A MULTI-COUNTRY STUDY OF TEACHERS' BELIEFS ABOUT IMPLICATIONS OF COVID-19 FOR CHANGING THE TEACHING OF STATISTICS AND MATHEMATICS

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This paper reports on a jointly organized exploration by researchers from four countries (Brazil, Australia, South Africa, Israel) concerning teachers' perceptions about statistics and mathematics content in print and digital media regarding COVID-19 (coronavirus) issues and its possible impact on future statistics education. The study involves a mixed-methods, multiple case-study design, with an online survey followed by focus groups. Preliminary and selected results are reported, highlighting teachers' views of new topics that should be added to the curriculum, teachers' perceived autonomy to make changes, tensions regarding teaching methods that can be used to implement new needed content, and more. The study has numerous implications regarding the link between curricula, school-level processes, teaching practices, and new societal needs for statistics and mathematics knowledge.

BACKGROUND

The study is motivated by the nature of the COVID-19 (coronavirus) pandemic and its sweeping impact on most facets of life, both nationally and internationally, including on education systems. The pandemic that started in early 2020 and is still ongoing flooded citizens and (young) adults from all walks of life across the globe, including teachers and learners, with vital statistical and mathematical information via diverse media channels (Gal & Geiger, 2022). We focus on teachers' beliefs and views regarding the aspects of the mathematics and statistics curriculum that may need to be re-examined in light of the nature of the information in news media that citizens, including young adults and school pupils, need to comprehend and critically evaluate.

There is a rich literature on beliefs of teachers (both in-service and prospective). Fives and Bruhl (2012) pointed to several general areas of beliefs: contextual and systemic issues; self-views (e.g., identity, professional role); content and subject-matter knowledge; teaching practices and approaches and their usefulness; and students (i.e., their skills, motivations, etc). Studies overall suggest that teachers' beliefs about these and related areas have an important role in shaping their professional decisions and actual practices, including in mathematics classrooms (Forgasz & Leder, 2008). However, few studies relate to teachers' beliefs about the actual *content* of instruction. Further, very few studies have addressed any facets of teachers' beliefs about the statistics or numeracy-related aspects of mathematics or STEM education (Umugiraneza et al., 2018).

New research on teachers' beliefs about instructional content in statistics is essential in light of the unique situation caused globally by the COVID-19 pandemic. Governments and other stakeholders needed to monitor the progression of the pandemic and inform the public about related findings and projections. This led to the production of large volumes of statistical and mathematical information and visualizations with many novel elements (Gal & Geiger, 2022), and to its communication to the public via multiple channels such as news media, websites, social networks, and blogs. Examples of notions that frequently came up in the media and in official communications include: 'flattening the curve'; 'replication/reproduction rates'; '7-day average'; and the extensive use and discussions regarding modelling, predictions, error, and strength of evidence. These are different or more advanced than the standard statistics content included at the school or even university levels and are not necessarily well understood by the public (Heyd-Metzuyanim, et al., 2021).

To date, however, virtually no research has examined what views and beliefs *teachers* may have developed regarding the knowledge demands on citizens and on themselves related to the COVID-19 pandemic, or regarding needed changes (if any) in subject-matter knowledge and curricula or in instructional methods in this regard. This is despite the importance of the connection between teachers' beliefs to the adoption of educational change or reform in the areas of statistics education (März & Kelchtermans, 2013) and data literacy (Shreiner & Dykes, 2021).

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Given this background and knowledge gaps, this study was designed to examine teachers' beliefs and views about pandemic-related changes in curricular content and teaching methods in mathematics and statistics. Due to space constraints and given that data analysis is ongoing, this brief paper presents only selected and preliminary results, aiming to illustrate some of the topics examined and demonstrate the potential of the project to contribute to new knowledge. The need for such research is pressing given the expectation that education will prepare learners for their future roles as numerate, engaged, and empowered citizens, as well as enable nations worldwide to address both current and future crises and societal changes.

METHOD

Approach. We chose to collect data in three countries (Brazil, Australia, South Africa) with diverse demographics, diverse education systems, and different profiles of progression through the pandemic. A multiple case-study, mixed-methods design was preferred, with an online survey followed by focus groups because the research literature on teachers' beliefs shows the value of combining both quantitative methodologies (e.g., surveys asking teachers to rate the strength or occurrence of different beliefs) and qualitative methodologies (e.g., open-ended survey items, interviews or focus groups that enable verbal explanations that expand beyond numerical ratings). We emphasize that we do *not* aim to compare the responses collected in the three countries to each other because the samples are convenience samples and are not fully comparable. Rather, we treat each country's data as a stand-alone case-study to benefit from the rich picture created when all findings are viewed holistically.

