





Bridging powerful knowledge and lived experience: Challenges in teaching mathematics through COVID-19



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The coronavirus disease 2019 (COVID-19) pandemic supported an investigation of ongoing challenges as to whether and how to make mathematics relevant to learners' lifeworlds. Given that COVID-19 created major disruptions in all learners' lives, we developed and taught tasks that attempted to make links between their experiences of the pandemic and disciplinary mathematical knowledge. We located our investigation in current debates about the extent to which disciplinary knowledge can be linked to learners' out-of-school experiences. We developed and analysed two tasks about COVID-19 that could support link-making and productive disciplinary engagement, and analysed one Grade 10 teacher teaching these tasks. We found that linking mathematics to learners' lifeworlds is both possible and extremely difficult in relation to task design and how the teacher mediates the tasks. In relation to task design, we argue that teachers cannot do it alone; they need to be supported by the curriculum and textbooks. In relation to mediation, we saw that teacher practices are difficult to shift, even in the best of circumstances. We articulate the complexities and nuances involved in bridging powerful knowledge and lived experience and thus contribute to debates on how to teach powerful knowledge in relation to learners' lifeworlds.

Keywords: mathematics curriculum; pedagogy; relevance; powerful knowledge; learner engagement.

Introduction

The coronavirus disease 2019 (COVID-19) pandemic has created major disruptions in the lives of many South Africans. A study by Spaul et al. (2020) shows that three million South Africans lost their jobs between February and April 2020, two million of whom were black women. The pandemic and the accompanying lockdowns have caused great hardship in South Africa (SA) and around the world and exacerbated already-existing social and economic inequalities. Spaul and Kotze (2015) show that in poorly resourced schools, learners lag three to four grades behind their peers in better-off schools. The shutdown and concurrent loss of time in schools may have disadvantaged learners even further, particularly those who did not have access to online learning. Jansen (2020) notes the unequal experiences of learners through the lockdown period and Hoadley (2020) shows how much time was missed by learners in government schools, given school closures and rotational timetables when schools were open.

In dealing with the Coronavirus, scientists and governments have been publishing a range of information: how the virus infects people and causes damage to our bodies, how the virus spreads and how the spread can be prevented, and statistics on the demographics of those who are becoming infected, ill and dying and how these differ across countries, regions and socio-economic circumstances. Much of the information has been communicated on social media and so there is also much misinformation, with severe consequences for the spread of the disease and the health of communities (Barua, Barua, Aktar, Kabir, & Li, 2020).

We are South African high school mathematics teachers, who studied together on a master's programme at Wits University. We have written this article together with our professor on one of our courses: Studies in Pedagogy. This course looks at why the school system fails the majority of poor, black learners in SA and internationally, asking why learners from marginalised communities do not achieve as well as those from better-off communities (Spaul & Kotze, 2015) and why many learners in all communities experience their mathematics learning as irrelevant to their lives and

Note: Teaching and learning mathematics during COVID-19.

as boring and unenjoyable (Boaler & Greeno, 2000; Motala, Dieltiens, & Sayed, 2012).

The intersection of the pandemic and our course gave us an opportunity to rethink how and why we teach mathematics, particularly in relation to its relevance to learners' lives. Much has been written on the relevance of mathematics and there are contradictions and tensions relating to incorporating everyday knowledge into the curriculum. The decolonisation movement (Howard & Kern, 2019; Le Grange, 2019) argues that mathematics arises out of people's lived experiences and can and should be taught in relation to these, particularly, but not only, to learners' cultural traditions and social circumstances. Others argue that mathematics as a discipline is somewhat removed from everyday experience and functions with its own internal rules and thus cannot be easily related to everyday lives and knowledge.

Our course investigated the connections and tensions between teaching disciplinary mathematical knowledge and how we as teachers might take account of who our learners are, what their lived experiences are and how we might develop rich and just pedagogies that value everyone and teach powerful knowledge (Zipin, Fataar, & Brennan, 2015). The COVID-19 pandemic gave us a unique opportunity to think about whether we could use information about the pandemic to teach mathematics and to use mathematics to develop more sound knowledge about interpreting COVID-19 information among our learners. We were challenged to use the theoretical resources of the course to develop and analyse tasks that could be relevant and teach mathematics at the same time. While many others have written about making mathematics relevant, we wondered whether, given the scientific and mathematical nature of information about the pandemic, we could find new ways of connecting mathematics and learners' lived experiences during the COVID-19 pandemic.

This article focuses on the following research questions:

1. Can we use mathematics to support learners' understandings of COVID-19 and, if so, how?
2. Can we use information about COVID-19 to teach mathematics and, if so, how?
3. Can we use mathematics and COVID-19 to develop powerful and relevant mathematics for our learners?
4. What challenges are created in trying to link mathematics and COVID-19?

We begin by framing the questions in terms of the current debates.

Powerful knowledge or lived experience: the debate

Social realists (for example, Young & Muller, 2013) and critical sociologists (for example, Zipin et al., 2015) disagree on whether powerful knowledge and everyday knowledge can be taught without diminishing either. For social realists,

powerful knowledge refers to specialised knowledge, built systematically over time in a discipline such as mathematics, with agreed upon methods or criteria for determining 'epistemic bestness' and validity (Young & Muller, 2013, p. 236). Powerful knowledge allows people to generalise beyond their particular experiences (Young & Muller, 2013) and to envisage the 'not yet thought' (Bernstein, 2000, p. 30). The concepts of powerful knowledge are systematically related to each other and support more systematic and deeper understandings of the world, that is, powerful knowledge explains and possibly predicts what happens or might happen in reality (Young & Muller, 2013). Powerful knowledge is dialogic in the sense that multiple voices and interpretations of scholars in a discipline contribute to this knowledge through constructing and critiquing claims and evidence (Ford & Forman, 2006). Powerful knowledge is distinguished from 'knowledge of the powerful' in that the latter gains its power from those who develop and use it, while the former gains its power from what it can achieve and how it is organised. Powerful knowledge is considered to be structurally distinct from context-dependent, everyday knowledge acquired from everyday discourses given the different contexts of their development and use (Charlot, 2009).

Young (2011) argues that the primary function of schooling is to enable learners to acquire powerful knowledge because of the potential power this knowledge provides in empowering us to envisage and interpret the world beyond our everyday understandings. Muller and Hoadley (2019) argue that schools are the main institution where marginalised learners acquire specialised, context-independent academic knowledge and that access to powerful knowledge is a social justice issue since all learners should have epistemological access to powerful knowledge, and many, particularly from marginalised communities, can only get it at school. Charlot (2009, p. 92) elaborates that to acquire powerful knowledge during schooling, learners need to move from perceiving the world as a 'place of experience' towards perceiving it as 'an object of thought', and from seeing themselves as an 'empirical self' and allow for the emergence of the 'epistemic self'.

