Investigating Pre-Service Teachers' Skills in Designing Numeracy Activities Across Curriculum Areas Involving Statistics

Seyum Getenet
University of Southern Queensland
seyum.getenet@usq.edu.au

Informed by teaching statistics across curriculum areas strategies, this study investigated the skills of 36 pre-service teachers (PSTs) who designed numeracy activities that focused on the statistics strand of the Australian curriculum. The data were analysed using descriptive statistics. The results showed that the PSTs designed numeracy activities focused on the science curriculum area. The results further showed that PSTs emphasised a few year levels and focused on collecting and recording data. The first stage of teaching statistics (designing effective questions) is often ignored in their activities. The approach adopted in this study can be used to identify PSTs' knowledge gaps and their professional learning requirements.

Numeracy is an essential skill for students, and teachers are expected to provide opportunities for them to use their numeracy knowledge in multiple contexts (ACARA, 2019). Across the globe, various strategies and approaches have been implemented to enhance students' numeracy skills. These approaches include teaching numeracy as a separate discipline or across curriculum areas (Forgasz et al., 2017). In Australia, for example, teachers are encouraged to develop students' numeracy skills by using mathematics confidently across non-mathematics curriculum areas, and numeracy is added as a general capability in the Australian national curriculum (ACARA, 2019). Similar approaches are adopted in other countries, such as England, the United States, and New Zealand, where numeracy is considered cross-curriculum areas (Brown et al., 2002; Ford, 2018; Neill, 2001).

Statistics is an essential component of numeracy, and it is increasingly being taught not only as part of mathematics but also across the curriculum in various countries (Watson & Smith, 2022). The development of statistical literacy is essential in a society that places great emphasis on using data to make decisions and interpretations (Booker et al., 2020). In Australia, statistics is taught as one of the major concepts within the Australian mathematics curriculum and developing students' skills in using statistics and data is necessary to validate decisions and inform conversations across all societal contexts (Watson & Callingham, 2020). However, the design of numeracy activities, including the focus on statistics across curriculum areas, requires competent teachers who can design and implement these activities (Bennison, 2015; Carter et al., 2015; Geiger et al., 2015). Initial teacher education institutions (ITEs) are responsible for developing pre-service teachers (PSTs) competencies, skills, and confidence to teach numeracy in schools across the curriculum areas (Sabbag et al., 2018). PSTs who are competent in teaching numeracy across curriculum areas can help students see the relevance of statistical skills in everyday life.

This study investigates the skills of PSTs who designed numeracy tasks that focus on statistics activities. Guided by the research question of how PSTs used statistics concepts in the design of numeracy activities across curriculum areas and which curriculum areas and year levels are focused, the study uses the concept of teaching statistics across the curriculum areas (Usiskin & Hall, 2015) and the process for teaching statistics (Bargagliotti et al., 2020) to frame the study. The study's approach can be used to identify PSTs' knowledge and skills gaps and their professional learning requirements to design statistics activities across curriculum areas. In addition, identifying these gaps can inform course and professional development design strategies to ensure competent teachers who can develop students' strong foundation in numeracy skills, including statistical literacy, to succeed in various academic disciplines and in their personal and professional lives.

(2023). In B. Reid-O'Connor, E. Prieto-Rodriguez, K. Holmes, & A. Hughes (Eds.), *Weaving mathematics education research from all perspectives*. *Proceedings of the 45th annual conference of the Mathematics Education Research Group of Australasia* (pp. 219–226). Newcastle: MERGA.

Background

This study focused on teaching statistics across the curriculum areas in the primary school context. As a result, the study delved into the intersections between numeracy and different curriculum domains, using statistics teaching as a key framework. More information on these topics is provided in the subsequent section.

Numeracy Across the Curriculum Areas and Statistics

Numeracy activities designed across non-mathematics curriculum areas are encouraged to enhance students' numeracy skills, critical thinking and transfer of mathematical skills to contexts outside the mathematics classroom (Bennison, 2015; Brown et al., 2002; Mathieson & Homer, 2021; Thornton & Hogan, 2004). This approach has the potential to empower students more than approaches that solely focus on developing numeracy skills through mathematics curriculum areas (ACARA, 2019; Bennison, 2015). The teaching of various mathematical concepts such as numbers, geometry, statistics, and data is integrated into this approach, with teachers often preferring to teach basic statistical concepts across curriculum areas (Gough, 2007; Geiger et al., 2015; Koellner et al., 2009).

