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The effect of the COVID-19 pandemic on pre-service teachers' mathematical perceptions and motivation at a selected higher education institution in South Africa

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Abstract: There is a need for knowledge that contributes to the development of educational resilience and enhances the understanding of the complex relationships among teacher education, mathematics educators, and learner outcomes. This study investigated the perceptions and motivation of pre-service teachers in learning mathematics in the post-COVID-19 era. It employed a qualitative research methodology to explore pre-service teachers' perceptions and motivation. Data were collected through both closed- and open-ended questionnaires from a case study involving twenty pre-service teachers, providing insights into their experiences. The findings indicated significant declines in mathematical performance and motivation to learn mathematics, accompanied by increased anxiety and decreased confidence. Additionally, the study revealed that pre-service teachers face challenges such as limited practice opportunities, lack of group work, and difficulties adapting to e-learning systems. Despite these challenges, they were motivated by factors such as problem-solving skills, creative thinking, and the importance of mathematics in daily life. This research underscores the importance of motivation, adaptation, and support in facilitating effective mathematics learning among pre-service teachers, even under challenging circumstances. The findings have important implications for teacher education programs and policymakers aiming to optimize support for pre-service teachers during times of academic crisis.

Keywords: *COVID-19, Experiences, Higher education institutions, Mathematics, Motivation, Perceptions, Pre-service teachers.*

1. Introduction

The COVID-19 pandemic has had a profound impact on the education sector, and teacher preparation programmes were no exception. Pre-service teachers faced unprecedented challenges in developing mathematical knowledge and pedagogical skills [1]. Mathematics teaching and learning have special challenges in online learning. Presenting mathematical text on the computer screen is not an easy feat for both pre-service teachers and the lecturer during instruction and assessment. Pre-service teachers are faced with a situation where they cannot include mathematical symbols in the comment sections on the online platforms. If they attempt to use the word processor to typeset mathematics text, this requires more time, unfortunately. Neither could students give feedback on problems which required mathematical text appropriately. They had to resort to writing with a pen on paper, scanning the paper, and then uploading it to the chat section. It worked in some cases, but it was time-consuming and the quality of the print was not good. The same challenge is faced by the lecturer, too. Without a whiteboard facility on Teams, the lecturer found it hard to present mathematical text to the class during online teaching. According to Tatira [2] "typesetting mathematics text is clumsy" as some characters are not directly found on the keyboard. The COVID-19 pandemic has indeed brought

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about unprecedented challenges to the education sector, with the sudden shift to online learning posing significant difficulties to both instructors and students.

Pre-service teachers have been heavily impacted as they navigate the complexities of remote teaching while also developing their mathematical knowledge and pedagogical skills [3]. Mathematics education has been particularly affected, as the online environment has created new barriers to student engagement, motivation and understanding [4]. Pre-service teachers' mathematical perceptions and motivation are crucial factors in determining their future success as qualified mathematics teachers. Pre-service teachers, who are crucial for the future of education, consequently faced significant challenges in their mathematics education, which encompassed limited practice, lack of group work and difficulty adapting to e-learning systems [5]. Research has shown that the pandemic has created new challenges that may impact pre-service teachers' motivation and ability to learn mathematics effectively [6].

The importance of this research cannot be overstated. Firstly, teacher quality and mathematical proficiency are critical factors in learner achievement. Understanding how the pandemic has affected pre-service teachers' mathematical development is essential for ensuring the effectiveness of future cadres of mathematics teachers [7]. Secondly, teachers' mathematical knowledge and motivation have a direct impact on learner achievement, making it crucial to investigate pre-service teachers' mathematical performance and motivation. Thirdly, the findings of this study will provide valuable insights for teacher preparation programs, enabling them to adapt their curricula and pedagogies to better support pre-service teachers' mathematical development in the post-pandemic era. Finally, this research study will contribute to the development of evidence-based policies and decisions related to teacher preparation, mathematics education and crisis management in education.

The COVID-19 pandemic's impact on pre-service teachers' mathematical performance and motivation has far-reaching implications for the future of education, economy and society. By addressing this issue, researchers can ensure high-quality mathematics education, inspire future innovators, and drive economic growth, ultimately benefiting society.

The findings of this study will contribute to the development of programmes aimed at supporting pre-service teachers' mathematical development in the post-pandemic era. By shedding light on the pandemic's effects on pre-service teachers' mathematical performance and motivation, this research will play a critical role in shaping the future of mathematics education and ensuring that teachers are equipped to provide high-quality instruction in the post-pandemic era.

This study's context is also influenced by the growing recognition of the importance of mathematics education in developing problem-solving skills, critical thinking, and creativity [3]. Mathematics education has been identified as a critical area of focus in many countries, with an emphasis on developing teachers' mathematical content knowledge and pedagogical skills [8]. The pandemic has disrupted traditional teacher education programmes, creating a need for research that explores innovative approaches to supporting pre-service teachers' mathematical development in online and blended learning environments.

