Teachers' content knowledge, teaching methods and their encouragements that influence Grade 10 students' mathematics learning in Port Moresby, Papua New Guinea

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Abstract

Teachers' content knowledge, teaching methods and their encouragement of students are important as they determine the students' mathematics performance at secondary schools in Papua New Guinea (PNG). However, it is evident that significant number of students cannot continue to Grade 11, and simultaneously decline in student enrolment in science related degrees at the university level in PNG. That being the case, this study aims to examine teachers' content knowledge, teaching methods and their encouragement that influence Grade 10 students' mathematics results. A qualitative research approach (interview) is applied in this study. The interview data of nineteen Grade 10 mathematics teachers were analysed through thematic approach to capture rich information. This study highlights that teachers' content knowledge, teaching methods and their encouragement of students have a significant influence on Grade 10 students' mathematics learning. The study concludes that more attention should be given to these three factors at schools, in order to improve Grade 10 students' mathematics learning.

Keywords: Content knowledge, teaching methods, encouragement, mathematics and learning

Introduction

Mathematics teachers need a solid understanding of mathematics so that they can teach it as a coherent, reasoned activity and communicate its elegance and power. However, research studies indicate that many teachers possess a limited knowledge of mathematics in key content areas such as calculus (Ekawati, Rosyidi, Prawoto, Prahmana & Lin, 2022; Adelabu, & Alex, 2022). This is particularly true in the case that most teachers find it difficult to teach the most complex mathematical problems, the most cognitively challenging, and the most essential to success in higher mathematics and science. Researchers investigating the connections between mathematical content knowledge and teaching methods (e.g., Askew, 2008; Ward & Thomas, 2008) have found clear relationship between these two categories. Ward and Thomas (2008) found that teachers with low levels of mathematical content knowledge also had low levels of teaching methods, but those with high levels of content knowledge had wide range of teaching methods. This evidence supports the claim that a certain threshold of mathematical content knowledge is necessary for good teaching.

In this study, the interview data of teachers are analyzed to identify common themes emerging from the teacher group. Interviews are only for the teacher-level to obtain perspectives on educators' teaching methods, content knowledge and their encouragement that might affect their students' mathematics achievements. As the literature indicates that students' mathematics achievements are affected by teacher-level factors, it is important to discuss the issues that are identified in the interviews with teachers. This study will answer the research question "What are the attributes that are deemed important by teachers regarding their mathematics content knowledge, teaching methods and encouragement of students?" In order to answer this question, three main themes are identified and discussed, including content knowledge, outcome of teaching methods, and encouragement towards mathematics. In analysing the interviews, the main themes are first discussed, followed by discussion of participants' responses under each theme. After that, the discussion of the responses are presented, according to the main themes identified.

Literature review

Researchers in mathematics education have proposed different conceptual structures for mathematics knowledge (Ekawati, Rosyidi, Prawoto, Prahmana & Lin, 2022; Adelabu, & Alex, 2022). These conceptual structures often separate pure content knowledge (CK) from the knowledge that facilitates teaching. However, some scholars such as Yang, Schwarz & Leung, (2022) and Maher, Muir, Chick, (2022) doubt whether CK is separable from the knowledge needed for teaching, and empirical work on the distinguishability of these two components provides mixed findings.

Mathematical content knowledge for teachers is important for students learning in mathematics. According to Estrella, Mendez-Reina, Olfos & Aguilera, (2022) subject matter knowledge (SMK) is subdivided into three parts: *Common content knowledge, knowledge at the mathematical horizon,* and *specialized content knowledge*. *Common content knowledge* is the body of knowledge and information that teachers teach and the students are expected to learn in mathematics or its content area. For example, mathematics teachers and engineers both use knowledge of how to solve algebraic problems in conducting their day-to-day work. *The knowledge at the mathematical horizon* gives an awareness of how mathematical topics are related over the span of mathematics included in the curriculum (Escudero-Ávila, Montes & Contreras, 2021; Yang, Kaiser, König & Blömeke,2021). Moreover, the *specialized content knowledge* is type of mathematical content knowledge specifically needed for teaching (Koyuncuoglu, 2021; Mwinuka, & Tarmo, 2021). These types of knowledge, serve as a critical component for defining mathematics teacher to be effective in their daily preparation and teaching. Literature claims that teachers cannot teach what they do not know themselves (Cavadas, Rézio, Nogueira & Branco, 2022; Getenet, & Callingham, 2021) and, to meet the challenging demands of teaching, teachers must possess sufficient mathematical content knowledge. For instance, according to the Commonwealth of Australia (2008, p. 21), one of the main issues associated with Australia's mathematics and numeracy teaching workforce is that " teachers are not being adequately prepared for teaching numeracy and mathematics". On the other hand, ACDE report also highlights that, "the teaching of mathematics depends on the teachers' mathematical content knowledge and also on their attitudes to teaching mathematics and their understanding of mathematics pedagogy" (2012, p. 14).