In an important study, Hoadley (2007) shows how working-class learners are disadvantaged when teachers are unsuccessful in linking powerful mathematics knowledge with everyday knowledge. Comparing mathematics lessons in working-class and middle-class schools in Cape Town, Hoadley notes that teachers in the working-class contexts employed mainly 'localising strategies' which left learners grounded in rudimentary, concrete ways of counting without moving to 'specialising strategies' requiring generality. Conversely, middle-class learners were granted access to developing specialised knowledge of mathematics through 'specialising strategies' and these learners had 'a base from which more advanced conceptual work could be done' (Hoadley, 2007, p. 693). Hence, the working-class learners were left with a thin and denuded version of mathematics through valorising everyday knowledge in relation to

disciplinary knowledge. This is perilous for learners from working-class contexts who are potentially denied mathematical futures since they are not granted access 'to move, intellectually at least, beyond their local and particular circumstances' (Young, 2011, p. 15).

At the same time, we know that conventional mathematics education has not supported most learners, particularly poor, black learners, to be successful in mathematics (Fataar, 2012; Spaul & Kotze, 2015). While Zipin et al. (2015) agree that powerful knowledge is an important endpoint of schooling, they argue that it is not the only endpoint and that strong distinctions between powerful knowledge and learners' lifeworlds are counterproductive, particularly for marginalised learners (see also Civil & Hunter, 2015; Ladson-Billings, 1995). They disagree that boundary crossing between powerful and everyday knowledge is not possible, that the two knowledge forms are structurally distinct and that incorporating the everyday aspects of learners' lives will necessarily dilute the powerful knowledge. While powerful knowledge may be defined by its structures and functions, in fact it intersects strongly with knowledge of the powerful, and powerful people continue to control powerful knowledge (Zipin et al., 2015). While giving access to powerful knowledge can be seen as an element of social justice, making hard distinctions between powerful and everyday knowledge in the curriculum continues to serve the interests of the already powerful, whose cultural capital aligns with the 'school code' (Ladson-Billings, 1995; Zipin et al., 2015). Learners from working-class backgrounds continue to be intellectually excluded, alienated and disengaged, finding instead that their community knowledge is more useful and meaningful to them (Charlot, 2009; Fataar, 2012). Middle-class learners are more successful at acquiring the 'school code' compared to working-class learners since they are enculturated into similar discourses at home (Charlot, 2009; Hasan, 2002).

While we have presented two apparently opposing positions in the debate, we note that there is some overlap and possibilities for reconciliation, relating to how connections may be made between powerful knowledge and lived experience. In particular, Young (2013) and Muller and Hoadley (2019) argue that while it is important for the curriculum to distinguish clearly between powerful and everyday knowledge, with powerful knowledge as a key outcome, there is space in pedagogy for teachers to make links with learners' lived experience as long as this is done in the service of powerful knowledge. They make a strong distinction between curriculum and pedagogy. Fataar (2012) notes that 'thin' pedagogies may produce a denuded curriculum, achieving neither powerful knowledge nor relationships with lived experience for the learners. Together with Fataar, we do not see such a strong distinction between curriculum and pedagogy, noting that if links are to be made, then teachers will need guidance on how to do this and a curriculum that supports it (Lampen & Brodie, 2020).

This debate resonated with us in a number of ways. We appreciate the idea of mathematics as powerful knowledge – this is what draws us to mathematics. And yet we know that our learners tend not to see this power in mathematics, often because we do not show them how it supports stronger and deeper interpretations of the world, nor how it intersects with their lifeworlds. This may be because of the instrumental and utilitarian nature of our current schooling system, which is examination-driven and employs 'a "thin pedagogies" approach to curriculum implementation' (Fataar, 2012, p. 62). Teachers work mainly to ensure that learners pass examinations, thus emphasising the procedures of mathematics at the expense of its full power. When we try to make mathematics more relevant in class, we often find ourselves denuding the power of mathematics, as Hoadley (2007) shows. We have not found many ways to show our learners what we love and find useful in mathematics. We wondered whether COVID-19 would give us a new opportunity to bridge the power of mathematics with the meaning of learners' lived experiences.

Bridging powerful knowledge and lived experience

Perhaps the best reconciliation of the two sides of the debate comes from Delpit (1988). She argues that we have to teach learners both the codes of power, and respect for their own community knowledge. She argues: 'if you are not already a participant in the culture of power, being told explicitly the rules of that culture makes acquiring power easier' (Delpit 1988, p. 282), recognising that redistributing powerful knowledge for all learners is not enough as codes for academic success will still remain implicit for working-class learners (Zipin, 2015).

However, we note Delpit's (1988, p. 286) concern that in redistributing cultural codes needed for academic success, learners cannot lose their cultural identities, as this would be a form of 'cultural genocide'. This resonates with Fataar's (2012, p. 56) concern about the dangers of 'cultural assimilation' evident in SA's post-apartheid schooling system. With 'an explicit pedagogies approach', Fataar (2012, p. 58) proposes that the teacher act as a mediator in making visible the cultural codes needed for academic success while recognising that teachers need to connect the rich cultural knowledge of learners with disciplinary knowledge through their pedagogical approaches in ways that do not diminish either knowledge form.

Two possibilities of such connections are given by Hedegaard's (1990) 'double move' and Engle and Conant's (2002) notion of 'productive disciplinary engagement'. The double move refers to moving from theoretical to empirical knowledge and back again. Theoretical, disciplinary knowledge is first made available to learners through important theoretical questions in the field, which learners explore with examples (in Hedegaard's case they work in Life Sciences). The examples help to develop the theory further, which learners can then use to see more in the

examples, thus creating cycles of theoretical and empirical exploration. We wanted to see whether we could build the double move into mathematics tasks.

Engle and Conant (2002) argue that in order to bring learners into contact with disciplinary knowledge, learners need opportunities to problematise the content, to develop authority in relation to the knowledge, to be accountable and hold others accountable to how they make the claims that they do, and they need sources and resources to support their engagement. Ford and Forman (2006) resonate with Engle and Conant's authority and accountability when they talk about allowing learners to take on the roles of constructors and critiquers of knowledge. We were intrigued as to how these roles could be embedded in mathematics tasks.

The concepts of productive disciplinary engagement (Engle & Conant, 2002; Ford & Forman, 2006) as well as the double move (Hedegaard, 1990) typically require substantial class discussion, in groups or in the whole class, as well as a range of textual resources. As Brodie (2007, p. 17) argues, classroom conversations 'allow learners and the teacher to consider, question and add to each other's thinking and to co-produce generative mathematical ideas and connections'. Brodie also argues that developing conversations where there is genuine communication that supports learner engagement and thinking is difficult to achieve, particularly when discussions may take different directions from those expected by the teacher. Teachers often have to make in-the-moment decisions about whether and how to follow up different learner contributions, while maintaining a focus on the key concepts they want to teach.

