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Perceived Effectiveness of Online Learning for Mathematics Pre-Service Teachers in a Rural University During the Covid-19 Pandemic

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Abstract

In this article, we delve into the engagements of second-year mathematics pre-service teachers at a rural university who had to adapt to online learning due to the COVID-19 pandemic. Through purposeful sampling and a questionnaire, we gathered quantitative data on how students coped with online learning engagements during that challenging time. Unfortunately, educational institutions in socio-economically challenged communities that lack resources contribute to education disparities. The pandemic has had an even greater impact on vulnerable populations residing in rural areas due to their limited access to online learning. The Universal Design for Learning (UDL) framework was adopted as a lens to guide this study. UDL emphasises inclusivity in diverse rural demographics in South Africa through multiple means of engagement, action, and expression. To mitigate the learning disruptions, several online platforms such as radio, television, social media, Blackboard, Moodle, Zoom, and Skype were used. However, rural universities faced challenges when transitioning to online mathematics learning. The null hypotheses were rejected, suggesting that there is an effect of online learning engagements on mathematics pre-service teachers' overall level of challenges and expectations of the second-year mathematics education module during the pandemic in a rural university. Findings range from less access to data and poor network reception in most areas, lack of engagement among students, and untimely as well as inadequate feedback with less support from lecturers. We recommend that policymakers should prioritise providing equal access to online education to empower underprivileged students, especially female students, and marginalised communities. As lecturers continue to adapt and fine-tune their approach, the future offers promising opportunities for an effective and efficient online mathematics teaching experience to enhance better online learning engagements. Furthermore, we advocate for policies that foster inclusivity, enhance learning outcomes, and empower teachers in the Fourth Industrial Revolution (4IR) era.

Keywords: *Engagements; Online Learning; COVID-19 Pandemic; Inclusivity*

Introduction

This quantitative article highlights second-year mathematics pre-service teachers' (MPSTs) online learning engagements during the COVID-19 pandemic in a rural university campus. Education is critical in improving the future of deprived students (Corbett & Fikkert, 2009). Still, the under-resourced institutions in socio-economically challenged communities contribute to, rather than address, the problem (Engelbrecht et al., 2016) as the curriculum is not contextualised to the demographics. Despite technological and other forms of student support in South Africa and globally, the dichotomy between access and success seems to be resurfacing during COVID-19, even today.

Due to the need for social distancing to prevent the spread of the virus, schools and higher education institutions around the world have been forced to shut down and adopt precautionary measures. (Demuyakor, 2020). The most vulnerable populations, especially in rural areas, have again been the worst affected since they do not have the financial resources to enable online learning, as do their more privileged counterparts. The COVID-19 pandemic brought about a sudden and significant shift in the way education is delivered and received globally, as noted by Tam and El-Azar (2020), ushering in a transformative digital age.

During the lockdown, a diverse range of online platforms facilitated continuous learning. Lessons were delivered through various channels such as radio and television, social media platforms, Blackboard, Moodle, and other learning management systems. Additionally, Zoom, Microsoft Teams and Skype, among other alternatives, played crucial roles in swiftly adapting to the abrupt shift to online education and effectively absorbing the challenges that came with it. Face-to-face educational institutions had to design ways of making sense and logical solutions that were not ruined by the pandemic challenges (Kincheloe, 2005) for teaching and learning to continue.

However, multiple innovations created fit the purpose (Rapport & Overing, 2014) of blended learning available in digital resources. In a study by Händel et al. (2020), it was found that the predominant difficulties in online education are the shift from conventional face-to-face teaching, the speed of adjustment, availability of technology, user aptitude, and funding for online education. Mukute et al. (2020) have also noted that at the onset of the COVID-19 pandemic, worries emerged regarding students' capacity to acclimate to digital learning. Although online learning may not be suitable for everyone, it can be a beneficial and satisfying choice for numerous students who aspire to achieve their educational objectives.

Before the pandemic, online education was not widely utilised in rural institutions. As stated by Nkoane (2010, p. 113–114), "I am opposed to any classroom practices that undermine the rights of rural learners". Du Plessis and Mestry (2019) argue that in order to improve student achievement and promote the development of human capital in rural areas, strategies must be put in place to improve working conditions and teaching at rural institutions. Furthermore, Shibeshi (2006) emphasizes the importance of implementing solutions that are tailored to the diverse needs of rural populations in the context of COVID-19 and distance learning. Although there have been changes in other institutions elsewhere, the shift to online mathematics learning has faced serious challenges for students in rural universities.