Moreover, studies reveal that mathematical knowledge assist teachers to carry out the work of teaching mathematics. Important to note here is the teaching methods employed by teachers (Yang, Hsu, & Cheng, 2022; Rieu, Leuders & Loibl, 2022). It is concerned with the tasks involved in teaching and the mathematical demands of these tasks. Because teaching involves showing students how to solve problems, answering students' questions, and checking students' work, it demands an understanding of the content of the subject matter (Copur-Gencturk & Tolar, 2022; Arnold, Burroughs, Fulton & Álvarez, 2021). Beyond these obvious tasks, we seek to identify other aspects of the work and to analyze what these reveal about the content demands of teaching. To teach all students according to today's standards, teachers need to understand subject matter deeply and flexibly so they can assist students create useful cognitive maps, relate one idea to another, and address misconceptions (Grilo & Cerqueira, 2022; Shongwe, 2021). Teachers need to see how ideas connect across fields and to everyday life since teachers' content knowledge and teaching methods have significant positive effects on student mathematics learning (Rahman, Rosli, Rambely, Siregar, Capraro & Capraro, 2022).

Teaching method is the mechanism that is used by the teacher to organize and implement a number of educational means and activities to achieve certain goals (Bieg et.al, 2017; Ardeleanu, 2019;). Teaching techniques are the means that reflect the success of the learning process and the competencies of the teacher (Malik & Masri, 2019; Voskoglou, 2019). For instance, from the author's teaching experience, teacher always looks for new ways to deliver knowledge to the learners, and in many occasions, discovered that traditional teaching methods become not effective as it used to be due to the current advancement in technology. Teaching becomes more effective when it is performed in a quicker response to the needs of the learner (Malik & Masri, 2019; Voskoglou, 2019). Studies suggest that design and selection of teaching methods must take into account not only the nature of the subject matter but also how students learn (Ardeleanu, 2019; Asghar, Malik & Masri, 2019). In today's school the trend is that it encourages much

creativity. This is due to the fact that human advancement comes through reasoning to enhances creativity. This is evident in mathematics teaching where creativity is encouraged to engage students interest in learning mathematics.

Encouragement is one of the most powerful tools a teacher can use. Studies highlight that encouragement is the key to unlocking untapped potential in students especially those that have negative approach towards learning mathematics (Khairnar, 2021; Wise, 2022; Osman, Daud & Kumar, 2021) Teachers actions have the ability to lift students up or break them down. Encouraging words and actions are often internalized by students and have the power to motivate them to succeed (Osman, Daud & Kumar, 2021; Khairnar, 2021). A study by Snead, Walker & Loch (2022) found out that encouragement assists students to learn better in mathematics and never giving up on themselves. Literature reveals that it is easy to offer encouragement when a student is succeeding (Lugosi &Uribe, 2022; Aliyu, Osman, Daud & Kumar, 2021). However, encouragement is often the most effective when students receive it while they are struggling to master concepts. Several studies affirm that when a student is failing or struggling, by offering support the teacher can reaffirm their unconditional positive regard for the student to build trust and rapport with the student (Lugosi &Uribe, 2022; Aliyu, Osman, Daud & Kumar, 2021).

There are many steps that teachers can take to encourage children to succeed. Students look to teachers for approval and positive reinforcement (Khairnar, 2021; Wise, 2022), and are more likely to be enthusiastic about learning if they feel their work is recognized and valued. Teachers should encourage open communication and free thinking with their students to make them feel important (Dagdag, Palapuz & Calimag, 2021). Be enthusiastic and praise students often in their learning and recognize them for their contributions. Studies indicate that when classroom is a friendly place where students feel heard and respected, they will be more eager to learn (Astuti, 2021; Khairnar, 2021; Wise, 2022).

Aim and research question

The study aim was to identify the mathematics content knowledge, teaching methods and encouragement from teachers that influence Grade 10 students' mathematics learning.

The guiding research question for this study is: What are the attributes that are deemed important by teachers regarding their mathematics content knowledge, teaching methods and encouragement of students?"

Research methodology

This section of the paper discusses the methods and procedures used to collect and analyse the interview data.