More generally, we can take opportunities in teaching about COVID-19 to ask moral and ethical questions that are not usually addressed in mathematics classrooms but can be important. For example, how do we know which sources of information can be trusted? Are all sources equally valuable or powerful, especially in relation to social media? This comes back to Delpit's (1988) point about relationships between powerful knowledge and lived experience, connecting what learners experience in their everyday lives with the codes of power. We can also create opportunities for learners to experience and explore empathy, self-reflection, critical thinking and personal growth. It is important for us as teachers to teach with sensitivity and care (Brodie, 2017), knowing that our learners' experiences of the COVID-19 pandemic may have been very different from each other's and our own, and that a number of them might have experienced disruptions and even death among their families.

Methodology

Our contexts

Table 1 shows the variation in contexts among us, with one of us (Teacher2) teaching in a public, no-fee government school while Teacher1 and Teacher3 teach in private schools.

Our teaching contexts supported different experiences of teaching during the COVID-19 lockdown. Teacher2 could only rely on WhatsApp to communicate with her learners, Teacher1 made use of WhatsApp and Microsoft Teams, while Teacher3 had some advanced technology such as a digital pen which was used when presenting to learners in real time on Google Meet. Teacher1's and Teacher3's learners connected with them every day. Fewer than a quarter of Teacher2's learners connected regularly, because they did not have access to devices and, if they did, could not afford data (see also Jansen, 2020) and because of unstable network connectivity and regular power disruptions. It is extremely difficult to teach mathematics on WhatsApp, and we felt quite despondent at the school time our learners were missing and how already existing inequalities might be exacerbated between schools.

When schools re-opened, depending on the schools' management and infrastructure, teaching and learning was very different from the past (see also Hoadley, 2020). Some schools opted for weekly or daily rotations for Grades 8 to 11 in order to comply with standard operating procedures that are COVID-19 compliant. This greatly impacted contact times with learners. Some schools combined face-to-face with online learning, making teaching more demanding for teachers new to online teaching. Grade 12 learners would write their final, national, high-stakes examinations on the same curriculum as in previous years, and we needed to catch up a lot of work, because of lost time during lockdown. We also needed to deal with learners', and our, anxieties about being back at school in the midst of a pandemic, work with them on maintaining safety procedures regularly and systematically at school and at home and try to focus them on their studying during a difficult time.

Our own learning was disrupted after five face-to-face sessions towards the end of March 2020. Fortunately, during lockdown we received free data from the university and connected on Microsoft Teams for our class discussions, although these were more difficult to learn from than our in-class sessions. This double disruption to our working and studying lives, together with the anxiety about a rampant disease, brought challenges and opportunities. One opportunity was to think about how we might teach about COVID-19 to our learners, either online or once we got back to school. Another was to think about how COVID-19 might be an opportunity to bring some relevance to a mathematics curriculum dominated by rules and algorithms (Boaler, 2016).

Data collection and analysis

In this article, we analyse some ideas for mathematics tasks for learners related to COVID-19. This was the central thread

TABLE 1: Our teaching contexts.

Teacher	Public/Private	Teacher:learner ratio	Biggest class	Smallest class	Grades currently teaching
Teacher1	Private	1:25	25	14	Gr4, Gr10–12
Teacher2	Public	1:50	58	35	Gr9–12
Teacher3	Private	1:10	8	4	Gr9–12

of the second part of our course (eight sessions) and each week we worked on different ideas in relation to COVID-19 related tasks. Our first set of data is therefore the tasks that we developed and analysed. We developed the tasks by looking for information in the press and on social media, and then asking questions about the information to create tasks that learners would think about, research and discuss, alone, in groups or in whole class discussions. We analysed the tasks using the analytic framework shown in Table 2, developed from our theoretical framework discussed above. The process was iterative: as we analysed, we changed some aspects of the tasks, and then re-analysed. Not all the analytic questions are applicable to all of the tasks but as a whole the tasks should engage learners as described in our discussion.

Towards the end of the year, we decided to try some of the tasks in one of our Grade 10 classrooms. Teacher3's classroom had the best conditions and we were able to videotape the lessons. While we cannot generalise from such a small class to any other classrooms, we are able to draw out important lessons for other teachers and researchers.

We used the same analytic framework to analyse the in-class enactments of the tasks (Table 2), looking in particular for how what happened in class differed from the task intentions. The first author did an initial analysis of the lessons in relation to the analytic framework. After this, the other authors commented on the analysis and added some important points, while Teacher3, who was the class teacher, responded to questions from the analysts and added some additional points. Teacher3 had also written reflections on the lessons immediately after them and transcribed the two

TABLE 2: Analytic frame.

Research question	Related analytic questions
1. Can we use mathematics to support learners' understandings of COVID-19 and, if so, how?	1.1 Can mathematical concepts support understandings of COVID-19? 1.2 Can mathematical knowledge support learners to problematise knowledge about COVID-19? 1.3 Can mathematical knowledge support learners' authority and accountability in relation to COVID-19, and support them to construct and critique this knowledge?
2. Can we use information about COVID-19 to teach mathematics and, if so, how?	2.1 Can ideas about COVID-19 support the development of mathematics concepts? 2.2 Can COVID-19 resources support learners to problematise mathematical knowledge? 2.3 Can COVID-19 resources support learners' authority and accountability in mathematics, and support them to construct and critique mathematical knowledge?
3. Can we use mathematics and COVID-19 to develop powerful and relevant mathematics for our learners?	3.1 Can we develop the 'double move' in relation to mathematics and COVID-19? 3.2 Can we develop a relationship between COVID-19 knowledge and disciplinary mathematics knowledge?
4. What challenges are created in trying to link mathematics and COVID-19?	4.1 What challenges did learners experience? 4.2 What challenges did the teacher experience? 4.3 Did we develop 'productive disciplinary engagement' through relating mathematics to COVID-19? 4.4 Did we develop the 'double move' in relation to mathematics and COVID-19? 4.5 Can we work with moral and ethical questions, as well as with sensitivity and care?

lessons. While we developed a set of four tasks, only two were used in the classroom, so we only discuss those two here.

Ethical considerations

Permission was granted from the research ethics committee of the university (ethics clearance number: H20/11/08). Informed consent was obtained from Teacher3, learners and their guardians. Names of all learners have been kept anonymous to preserve the confidentiality of participants. The teacher numbers do not correspond to the order of authors, again to preserve anonymity.

