interviews are presented with some discussion below. ‘How do educators' Mathematics Pedagogical Content Knowledge (MPCK) affect the learning of Grade 12 Mathematics using PBL?’

Responses from both Mathematics educators contended that a lack of content knowledge would translate into students being unable to comprehend the content disseminated and would result in no learning of the new content. Similarly, Ball et al. (2008) opine that educators lacking content knowledge cannot grow the students' capacity to assimilate the new knowledge, which becomes a learning challenge. The participants responded to the first research questions as follows:

I think if you don't know the content properly, the students are not going to understand… If you don't know the answer, it becomes a problem. (Educator 1)*… Sometimes you get educators that don't know the content, and it will negatively affect their learning of the content…* (Educator 3)

However, Educator 2 suggested the following:

Without very good pedagogical strategies, the lesson will not work… An educator must have varied methodologies for heterogeneous classes with different performance levels, the pedagogical strategies of the educator must be varied to accommodate every student and every possibility because not every student is good at learning Mathematics.

Educator 2 further elaborated that Mathematics educators should be knowledgeable about different learning support strategies and be able to implement and integrate them in their lesson presentations so that Grade 12 students can learn Mathematics successfully. The educator's response suggested that Mathematics educators must know the content and successfully use various communication strategies in the classroom. This aligns with the sentiments shared by Stols et al. (2015) and Ubah (2021) that Mathematics educators should use PBL in the classroom because it emphasises student-centeredness with learning activities that complement the various learning demands and their diverse home backgrounds.

Responding to the question, 'Explain how you would use PBL in the mentoring of Grade 12 Mathematics?'

Both Educator 1 and Educator 2 asserted that Grade 12 Mathematics is abstract to the extent that students are challenged in learning the new content. Therefore, both educators suggest that creating real-life situations in the Mathematics classroom could assist students in learning Mathematics. Their responses suggested that educators must be able to relate authentic life scenarios to Mathematics concepts so students can grasp the content nicely. This aligns with Anthony and Walshaw's (2009) sentiments that effective learning of Grade 12 Mathematics begins in the classroom when the educators duplicate real-life scenarios with group work collaboration and students actively understand the content together. The respondents commented as follows on research question 2:

Educator 1: *Okay, so I understand that they find their work very abstract... So we actually take them to the school grounds with measuring tape and get them to measure... e.g. a cylinder, we show them the bins, or the Pritt. So, it helps them visualise what it is.*

Educator 2: *The Grade 12 curriculum is more abstract... you have to give them a lot of manipulatives, that is, worksheets…*

Furthermore, both educators asserted that group work produced positive learning achievements in Grade 12. Their responses suggested that students collaboratively learn Mathematics while the educator facilitates learning by supporting their learning needs. This finding corroborates Klang et al.'s (2021) ideas that Mathematics students involved in group work actively learn new concepts and thinking skills that enable knowledge transfer to their peers. Therefore, Mathematics educators must possess MPCK or knowledge and skills to facilitate Mathematics learning amongst groups of students to make sense of it (Shulman, 1986).

Educator 3 gave the following response:

Problem-based learning involves a group of students coming together, looking at different problems, and trying to figure them out themselves. If there's someone from there that understands, they're able to explain it to those that don't understand.

Responding to the last question, ‘What skills and knowledge do you think a Grade 12 Mathematics educator must have to implement PBL in the Mathematics classroom successfully?’

Both educators believed that Mathematics educators must be masters of the content to comfortably guide students on Mathematics questions of any level. The interviewees contended that mastery of the content allows educators to implement PBL successfully in the classroom. Educator 1 also believed that apart from content mastery, Mathematics educators should be able to use different teaching strategies to transfer the content to students successfully. This finding supports previous research by Kar (2017) that MPCK addresses how-to-teach Mathematics; the educator's level of MPCK determines how successfully the educator can present particular topics and problems appropriately to students to cater to their needs varying learning abilities, and backgrounds.