According to Dieltiens (2008), rural institutions face unique challenges that require creative solutions and systemic efforts. In less favourable policy environments, rural areas encounter significant barriers to low student achievement. Some of these obstacles include limited access to devices, poor network connectivity, and power outages. Providing quality education services in rural areas is more difficult for governments and various factors weaken the quality of learning and teaching in South Africa's rural regions (Du Plessis & Mestry, 2019). This is consistent with the findings of the Parliamentary Monitoring Group (2015), which notes that rural education has played a significant role in South Africa's history.

Furthermore, the introduction of online learning and resources questions the efficacy of current mathematics teaching practices and traditional classrooms (Gueudet & Pepin, 2020). MPSTs are exposed to the more significant digital divide between their achievement and opportunity within a digital classroom in various universities. Mathematics education lecturers (MEL) had to support MPSTs' needs and how to apply instructional design through responsive teaching best to assist student-centred engagements. In today's rapidly evolving educational landscape, focusing on tech equity in online and in-person instruction and engagements strengthens 21st-century skills.

Literature Review

COVID-19 induced challenges in education had a comparable pattern globally (Mandikiana, 2020; Matimaire, 2020). Lockdown and shutting down of institutions were broadly used as strategies to prevent the spread of the fatal disease. Mandikiana (2020) details that former pandemics had evidenced that closing institutions inhibited the diffusion of pandemics. This could have prompted worldwide decisions on lockdowns, the use of personal protective equipment, social distancing, and quarantining alleged cases.

The advent of the online platform has revolutionized the landscape of teaching and learning, leading to a combination of face-to-face and online teaching, and in some cases, entirely virtual instruction (Trenholm & Peschke, 2020). The widespread availability of rapid internet access has significantly influenced the dynamic interactions between students and lecturers (Engelbrecht et al., 2020). Technological advancements over the past decade have blurred the lines between traditional classrooms and remote learning environments, challenging the clear distinction between leisure time and study periods (Borba et al., 2017). As education continues to evolve, the integration of digital tools and virtual spaces becomes increasingly essential for both teachers and learners.

While significant progress has been made in advancing pedagogy for distance e-learning and m-learning, the development of a dedicated pedagogy for guiding online mathematics modules engagements is still ongoing, with many institutions in the process of revising or creating new modules to replace outdated ones. As part of this transition, mathematics textbooks now offer online resources (Hass et al., 2019), and learning management systems like Canvas (http://canvas.net/) and Blackboard (https://www.blackboard.com/) are actively utilised to facilitate content delivery, teaching, learning, and assignment submissions within the university under study. As lecturers continue to adapt and refine their approaches, the future holds promising possibilities for an enriching and effective online mathematics education experience.

The availability of online mathematics learning resources has challenged the traditional belief that knowledge flows solely from teachers to students. New teaching methods like the flipped classroom have redefined the roles of teachers and learners (Borba et al., 2017). However, designing and developing effective online mathematics resources is crucial for promoting meaningful learning. A question that remains relevant today is whether the essence of mathematics is conveyed in online classes, particularly in rural regions (Engelbrecht & Harding, 2005). This has been a topic of debate among mathematics teachers (Engelbrecht & Harding, 2005, p. 255).

In this repute, Hoppers (2001) probed the effect of the online atmosphere on fostering a milieu for students compared to the use of face-to-face teaching at university. Hoppers further posits that in teacher-centred classrooms, there is an acknowledgement and connection of physical presence, mutual responsiveness and engagement, and the student who simply listens courteously may encounter a highly warm and fulfilling learning and social environment. Some experiences of face-to-face teaching are not presented in online engagements. However, this should not deter lecturers from making prospects for students to foster their interactive comprehension of mathematics.

In online synchronising, lecturers have to think cautiously about how they can offer synchronous and student engagements and strategize how students could interrelate with the content, peers and lecturers (Engelbrecht & Harding, 2005). Teaching flows faster using current technologies (e.g., voice-overs on slides, videos recorded lessons, etc.) and assessment methods (automated marking, turn-it-in, etc.). It is now possible to include symbolic, graphical, and interactive content in mathematics modules that are available online, as per Voskoglou (2019). Mathematical representations and animated figures could assist students in better understanding mathematical concepts and solving mathematics problems using digital technologies.