Findings: Tasks and teaching

Tasks

We present the analysis of two tasks that can support learners to use mathematics to understand elements of the COVID-19 infections in SA and also to develop mathematical knowledge based on thinking about the outbreak (see Appendix). The tasks were developed from information on the COVID-19 South African Online Portal (2020) and can be adapted for different grades and used in different ways by teachers. The images in the tasks were found in July and September 2020 and suggest ways to bring together ideas about the Coronavirus and its impact, and mathematics. But we note that as things change, we would want to develop similar activities around more current data about the virus.

Our task questions are based on information that is presented in the images. Disciplinary engagement with school content means that learners are engaged in activities that draw upon actual practices of a discipline such as constructing and critiquing knowledge (Engle & Conant, 2002; Ford & Forman, 2006). We devised questions for learners to draw on the information presented in the images about COVID-19, and their knowledge, experiences and feelings about the pandemic. We hoped that the tasks and our methods of teaching would help learners' development of mathematical concepts and we devised both mathematical and non-mathematical questions that would support the learners to problematise or deepen their ideas about COVID-19.

Image 1 illustrates the number of deaths in different countries around the world and this gives learners a perspective on the pandemic from both a local and an international standpoint. Some learners may have been directly affected by the statistics as they could have had deaths in their families due to COVID-19. The numbers are given as absolute deaths rather than death rates, and we hoped that learners might raise the issue of death rates and the difficulties of comparing numbers of deaths without knowing the population of each country (which could be looked up). Much of the information in the press about deaths from COVID-19 is given as absolute numbers, so this is an important question to bring up in class.

Question 1 can initiate a discussion about deaths from the pandemic across the world. The discussion should be relatively open at first allowing learners to explore different questions that they might ask and identify what mathematical or non-mathematical resources (Engle & Conant, 2002) they might use to answer their own questions. The learners' questions can support the problematisation of everyday knowledge, for example the difference between number of deaths and death rates, and set up possibilities for using mathematical knowledge to answer these (Q1.2)¹. How the discussion proceeds will depend on the teacher (Scott, Mortimer, & Aguiar, 2006) and how they make links to mathematical concepts that they want to teach (Q1.1, Q2.1). Question 2 might help with the discussion in question 1, because it supports the learners to be more specific about what they see in the graph but, if not, it can be asked separately as an important mathematical question, supporting sense-making of the graph (Q1.1, 2.1). The bar graph is presented horizontally rather than vertically, which is unusual since learners usually encounter bar graphs with vertical bars, and this might lead to some discussion (Q2.2). Question 3 asks an important mathematical question about percentage increase and allows learners to relate their previous disciplinary knowledge to the COVID-19 numbers and to answer important questions about the numbers (Q1.1). Knowledge about COVID-19 might also help learners to make sense of percentage increase (Q2.1).

Question 4 asks learners which measure of central tendency is most appropriate for this data. This question should raise a number of issues relating to measures of central tendency, particularly whether and when they are appropriate in relation to a particular data set. Such discussions may help to problematise the content and can serve as a catalyst for initiating a rich mathematical conversation, particularly if it is related to discussions around questions 1–3 about what the data represents (Q1.2, Q2.2). Therefore, learners are given some authority to make judgements about the data, and are held accountable to the discipline to justify their viewpoints (Q1.3, Q2.3). Question 5 asks learners to comment on the skewness of the data, which presents yet another opportunity to ask questions about what is represented and they are required to link their disciplinary knowledge with the COVID-19 resource and take authority and accountability for their responses (Q1.1, 1.2, 1.3, 2.3). The task as a whole, particularly question 4 and question 5 suggest the possibility of a double move: moving from everyday knowledge to mathematics and back again or cycling through everyday and mathematical knowledge (Q3.1, 3.2).

Image 2 is an infographic that conveys information about COVID-19 statistics in the different provinces of SA, published every day in SA. Learners may have seen this in their everyday lives but not necessarily in their mathematics classrooms. This image may support learners to see the importance of mathematics in their everyday lives and may change their perception of the importance and incorporation

1.The brackets refer to the questions in the analytic framework.

of mathematics with lifeworld knowledge. There is some information missing, for example the numbers of tests conducted per province and the population size per province (similar to Task 1). It was hoped that if learners needed these to complete the task, they would ask about them and, in the latter case, could find out what these numbers are.

Question 1 requires learners to think about why a province has recorded the lowest percentage of confirmed cases based on calculations they performed (Q1.1, 1.2). It could raise a number of questions such as: what is a high death rate in a province, how do the death rates across provinces compare to the national death rate, and which province has been most affected by COVID-19 deaths? These mathematical questions could then lead to non-mathematical questions such as: why do some provinces have higher death rates than others and might this be related to poverty or healthcare systems in the province.

Question 2 supports learners to talk about their perceptions about being back at school and asks learners to use statistics to support their reasoning (Q1.1, Q2.1). Here learners would need to refer to the provincial statistics as well as the national statistics. We hoped that this question would bring up the limitations of statistics in understanding our current circumstances. Question 2 also allows social issues that affected learners to be foregrounded and may allow learners to engage with the emotional and psychological effects that COVID-19 has had upon their lives (Q4.5). Teachers will get further insight into learners' anxieties associated with being back at school in the time of a pandemic. Teachers will need to attend to basic human values of care and compassion (Brodie, 2017) when listening to learners' experiences of schooling during lockdown as there may be learners who experienced deaths in their families or learners whose family members lost jobs. This question also allows the teacher to engage with both the academic and the human project (Jansen, 2016) such that teachers come to see their learners as whole people who have their own unique perceptions and experiences of schooling under lockdown. Brodie (2017, p. 175) notes that attention to 'the human and academic project are equally important in schools and in mathematics pedagogy if we want to transform our school into spaces where all can and do learn mathematics'.

Question 3 is not usually seen in mathematics classrooms. It asks learners to be curious and gives the learners agency to suggest what they find relevant and interesting in the image (Q2.3). Given question 1 in task 1, we hoped that learners would ask both mathematical and non-mathematical questions, although we expected they might need prompting to ask mathematical questions. They are encouraged to pursue or ask questions that they find interesting as a result of this image and are accountable to the teacher and fellow learners for justifying why they chose to pursue these questions. Curiosity is an important attribute in a 21st century world and this attribute is typically overlooked in mathematics classrooms where learners often surrender their

human agency to the agency of the discipline (Boaler & Greeno, 2000). Question 4 and question 5 require learners to make judgements about political decisions that were taken on the basis of mathematics and the nature of the information given to the public. With question 4, statistics is used to problematise knowledge and make learners think critically about the efficacy of lockdown (Q1.2). Question 5 asks learners to be critical and justify whether the image is a reliable source of information (Q1.2). For these questions, it will be important for the teachers to make sure that ideas such as accountability based on knowledge are made available for discussion in the classroom. As with task 1, we hoped that working through all five questions would allow the teacher to make links between COVID-19 and mathematics (Q3.2).