Teaching numeracy across the curriculum, specifically statistics, is one of four possibilities discussed by Usiskin and Hall (2015) for teaching statistics as shown in Figure 1.

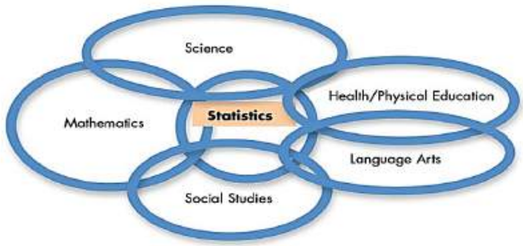

Figure 1. Statistics across the curriculum (Usiskin & Hall, 2015, p. 12).

The other three options are to teach statistics within mathematics, as applied mathematics or as an independent subject. The cross-curriculum approach to numeracy aligns with the expectation of the Australian Curriculum, where numeracy is viewed as one of the seven general capabilities essential across the curriculum. Interpreting statistical information is a key concept highlighted in the description of numeracy general capability (ACARA, 2019). To develop this skill, students need opportunities to solve problems in authentic contexts that involve collecting, recording, displaying, comparing and evaluating the effectiveness of data displays of various types. As a result, the teaching of statistics and data is embedded at all levels across all the curriculum areas to support students' understanding of other subject areas.

The design of numeracy activities across curriculum areas requires teachers to be competent in designing and implementing these tasks (Bennison, 2015; Carter et al., 2015; Geiger et al., 2015; Goos et al., 2013). ITEs are responsible for developing PSTs' competencies, skills, and confidence to teach numeracy in schools across the curriculum areas (Bargagliotti et al., 2020; Franklin et al., 2007).

Teaching Statistics

To effectively engage with numeracy aspects beyond the math curriculum, teachers require enhanced knowledge and competencies. ITEs must equip PSTs with the necessary skills, confidence, and understanding of numeracy teaching, including statistics. Therefore, ITEs should provide PSTs with the essential knowledge and skills for teaching statistics as part of their degree program courses.

Studies, such as Bargagliotti et al. (2020) and Franklin et al. (2007), have proposed a four-step process for teaching statistics to school students. For instance, Franklin et al. (2007) suggested the following steps: (1) formulate questions and anticipate variability, (2) design and implement a data collection plan, (3) analyse data using appropriate graphical and numerical methods, and (4) interpret the results and identify any relationships. Similarly, Bargagliotti et al. (2020) presented a comparable four-step process for teaching and solving statistical problems, illustrated in Figure 2.

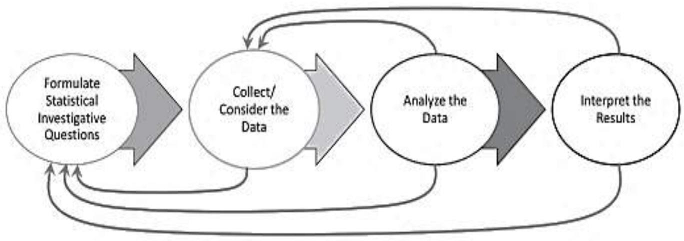

Figure 2. Statistical concept teaching process (Bargagliotti et al., 2020, p. 13).

Bargagliotti et al. (2020) stated that the main objective of statistical teaching is to gather and examine data in order to address statistical inquiry questions. This viewpoint is shared by several authors, including Booker et al. (2021), Reys et al. (2022), and Sabbag et al. (2018), who emphasised the significance of the four stages of teaching statistics and advancing through these stages to enhance primary school students' comprehension of statistical concepts. Each step and its description are provided in Table 1.

Table 1

Summary of Steps for Teaching Statistics Processes and Description

Steps	Description
Formulating questions	Analyse the situation being investigated and narrow it down to a series of specific questions
Collecting and recording data	Begin gathering and organising the data according to the plan developed. Tables or spreadsheets might require alterations to better incorporate the data being collected
Organising and representing data	What graphs or charts are needed to display and emphasise patterns or various statistical measures
Analysing and interpreting data	What does the data say?' Conclusions may be drawn based on the available data

According to Bargagliotti et al. (2020), the first step in teaching statistics is to formulate clear questions to be answered with collected data. Stating a good question gives students a reason and motivation for collecting and analysing data. Booker et al. (2021) and Reys et al. (2022) reviewed other studies and suggested that it is beneficial to encourage students to identify their own questions or problems rather than using pre-designed questions. After data is collected, the third step is to organise the information so that the results can be analysed and interpreted. Sabbag et al. (2018) and Reys et al. (2022) suggest that graphs can be used to present or organise data visually. Finally, interpreting data can be done through the use of questioning. Teachers should encourage students to examine their results and discuss questions that may be answered by the data at the final stage of teaching statistics.