2. Problem Statement

The COVID-19 pandemic has brought about a global health crisis, leading to widespread closures of educational institutions and a sudden shift to online learning [4]. This rapid transition to online learning indeed posed significant challenges to the education sector, particularly in the field of mathematics education [1]. Pre-service teachers, who are crucial to the future of mathematics education, have been heavily impacted by this shift [9]. The COVID-19 pandemic has forced pre-service teachers to learn mathematics online, resulting in difficulties that have led to low performance in mathematical concepts and a decline in motivation to learn mathematics. However, the pandemic's impact on these aspects remains largely unexplored [1]. By exploring the effects of the COVID-19 pandemic on pre-service teachers' mathematical performance and motivation, this study aimed to contribute to the development of effective strategies for supporting teacher preparation, learner learning and educational resilience in the face of crisis. Moreover, this research investigated the effects of the

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pandemic on pre-service teachers' mathematical performance and motivation, a crucial aspect of teacher preparation. This study sought to answer the following research questions: "*How did the COVID-19 pandemic affect pre-service teachers' mathematical performance?*" and "*What are pre-service teachers' experiences with emergency remote teaching that affect their confidence and self-efficacy in teaching mathematics?*"

3. Significance of the Study

This study contributes to the development of theoretical frameworks that explain the complex relationships between emergency remote teaching, mathematical performance and motivation, ultimately enhancing teacher education's understanding of how to support pre-service teachers' growth and development into mathematics teachers. By exploring the obstacles and difficulties encountered by pre-service teachers during the pandemic, this study will provide actionable recommendations for mathematics teacher preparation programs, schools, and policymakers, enabling them to provide targeted support and resources to pre-service teachers. Ultimately, the study's findings will have a positive impact on the quality of mathematics education, ensuring that pre-service teachers are prepared to provide high-quality instruction to their future learners, even in the face of unprecedented challenges.

4. Literature Review

Pre-service teachers, in particular, have been affected, as they navigate the challenges of remote teaching while developing their own mathematical knowledge and pedagogical skills [9]. Studies have investigated the impact of the pandemic on pre-service teachers' mathematical performance, with mixed results. Some research has found significant declines in mathematics performance [1], whilst Gupta, et al. [8] reports minimal effects on pre-service teachers' mathematics performance. The pandemic's impact on pre-service teachers' motivation to learn mathematics has also been explored, with findings suggesting a significant decrease in motivation and interest [9]. Pre-service teachers' motivation to learn mathematics is influenced by their beliefs about mathematics and their perceived ability to teach mathematics [10]. However, the pandemic has affected pre-service teachers' motivation, with many reporting decreased motivation to learn mathematics due to the lack of face-to-face instruction and support Yang [6]. Jin [11] found that pre-service teachers' experiences with online learning during the pandemic were mixed, with some reporting increased flexibility and others reporting decreased engagement.

Several studies have examined pre-service teachers' experiences with online learning during the COVID-19 pandemic, highlighting both positive and negative aspects. For instance, Ogbonnaya, et al. [12] found that while pre-service teachers in Ghana appreciated the flexibility of online learning, they also faced challenges such as poor internet connectivity and high data costs. Similarly, Pule and Ngoveni [13] reported that mathematics pre-service teachers at a rural South African university experienced decreased engagement due to limited access to data and poor network reception. These findings suggest that while online learning offers increased flexibility, it can also lead to decreased engagement among pre-service teachers.

The pandemic has highlighted the need for innovative and flexible support strategies for pre-service teachers, including online resources and peer support groups. Research has shown that these support strategies can improve pre-service teachers' subject matter knowledge and teaching abilities, as well as their motivation to learn mathematics [5]. To support pre-service teachers' mathematical learning and motivation, studies have recommended various strategies, such as online collaboration, virtual mentoring and adaptive technologies [1]. A study by Gupta, et al. [8] found that pre-service teachers who received support from peers and instructors reported increased motivation and decreased anxiety.

Despite the challenges posed by the pandemic, pre-service teachers have shown resilience and adaptability in their learning and teaching practices [8]. Research has highlighted the importance of acknowledging and building on pre-service teachers' strengths and experiences, rather than solely focusing on their shortcomings [10]. A study by Swars, et al. [14] found that pre-service teachers' views about mathematics and teaching can be positively influenced by mathematics methodology

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courses. Overall, the literature suggests that the pandemic has posed significant challenges to pre-service teachers' mathematical education and preparation.

4.1. Social Constructivism Theory

This study is underpinned by the social constructivist theory of learning as its theoretical foundation. A theoretical framework serves as a lens derived from established theories that guides every phase of the research process, from formulating research questions to interpreting data [15]. Constructivism is a main research paradigm in mathematics influenced by Jean Piaget, which claims that knowledge is built actively rather than found [16]. Social constructivism is a philosophical stance which accepts that both individual construction of meaning and social interaction plays a pivotal role in the learning of mathematics [17]. The essence of constructivism is social interaction among students rooted in culture and context that leads to higher levels of learning and reasoning [18].