We note here that research question 4 and analytic questions 4.1–4.5 relate more closely to what actually happened in the classroom and we will address them in the next section.

Teaching

Our main finding was that the learners found it difficult to link mathematical concepts with COVID-19 in a sustained way through the lessons. Teacher3 reflected:

‘Learners tended to operate at one end of the spectrum in many instances whereby either disciplinary knowledge was favoured and everyday knowledge was made subordinate or everyday knowledge was favoured making disciplinary knowledge subordinate. ... Developing better links will require more skilful mediation from my part.’

Our analysis shows much better linking between mathematics and everyday knowledge than seen in Hoadley (2007) because the tasks and the teacher prime the learners to think mathematically; however, we do see instances where the mathematics gets lost in the everyday.

We note that Teacher3 is more qualified than many others, having nearly completed a Master’s in Education at the time of this study and was able to make important pedagogical moves such as: giving learners time to think and respond, validating learners’ responses, helping learners to articulate their ideas, and supporting learners to take authority and accountability for their thinking. However, the teacher still experienced challenges, noting that these tasks were ‘different from typical mathematics lessons whereby I present a formula and learners practise how to perform a calculation’. So even a well-qualified teacher, with expertise in the current curriculum and pedagogy, struggled to shift to making links between learners’ lifeworlds and the discipline.

Noting these difficulties, we also noted that the tasks and the teacher’s pedagogies did succeed in making some links between mathematics and the everyday, presenting more nuanced findings than Hoadley (2007). It is in these nuances that we believe the seeds for working on more relevant curricula might lie. The teacher also expressed some dilemmas and uncertainties, which show why teaching in

this way is a difficult undertaking. In order to convey the depth of what happened in the lessons, we present the tasks in the order they were taught with a narrative analysis backed up by quotes from the lessons and the teacher.

Task 1

For question 1 learners began by suggesting non-mathematical questions such as: How were the countries in the graph chosen? Why is the SA death rate² lower than the others when we are a poorer country? Why is the United States (USA) death rate the highest? Some answers were suggested: wearing or not wearing masks, and the different lockdowns in SA and the USA, one more systematic and stricter while the other was more variable. One learner made a sarcastic comment about Donald Trump. The teacher reworded the comment, suggesting to the student that he express his ideas in a ‘more gentle’ and ‘less-biased’ way, taking the opportunity to teach a way of working in mathematics (and other) classrooms. When the teacher asked why the questions were non-mathematical, a learner answered, ‘because you don’t have to do calculations’, suggesting a particular view of mathematics as calculations.

Among the mathematical questions were:

- Why are Iran and Peru so close to each other given that one is war-torn and the other not (which could have been a non-mathematical question)?
- Calculate the difference between SA and USA, to see the difference between the two extremes.
- Calculate the difference between Brazil and the USA.
- Find the average.
- Find the median.

It is interesting to note here that the mathematical questions are expressed as instructions rather than questions and ask for a calculation, supporting the view of mathematics as calculation and suggesting a view of mathematics as instructions to do something, rather than questions to be thought about. This question worked to orient the learners to the graph and what they might see but did not immediately support any links between COVID-19 and mathematics. We note that this is entirely appropriate: teaching is a long-term endeavour and not every goal is achieved with every task. We saw learners slip between actual deaths and death rate and this error was not addressed by the teacher, even though the error was expected in the task design. Learners also suggested that we might find the average and median. Again, the teacher could have, but did not, raise the issue about what the mean and median would show, in relation to the actual deaths and the death rate.

For question 2, a learner gave an appropriate answer, noting the vertical as countries and the horizontal as number of deaths. The teacher acknowledged the answer, but did not focus on the mismatch between number of deaths and death rate, asking whether the graph seemed ‘strange’. The learners

²We note that the learners’ word usage ‘death rate’ was problematic since the learners meant number of actual deaths when referring to the image.

nodded and showed how it 'should' be oriented (with the bars vertical rather than horizontal). Unfortunately, the teacher missed the opportunity to talk about how graphs appear in different forms because another learner made a comment, although the learners may have grasped this point.

For question 3, the teacher wrote responses on the board and we rewrite them here:

$$\text{Learner1: } 4172/15447 = 27\%$$

$$\text{Learner2: } 4172/15447 = 27\%, 100 - 27\% = 73\%$$

$$\text{Learner3: } 4172/100 = 41.72; 15447/100 = 154.47; 154.47/41.72 = 3.7\%$$

$$\text{Learner4: } 15447 - 4172 = 11275. 11275/15447 \times 100 = 73\%$$

$$\text{Learner5: } 15447 - 4172 = 11275. 11275/4172 = 270\%$$

Learner5's solution is correct and noting this could have led to interesting discussions about what a percentage increase higher than 100% means, and why Learner4's solution is partially correct but has a common error. Also interesting is how Learner2's and Learner4's solution have the same answer with different methods and are both incorrect. The teacher decided not to discuss the solutions here, saying that the learners should go home, think about the problem and they would come back to it. The teacher reflected that:

'Three responses did not make sense to me in the moment. Subsequently, I decided to probe learners who provided incorrect responses and their reasoning still appeared opaque to me. I decided to not provide finality to this question and postponed providing a solution to this question until the next day.'

When the teacher probed Learner1, the learner immediately assumed that he was wrong, a typical response when learners first experience such probing. The teacher's response is also typical for teachers who begin to allow different mathematical ideas into the classroom and become interested in methods and not only answers, particularly not only right answers. It suggests that for such strategies to work, teachers need to build ways to anticipate correct and incorrect answers and possible methods that learners might use, with different degrees of correctness.

Interesting in this regard are the learners' responses to the teacher. They asked whether any of the solutions were correct, leading to the following exchange:

Learner2: Is there a correct answer?

Teacher: I'm not going to answer ...

Learner4: Please ...

Learner5: Wait is there an answer that's correct. We don't need to know who. We just need to know someone got it.

Teacher: I want you guys to think. ... Guys, quite a few of you got different answers. I want you to compare with each other and how did different people reason about this. You all got different ideas here. On Wednesday, when I see you, we're going to discuss this question again in more detail.

Learner5: Will you tell us the correct answer?

Teacher: Yes, on Wednesday. I want you guys to think.

The exchange suggests the learners' need for correct answers rather than to understand why particular solutions are correct. This comes from years of mathematics pedagogies where correct answers are seen to be more important than other aspects of learning mathematics such as understanding why procedures work and justifying and communicating mathematical ideas. If such pedagogies are to change, they need to support and be supported by expanded views of what mathematics is (Boaler, 2016), particularly if curricula are to make links between learners' lifeworlds and mathematics. The exchange also shows that the teacher is beginning to push learners to take authority for their ideas and to be accountable for them, taking an initial step in this direction.