Digital technologies like the Photo Math app, WolframAlpha, Desmos, and Cramster offer valuable support in presenting mathematical concepts, symbols, and solution processes to enhance student engagement in online teaching and learning. Extensive research has explored the advantages and challenges of both face-to-face and online teaching methods (Basilaia et al., 2020; Trenholm & Peschke, 2020). Among the benefits of online teaching, the convenience of accessing materials from any location at any time stands out, fostering active student engagement and prioritising individualised learning needs (Tareen & Haand, 2020). With the ubiquity of network coverage, students can readily immerse themselves in the virtual classroom environment, opening up new opportunities for education and knowledge-sharing.

In contrast, Trenholm and Peschke (2020) documented that fully online mathematics modules are not fascinating to most undergraduate mathematics students. The challenges encompass the need for specific equipment, such as a computer, webcam, stable internet connection, and, in some cases, a touchable screen or tablet with a digital pen for collaborative work sharing (Engelbrecht & Harding, 2005). Additionally, online teaching demands a level of high-tech knowledge (Trenholm & Peschke, 2020) and lacks the benefits of face-to-face interaction (Jones, 2015) along with the occasional concern about power supply reliability. According to Tareen and Haand (2020), the assessment approach lacks clarity and precise feedback, and students receive minimal support from their lecturers, leading to a general lack of interest in learning. Moreover, the power outages in our country further exacerbate these challenges, particularly in rural areas where network connectivity is severely impacted. Geng et al. (2019) maintain that not distinguishing the social disposition of students' engagement in learning and repeating the traditional instructive methods when employing technology are among the key issues in designing web-based modules.

Some of the tools used in online education to enhance student engagement are the opportunity to create discussion forums, Chats, WhatsApp groups, and tweets to create a video on YouTube etc, within online platforms. Of course, students engage with brands they do not mind being associated with and like. Those are brands they understand, value, relate to, and trust. It's essential for students to actively participate in discussion forums because this allows them to gain exposure to different perspectives on mathematical concepts from their peers. This exposure can be beneficial in helping them develop a conceptual understanding of mathematics (Petty & Farinde, 2013).

The shift to online mathematics teaching and learning during the COVID-19 pandemic has led to a notable decline in student engagement, motivation, and interpersonal interactions. Lack of enthusiastic peer engagement has been linked to students achieving only a shallow understanding of mathematics (Petty & Farinde, 2013). However, some lecturers have found success with direct instructional approaches in online tutorials, providing clear explanations and step-by-step problem-solving examples, helping students overcome various challenges encountered in remote learning, such as difficulty rewinding video recordings and limited interaction with peers on online platforms (Lane & Ríordáin, 2020).

Although our approach may not be universally applicable to all online classrooms, focusing on this rural university is crucial for enhancing online teaching and learning experiences. Thus, researching the online learning engagements of second-year mathematics MPSTs during the COVID-19 pandemic in this specific setting is highly relevant. Despite existing literature debating remote learning across various educational levels and stages of the pandemic (Radmehr & Goodchild, 2022; Sims & Baker, 2021; Trenholm & Peschke, 2020), there is a significant gap in understanding the challenges faced by MPSTs during COVID-19, the prevalent learning platforms used during this period, and the overall impact of online learning engagements on these students in rural universities, particularly in developing countries. Exploring these areas can offer valuable insights to optimise online mathematics education and address the unique needs and obstacles encountered by students in this specific context.

Theoretical Framework

This study adopted the Universal Design for Learning (UDL) framework under the principles of multiple means of engagement, action, and expression for its divergence in terms of technological deployment for online learning and inclusivity for learners in diverse rural demographics. These two principles simply highlight the 'why' and 'how' of learning. The emergent closure of schools and institutions of higher learning left little time to prepare educational lecturers for online learning during COVID-19. Online learning through UDL can help MPSTs by providing options for self-regulation, expression and communication without watering down learning outcomes (Center for Applied Special Technology [CAST], 2018). The diverse demographics were not taken into consideration by authorities for the continuation of learning through the online venture. Nonetheless, UDL provides a framework that can enhance unforeseen uncertainties to MPSTs on the online platforms in rural institutions though it is not one size fits all. Amid the pandemic, this framework allows for better teaching and learning by providing unique techniques that give MPSTs the necessary guidance to optimize engagement, action, and expression through technology. With this framework, MPSTs can improve their skills and strategies to cope with the medium of instruction and self-regulate accordingly. These particular UDL approaches offer diverse avenues for MPSTs to participate with mathematics module content, their peers, and the lecturer. By building various engagement opportunities, MPSTs were assisted to see the relevance of mathematics knowledge in their academic strategies and personal coping skills. The framework can enhance the MPSTs to optimise access to tools and assistive technologies with the facilitation of information management and online engagement resources for mathematics learning.