Development and administration of interview questions

The interview questions were developed following basic guidelines (Archibald, 2016; Bamberger, 2012; Creswell, 2008). Each question was constructed with reference to the topic and the purpose of this study. Accordingly, the brevity and clarity of the instrument was prioritised. Biased and negative wordings that may have influenced teachers' responses were avoided. The questions developed were then discussed with three experienced teachers**.** Feedback from these researchers related to designing the questions on quality of teaching aspects adapted from the teaching quality model in NSW schools, and how the researcher would engage teachers to truthfully express their feelings towards teaching mathematics. Consideration of validity and reliability were paramount for interview questions for the teacher participants (Archibald, 2016; Creswell, 2008). As this study aimed to get Grade 10 mathematics teachers' views about their content knowledge, teaching methods and encouragements to students, they were interviewed. Grade 10 teachers are selected in this study because their students sit for PNG national examination each year. The results of these examinations continues to decline over the years and many students cannot go to universities and colleges, respectively. Prior to the administration of this study, it was necessary to obtain ethical research

approval from the University of Adelaide's Human Research and Ethics Committee (UAHREC). The UAHREC granted approval for this study to proceed on 14 July 2017 (Ethics Approval No H-2017-133).

Participants

Mathematics teachers of Grade 10 students were selected. Teachers were purposefully selected with a mixture of experience, from expert and novice, to ensure that a balance of views and opinions was received (Creswell, 2002; Creswell , 2017). Interviews were scheduled during teachers' non-contact periods. Once the participant appointments were made, interview questions were provided to teachers, in order to obtain as honest and detailed answers as possible. Interviews were then conducted in the 16 schools, with 19 teacher participants. Participants were informed that the whole interview was audio-recorded. Prior to the interview, the researcher explained to participants the purpose, importance, and confidentiality of the interview (Creswell, 2008). After that, the researcher began to ask questions using the interview protocol. Consideration of questioning strategies was sought and observed to elicit the appropriate responses. Questions were rephrased and examples were highlighted relating to scenarios for the participants to more easily understand the questions. At the end of the interview, the researcher thanked the participants, and assurance of the confidentiality of their responses was emphasised.

Data Analysis

Thematic analysis is the most common analysis approach used in qualitative research. This approach emphasises pinpointing, examining and recording patterns (themes) within data. Themes are patterns across data sets that become the categories for analysis, and are important in describing a phenomenon associated with a specific research question. In this approach, themes are used to capture the essence and spread of meaning; they unite data that might otherwise appear disparate, and correct meanings that occur in multiple and varied contexts. "Thematic analysis can be an essentialist or realist method, which reports experiences, meanings and the reality of participants" (Braun & Clarke, 2006, p. 81). Therefore, thematic analysis works both to reflect reality and to unpack the surface of 'reality'.

In this study, thematic analysis is performed following the six processes of coding phases outlined by Brinkmahnn and Kvale (2015) and Braun & Clarke, (2006) to create established and meaningful patterns. The first step is familiarisation with the data to sort out ideas through transcribing, reading and re-reading. Second, codes are generated in a systematic approach across the entire data set, in order to collate data that are relevant to each code. Third, themes are identified for coding, and to gather the data for each relevant and potential theme. Fourth, these themes are reviewed to ascertain that they work in relation to the coded extracts and the entire data set, to generate a thematic 'map' of the analysis. After that, the themes are defined and named to tell a clearer story of the data. Finally, a scholarly report of the analysis is produced that relates back to the research question and literature. These six steps to analyse the quantitative data using the thematic approach were organised and expedited through use of the NVivo 12 software.

NVivo 12 is used to analyse the interview data in this paper. NVivo is a data management tool (Hart & Achterman, 2017), that organises and assists in making sense of data during analysis (Hamrouni & Akkari, 2012; Hart & Achterman, 2017). NVivo organises, stores and retrieves data more efficiently than manual methods, saves time, and helps to rigorously back up findings with evidence (Hamrouni & Akkari, 2012). The data were imported from a text file and analysed with NVivo's visualisation tools. The software allows the researcher to classify, sort and arrange information; examine relationships in the data; and combine analysis with linking, shaping, searching and modelling (Hamrouni & Akkari, 2012; Hart & Achterman, 2017). The researcher can test theories, identify trends and cross-examine information in a multitude of ways using the software's search engine and query functions.

There were several steps involved in analysing the interview data with NVivo 12. First, the teachers' transcribed interviews were loaded into NVivo. After that, themes and sub-themes from the scripts were identified and created. Next, the teacher transcripts were sorted into the appropriate themes and sub-themes and, a mind map was formulated through the NVivo software to create relationships among the themes. This process created a frequency of the number of teachers under each of the themes, making it easier to trace the teachers' responses on the themes. For instance, in this study, four themes were identified, and the software assisted in putting together all the responses of the participants according to their respective themes, with the percentages of responses and the frequency of respondents listed under each theme. This organisational approach of the software requires less time and allows more flexibility than manual methods in comparing interview responses and analysis of data.