In summary so far, learners have engaged with the graph in mathematical and non-mathematical ways. There have not been explicit links between the mathematical and the non-mathematical but the potential for links can be seen. Linking was derailed by traditional views of what counts as mathematics and the teacher's surprise at students' incorrect mathematical answers in question 1 and question 3.

Question 4 and question 5 pose mathematical questions that support stronger interpretations of the graph. The learners answered the questions mathematically and justified their answers. They eliminated mode as a measure of central tendency because no numbers are repeated and spoke about the different information that mean and median give about the graph. They returned to the question asked previously about how these countries were chosen and by implication what the measures of central tendency can show about the pandemic more generally. Neither learners nor the teacher raised the issue about actual deaths and death rates referred to earlier. However, this limitation notwithstanding, in discussing the skewness of the data, the learners looked at the difference between the mean and median and thought more carefully about the information they give in relation to the graph. So, in the case of these two questions, the class was achieving links between COVID-19 data and mathematical ideas about representing data, relating to questions 1.1, 1.2, 2.1, 2.2 and 3.2 in the analytic framework. Although we had anticipated that the task would support the double move (Hedegaard, 1990), the analysis shows that this would need to be more carefully structured into the task.

The transcript also shows that the teacher pushed the learners to justify their thinking and not only their calculations:

Teacher: Ok guys. Who would like to add on to Learner2?

Learner5: I agree.

Teacher: Why do you agree?

Learner5: Cause I worked out the mean and got 5 million.

Teacher: How did you get 5 million? None of these numbers are in millions.

- Learner5: Well I added them altogether and divided by 11.
 Teacher: Yeah. There are 11 countries.
 Learner5: I got a wrong value.
 Teacher: That was what I was thinking. But Learner5, it wasn't about a calculation here.
 Learner5: It's the average so you get a collective value of all the countries.
 Teacher: So, you're saying a collective value for all the countries. Fair enough. And then Learner2 was saying about median, do you agree with her that we could use median?

Here the teacher pushed Learner5 for accountability for his answer and made the point that while the calculation is important, and its correctness can be estimated, in the end the actual number is not the endpoint, rather what it tells about the graph is. Learner5 understood this point and made a good argument about what the mean shows about the graph. The teacher then moved on to the median. So, we see the teacher building on what was said earlier in the lesson about authority and accountability, and pushing at least one learner to achieve these, thus achieving 1.3 and 2.3 in this case.

In summary then, task 1 supported the teacher and the learners to make links between some mathematical ideas and a graph of COVID-19 deaths. The teacher worked hard to support link-making by the learners and was able to deal with a number of challenges as the lesson progressed. The challenges included: a view of mathematics as about calculations only, unanticipated difficulties with mathematical concepts and difficulties in making sense of these in the moment, learner dependence on correct answers and the teacher's authority to decide on these, learners making a number of comments that may or may not be connected to the task, and how to follow up on all of these. These challenges have been documented in the literature on teaching mathematics responsively (Franke et al., 2009; Heaton, 2000). Here we are interested in how the teacher worked with them and how others might also do so.

Task 2

For question 1, learners were asked to calculate the percentage of confirmed cases in the Northern Cape and compare this with the other provinces. Two learners offered solutions: Learner4 offered 56% and Learner2 2.1%. The teacher asked them both to explain. Learner2 added the three numbers for the Northern Cape and divided the number of deaths by that total. Learner4 divided the number of deaths by the total positive cases in the country. Learner2 may have struggled to determine an appropriate denominator because of the ambiguity in the question and the graph – should the percentage of confirmed cases be in relation to the tests conducted in the province, the total number of people in the province or, as Learner4 decided, the total confirmed cases in the country?

The teacher did not explicitly evaluate either answer as correct but asked what the answer of 2.1% means in relation

to the size of the province in relation to other provinces, which may have been interpreted as an implicit evaluation that 2.1% is correct. Faced with a choice about whether to explore the mathematics of the two very different mathematical solutions and thus the missing information on the graph, or whether to explore their meaning in relation to the current information on the graph, the teacher chose the latter. This is likely to be a choice point in many cases for a teacher trying to make links between learners' lifeworlds and mathematics, that needs to be explored if teachers want to do this work. The teacher reflected:

'I was surprised that Learner2 could not answer the question as I predicted in my planning that this was an easy question. I then moved on to Learner4 to see if she reasoned like Learner2. Perhaps, I could have probed Learner2 more on her reasoning. Maybe there could be others in the class who reasoned like Learner2 about adding the three numbers.'

Ideally, the teacher could explore the mathematics of the different solutions, and then link these to each other and to the graph to see whether and how they make sense and what they mean.

Question 2 asked the learners to relate to the image in a more personal way, as to how they felt about their own safety at home and at school. The learners spoke about their feelings and experiences initially only in terms of the everyday and the teacher accepted their contributions sensitively and tried to refocus them on the graphic by saying: 'Okay, then ... I'm curious I haven't heard from any of you ... don't any of you worry about the COVID-19 pandemic, about the deaths and all of that?' In response to the question, one learner spoke about fears of a second wave, but this was not related to the numbers on the graphic. The teacher reflected:

'I was thinking about the infographic when I asked this question. However, learners were operating in the realm of everyday knowledge (not thinking about the infographic) and I found that it would be difficult to get them back into the realm of disciplinary knowledge with this question.'

Question 3 again asked learners to generate questions, similarly to question 1 in task 1, but here it did not ask for distinctions between mathematical and non-mathematical questions. The learners' questions varied between mathematical, which gave opportunities for linking the mathematical with the non-mathematical, and purely non-mathematical. In the first case, there were questions like: Why were nearly 4 million tests conducted? What is the correlation between confirmed cases and deaths across the provinces? What is the distribution of cases and deaths across the provinces? In the latter two cases, the learners expressed the ideas in everyday language and the teacher had to recognise them as mathematical and help the learners express them mathematically, an important part of doing the linking work. A non-mathematical question was: When will COVID-19 end? The teacher tried to get the learner who asked the latter question to focus on the graphic and relate her question to the numbers but it was clear that she did not want to do this, perhaps because of distress about COVID-19.

In question 3, the teacher did not push for accountability for the learners' questions, for why these questions were important to ask in relation to both the epidemic and the mathematics. The teacher reflected 'Perhaps, I should have held them accountable for posing the questions they asked and asked them to give a reason why they were interested in pursuing these questions'.

Question 4 and question 5 followed a similar pattern. Learners made non-mathematical contributions, the teacher tried to focus them on the mathematical but they stayed with everyday discussions about lockdown levels and reliability of sources. The analysis and teacher's reflections suggest that more could have been done with question 4 to make it mathematical in class but question 5 did not lend itself to mathematical thinking, so this was an issue of task design.