Data collection. All data collection was conducted remotely using virtual questionnaires and online group interviews (using Zoom) because many schools around the globe were closed for extended periods. In each participating country, given the complexities of contacting teachers and schools, we surveyed a convenience sample of teachers working in diverse schools and localities with sample sizes as follows: $N = 35$ for Australia, $N = 113$ for Brazil, and $N = 58$ for South Africa. To expand and deepen the information collected, each country team conducted two or three focus groups (FGs), each with four to eight teachers, that were recorded and transcribed.

Instruments. Questions for the survey and group interviews combined items from established scales (see Umugiraneza et al., 2018) with new questions developed by the multinational team to capture pandemic-related issues. The survey covered a wide range of topics, including teachers' perceptions regarding their exposure to pandemic-related print and digital media, perceived self-understanding of key mathematical and statistical ideas in the pandemic-related media, thoughts regarding needed changes to content and teaching methods, a teacher autonomy scale, and background and personal information. FG protocols expanded on several of these issues, including questions on changes in teaching practices during the pandemic, autonomy issues, and more. FGs also examined how teachers addressed in class or understood statistical topics that were commonly used in the media such as '7-day rolling averages' or comparisons 'per 100,000.' Each country team could adapt the instruments and FG questions to the unique circumstances of each country.

Analysis: The FG transcriptions were analyzed from a grounded qualitative approach of social research (Minayo & Deslandes, 2009) that aims to expand a theoretical framework on the subject studied within the cultural context, in this case the period of the COVID-19 pandemic, and is not intended to generalize. The survey results were analyzed after checking that internal consistency values for all scales were adequate (Cronbach's alpha above 0.70).

RESULTS

The sections below present preliminary findings from the three case studies (Australia, Brazil, South Africa). Given space constraints, we report selected findings to illustrate the potential of our approach and the range of issues that emerged or could be examined in connection with the pandemic's impact on statistics education topics. For all three countries, we focus on diverse insights from the FGs. For Australia, we also sketch some results from the survey.

Australia Results

The online survey included $N = 35$ teachers from diverse independent and government high schools. Here we refer to three topics: the pandemic's impact on teaching statistics; curricular topics

that should be changed due to the actual statistical and mathematical content in the media; and perceived teacher autonomy related to making changes to content or sequencing of topics.

How teachers addressed the pandemic in class. Most teachers surveyed indicated that they discussed the pandemic several times in the passing months, with the majority linking the pandemic to mainly statistics and probability curriculum strands of the mathematics curriculum. A few teachers responded that they had not discussed the pandemic at all, providing diverse explanations for that. For example, some teachers indicated that their school had made the decision to avoid the topic for students' emotional or mental wellbeing: "I'm concerned this could increase anxiety/trigger trauma in some students, although in other ways it would be helpful to their understanding of the situation. I have been collecting interesting COVID-19 graphs for use when appropriate." Some teachers indicated they could not fit pandemic-related issues into their teaching time or that they would like to do more about the pandemic but were constrained by the need to cover as much content as possible in an already overcrowded curriculum:

- Given the high stakes and long planning lead times required for Year 12 subjects, there is little scope to react in real time to current media events. Example questions can be drawn from the media and some discussions had, but the pace of the course usually precludes meaningful exploration of something that is not already planned.

Curricular topics that should be expanded or reduced due to the actual statistics and mathematics in the media. Teachers were presented with a list of specific topics to which they were asked to react. Most teachers felt that *more* time needs to be allocated to most topics mentioned, as displayed in Table 1.

Table 1. Topics and percentage of teachers indicating that more time needs to be allocated to the topics

Topic	Teachers (%)
Interpreting complex graphs that compare multiple groups or places	88
Using graphs to understand trends and how variables change over time	88
Understanding how probability is related to risk	71
Understanding the outputs of models	82
Doing mathematical modelling	76
Understanding assumptions and limitations in mathematical modelling	82
Comprehending mathematical/statistical ideas expressed in texts (e.g., newspaper)	94
Critically interpreting mathematics/statistics in news articles	71
Understanding statistical arguments must be supported by evidence	76
Conducting a complete statistics investigation research cycle	71

The only noteworthy exception was "calculating the probability of simple events"—only 11% of respondents suggested more time for this topic. In general, very few responses suggested any of the topics identified should be *reduced* in the curriculum. Teachers also supported increased time for inquiry-based and problem-based learning (PBL) as well as connections to real-life applications.