The Australian Curriculum Version 8.4 (ACARA, 2019) includes statistics and probability across year levels, forming one of the three central content strands. At the Foundation level, students are expected to collect information to answer yes/no questions and make basic inferences (ACARA, 2019). In Year 2, students are required to collect categorical data on a topic of interest, sort the data, create data displays using tables, picture graphs, and lists, and interpret their data (ACARA, 2019). Similarly, in Year 5, students conduct similar statistical investigations but also examine numerical data and may represent their data using column graphs and dot plots, as well as present their work using digital technologies (ACARA, 2019).

Booker et al. (2021) suggest that these steps can be utilised as a roadmap to enhance students' proficiency and mastery in statistical analysis, allowing them to become active contributors when gathering, analysing, illustrating, and interpreting data. Moreover, it aids students in meaningfully engaging in the study of statistics and the acquisition of knowledge about it. In summary, these steps serve as a useful tool for PSTs seeking to improve students' statistical literacy.

Method

Context

This research is part of a broader investigation in which PSTs developed numeracy activities across various curriculum areas to determine their knowledge gaps. The research was conducted in the School of Education of an Australian university. Final-year PSTs who were prepared to teach students ranging from Foundation (average age of 5 years) to Year 6 (average age of 11 years) were recruited for this study. As part of their 4-year degree program, primary specialisation PSTs must complete three core mathematics curricula and pedagogy courses. The first two courses concentrate on teaching the Australian curriculum, including data and statistics that include the steps outlined in Table 1. The third mathematics education course emphasises the use of numeracy across curriculum areas. The current study was set in this course. The author of the present study was one of the course designers and has assessed PSTs assignments. In this course, PSTs must design numeracy activities across different curriculum areas, including humanities and social sciences [HASS] (Civics and Citizenship, Economics and Business, Geography and History), English, science, arts (music), technologies (design and technologies, and digital technologies), and health and physical education (HPE), according to version 8.4 of the Australian Curriculum. The general concept of designing numeracy activities was introduced to be used in ways that serve the PSTs' specific choice of curriculum areas and context to design numeracy activities.

The PSTs' design of numeracy activities must meet two requirements. First, they must comprehend the identified mathematical concepts by explaining the mathematical and non-mathematics concepts involved in the designed activities with examples. Furthermore, the PSTs must identify and explain the relevance of the concepts to the Australian Curriculum. Second, PSTs must develop numeracy activities in the specified curriculum area to teach the intended concepts. The numeracy activities must demonstrate how mathematics must be integrated within the identified non-mathematics curriculum area. Furthermore, the activities must be pertinent to the national curriculum outcome.

Participants and Data Collection

Data were part of the larger study gathered from 100 PSTs’ course assignment submissions. The submissions were all from the same group of PSTs. Ethical protocols for collecting the PSTs' archived assignment data were provided by the relevant University and School authorities. The PSTs were given the freedom to choose and design numeracy activities, with the option to select any mathematical concept and any non-mathematics curriculum area ranging from the foundation to Year 6. However, most PSTs focused on statistics (36%) and measurement and geometry strands (25%) of the Australian Curriculum when designing their numeracy activities. The focus of this study was on the 36 PSTs who designed their numeracy activities based on statistics. The participants' year level was all fourth year, and the author of the study had access only to their year level and archived assignment submissions.

Analysis

The analysis of the data was a two-step process. Initially, the assignment submissions were evaluated to meet the course requirements, and notes were taken for the second step of the analysis. In the first step, the numeracy tasks were evaluated based on two criteria and supported by a marking rubric. The first criterion aimed to understand the identified mathematical concepts by explaining the mathematical and non-mathematics concepts involved in the designed activities, with examples. In the second part, PSTs were asked to design numeracy activities in the identified curriculum area to teach the intended concepts. PSTs who designed numeracy activities focused on statistics were identified, and descriptive statistics (mainly frequency and percentage) were utilised to describe the focus of the year levels and curriculum areas using SPSS. Additionally, the focus of the four-step process of teaching statistics was also identified.