Emerging themes

This section highlights each of the main themes that were identified in the data by frequency analysis of the teacher-level interview. The three key themes that emerged from the data analysis are: (1) content knowledge, (2) outcome of the teaching methods used in the classroom, and (3) encouragement towards mathematics (practice exercise and students' attitudes/approaches). All of these themes seem to have an influence on the mathematics learning outcomes of students.

Theme 1: Content knowledge

Mathematics content knowledge is important for teachers to possess in order to deliver effective lessons to students. Teachers use teaching methods variously to deliver the content of mathematics topics, and it is believed that showing confidence with the content knowledge towards a particular topic is likely to have an impact on students' mathematics results. As mentioned earlier, the content knowledge of the teachers interviewed was used to ascertain its impact on the students' mathematics achievements. Therefore, the results of teacher interviews will instead provide an in-depth exploration of how the content knowledge of mathematics teachers can affect students' mathematics results through their teaching.

The results of the interviews indicate that eight teacher participants have adequate content knowledge and are confident in teaching all topics in the mathematics syllabus. Six other teacher participants are confident in teaching both Geometry and Trigonometry. Two teachers are confident in teaching Series and Sequences, Vectors, Statistics and Money, and only one teacher is confident in teaching Calculus. Algebra is the only topic that all the 19 mathematics teachers are confident in teaching. These findings indicate that some of the teachers are less confident with their content knowledge when teaching some of the mathematics topics. Moreover, the results also reveal that there are six teacher participants who are less confident in teaching Calculus, and four participants who are less confident in teaching Vectors. Furthermore, three other participants are less confident in teaching Probability, with another two participants are lacking confidence in teaching Money. Geometry, Trigonometry, and Statistics are topics that one teacher each has less confidence in teaching. These results indicate that teachers' confidence in teaching mathematics topics can have influence on students' mathematics achievements.

Some participants gave their reasons for feeling less confidence in teaching these mathematics topics. One of the participants stated that:

> *Trigonometry in Grade 12 especially, to do with quadrants and all that yeah and then going on to circular functions, the graphs because there a lot of details to be analysed. Information like the graphs to be analysed for the sine function, cos functions, the features of the graphs, you know what this letter is on the equation, what its meaning and all that, and they have to remember all those. Too many properties and inequalities*

> *to remember about certain equations make me you know to forget many things when I am teaching that topic and it makes me feel not confident [Teacher 3].*

Two other teachers also shared similar sentiments:

> Sometimes when I see that there is no time. *May be because the nature of the topic. So many things in there where we need to put together and understand. Find some ways to simplify for the students to understand [Teacher 12].*

> *It takes time and effort for teachers to sit down to read through different books to see the way it's been set up. Where you understand it you can be able to tackle it [Teacher 16].*

The above three teachers' views indicate that teachers lack knowledge in the detailed aspects of topics such as Trigonometry, and as a result consume more time and effort attempting to consult different sources in preparing their lessons. Teachers also struggle to confidently deliver content knowledge that they are less familiar with, even despite extra time and effort put into the preparation of lessons.

These problems arise when teachers are less trained or are recruited directly from non-teacher training universities without the necessary content knowledge. Two teachers emphasised that:

> *Vectors and small part of calculus. That very area that I am not confident is because I did not pick at my studies at university [Teacher 4].*

> *I am a person I am not a trained teacher but I graduated from university and looking for a job and joined teaching. Because of my background as physics [Teacher 5].*

These two participants' views suggest that teacher-training institutions lack the capacity to impart much needed content knowledge to the student teachers in the necessary topics. Further, schools are employing teachers who are not trained to teach mathematics. This results in teachers who lack confidence in teaching some mathematics topics. As a result, students in turn might have different attitudes towards learning mathematics, which can affect their results. One teacher highlighted that:

> *Sometimes maths is a difficult subject in PNG; there are many students who finds it very hard to understand maths so sometimes in my lesson I try to break the example down to detail to explain for students to understand the concept on how to solve the particular problem [Teacher 7].*

This attitude aspect of students is also found in the quantitative studies, showing that students' positive attitudes have a significant effect on their mathematics results. However, the results of the interviews also show that students can have negative attitudes towards mathematics (e.g. that is 'too hard') if their teachers struggle to prepare and deliver lessons.

Teachers' feelings of confidence/lack of confidence to teach mathematics content are compared below in Table 1.1. This comparison is conducted through independent samples t-test analyses.

Table 1.1 Descriptive statistics of the teachers' confidence in teaching mathematics content

Group statistics					
	Confident Level	N	Mean	Std.Deviation	Std.Error Mean
Maths Results	Confident	119	498.91	7.64	0.70
	Not confident	181	495.08	5.72	0.43

The descriptive statistics associated with the confidence level for teachers are reported in Table 1.1. From this table, it can be seen that teachers who are confident with mathematics content are associated with the high mean (*M*=498.91,*S.D*=7.636) compared to teachers who are not confident with mathematics content (*M*=495.08,*S.D*=5.72).