Methodology

Quantitative descriptive design primarily uses purposeful sampling and a variety of purposive sampling has been described (Palinkas et al., 2015). Purposeful sampling is widely used in qualitative and quantitative research to identify and select information-rich instances for the most valuable use of restricted resources. This involves identifying and selecting individuals or groups (MPSTs in this study) familiar with or experienced with a phenomenon of concern (Cresswell & Plano Clark, 2011). This phenomenon of interest involves comparing to identify similarities and differences in the current study. The data was accumulated by a questionnaire instrument designed in line with the five-point Likert scale (McMillan & Schumacher, 2014) and bibliographic data to highlight the student populace in this rural university campus. A constructed set of questionnaires' face and content validity was essential in determining its reliability and applicability (Daud, et al., 2021). Each completed questionnaire went through this validity process to strengthen the questionnaire. The need to execute this validity is to meet the requirements of the study's objectives and the integrity of an item constructed. However, the scope of the questionnaire was broadened to include suggestions from second-year MPSTs (141) who participated in this study. The nominal data, questionnaire, and students' suggestions aimed to gain valuable insights into the praxis of online learning engagements of second-year mathematics pre-service teachers during the COVID-19 pandemic in a rural university campus.

The researchers have undertaken the required processes to obtain ethics approval through the General/Human Research Ethics Committee of this university. We provided information to the respondents about their voluntary involvement, confidentiality, anonymity, and to prevention of harm. We have taken all measures under the South African POPI Act suitable for this project. An online survey was designed and accessed by MPSTs to conduct an analysis with carefully crafted questions targeting different dimensions of their online engagements.

The research questions are based on the online survey consisting of two main themes:

1. Reflection on how MPSTs engaged during the online learning experience.
2. Reflection of MPSTs on the overall level of challenge and expectations of the second-year online mathematics education module.

Hypothesis

The researchers used two null hypotheses at a *p*-value of 0.05 (5%), a limit level of significance (Di Leo & Sardanelli, 2020). In general, the smaller the calculated *p*-value, the further we *consider* the null hypothesis improbable; subsequently, the smaller the *p*-value, the more we think the alternative hypothesis is probable, *i.e.*, the groups are certainly distinct (Sardanelli & Di Leo, 2009)**.** The *p*-value advance to inferential statistics for sufficiently powered studies relates to a significant false finding rate when 0.05 or 5% is employed as the impact threshold (Krueger & Heck, 2017). The effect size-only approach wanes in terms of false discovery rate for low-power studies or when the effect size is relatively small. A procedure that combines *p* values with the effect size can affect investigative but non-definitive facts. The null interval should limit all reasonably same points and the particular null hypothesis. An interlude null hypothesis for an odds ratio (OR) may be H_0 0.95 ≤ OR ≤ 0.05 as a substitute for H_0 OR = 1, as normally done in clinical research. It purely suggests rejecting the null hypothesis that two effects are matching is not valuable since they could even be nearly alike for all feasible purposes.

Ho 1: There is no significant effect of online learning experiences on the MPSTs during the pandemic in a rural university.

Ho 2: There is no significant effect on MPSTs' overall level of challenges and expectations of the second-year online mathematics education module during the pandemic in a rural university.

Results and Discussions

Introduction and Disclaimer

As we analyze the data, it's important to keep in mind that our judgments are based on the perceptions of individuals, specifically the MPSTs who participated in the survey. It's worth noting that students who choose to respond to surveys may not necessarily represent the entire population. Additionally, the survey was only given to a specific group of people - MPSTs - so we should be cautious about applying the results to a wider audience without thoroughly considering any potential differences between MPSTs and other groups.