In summary, task 2 was less successful than task 1 in supporting links between mathematics and COVID-19. While questions 1–4 could have supported such links, the teacher found it more difficult to mediate this process. The challenges that the teacher experienced in this task were focused on how to make the links, possibly because the task design supported more everyday type responses, including learners' feelings. Mathematics teachers are not used to working with these responses and so mediating such tasks is challenging.

There are two additional points that we saw across the two tasks and that are important. First, the teacher encouraged the learners to use the internet to find information, both about mathematics and about COVID-19. While this may be difficult in bigger classes because of monitoring what the learners are actually doing on the internet, and because many may not have access, it does bring in other sources of authority, which can be discussed in relation to authority and accountability in mathematics and beyond. Second, the learners in this class participated actively and the teacher clearly had good relationships with them. In other classes it might be difficult to get learner participation, an aspect of making links that has to be worked on (Scott et al., 2006). In this class, there was sarcasm from some learners, for example in the comment referred to above about Donald Trump, or a question about how many corpses had to be buried. The teacher dealt well with these but such comments might prove more difficult in bigger classes. While these sarcastic comments were not the reason for a focus on the everyday in this class, expecting them and working out how to deal with them so that the links and the mathematics are not derailed could be an important challenge for teachers.

Discussion

We discuss a number of important implications that come from our analysis and that can be helpful to teachers trying to move between learners' lifeworlds and mathematical

knowledge, and to researchers studying this process. Our analysis shows that making these links is both possible and difficult. We thus take a position different from both Muller and Hoadley (2019) and Fataar (2012). We also note that suggestions for moving between these positions (Delpit, 1998; Engle & Conant, 2002; Hedegaard, 1990) are not easy to implement, and we have articulated a number of issues in relation to these.

The first issue relates to task and curriculum design and we concur with Jones and Pepin (2016, p. 115) that task design is 'by no means a trivial matter'. We have noted some of the task design issues in our analysis where a different formulation of the question might have led to better links being made. In particular, when relating tasks to information in the public domain, the extent to which ambiguity should be edited out is an important one. When working mathematically with real-world situations, the information is not always clear, and learners need to be able to think about what other information might be needed and what is superfluous. However, tasks that support such ambiguity may be misinterpreted and may be more difficult for the teacher to mediate.

We thought carefully about the tasks and reworked them a number of times before trying them in the class, and the lessons still suggested further improvements. This finding suggests that tasks that support link-making need to be developed and tested, as conventional textbooks are. Tasks that are developed by teachers can be shared and tested by others and developed into stronger tasks. Ad hoc tasks developed by individual teachers are less likely to be successful. The role of tasks also points to the role of the broader curriculum in supporting link-making. As long as our curriculum focuses on performance of calculations and supports 'thin pedagogies' (Fataar, 2012, p. 58), it will always be difficult for teachers to develop tasks relating to learners' lifeworlds that focus on mathematical thinking and justification and that support teachers to develop learners' authority and accountability.

The second issue relates to the kinds of mathematical content that supports linking with learners' lifeworlds. Our two tasks focused on data representation, as did the two tasks that we did not analyse here. Writing in the context of decolonisation, Mudalay (2018) shows how difficult it was for teachers studying decolonisation to come up with tasks that related to learners' heritage and also developed mathematical depth. While COVID-19 is particularly amenable to data representation, the question remains as to how much of the mathematics curriculum can be linked with learners' lifeworlds. While it does not have to be, and should not be, the entire curriculum, if we are to take this endeavour seriously, we cannot do it only in token ways, with one section and in a few lessons. As our analysis begins to show, the capabilities of teachers and learners to engage in this work need to be built over time.

A third issue is the extent to which mathematics, as one possible way to look at the world, tells the 'whole' story. An aim for linking mathematics to other contexts must be to show that in complex situations, we need a range of data and methods to understand them. Much of the information about the pandemic is already combined with scientific and mathematical knowledge, which makes it particularly useful for showing the use of mathematics. In their everyday lives, learners may look at graphs and newspaper articles in order to keep up to date with the trends of the Coronavirus in SA without considering the deeper meaning of how the information came about or if the information is valid or not. A focus on the powerful knowledge involved in producing and interpreting the information supports learners to understand more deeply that although mathematics gives us some important ways to understand the world, it will never tell the whole story. In order to go beyond the obvious in the graphs and numbers, it is important to help learners understand that there are many other variables involved, and that we might need to find out about some of them when wanting a deeper understanding of the situation. For example, the issue of excess deaths in relation to previous years, deaths not attributed to COVID-19, could have been raised in relation to task 2. Applications of mathematics to the real world are seldom exact, but help us to understand our situations.

Our remaining points relate to how the teacher mediates the tasks. In these lessons we saw two occasions where the teacher overestimated learners' abilities to do the mathematical calculations and was not prepared to address their unexpected errors. It might be that teachers who are used to typical mathematics lessons where they present formulae and learners practise how to perform a calculations are not aware of some of the typical errors their learners might make when performing calculations learnt in previous years. In addition, they may underestimate difficulties for learners in relating mathematical techniques learned previously to real-world situations. We saw the teacher faced with a number of choice points, which might take the class in different directions, particularly too far into either the mathematics or the everyday. These choice points will present themselves in this kind of teaching and teachers can be aware that they might happen and think in advance about how to deal with them. While it is never possible to predict everything that might happen, it may be possible to develop a set of principles as to how to bring the discussion back to linking the mathematics and the everyday, and how to make the most of mathematical and linking opportunities.

Finally, a crucial element of all learning, particularly mathematics learning, is that it involves emotions (Frenzel, Lampen, & Brodie, 2019), as well as moral and ethical concerns. In particular, when linking learning to learners' lifeworlds, emotions may come to the surface more readily.

This means that teachers who do this work, need to be aware of potential emotions and be in a position to deal with them, as the teacher in this article did.

Conclusion

The incorporation of learners' experiences into school knowledge can have advantages and disadvantages, as Charlot (2009) notes:

Very often an attempt is made to solve school failure by linking everything to the pupil's daily life. This connection, however, can constitute both a support and an obstacle at the same time. (p. 91)

All learners bring with them their own everyday experiences, which influence how they engage with school knowledge. As a contribution to current debates on building relationships between learners' lifeworlds and school mathematics knowledge we have shown that this is a complex and nuanced endeavour. We articulated the complexities and illuminated some of the nuances involved through an analysis of one teacher working with two tasks related to COVID-19.