Social constructivism in mathematics teacher education emphasises that mathematical knowledge is not passively received but actively constructed through social interaction and negotiation within a learning community. It views mathematics as a cultural and social artefact, shaped by the practices and experiences of mathematicians. To account for this social and participatory learning with a teacher or more informed peer, the concept of the zone of proximal development (ZPD) was developed by Vygotsky [18]. He described that as "the distance between the actual developmental level as determined through independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers" (p. 86). According to Figure 1, students can move from actual development to the ZPD through the assistance of knowledgeable others or technological tools. The knowledgeable others could be more capable peers or the teacher. Under constructivism, the ZPD keeps on expanding as students construct more knowledge, thus reducing the size of the knowledge currently unattainable.

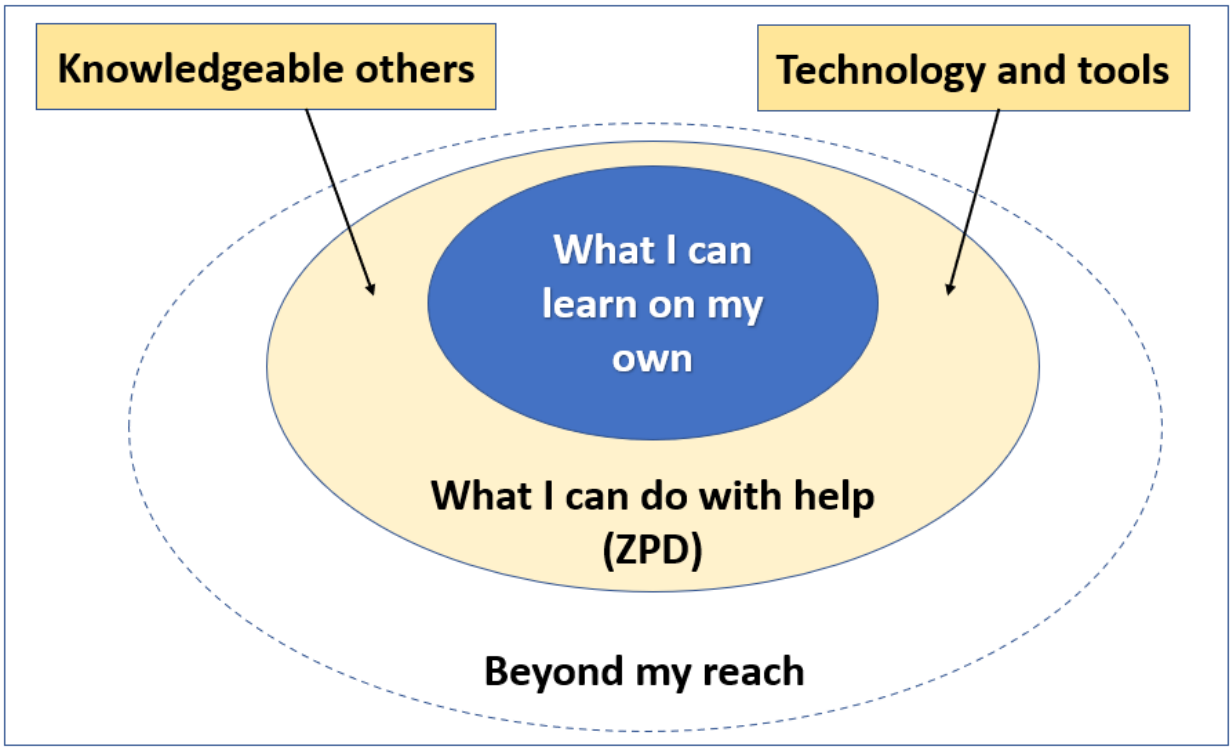

Figure 1.
Model of Vygotsky's zone of proximal development.

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For instance, Mathematics is not a fixed set of facts but a body of knowledge that emerges from human interaction and agreement. Students construct their understanding of mathematics through collaboration, discussion and shared problem-solving. The teachers' role shifts from imparting knowledge to facilitating a learning environment where students can actively engage with the material.

Mathematics teacher education programmes should emphasise preparing teachers to create learning environments that foster social interaction and collaborative problem-solving. Teacher educators need to help future teachers understand the underlying principles of social constructivism and how it informs their teaching practices. Technology can be used to support social interactions and collaborative learning where possible, allowing students to explore mathematical ideas in a shared online space.

5. Research Methodology

This study employed a qualitative methodology to explore the effects of the COVID-19 pandemic on pre-service teachers' mathematical perceptions and motivation. This study was conducted after the COVID-19 pandemic, which was a global health crisis that significantly impacted education systems worldwide. The study's context was rooted in the sudden shift to remote learning, which exacerbated existing challenges in mathematics education.

The sample of this study consisted of twenty pre-service teachers out of about 200 enrolled in an education degree programme in mathematics and science at a higher institution in South Africa. Participants were purposively recruited, and the inclusion criteria required them to be currently enrolled in a mathematics education course. The sample was diverse, with participants from various age groups, genders and ethnic backgrounds. Participants' anonymity was maintained using pseudonyms for ease of reference, which were P1, P2, and so on until P20. The ranking of the participants carried no significance [19]. By recruiting participants from a single institution, the study controlled variations in teacher education programmes, enabling a focused exploration of the pandemic's impact on pre-service teachers' mathematical perceptions and motivation.