Table 1.2 The output of independent sample t-test analysis

				Independent Samples test						
		Levene's Test for Equality of Variances							95% Confidence interval of the Difference	
							t-test Equality of Means			
		F	Sig.	*t*	df	Sig.(2-tailed)	Mean Difference	Std.Error Difference	Lower	Upper
Maths Results	Equal variances assumed	4.95	0.02	4.95	298	0.00	3.82	0.77	2.30	5.35
	Equal variances not assumed			4.66	203.06	0.00	3.82	0.82	2.21	5.44

Table 1.2 shows the output of the independent sample t-test analysis indicating whether there is a statistically significant difference between teachers with confidence in teaching mathematics content and teachers who are not confident. Both the results of the assumption of homogeneity of variances via Levene's F test, F (298) =4.94, p=0.027 and the independent t-test t (298) =4.95, p=0.00,95% *C.I* [2.303-5.345] are associated with statistically significant effects on the teachers' confidence levels. Thus, the teachers who are confident in teaching mathematics are associated with a statistically significant ($p<0.05$) effect with larger means than the teachers without confidence, in determining students' mathematics learning.

Furthermore, professional development (PD) is crucial to overcome challenges associated with less confident teachers. PD can help with gaps in teachers' content knowledge, and provide methods to enable them to gain confidence in the effective teaching of mathematics topics. However, 16 out of the 19 teachers interviewed stated that they do not have access to PD for the topics they are less confident in teaching. These teachers stated that PD is not initiated at the department level, nor at their schools as a whole. Six of the teachers said:

> *No. In that case no. Specially that particular topic ah. Any professional development or in-service there is nothing. But I am interested in taking up any of those [Teacher 1].*
>
> *I haven't any. The only way is to do is to do research to understand examples and deliver to the students [Teacher 16].*
>
> *No in-service. We lack teachers so we go in and teach as long as we achieve our objective [Teacher 3].*
>
> *So far we do not have any in-service. May be because of the head of department have not done a schedule [Teacher 17].*
>
> *Zero. There is no assistance in that area, no in-service in topics we are not confident to teach [Teacher 3].*

> *No in-service in the school and department [Teacher 7].*

These responses indicate that professional development is less prioritised by most of the mathematics departmental heads at schools in Port Moresby. This could have multiple effects on the teaching and learning of teachers and students: teachers may remain less confident in teaching topics, and cannot deliver content knowledge to students effectively or with creativity. This implies that students are likely to get less out of the teachers, and that may consequently affect their mathematics learning.

Theme 2: Outcomes of the teaching methods

Outcomes of the teaching methods in the delivery of content knowledge (topics) by teachers are important to determine and evaluate students' learning processes. This evaluation of teaching methods is observed through the students' positive responses towards lesson participation, approaches towards exercises, results of their assessment tasks (e.g., tests and assignments) in classrooms and the results of their standardised national examination. These elements of the students' learning processes indicate the effectiveness of the particular teaching method employed by their teachers. The effects of these teaching methods determine the outcome of the students' mathematics learning, and are also evident in the teachers' interview responses.

Of the teachers interviewed, 12 out of the 19 teachers employing traditional teaching methods (discussed earlier) gave responses on how these methods influence learning outcomes. Two of the participants stated that:

> *I give students exercises and when they get them correct I know they understand. Sometimes students have to explain correctly in a logical order and that means that they really understand the concept [Teacher 14].*

> *They learn very well I think. Students do more examples and want more practical examples to do the exercises. The method that I use is very good and I think students are learning more on that [Teacher 10].*

These participants' responses indicate that students' understanding of the mathematics concepts are determined by the competence level (number of correct answers) that students display when attempting practical exercises, and teachers' logical explanation of ideas.

The other three participates mentioned that student participation and interaction with teachers shows that students have sufficiently understood the mathematics content. These participants said:

> *I see the students' response favourable to the method that I use. There seems to be an interaction between a teacher and the student. When I ask questions, students are able to raise their hands and answer the question. In that where I know and realise that, the students are into the lesson that is been presented and are following. I also call the attention of students who do not really participate, who are doing other things. When I am teaching I look around and see that I direct questions to them. In that, way I make them pay attention to what is been discussed [Teacher 7].*

> *The learning is OK. It's not high standard of learning as expected. They need various strategies in order to fully understand the subject [Teacher 13].*

> *Students learning, the most method they are catching up in learning is through chalkboard doing calculation on the board and doing corrections, word problems you know this. The board is a good way of learning that is improvement [Teacher 2].*