We have argued that linking mathematics to learners' lifeworlds is possible and extremely difficult in relation to task design and how the teacher mediates the tasks. In relation to task design, we have argued that teachers cannot do it alone; they need to be supported by the curriculum and textbooks. We have also argued that we need to think about the full range of mathematics content in relation to applications to the real world, the extent to which the ambiguity of everyday and real-world examples can support or inhibit mathematical discussion and thinking in the classroom, and the strengths and weaknesses of mathematics as a gaze on the world. In relation to mediation, we saw that the teacher's practices were difficult to shift. Other research has shown that even in the best of circumstances, given the traditional ways of working in mathematics classrooms, changing practices is a challenge for many teachers. We saw that the teacher's expectations of learners may overdetermine decisions made in class and that decision points as to which direction to take the class may be more difficult than usual when trying to make links.

Although this study was conducted in a privileged situation, we think that the questions, challenges and dilemmas raised can be applied more broadly and that this case can resonate with other, more challenging, contexts and thus can be of use to others.

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Authors' contributions

All authors contributed equally to this work.

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Data availability

New data was created for this study.

Disclaimer

The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of any affiliated agency of the authors.

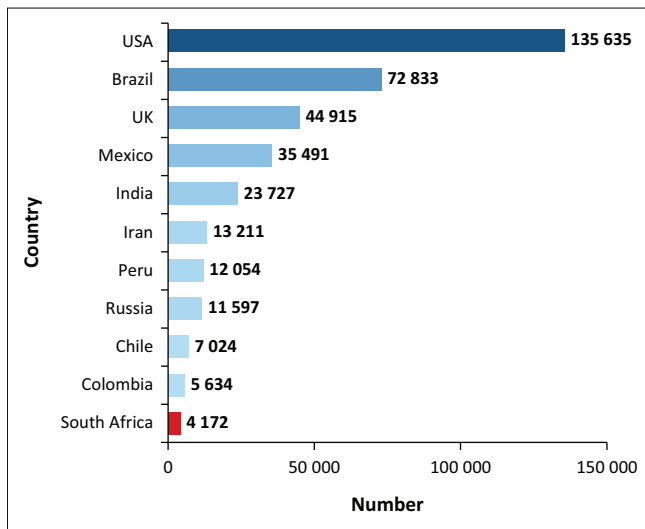
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Appendix starts on the next page →

Appendix 1

Images and tasks



Source: <https://www.news24.com/news24/SouthAfrica/Investigations/sa-recording-more-new-covid-19-cases-a-day-than-any-other-country-but-has-one-of-lowest-mortality-rates-20200715>

FIGURE 1-A1: The number of COVID-19 deaths in different countries as of 13 July 2020.

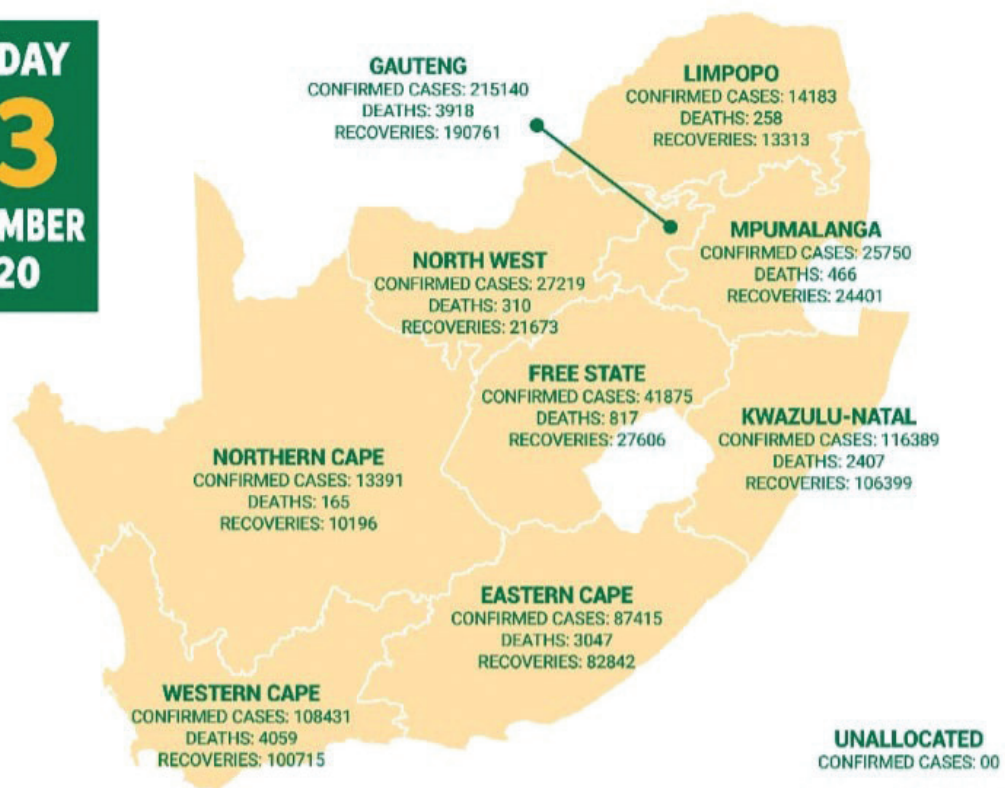
Questions about image 1

1. Make a list of questions that you think of when you look at this graph. Divide your list into questions that are mathematical and those that are non-mathematical.
2. Provide an appropriate label for each axis.
3. As of the 13th September 2020, South Africa has reported 15 447 deaths. What was the percentage increase in deaths between 13th July 2020 and 13th September 2020? What does this tell you?
4. Which measure of central tendency do you think is most appropriate for this set of data? Why?
5. Comment on the skewness of the data by comparing the mean and median. What does this tell you and why is it important?

COVID-19 STATISTICS IN SA

				
3 918 478	649 793	577 906	15 447	1 579
TESTS CONDUCTED	POSITIVE CASES IDENTIFIED	TOTAL RECOVERIES	TOTAL DEATHS	NEW CASES

SUNDAY
13
SEPTEMBER
2020



Learn more to Be READY for #COVID19:
www.sacoronavirus.co.za

Covid-19 public hotline: 0800 029 999
WhatsApp 'Hi' to 0600 123 456

Source: <https://sacoronavirus.co.za/2020/09/13/update-on-covid-19-13th-september-2020/>

FIGURE 2-A1: COVID-19 statistics as of 13 September 2020.

Questions about image 2

1. Calculate the percentage of confirmed cases in the Northern Cape and compare this with the other provinces. What does this suggest to you?
2. Based on these statistics (such as the confirmed cases and deaths), how do you feel being back at school and what were your experiences of schooling during lockdown?
3. When you are looking at this image, what do you find the most interesting or revealing about this data? Are there any questions that you wish to pursue or ask when you are looking at this data?
4. When looking at information on this image, how do you feel about the current level of restrictions in South Africa? Do you think it was wise for restrictions to be dropped to level 1? Justify your answer.
5. Do you think this information in this resource is trustworthy? Justify your answer.