Data collection employed an online questionnaire with both closed- and open-ended items. The items were piloted with a small group of pre-service teachers to ensure clarity and validity. The questionnaire consisted of items related to demographic information, mathematical content knowledge, pedagogical skills, motivation and experiences with online learning during the pandemic. The four open-ended questions were as follows:

- *Explain the challenges you experienced in learning mathematics.*
- *What motivates you to learn mathematics?*
- *In what way did online learning affect your learning of mathematics?*
- *How did COVID-19 affect your learning of mathematics?*

Qualitative data from questionnaires were coded manually, with emerging themes and subthemes identified through iterative analysis.

This study adhered to ethical guidelines, ensuring participants' rights and dignity were protected. All participants provided informed consent prior to participating in the study, having received a clear and comprehensive explanation of the research purpose, risks and benefits. The study's online platform ensured security, with data encrypted and password-protected. Participants were free to withdraw from the study at any time, without penalty or loss of benefits. The study ensured a safe and respectful research environment for all participants by prioritising ethical considerations.

5.1. Findings

The age distribution of the participants from the questionnaire is shown in Figure 2. Most participants were between the ages of 20 and 23 years, followed by the 23-27 years age group, and the youngest age group was 17-20 years. Though they were all doing a four-year degree in education, data showed that most were in the final years of their study at the time of the study. The participants in their fourth year of study were 17, while three were in their third year of study.

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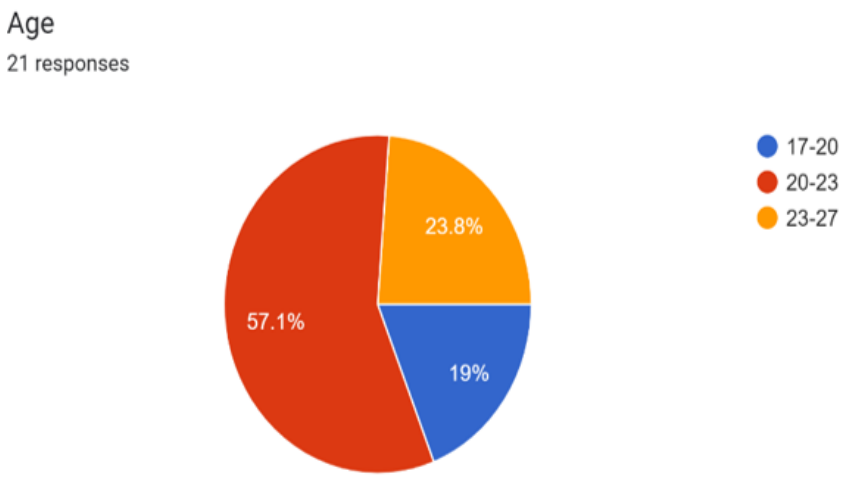

Figure 2.
The age of participants.

More males participated in the study, represented by eleven against nine females. This is typical of mathematics and science enrolments in South Africa, where females are fewer than males.

The summarised results of participants' perceptions and motivation to learning and teaching mathematics are shown in Table 1.

Table 1.
Summary of the participants' response ratings to the closed-ended questions.

	Frequency				
Criteria/rating	**1**	**2**	**3**	**4**	**5**
Frequency of practising mathematics?	1	2	4	9	4
Interest in learning mathematics?	0	1	1	6	12
Confidence in your ability to teach mathematics?	0	0	3	11	6
The pandemic has impacted your overall confidence in learning mathematics.	3	3	6	5	3
Importance of mathematics to your career?	0	0	0	3	17

Note on ratings: 1 – very poorly; 2 – poorly; 3 – neutral; 4 – highly; 5 – very highly.

Mathematics education students are expected to practice mathematics daily to succeed. Despite the COVID-19 pandemic, the participants still registered interest in practising mathematics even though it meant doing it independently. Over half of the participants rated at least highly on practising mathematics alone. However, the neutral rating stood at 25%, which may be a bit worrying. Moreover, the participants indicated a huge interest in learning mathematics, representing about 57% of the participants. Most participants showed interest in learning and practising mathematics despite the COVID-19 pandemic. The shift to online learning as a result of the pandemic did not take the love of mathematics from their hearts. In contrast, no one had a severe negative rating for the interest in learning mathematics. As the participants found doing mathematics interesting, thereby practising it a lot, their confidence to teach mathematics was not dampened by the pandemic. About 28% were confident that they were able to teach mathematics. The highest rating was 4, with 55%. There was 19% for rating 3, which represented the neutral group. The challenges that students encountered in learning mathematics in the COVID-19 era impacted their overall confidence in teaching mathematics. There was uncertainty in teaching mathematics because learning it posed many challenges.