I think content knowledge is very important for us because if we don't understand the content, it's very difficult to explain it to the students. So, I feel communication is also important because everyone must understand the content, but not everyone can teach the subject. (Educator 1)

I would say the educator must be well endowed with subject matter content so that whatever worksheets or problems you give to the students, you must have test-proven it. And that it is achievable for them… (Educator 2)

The key findings of our research are based on the overall aims of the study, that is, the effects of educators' Mathematics Pedagogical Content Knowledge on the mentoring of Grade 12 students using problem-based learning. The first probing question was, ‘How do educators' Mathematics Pedagogical Content Knowledge (MPCK) affect the learning of Grade 12 Mathematics using PBL?’ Responding to the first research question the results advocate that educators highly skilled in MPCK can use various teaching methodologies in their Grade 12 mathematics lessons to cater to the appropriate learning needs of different students. Therefore, the educator can design mathematics lessons to successfully overcome students' difficulties in learning mathematics (Shulman, 1986). To achieve this, educators need additional information, like the curriculum's scope, educational objectives, and adequate teaching resources or MPCK (Moh’d et al., 2021). Furthermore, the participants contend that the mastery of content and delivery (MPCK) enables them to produce differentiated learning strategies to match the academic needs of the students. The view such as " *In a nutshell, the pedagogical strategies of the educator must be varied to accommodate every student and every possibility because not every student is good at learning Mathematics.*" This finding is supported by Shulman which is, that mathematics educators must have knowledge of the curriculum, or be content masters, and have knowledge of students and their various learning abilities; so that educators can teach mathematics with an understanding of students' age-appropriate learning difficulties to classrooms of students at their various stages of knowing the content (Shulman, 1987). Similarly, educators with a powerful command of MPCK can implement various methodologies to

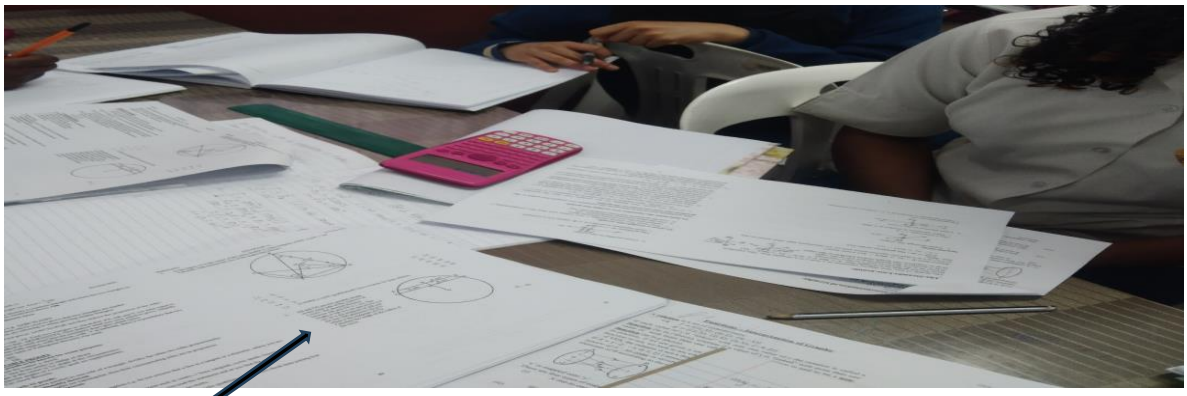
practically represent the theoretical concepts, appealing to Grade 12 mathematics students. When the content appeals to the cognitive-developmental levels of each student, then only positive learning of mathematics can occur.

Conversely, the findings also demonstrated that educators with low levels of MPCK, more specifically, the lack of knowledge of instructional environments, and insufficient knowledge, struggled to facilitate a successful lesson. This is evident in Grade 12 mathematics educators with limited content knowledge who used educator-centred activities in teaching and learning while students passively witnessed the content being demonstrated to them on the whiteboard. The view is, *" I found group work difficult, and it doesn't work for me. Students in a group of six… one person knows the others write down the answers. So, can I say the other students understand the work? No, I can't. Unfortunately, some people believe in group work, but I don't know how they do it…"* This finding supports the theory put forward by Shulman, that Mathematics educators' knowledge of instructional environments, from group work or classroom dynamics to the understanding of different students' cultural diversity located within them, is important to ensure successful mentoring of the subject (Shulman, 1987).