It is evident in these participants' responses that participation in the lesson indicate that students are learning from the teaching method. However, to facilitate students' participation in lessons, teachers must expend effort to get all students' attention by asking questions. Furthermore, teachers' use of the blackboard for doing calculations, and correcting mathematics problems together with students, effectively improves

student learning in mathematics. However, in order to better disseminate mathematics ideas to students, it is still necessary to also utilise other teaching strategies such as student-centred methods. The other six teachers using the student-centred methods also provided responses detailing their methods. Two of these participants highlighted that:

> *Ok other one when we give in groups, we find that learning is quite effective, because within their own groups, they kind of check on each other. And everyone has part to play in the group and they report to each other so nobody seems to be sleeping [Teacher 3].*
>
> *One way is they are helping each other during group work. They share ideas in groups esp. those bright ones are assisting the weak ones to understand what was taught in class and doing their presentation to does the same thing [Teacher 12].*

These two participants' responses denote that student-centred methods are effective, as students work in groups sharing ideas to assist each other with lessons. This suggests that high-achieving students could assist weaker students when group and peer learning is encouraged, with students checking each other's learning and sharing ideas through presentations. Teachers act to facilitate their students learning processes, and students take ownership of their own learning for desirable learning outcomes.

Another teacher further stated that:

> *What I find is in certain topics where I demonstrate but the other where I feel that they can be able to help with their peers I give the task to them and they enjoy working with the peers. This is because they understand their peers and friends [Teacher 6].*

This response supports the previous two participants' responses emphasis on students of working together in groups to learn from each other, indicating that students work and learn with their peers better than with their teachers.

Theme 3: Encouragement

Teachers' encouragement of their students is important in improving their mathematics results. Encouragement from teachers can influence students' approaches to learning mathematics. The two important sub-themes that emerged from analysis are practice with more exercises and students' attitudes/approaches towards mathematics.

Working consistently on mathematics exercises can give students greater confidence in solving mathematics problems, and deepen their understanding of the subject. For instance, the more they practice and actively solve exercises, the better they will be in mathematics. This view was confirmed by three participants' responses. They highlighted that:

> *Maths is not something that you can study and memorise, but maths is something you must practically do. I encourage them to do more activities/exercise and do everything so that you can be used to [Teacher 10].*
>
> *Tell them to do a lot of exercise because they do more practice to understand the concept in mathematics [Teacher 14].*
>
> *You must do a lot of exercises [Teacher 4].*

The responses above clearly indicate that teachers encourage students to do more practice with mathematics exercises to learn and master mathematics knowledge and skills. Similarly, a teacher participant emphasised the importance of relating abstract mathematics knowledge to more practical applications in society. The participant stated that:

> *One of the things I tell them esp. those who do not show much interest in mathematics is whatever we learn in school we apply outside in real life. Put in practice what we learn in the classroom. Get yourselves involved and learn more to put in practice outside. Money or formula can be applied in real world esp. every way you go in shops or markets there is mathematics. Therefore, you must learn and really understand mathematics [Teacher 7].*

Students' attitudes/approaches towards mathematics is another sub-theme identified from the analysis. Of the teacher interviewed, 12 of the 19 encourage students to have positive attitudes or approaches towards mathematics. The sub-theme of students' attitudes towards mathematics was also discussed in the quantitative analysis of this study (Chapter 7). For instance, three of the participants emphasised that:

> *Cheer them up and tell them you can do it. Mathematics is not that difficult it's fun. I make sure they do questions I give and check their work [Teacher 16].*
>
> *Maths is interesting because it's all to do with numbers. It interesting in the way I teach mathematics to students [Teacher 19].*
>
> *I always tell them that it's like you learning 1 + 1 like you did in Primary school. So you do not learn something very hard. Know your basics well then you can do better and understand because that will be applied and carried on to Grade 9, 10, 11 and 12 [Teacher 12].*
>
> *I encourage students to be active and be energetic when learning mathematics [Teacher 2].*

These responses suggest that the teachers encourage their students to have positive attitudes towards mathematics, for instance, encouraging students by communicating that mathematics is not hard but is interesting and fun. These teachers support their students to understand basic mathematics skills in order to progress to problems at higher-grade levels that require higher skill levels. This encouragement can be prompted through active learning with greater energy. Similarly, some teachers encourage students to approach them (or others they are comfortable with) when they have difficulty understanding mathematics ideas/concepts. Two teacher participants pointed out that:

> *Encourage Feel free to come and see me when they need help or assist. In addition, I encourage them to help each other. Otherwise, they are not comfortable with me as their maths teacher I encourage them to see their friends, parents or seek assist from other mathematics teachers. My biggest encouragement is to open up, to love the subject and to do what they can be able to do. Any difficulty they can come to see me [Teacher 6].*
>
> *I always encourage students especially those with problems, those who find work difficult to come and seek help. My own experience in this school for the last five years I give help to anybody because I opened the door. Anyone with problem even they are not from my class I help as the head of department I make my business to do that. I am helping average students and lower achieving students but the bright ones do not come [Teacher 9].*

These responses show that teachers are willing to allocate time to assist students that have difficulty understanding mathematics concepts. This approach for students seeking help is important to unpack their uncertainties about mathematics problems, and encourages them to improve in their learning practices thereby subsequently improving their mathematics learning.