Despite the COVID-19 pandemic, all participants found mathematics important to their future careers. About 85% of the participants were on a scale of 5, 15% were on a scale of 4, while there were no participants on a scale of 1, 2 or 3. The participants still regarded their mathematics career highly as they realised that with or without the pandemic, their mathematics career is a priority. At the time of

the study, it was not yet clear whether the pandemic was there to stay or not. Nevertheless, the changes to the mode of learning brought by the pandemic had some effect on the participants' motivation to learn mathematics. Thus, only 10% of the participants were on the scale rating of 5, which was the lowest. Six participants apiece rated highly and very poorly. The participants who rated learning mathematics during COVID-19 at least poorly were close to fifty percent.

On the challenges that the participants encountered in learning mathematics online, Figure 3 illustrates that an equal number experienced and did not experience challenges. This means there is a fifty percent chance of encountering problems in learning mathematics online.

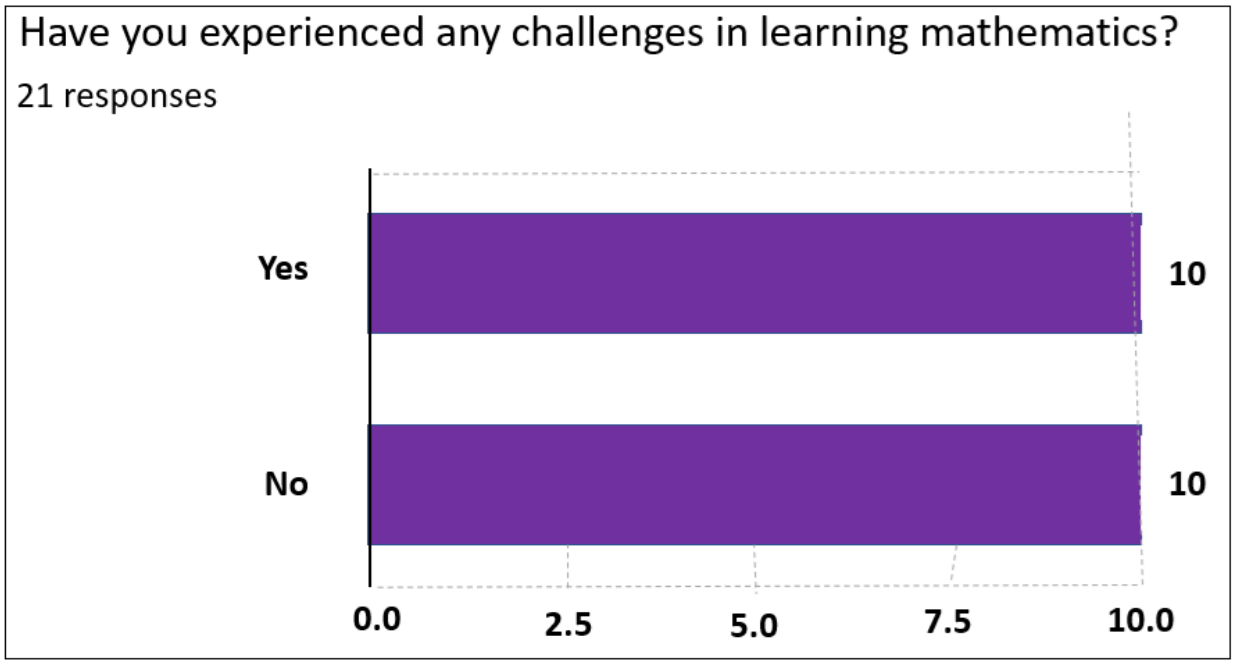

Figure 3.
Challenges to learning mathematics online.

Access to resources and support to learn mathematics negatively affects students' efforts to learn during the COVID-19 pandemic. Many students were attending classes remotely and sometimes they had to deal with connectivity issues. The issues were mainly the availability of data and the strength of the network signals in some remote locations of South Africa. Figure 4 depicts the students' responses to challenges in accessing resources and support.

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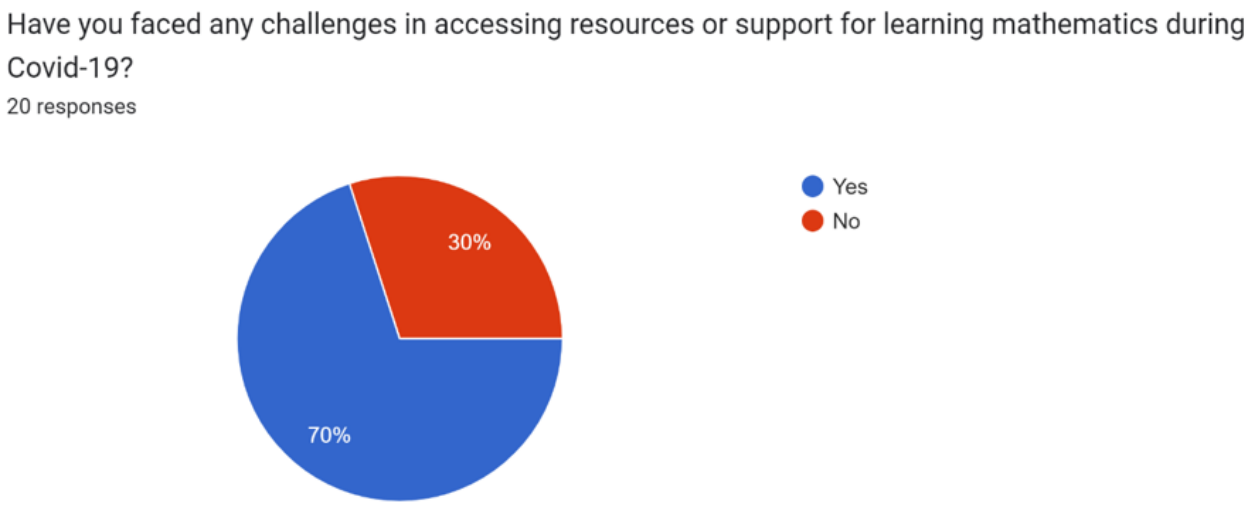