It is important to note that the data analysed in this study is inherently random, meaning that if the survey were to be repeated, the results would differ. Although we attempted to estimate the extent of this variation, our estimates themselves are uncertain. While the R computer software used in the analysis is reliable, it is important to acknowledge that there are multiple human elements involved in the research process, including the researchers and statistician, which may introduce human error at various stages. Additionally, we have provided links to colloquial sources to aid in understanding statistical concepts, but these should not be used as academic references. Should the reader require academic references for specific topics, we have included links to appropriate sources.

A good survey tells you only about people like the MPSTs who answered the survey. The most basic form of statistics is a simple tabulation of responses into frequencies and relative frequencies. Should one wish to compare two nominal variables to each other and test for independence, then one might do a χ^2 (Chi-Square) test. The t-test is all about averages, the most popular statistical test for lots of reasons: People like to think in averages and ask whether things are the same on average. It is easy to do and fairly reliable.

Frequencies of Responses

We experimented and saw something that looked interesting. No experiment is perfect, there are always errors and uncertainties. So, we ask the question, “How interesting is this thing?” We created summary tables for each nominal question and each scale question as if it were purely categorical.

Table 1. Gender

Response	Frequency	Relative frequency	Percentage
Female	97	0.69	69
Male	43	0.30	30
Not answered	1	0.01	1

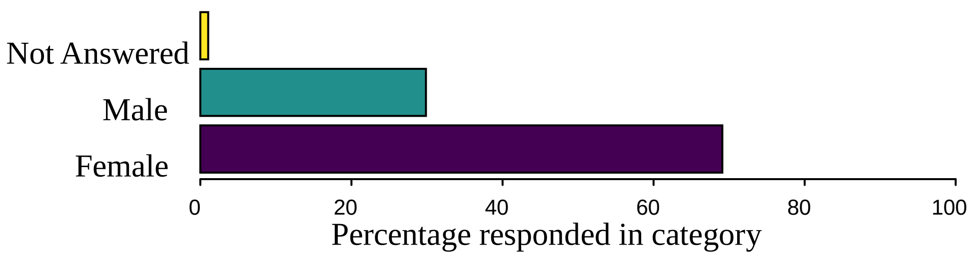

Figure 1: Percentage responses on gender

A total of 213 MPSTs gained access to the survey link. 141 MPSTs consented to participate while 72 declined participation. The sample of 141 participants (n = 141) is representative of the MPST population in terms of gender and race. According to the gender profile, 97 are females, 43 are males and did not indicate gender. Most of the MPSTs participating in the survey were females at 69%, which allows them to articulate the concerns of digital equity and access especially in the rural university campus from broader engagements in tech due to economic, historical, and social challenges. The skill development is required to advance the digital engagements of this cohort to ensure that these female MPSTs have a fair share of opportunities to succeed in teaching mathematics despite being in a rural university.

Table 2. Race

Response	Frequency	Relative frequency	Percentage
African	131	0.93	93
Coloured	2	0.01	1
Not answered	8	0.06	6