Discussion

It is clear from the findings and literature review that the impact of teachers' content knowledge of mathematics topics on their students' results can be quite significant. The interview data indicate that the impact seems to be greater when teachers are less confident in teaching some mathematics topics. This could be attributed to the fact that only eight of the teachers interviewed are competent to teach all of the mathematics topics, while 11 are confident in teaching just some of the topics. Besides that, most of the teachers still lack the skills and knowledge in topics such as Vectors and Calculus. The teachers' knowledge gaps in mathematics topics in turn can affect their students' mathematics results (Kelcey, Hill & Chin, 2019), as these topics frequently appear in the Grade 10 national examination. A study by Kelcey, Heather, Hill and Chin (2019) indicates that there are significant correlations between teacher content knowledge, instruction, and student achievements. This argument links well with the ANOVA results of the different teaching methods discussed earlier. This is because using student-centred teaching method and mixing both teaching methods have a high significant influence on students' mathematics learning and these methods can be used to effectively deliver content knowledge to students in the classroom. Teachers using these methods consistently, and who have adequate content knowledge in all mathematics topics can teach and guide students to obtain better mathematics results. This is because teachers having sufficient mathematics knowledge allows them to focus on teaching, readily provide alternative explanations, and incorporate additional resources into lessons (Hallman-Thrasher, Connor & Sturgill, 2019).

However, for teaching to be successful, it is also key that teachers possess content knowledge in multiple ways and have an ability to make this knowledge accessible to students. For this to happen, the evaluation of knowledge in terms of content and pedagogy are important as they are interrelated for teachers' success in their practice. This is because the knowledge needed to make specific content accessible to students, which forms a critical component of teacher knowledge, has been shown to have an impact on teaching effectiveness (Hallman-Thrasher et al., 2019). This involves teachers' knowledge of content, students, teaching and curriculum in a holistic approach. This knowledge also includes teacher understanding of the student learning process of a particular topic, for instance, the process of how students might solve a problem, and common conceptions and misconceptions about a topic. Further, the knowledge of how a teacher might teach a particular concept needs sharpening, for instance in areas such as representations, sequencing, pacing, and providing examples that are most appropriate for a given topic (Appova & Taylor, 2019; Hallman-Thrasher et al., 2019). The knowledge of content and curriculum involves knowing what instructional resources are available to teach a given topic and under what conditions they should be used (Appova & Taylor, 2019). It is true that content knowledge that is common to any mathematical profession is needed to teach and learn mathematics, for instance, knowing how to solve an algebraic equation. However, the components mentioned above are fundamental to fully utilise this specific content knowledge in mathematics. In other words, teachers need to develop not just a deeper knowledge of mathematics content but also an understanding of the mathematical process of inquiry and problem solving to enrich their teaching practices and to encourage the development of critical thinking skills in their students (Albert 2012). Teachers are required to know and understand not only mathematics, but also their students learning processes, teaching strategies, as well as how to challenge and support the classroom-learning environment. In addition, teachers need to know and use mathematics for teaching that combines mathematical and strategical knowledge, as they must continue to learn new or additional mathematics content and study how their students learn mathematics (Zhao & Zhao, 2016). These approaches allow teachers to see their knowledge in teaching mathematics in a wider perspective, and are likely to positively influence students' mathematics results.

However, many participants reported that professional development (PD) is not given priority by school heads to improve on those topics that they are not confident to deliver in the classroom. This reflects the mixed feelings reported in relation to the impact of teachers' relationships with school heads who do not organise PD opportunities, which may be affecting their students' mathematics learning. Though some participants have an interest in PD, they are not given the chance to improve on their weaknesses in content

knowledge areas. Studies have shown that PD equips teachers with content knowledge and skills they lack to teach students (Jacob, Hill & Corey, 2017), as it upgrades and updates their teaching processes and allows them to deliver mathematics content on topics more confidently.