Figure 4.
Challenges in accessing resources.

Most of the participants faced challenges in accessing resources or support for learning mathematics during the COVID-19 pandemic, which was 70%, while 30% of the participants did not face any challenges. Though the participants' challenges were diverse, students require resources, more tutors or mentoring and recorded videos of lectures, which they could not get due to the nature of teaching and learning after the pandemic. Print material was the least of the students' concerns in the post-COVID-19 era, as shown in Figure 5.

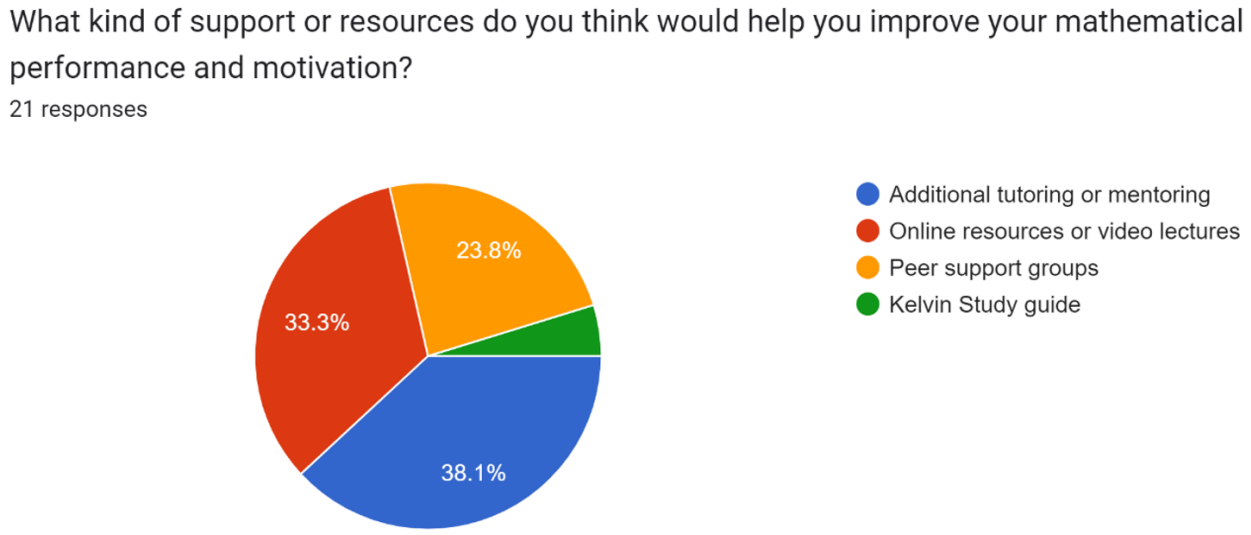

Figure 5.
Types of support or resources.

The majority of the participants preferred additional tutoring and mentoring when asked about the kind of support or resources they think would help them improve their mathematical performance and motivation. These are the auspices of the social constructivist theory, which was not fully supported by the online learning platforms used. The online tools were best suited for remote self-study.

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5.2. Open-Ended Responses

The open-ended items in the questionnaire corroborated and clarified some of the issues raised by the participants in the closed-ended ones. The perceptions of participants on the four items are explained below.

In response to challenges experienced in learning mathematics, the respondents' responses were varied. P1 and P2 indicated that they encountered content challenges in topics like probability and financial mathematics, respectively, as a result of online learning. Some of the challenges in understanding some topics may be attributed to a lack of practice, as was confirmed by P3. He said, "*I didn't have enough time to practice, only practised a day before the test*". To those students who committed themselves to sufficient practice, some could not get prompt feedback from peers and lecturers. P4 stated that, "*When learning mathematics online, you may not receive immediate response or feedback when you're stuck on a problem*". According to the constructivist theory, students construct knowledge jointly with peers and the knowledgeable facilitator. However, this was predominantly absent in remote online learning.