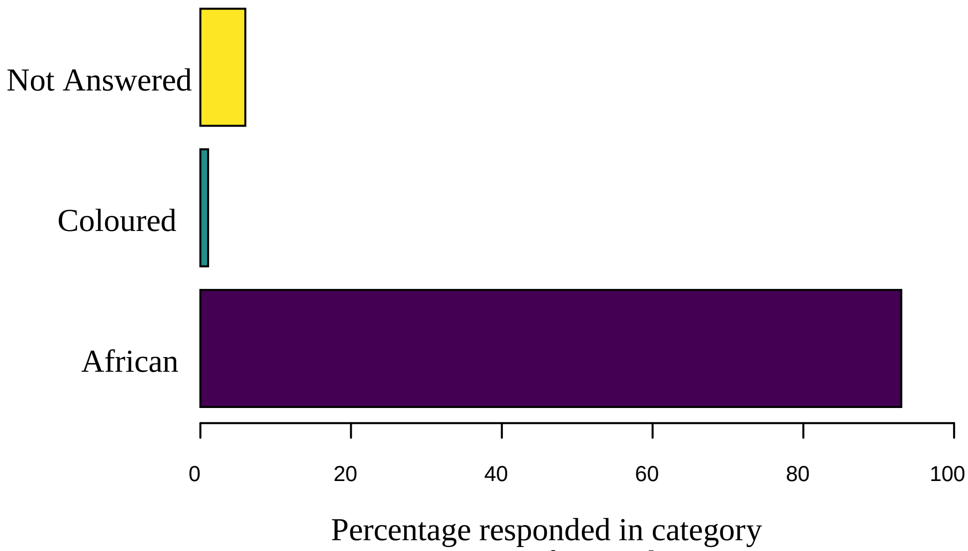

Figure 2. Percentage of respondents on race

The sample representative of the MPST population in terms of race profile is n = 141. We had 131 classified as African, two (2) classified as coloured and 8 classified as other there was no response (refer to Figure 2). There are more African students in this cohort which suggests that the university under the study is predominantly black students at 93 % of the sample.

Numeric Summary

An approach to numeric outcomes is more enlightening than an approach to effect signs (negative, positive or unknown) which is further informative than the approach of simple significance (non-zero or unknown). All statistical packages (including Excel, R, SAS, Statistica, SPSS, etc.) prefer data to be arranged on a single sheet with unique short headings in Row 1 ONLY and data arranged in rows from Row 2 down. There should be nothing else on the sheet. If the same type of measurement is done on multiple groups, then all those measurements should be in one column with a separate column indicating the group to which the measurement belongs. Create a second sheet with a table of the unique short names in one column and full descriptions in a second column. Other columns can include groupings, medium-length names, units, transformations, notes, etc. Each scale is mapped to numbers and multiplied by the direction, according to the scoring sheet.

We summarise the numeric responses in two stages, first using quantiles (based on sorting in ascending order). We take note of several aspects, including the number of responses, the minimum value, the first quartile, the median, the third quartile, and the maximum value.

Table 3. Theme: 1. Reflection on how MPSTs engaged during the online learning experience

Ques	Response	Min	Q1	Median	Q3	Max	Description
5.1	141	1	4.00	4	5	5	I used the opportunities provided to participate actively in this module using various tech resources.
5.2	141	1	4.00	5	5	5	I accessed Blackboard, announcements, emails, study materials, assignments, tests, and projects.
5.3	140	1	3.00	5	5	5	I actively engaged with my lecturer and tutors/facilitators' extra resources.
5.4	138	1	4.00	5	5	5	I stayed up to date with the year's schedule

							and attended scheduled classes.
5.5	140	1	3.00	5	5	5	There were different kinds of ways in which I could engage in the module (e.g. tutorials, recordings, assignments, discussions).

Table 4. Theme 2. Reflection of MPSTs on the overall level of challenge and expectations of the second-year online mathematics education module.

Que	Response	Min	Q1	Median	Q3	Max	Description
6.1	141	1	4.00	5	5	5	The way in which the module's content was presented by the lecturer helped me to get an excellent understanding of the subject matter.
6.2	140	1	3.75	4	5	5	I was challenged intellectually through the activities we did throughout the module. (Thus: It made me think, and question, and allowed me to 'stretch' my thinking and understanding.)
6.3	141	1	4.00	4	5	5	I was able to learn what I expected to learn by completing this module through the module guide containing exercises additional reading material, etc.
6.4	139	1	3.00	4	5	5	The assessments were difficult and the lecturer provided adequate feedback after some time.
6.5	140	1	3.00	4	5	5	I have less access to data exacerbated by poor network coverage in my area which hinders continuous internet access.

Then we summarise the numeric responses by their mean, standard deviation, standard error of the mean, the confidence interval for the mean, expected value under the null hypothesis that the responses are purely noise and *p*-value of testing that null hypothesis. In Table 5, no outliers indicate that items measure the intended objective. The third quartile (Q1) and maximum values are equal meaning that the sampled items are efficiently distributed and unbiased. Generally, the null hypothesis is an assertion of 'no difference' or 'no effect' denoted as H_0.