The second probing question was, **'**Explain how you would use PBL in the mentoring of Grade 12 Mathematics?' Responding to the second research question, the findings showed that a student-centred teaching approach was used by mathematics educators. Ideally, Grade 12 students are mutually engaged with each other to collaboratively build new knowledge on existing knowledge, under the guidance of the educator (Koh& Chapman 2019). Furthermore, the findings suggest that educators rich in MPCK used PBL in Mathematics lessons, focusing on students actively learning, and such students drive their learning. The view such as " *There is this chapter… Euclidean Geometry… How do I do it via problem-solving? Firstly, I give guidance in the beginning… I remind them of their previous work… then I want them to measure the angles and arrive at the answer. I don't give answers…they must figure it out themselves."* This complements Mulyanto et al. (2018) view that, student-centred learning develops students' accountability in their Mathematics learning. Therefore, students gain confidence in their group interaction and become responsible for their learning. In Figure 1, students are actively involved in group work, negotiating and collectively solving the Mathematics sums in their books, while the other students observe the process.

Figure 1.

Grade 12 students are actively involved in group work using manipulatives (worksheets)



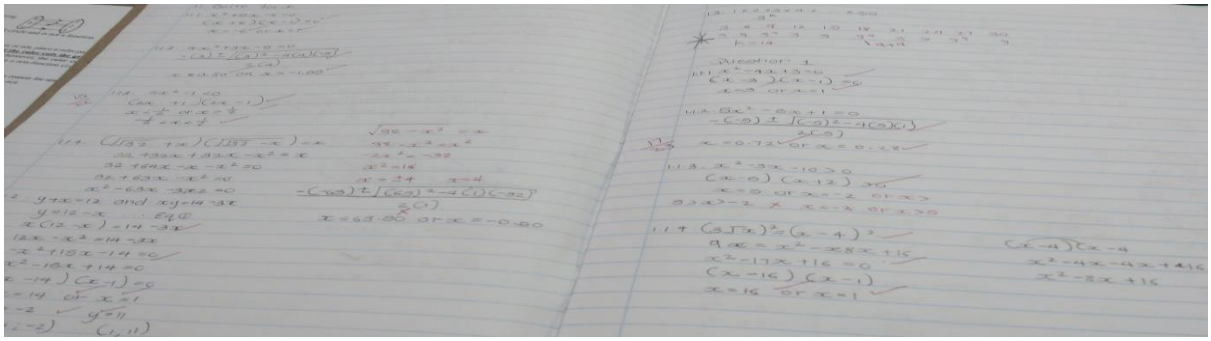
Worksheets

Source: Researchers' work

The findings also showed that Mathematics educators who used PBL in the mentoring of the content to their students often guided their students to discover the new knowledge on their own, by building on their existing content. In other words, the scaffolding of new content led to students developing higher-order thinking skills and inquiry abilities (Shulman, 1987). In group work, Grade 12 mathematics students, are collectively involved in a series of learning projects involving scientifically solving problems (Shulman, 1986). More specifically, the learning activities allow students to construct meaningful knowledge, skills, and attitudes in mathematics and simultaneously develop cooperative relationships under the guidance of the subject educator. Figure 2 shows that the educator mediated the lesson by guiding the students from their present knowledge to discovering the new content and mastering it.

Figure 2.

Evidence of a Grade 12 student mastering the content under the guidance of the Mathematics educator



Source: Researchers' work

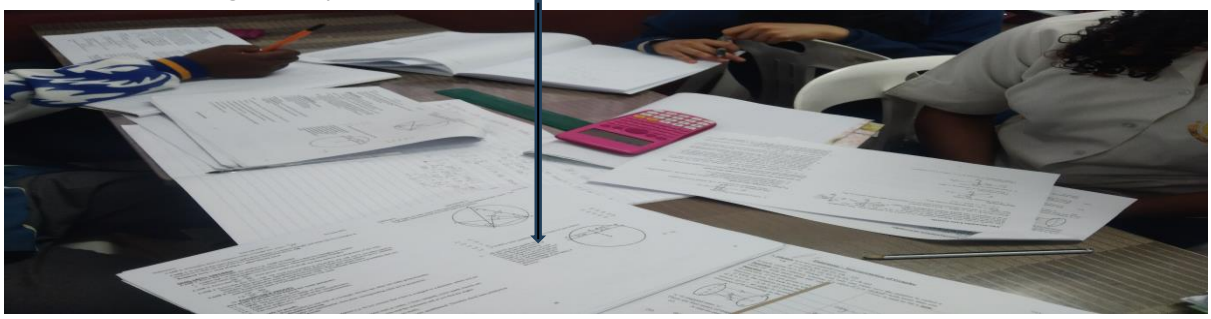
The final probing question was, 'What skills and knowledge do you think a Grade 12 Mathematics educator must have to implement PBL in the Mathematics classroom successfully?' Responding to the last research question the findings advocate that Grade 12 Mathematics content is abstract and is a problem for students learning Mathematics. Most