Rather than make learning collaborative, many lecturers resorted to direct instruction so that they could cover more content in a short space of time. P5 said, "*I would say I felt a huge challenge during my 3rd year, which was last year (2023). There was honestly a lot to cover in a short space of time, and also an inconvenience from the type of content we were given, yes, I wouldn't want to delve much on that, but it made me freak*". P16 added that, *"Wasn't motivated enough to learn the subject because learning online felt like listening to a pastor preach in church"*. Some students had initialisation problems to online learning but in no time they had adapted. P7 and P11 managed to adapt as shown: "*Yes, I did adapt even though am still struggling in some cases"*, *"I adapted to online learning during the pandemic although I did most of the learning on my own than when I would be in class with the lecturer and other students"*. The adaptation came at a price because P17 mentioned that focussing on the computer screen for a long time was not easy. As a result, some, like P4 and P9, said, "*I encountered issues in terms of adapting to the e-learning system*", "*I was used to doing mathematics manually, I was struggling to adapt to using technology*", respectively. Moreover, in response to a question on how COVID-19 affected their learning, P9 further said, "*I was not used to technology, so it was a bit difficult for me*".

Regardless of the adaptation challenges experienced by the participants, their zeal and competence in mathematics were not drastically affected by the change in the mode of learning. P6 said, "*My experience of learning mathematics was quite challenging, but I ended up consolidating all that and started to enjoy maths as usual!*". Some participants were already motivated to learn mathematics prior to coming for higher education, so that the COVID-19 pandemic could not take that away. These students continued holding on to mathematics learning with passion despite adverse online learning experiences. Some were motivated by the applicability of mathematics to day-to-day life (P1), by their secondary school teachers (P3, P12) and primary school teachers (P9). To others, mathematics is regarded as a tool for problem-solving and critical thinking (P2, P10, P6, P7, P11, P13, P14, P15). To P10, learning mathematics is encompassing: "*Learning mathematics can help me solve problems and think critically in all areas of life. Understanding mathematics concepts can also boost my confidence and help me make informed decisions. By learning mathematics, I can gain a powerful tool to succeed in my future career and make a positive impact on my country*". Solving problems and logical reasoning were the motivating factors for P11: "*The challenge of solving complex problems and the satisfaction that comes with finding solutions provide a continuous source of motivation. Additionally, the logical and critical thinking skills developed through mathematics are invaluable, not just academically, but in everyday life*".

Being student teachers with only a year or two before they commenced their careers in the classrooms, the majority of the participants' motivation to learn mathematics was career-related. Learning mathematics, despite the advent of the COVID-19 pandemic, did not distract pre-service teachers from achieving the goal of becoming teachers. P18 said, "*I am studying to become a maths teacher*". P16 was already inclined to the teaching of mathematics because he commented, "*being good at explaining*

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it [mathematics]". Considering the above-mentioned predispositions towards mathematics in the participants, the thing standing in the way of pre-service teachers from enjoying learning mathematics and teaching it was the mode of delivery. P1 was quick to say that online learning limited his ways of learning mathematics. The teaching styles mentioned earlier, whereby lecturers resort to direct instruction, partly contributed to the limitations of learning mathematics. Consequently, some participants like P2 commented that: "*I wasn't practising, then ended up losing the knowledge*". P10 further said, "*The Covid-19 pandemic made it hard for me to learn mathematics because I couldn't practice math problems every day, so my skills got a little weak. I also couldn't work with friends on a mathematics assignment, practising together, which made it harder to understand how to use mathematics in real life*". P10 brought up an important issue about the lack of group work or cooperative learning amongst the students. P6 corroborated and further said that she could not interact with her friends. P3 summed by saying, "*[COVID-19] affected by restricting groups of people in the same environment, which resulted in less group work, and this was effective when solving some problems*".

To try to mitigate the sudden limitations on gatherings like contact meetings amongst students themselves or with the lecturer, some participants resorted to the use of online tools instead. This was the strategy mentioned by P9 when he said, "*Yes! One way we used was through social media, e.g., WhatsApp groups and through YouTube videos*". In here, WhatsApp groups were used in lieu of physical groups in much the same way. P10 supported the use of YouTube videos as a learning tool for more explanations on the mathematical knowledge taught, in addition to normal classes. This meant learning by themselves outside of the virtual classes. P18 captured it well by saying, "*I was able to learn on my own, challenge myself more using YouTube videos, which was good*". This was confirmed by P14, who indicated that technology tools were highly encouraged during the times of virtual learning.

The fear of death due to the COVID-19 disease was cited as one of the reasons why the learning of mathematics was constrained. P7 said, "*We learned mathematics online, which is not nice, and I thought I was going to die since people were dying at that time*". The lockdowns were in place to distance people socially and physically, but that did not stop people from dying from the pandemic. Learning under the lockdown exerted pressure on both the lecturers and students. That is the reason primary and secondary schools shut their doors completely. Nevertheless, higher education went ahead with learning during lockdowns on the pretext that they were dealing with adult learners who could manage online learning. That created a difficult situation to which P5 commented, "*We were under lockdown, and when we came back from the lockdown, we were learning under pressure and a lot of information was missed*". The gaps in knowledge created further problems, as alluded to by P8. She said, "*COVID-19 affected my learning of mathematics by lacking the information in some topics because we skipped them, just like term 2*". On the contrary, P12 still had no difficulties learning mathematics during that time. He said, "*But I had a very passionate teacher who nurtured our minds and instilled a new love of mathematics, that way I learnt to push while enjoying learning mathematics even during those fearful, challenging and very dark times of COVID-19*".