Teacher autonomy and institutional pressures. The Australian team held three focus groups during which teachers were asked about the extent to which they believed they could adjust curriculum content or sequencing to address mathematical/statistical content relevant to the pandemic. In instances where teachers held sole responsibility for a subject at a year level, they reported some flexibility in being able to adjust the sequencing; however, they articulated the lack of capacity to do so if other teachers were involved or if the content was not already addressed in the syllabus:

- Only in the Year 12 syllabus was I able to do that [shift teaching sequences to address pandemic issues]. … Other than that, there wasn't necessarily enough in the other subjects to really match, it would have to be a tangent and those things are hard to make time for.
- As long as I could still cover all the areas I needed to across the course of the year … I had pretty broad flexibility if I wanted to move things around, I could do that without too much challenge by management. With the lower year levels [more classes] … there is much more of a focus on keeping those classes well-aligned.

Brazil Results

The survey in Brazil included $N = 113$ teachers who mainly work in public schools at the elementary level. However, here we refer to selected results from two focus groups held in Brazil, one with elementary teachers and one with high-school teachers, each with six participants.

How teachers addressed the pandemic in class. Given a lead question "Was the topic of the COVID-19 pandemic addressed in your classroom, and if so, how?", most teachers recognized the importance of bringing statistical issues from pandemic-related media and daily life into the classroom:

- In my math classes we discussed a lot what was emerging in the media, the issue of graphs that showed the evolution of the pandemic, contamination (infection) now more recently from vaccination as well, the issue of 'moving average' that was new.
- The class has to arouse their interest so that they do not disperse ... it was quite challenging, so I used some data ... from research (about COVID-19) that was reported in the media.

Needed changes in content and methods. Another group of questions presented teachers with visualizations that included terms and graphs that were common in the pandemic media in all three participating countries, and asked: *"Is there a need for any change in the curriculum content, or the teaching methods, so that students can understand this* [referring to the examples, such as a graph comparing multiple countries by showing a 'moving average' over several months in terms of 'deaths per 100,000']?" Responses indicated that teachers are aware of knowledge gaps and the need to make changes in this regard to mediate the unfamiliar terms and visualizations for students: "In my classes I also discussed the issue of data that are broadcast by the media, it is the issue of the exponential curve of the data." The following excerpt from the same focus group, however, demonstrates a broader construction, namely a belief about the meaning of a curriculum and specifically a belief that teachers can change the practice without even changing the curriculum:

- So a criticism I also make is that for me the curriculum does not prepare ... The curriculum will ... induce the institution to do something according to established parameters. So who actually prepares will be a teacher who will interpret that curriculum, how the teacher will mobilize their knowledge until that curriculum can be used in class …

South Africa Results

The South African team held a survey and two focus groups, one with four high school teachers of 'mathematics' and one with four teachers of 'mathematical literacy.' (Note: these are different curricular strands in South Africa.) Here we illustrate additional themes that came up in the group interviews beyond those that emerged from the focus groups in Australia and Brazil.

Deeply personal impact of COVID-19 on both teachers and learners. During the interview, teachers noted that because of their own experiences, COVID-19 has become so personal that it was now a priority for them to keep abreast of the latest news and to share their advice with learners: "So, I take a deeper interest I look deeply into what is happening because now, I can identify a little bit more with it because I had like a personal experience."

Teachers noted that the pandemic has become more real for learners as well. One teacher mentioned that one of her learners lost his mother to COVID-19, which meant that the teacher had to counsel other learners about how to relate to their classmate and the impact of the pandemic on the personal level. The teacher also noted that learners have many emotional issues due to home isolation.

Agreement that statistics is important to develop because it offered opportunities to raise issues about understanding the pandemic. All teachers agreed that new terminology appearing in the media is challenging, and the subject 'maths' could be used to help educate students about the pandemic-related information presented in the media.

- I think maths the subject allows them to analyze the stats, I know the media presents it in a very user-friendly way, we can see who's positive how many deaths and you know you could see it per province, and stuff like that, but I think math also allows them to … look at the seven day average and understand the meaning behind it.
- If we have a shift in the focus on what we doing in classroom ... That shift will be beneficial for the learners to try and make use of the statistics to understand what's happening in the real world, especially during this pandemic. And that is vitally important for them, because there's so much stats available about the pandemic and they need to interpret it.