Moreover, the interview results show that the three teaching methods (student-centred, teacher-centred and both methods mixed) are employed by teachers of schools in Port Moresby. As shown in the interview analysis, student-centred methods and mix methods have a high significant difference on the students' mathematics results, compared to the solely teacher-centred teaching method. One of the main reasons for this may be because of the shift of teachers' teaching methods from traditional (teacher-centred) methods to the student-centred and mixed teaching methods. Despite that, the traditional method is still prominent in schools in PNG. This suggests that students are generally dependent on teachers for their learning, and are not taking ownership of their own learning. As discussed above, teacher-centred methods treat students as passive learners, and encourage less creativity in learning. Studies have shown that teacher-centred methods have a negative influence on students' academic achievements (Basso, 2019; Olson & Stoehr, 2019). This phenomenon can be evidenced in the mathematics results of students who are taught by teachers using student-centred or mixed methods in Port Moresby, which demonstrate improvement over traditional methods.

Moreover, other studies have argued that student-centred and mixed methods have a positive influence on student academic outcomes (Saadati, Cerda, Giaconi, Reyes & Felmer, 2019; Ulandari, Amry & Saragih, 2019). This is because students are active and are more engaged in their own learning. With these methods, students are also able to construct their own knowledge through research and presentation in groups as mentioned by the participants in this study. Drawing from the researcher's experience as a teacher in Port Moresby, this may be tied to teachers' access to instructional resources, teachers' willingness to adapt, and many other strategies related to student-centred method and mixed methods. Despite this, however, the researcher believes that there remain many issues that are likely to continue to hinder teachers to effectively practice the non-traditional methods in delivering mathematics lessons in the classroom (PNG NDOE, 2006, 2009).

Furthermore, from the interview results, it is evident that the teachers encourage their students in studying mathematics through having positive attitudes and taking efforts to make mathematics more practical. This outcome is consistent with the literature review. Several other studies have also shown a correlation between students' attitudes towards mathematics and their achievements in the subject. Teachers' encouragement contributes to positive student attitudes influencing their decisions and improving their results (Khun-Inkeeree, Omar-Fauzee & Othman, 2016; Pepin & Roesken-Winter, 2015; Prendergast, Hongning & Block, 2016) Mathematics can be presented as a fun and interesting subject, and when students perform successfully in mathematics, this affects their attitudes towards mathematics in positive ways, and this perception can continue throughout their schooling (Mullis et al., 2012; Stephens, Landeros, Perkins & Tang, 2016). This is because negative attitudes towards mathematics can cause some students to lose self–belief in their abilities (Iqbal, Mirza & Shams, 2017; Kiss, 2018; Soni & Kumari, 2017). In the interviews, the teachers' efforts to eradicate their students' negative feelings towards mathematics is evident, as is the belief that more positive encouragement is likely to influence students.

Practical exercises further motivate students to learn mathematics, by allowing them to understand the concepts and steps involved in solving a problem. It is evident from existing studies that students gain interest and are engaged when concepts discussed in the classroom are practically demonstrated in the real world. In the mathematics context, this is achieved through relating the basic principles of how mathematics concepts apply to the every-day life. For instance, Kiemer, Gröschner, Pehmer, and Seidel (2015) discuss the case of an engineer who went to teach mathematics in India. In their study, Kiemer et al. (2015) demonstrated how the teacher motivated their students by relating what had been learnt in the lesson to what was outside the classroom. This approach was initiated due to the students' interest in applying mathematics theory into practice. Overall, the interview data show that there seems little doubt that teachers can better motivate students to study mathematics by emphasizing the relevance of mathematics in the real

world. For instance, Ali (2013) shows how teachers motivate students through solving mathematics problems relating to their everyday lives. This approach can generate excitement among the students to persevere in mathematics because of the practical skills and knowledge that underpin the mathematics lessons. Mathematics in this context promotes reasoning skills that are helpful in students' everyday lives. These kind of encouragements by teachers not only motivate students but also promote positive learning approaches that are likely to have an impact on the students' mathematics learning.

Conclusion

This study presented the results and discussion from the interviews with the nineteen Grade 10 teachers who participated in this study. The findings were presented in three sections that corresponded to the primary themes that emerged from the results: (1) content knowledge, (2) outcomes of the teaching methods used in the classroom, and (3) encouragement towards learning mathematics.

It is clear from the findings of these interviews that the student-centred method and mixed methods have significant effects, compared to teacher-centred method. As the interview results have shown, the teaching methods adopted by teachers can assist and promote students' learning. Furthermore, the confidence of teachers towards their own mathematics content knowledge has a positive influence on their students' mathematics learning. This means teachers' knowledge of mathematics content, pedagogy, instructional resources and curricula are contributing elements in producing better results. However, as identified in the analysis, teachers also face challenges such as student population increases and a lack of learning resources in classrooms that may affect the practical delivery of lessons to effectively communicate content knowledge. On a positive note, some of the participants involved in this study acknowledged that they encourage students to have positive attitudes towards mathematics learning. They also suggested approaches to help students overcome their struggles towards mathematics when the subject becomes difficult, assisting them to believe in their own mathematical abilities.

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