6. Discussion of the Data

The participants for this study were a cohort of relatively young and advanced students in their academic progression, aligning with the typical profile of pre-service teachers in South Africa. While the majority of participants engaged regularly with mathematical problems, half reported facing challenges in learning mathematics. This situation reflects the complexity of mathematics education, where engagement does not always correlate with ease of learning [20]. The participants had high levels of interest and perceived the importance of mathematics, with 60% and 81% of participants rating these aspects at the highest scale, respectively. Despite this, confidence in teaching mathematics was more variable, with only 28.6% rating their confidence as 5. This suggests that while participants valued mathematics and were interested in it, their confidence in teaching remained a concern, a trend supported by previous research on teacher efficacy [21].

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Access to resources like a steady internet connection and appropriate digital devices is limited due to the remoteness and impoverishment of the communities where the pre-service teachers originate from is a challenge for online learning. At a later stage, institutions opened to affected students to go to campus residences and attend classes from there. The findings revealed that many participants experienced challenges accessing resources during the pandemic, underscoring the disruption caused by COVID-19 [22]. This aligns with studies indicating that the pandemic has exacerbated educational challenges and reduced motivation [3].

The findings also revealed a strong preference for additional tutoring and mentoring (38.1%) and online resources (33.3%) as necessary support mechanisms. This preference demonstrates the need for diverse and flexible support strategies to address the varied needs of pre-service teachers [23]. The Support resources, such as tutoring and mentoring and peer support groups, are essential to improving mathematical performance and motivation. These findings reflect both the resilience and the struggles of pre-service teachers during the pandemic, emphasising the need for targeted support and resources to enhance their mathematical performance and motivation.

The pre-service teachers experienced various challenges in learning mathematics in some topics, like probability, and online learning as a mode of learning. Some participants struggled with the lack of immediate feedback and support when learning mathematics online, while others found it challenging to stay focused during online classes. Additionally, some participants experienced challenges due to the fast-tracked nature of the curriculum and the inconvenience of the content gaps. Despite these challenges, the pre-service teachers were motivated to learn mathematics for various reasons, including its importance in daily life, problem-solving skills, teaching careers and creative thinking. Some participants were motivated by their high school teachers, while others enjoyed solving problems and looking for challenges. In terms of adapting to online learning, most participants were able to adapt and even found it helpful in some cases. They used various strategies such as social media, YouTube videos and WhatsApp groups to support their learning.

The COVID-19 pandemic affected the pre-service teachers' learning of mathematics in various ways, including limited practice, lack of group work and difficulty adapting to e-learning systems. However, the participants' motivation and ability to adapt helped them overcome these challenges. Overall, this study highlights the importance of motivation, adaptation and support in helping pre-service teachers learn mathematics effectively, even in challenging circumstances such as the COVID-19 pandemic.

7. Conclusion and Implications

This study has provided valuable insights into the impact of the COVID-19 pandemic on pre-service teachers' mathematical perceptions, experiences and motivation. The findings reveal significant declines in mathematical understanding, increased anxiety, and decreased confidence, highlighting the need for targeted support and interventions. Pre-service teacher education programs should prioritise the development of pre-service teachers' mathematical content knowledge and pedagogical skills, particularly in the context of online learning [5]. This can be achieved through the integration of technology-enhanced instruction and collaborative learning activities that foster pre-service teachers' motivation and engagement. A study Zelkowski, et al. [24] disclosed that students learn mathematics better when appropriate digital technological tools are used. Despite the study's limitations, including its reliance on self-reported data, limited sample size, and geographical scope, the results underscore the pandemic's profound effects on pre-service teachers' mathematical development. The limitations of this study highlight opportunities for future research, including longitudinal designs, comparative analyses, and intervention studies. Future research should investigate the long-term effects of the pandemic, explore diverse populations, and examine the effectiveness of support programs. Additionally, studies should investigate the impact of the pandemic on teacher education programs, technology integration, and the development of theoretical frameworks to understand the complex relationships between mathematical performance, motivation, and students' well-being.

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Policymakers should provide adequate support and resources for pre-service teachers, including access to online learning platforms, mentorship programmes, and professional development opportunities [8]. This can help mitigate the challenges posed by the pandemic and ensure that pre-service teachers are well-prepared to teach mathematics in their future careers. By acknowledging the pandemic's effects, researchers can inform initiatives that support pre-service teachers in navigating the complexities of teaching and learning in a post-pandemic world. Ultimately, this study contributes to a deeper understanding of the pandemic's legacy on mathematics education, highlighting the importance of prioritising pre-service teachers' mathematical development, emotional well-being, and pedagogical preparedness to ensure high-quality mathematics education for future generations.

Transparency:

The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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