Table 5. Summary of numeric responses

Que	Mean	std d.	std error	Lower	upper	null exp	*p*-value	*p* adj
5.1	4.199	0.973	0.082	4.037	4.361	3	0	0
5.2	4.589	0.879	0.074	4.442	4.735	3	0	0
5.3	3.864	1.068	0.090	3.686	4.043	3	0	0
5.4	4.145	1.008	0.086	3.975	4.315	3	0	0
5.5	3.843	1.054	0.089	3.667	4.019	3	0	0
6.1	4.305	0.956	0.080	4.146	4.464	3	0	0
6.2	3.979	1.049	0.089	3.803	4.154	3	0	0
6.3	4.177	0.889	0.075	4.029	4.325	3	0	0
6.4	3.813	1.53	0.089	3.636	3.990	3	0	0
6.5	4.186	0.870	0.074	4.040	4.331	3	0	0

The standard deviation of each item tends to be a very small fraction meaning the MPSTs agree with itemized data and the normality of the distributed data qualifying the rejection of both null hypotheses (Sardanelli & Di Leo, 2009). A small standard deviation indicates that they are clustered closely around the mean as in Table 5 above. The *p*-value is an approximate probability of observing patterns in data at least as interesting as the patterns you see in Table 5, under the assumption that there actually are no patterns and that the data-generating mechanism is rather boring (the patterns you see are just a coincidence). In a well-designed experiment, a small *p*-value provides evidence against the null hypothesis of boringness. A small *p*-value says that the patterns you see can probably be extended beyond your experiment to some extent and may continue. *p*-values and significance tests, when properly applied and interpreted, increase the rigor of the conclusions drawn from data. In this study, the null hypothesis is rejected as the *p*-value is less than (or equal to) a predetermined level alpha as depicted in Table at the significance level. We rejected the null hypothesis given that it is a true set at or below 5% and its adjusted *p*-value is less than α (0.05 = 5%) which is zero in this study (Di Leo & Sardanelli, 2020). The rejection of the hypothesis show's effect of online learning experiences on the MPSTs during the pandemic in a rural university. A result is said to be statistically significant if it allows us to reject the null hypothesis. All other things being equal and smaller *p*-values are taken as stronger evidence against the null hypothesis. Rejection of the null hypothesis implies that there is sufficient evidence that there is a significant effect on MPSTs' overall level of challenges and expectations of the second-year online mathematics education module during the pandemic in a rural university. The null hypothesis is rejected if the *p*-value is less than or equal to a predefined threshold value ensuring the complementarity of *p*-values and alpha levels (Di Leo & Sardanelli, 2020). Since the null hypothesis was rejected, we conclude that there is at least one interesting thing to see and continue to find correlations and reliability analysis.

Correlations

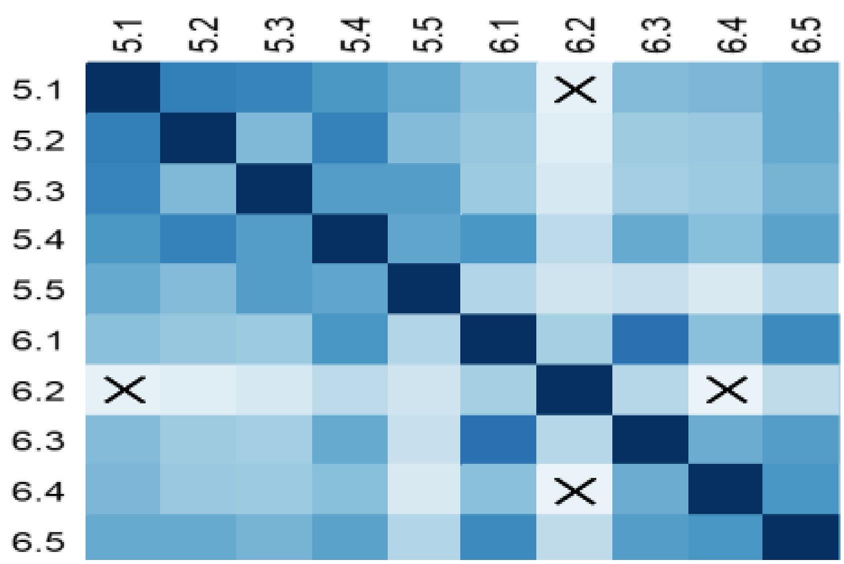

Figure 3. Correlation matrix

Correlation measures the tendency for things to move together. We used colours to present the correlation through the lens of UDL which this study hinges on. Blue and white represent positive and negative correlations respectively. A positive correlation says that when one item is above average, the other will also 'tend to' be above average (below average ↔ below average). We calculate the Pearson correlation coefficients using the scaled data. Positive correlations indicate responses that tend to vary (move around) in the same direction (same colours in Figure 3). Negative correlations are an indication of responses going counter to each other as indicated by Trenholm and Peschke (2020) that some students are not fascinated by online learning. Correlations that are not statistically different from zero will be marked as such with a cross in Figure 3. These items implicated are 5.1 and 6.2; and 6.2 and 6.4; 6.2 and 6.5. A correlation can be taken as evidence for a possible causal relationship, but cannot indicate what the causal relationship, if any, might be. Correlation in Figure 3 implies causation as items are linearly related shown by dark blue colour establishing a line of best fit through a dataset of two variables.