Teacher autonomy and institutional pressures. Teachers raised many perspectives and beliefs related to the interplay between themselves and the institutional environments within which they work. For example, some did not believe that they had autonomy to delve into pandemic-related issues during mathematics teaching time and discussed various reasons why they could not teach what they wanted to with respect to COVID-19. This included explicit instructions from school management not to engage in 'controversial' issues, such as dealing with COVID-19 or political debates. These teachers felt they were being monitored, and so they chose to stick to the curriculum. They felt under pressure to complete the syllabus (prescribed curriculum) and not add anything new because they need to finish preparing students to take, and succeed on, final exams that cover that given curriculum.

The following excerpts illustrate such issues regarding autonomy and institutional pressures.

- And management, we met face and the word comes from the top to say no discussion on this looking and stuff you cannot avoid it, and teachers, we had this before school started, we had a zoom session like this to say before you meet children, we have to tell you that you cannot allow discussions on this in your classrooms yeah.
- My classroom has got a camera. I'm being watched 24 hours all the time.
- With the learners they are only interested in learning those things like exams, they only interested in learning something if they're going to be tested on it.
- The reality of the situation is everything is assessment driven at the end of the year, we need to get a mark to promote these kids to the next year, and that is our circumstance.
- We are like stressed for time to finish, you know the syllabus. And all we're focusing, it is finishing the syllabus so that you know they can be ready for the exams.

DISCUSSION AND CONCLUSIONS

The results sketched above are preliminary because data analysis is still progressing. Several patterns can be seen already in the results of the surveys and the themes from the focus groups. These demonstrate the importance of studying teachers' beliefs and perspectives regarding the relevance of statistical and mathematical information in the (pandemic) media as a vehicle for educational reform, even if on a small scale (März & Kelchtermans, 2013).

Among other things, teachers recognized the importance of the COVID-19 pandemic as a change agent that should force long-term rethinking about educational processes related to statistics and mathematics and the need to strengthen the connections between classroom materials and information appearing in the media about the pandemic. Yet, teachers also pointed to many potential barriers to making changes to statistics-related curriculum or teaching practices even during the ongoing pandemic. They did not appear to believe that they had the autonomy to delve into new pandemic-based statistics during mathematics teaching time, and some had received instructions from school leadership to not discuss any controversial issues. Some teachers struggled with specific subtopics such as '7-day average,' proportionality aspects of comparisons 'per 100,000,' or 'modeling.'

Thus, our findings shed new light on tensions between formal mathematics and statistics school curricula and the teaching methods that can be used to implement them. This has implications for the links between curricula, schooling routines, and new societal needs. Teachers in all three participating countries, facing somewhat different profiles for their progression of the pandemic and working in different educational contexts, illustrate in their answers the importance of a strong professional identity and Pedagogical Content Knowledge (PCK) in the area of statistics. According to Shulman (1987), PCK refers to “the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners and presented for instruction” (p. 7). Certainly, the findings show that teachers hold beliefs related to their responsibility to teach new content and address topics that are not well understood by learners. However, teachers also identified barriers and pressures that may prevent them from acting on their beliefs or being able to implement changes in their teaching practices and curricular materials. Thus, the knowledge of the pandemic context, on the part of teachers, legitimizes pedagogical decisions related to the search for improving student engagement and including real-world contexts in the school routine. These findings corroborate prior findings (Schreiber & Porciúncula, 2021) regarding the specific PCK needed to teach statistics.

Teachers of mathematics and statistics face new professional dilemmas because of the pandemic (da Silva et al., 2021). We argue that this requires that school systems assist teachers to

engage with the mismatch between the established (intended) curriculum, and new societal needs in the media. Success in any curriculum reform process depends on the extent to which there is congruence between teacher beliefs and the vision driving the curriculum change (Handal & Herrington, 2003). This paper, although reporting preliminary results at this stage, illustrates that the pandemic has affected teachers in a deeply personal way, and it is imperative for them to help their students understand the information they see in the media. This study has identified specific areas in the curriculum that teachers believe need more attention. The results can inform professional dialogue about specific topics that learners in multiple countries need to understand but that are not addressed in mathematics and statistics curricula and instruction. Based on the results, future research should further examine related topics such as teachers' professional identity and autonomy, and how these affect teachers' ways of engagement with their school systems. We aim to further address such and related issues as this research project further evolves.

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