participants agreed that Grade 12 content is too theoretical for students to comprehend; they need Mathematics problem sums to represent real-life scenarios to facilitate their learning. The view, such as *"The Grade 12 curriculum is more abstract... So, whenever you teach them, you have to give them a lot of manipulatives, that is, worksheets. I will now use real-life situations and explain abstract concepts to them, for example, in Trigonometry,"* Similarly, Awuh (2018) agreed that Mathematics content is too abstract to arouse cognitive-developmental level for some students; therefore, subject educators should facilitate Mathematics learning through a more concretised approach using realistic scenarios. Therefore, educators need to concretise the abstract content that students may find challenging by scaffolding the content. This is complementary to the social constructivist Mathematics classroom in that constructive teaching and learning is through building new knowledge on students existing knowledge through cooperative real-life learning opportunities (Klang et al., 2021). Educators need to facilitate Mathematics learning through a more concretised approach. Mathematics educators should be well-versed in differentiated teaching approaches to cater to students with heterogeneous learning abilities in the classroom. In Figure 3, there is evidence of the Mathematics educator using worksheets to concretise the abstract content, to help students grasp the learning content.

Figure 3.

The educator used worksheets to concretise the abstract content which yielded gains in the students' mastery of the content.

Worksheets are given by the educator to the students to concretise the abstract content



Source: Researchers' work

Educators competent in MPCK have the skills and knowledge to comprehend Grade 12 students' age-related learning challenges and even pre-empt their learning barriers. With this knowledge, mathematics educators can present the Grade 12 learning content that would appeal to the collaborative learning needs of their students. These findings relate to the studies conducted by Baier et al. that the educators' understanding of teaching Grade 12 mathematics is crucial to the learning challenges the target audience may experience (Baier et al., 2019).

CONCLUSION

The educators' MPCK positively affects Grade 12 students' mathematics learning using PBL because educators that have a huge knowledge bank of MPCK, therefore can use a variety of

teaching and learning methodologies to mentor their students. This means that educators can design mathematics lessons using differentiated learning strategies to successfully overcome students' difficulties in learning mathematics and appropriately meet their educational needs. One way of meeting Grade 12 Mathematics students' educational needs, is to organise student-centred lessons. In this approach to mentoring Grade 12 students, students are mutually collaborating and building new content knowledge on existing knowledge (scaffolding), under the guidance of the facilitator. These opportune students to construct meaningful knowledge, skills, and attitudes in mathematics.

The empirical study builds on the body of existing knowledge on the effects of educators' MPCK on the mentoring of Grade 12 mathematics students using PBL. Based on these provisos, the new empirical study's results could be summarised for the Amajuba district. The findings could guide Grade 12 mathematics educators on the effects of educators' MPCK on the mentoring of Grade 12 students using PBL. The study would widen all stakeholders' conceptual knowledge and understanding of the factors affecting students' comprehension of Grade 12 mathematics.

Recommendations

Future research by tertiary institutions and other related organisations should be conducted on the impact of MPCK on the mentoring of Grade 12 Mathematics using PBL. This information would inform policymakers on generating effective guidelines on teaching practices that would contribute towards DBE's effort in addressing the poor performances of Grade 12 Mathematics at the NSC level.

Mathematics educators need to attend workshops and seminars hosted by DBE, to receive upskilling in PBL, as the preferred instructional approach to mentoring Grade 12 Mathematics. This will equip educators to implement various instructional strategies such as critical thinking, classroom discipline and group work engagements to cater for individual students' learning needs.

Furthermore, DBE and tertiary institutions need to create incentives and opportunities for Grade 12 Mathematics educators to enhance their qualifications in mentoring Mathematics.

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