Table 6 . Reliability analysis

	Lower	Alpha	Upper
Feldt	0.84	0.88	0.90
Duhachek	0.84	0.88	0.91

95% confidence boundaries in Table 6 depict that all items were reliable.

Table 7. Item statistics

	No. of participants	Raw reliability	Standard reliability	Reliability correlation	Reliability dropped	Mean	Standard deviation
5.1	141	0.77	0.77	0.76	0.71	4.2	0.97
5.2	141	0.71	0.72	0.70	0.64	4.6	0.88
5.3	140	0.72	0.71	0.69	0.64	3.9	1.07
5.4	138	0.82	0.82	0.81	0.76	4.1	1.01
5.5	140	0.62	0.61	0.55	0.51	3.8	1.05
6.1	141	0.74	0.75	0.74	0.67	4.3	0.96
6.2	140	0.42	0.41	0.31	0.28	4.0	1.05
6.3	141	0.70	0.71	0.69	0.63	4.2	0.89
6.4	139	0.63	0.63	0.58	0.52	3.8	1.05
6.5	140	0.76	0.77	0.75	0.70	4.2	0.87

In this section, the goal is to determine to what extent specific sets of questions measure the same thing or are consistent. It is based on factor analysis - we try to find an underlying factor explaining the responses to a group of questions as a whole. The measures calculated here are related to the famous Cronbach's α, but considered more accurate (although alpha is also given). Reliability measures lower than about 0.7 suggest that multiple concepts are being measured; while measures above 0.95 suggest that you are asking exactly the same thing in different words. If you are trying to measure a single concept reliably, then a value in the target range of 0.7 to 0.95 is desired as depicted in Table 6 that all items were reliable.

Most MPSTs used the opportunities and exposure provided to participate actively in this module using various tech resources and others lacked ease and familiarity of navigating Blackboard (BB) prowess on resources like announcements, emails, study materials, assignments, tests, and projects (Petty & Farinde, 2013) as depicted in Table 7**.** Given that MPSTs accessed BB mainly via their laptops and Apple/Android cellphones during scheduled synchronous meetings, it could also have interfered with students' ability to gain confidence in online engagements. Involving MPSTs in online modules signals another focus area where tools like BB, Moodle, Google Docs, Photo math app, WolframAlpha, Desmos, Cramster, etc. can be earmarked for future mathematics student training and development (Du Plessis &

Mestry, 2019)**.** At the same time, the high data costs associated with the use of BB or Moodle and the above-mentioned platforms in SA must also not be overlooked as a potential drawback of online learning engagements. This will enhance change in the lecturer-MPST role positioning the student as the driver, actively taking charge of their progress on meaningful learning engagements (Hass et al., 2019). Given the far-reaching positives associated with online learning, MPSTs accessed different ways in which they could engage in the module (e.g., tutorials, recordings, assignments, and discussions). There is a scope to overcome the challenges of some students while drawing from the online learning engagements to feed towards an institution-wide drive for greater inclusion and effort towards boosting pedagogy targeting all students rather than a select minority**.** The MPSTs further flagged challenges like poor network reception in most areas, and lecturers issuing inadequate late feedback which depicts less support (Petty & Farinde, 2013; Tareen & Haand, 2020). Lastly, the MPSTs signposted that they were challenged intellectually through the activities as the assessments were difficult exacerbated by late feedback.

Study Contributions

Policymakers and institutions of higher learning have to rethink fundamental questions on the future of online mathematics learning engagements in this era of 4IR. The bottom line is that the use and implementation of online learning are irreversible in education and must be guided by the core principles of inclusion and equity. For this to happen, policies must promote equitable and inclusive access to reasonably priced data with a focus on empowering female students as they are the majority in this study and disadvantaged socio-economic groups. In conclusion, online learning engagements should be geared toward improving learning for every student, empowering teachers and strengthening learning management systems.

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