Results and Discussion

The findings are organised into two sections. First, the identified curriculum areas and the dominant mathematics concepts across different year levels are presented. Second, a more detailed analysis of the statistics concepts in relation to the PSTs' focus and how the concepts were taught are presented and discussed. The results showcase how PSTs interpreted and responded to the assignment questions.

Focus on Year Levels and Curriculum Areas

The PSTs had the option to select and design numeracy activities for any year level from Foundation to Year 6 and using any non-mathematics curriculum areas. Table 2 summarises the frequency (N) of occurrence of the various curriculum areas across different year levels.

Table 2

Curriculum Areas Focused and Numeracy Activities Across the Year Levels

Year Level	Curriculum area and counts (N)					Total
	Business	Geography	History	HPE	Science	
Year 1	0	0	0	0	1	1
Year 2	0	0	0	0	1	1
Year 3	0	2	1	1	5	9
Year 4	0	1	2	3	3	9
Year 5	1	2	2	1	6	12
Year 6	0	2	0	2	0	4
Total	1	7	5	7	16	36

Table 2 displays that Science (N=16), Geography (N=7) and HPE (N=7) were the most frequently utilised curriculum areas in the designed numeracy activities. Specifically, Science was most commonly employed in Year 5 (N=6). On the other hand, English and Design and Technologies were not utilised in the designed statistical activities across curriculum areas. This may be due to PSTs' lack of confidence in using numeracy across other curriculum areas such as English and technology, or they may encounter difficulties identifying appropriate statistical ideas to embed in other areas. Similar to these findings, Geiger et al. (2013) and Koellner et al. (2009) reported that teachers were less self-assured in integrating numeracy across English/literacy. The majority of the designed activities focused on Years 3, 4, and 5 (N=30), with less emphasis on Years 1 and 2, as indicated in Table 2.

Statistical Teaching Steps and Year Levels

The PSTs were tasked with implementing the teaching principles of statistics in their designed numeracy activities, which involved the four-step process described in Table 1. As indicated in Figure 3, however, only a small number of PSTs (n=7) included all four steps in their activities. Five PSTs only utilised one of the four steps of teaching statistics, which was either analysing and interpreting data or collecting data. For instance, PST1 (with ID 1) incorporated numeracy activities that necessitated collecting, recording, organising, and representing data without a clearly defined question to answer (refer to Figure 2).

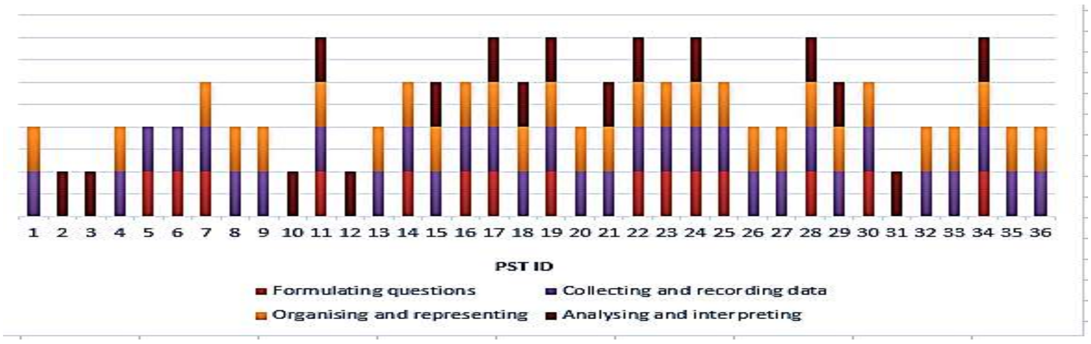

Figure 3. The steps used in the activities across year levels.

Table 3 reveals that a significant number of PSTs (N=29[31.9%]) incorporated the steps of organising and representing data in their designed numeracy activities. However, some critical steps for teaching statistics, such as formulating a good question, were overlooked. Only 15 PSTs included formulating questions in their designed numeracy activities, as indicated in Table 3. More than 50% of the activities did not entail formulating a good question. Nonetheless, stating a good question is a crucial step that provides students with a purpose and motivation for engaging in the other steps of learning/teaching statistics, such as collecting and analysing data (Bargagliotti et al., 2020; Reys et al., 2022; Sabbag et al., 2018). Table 3 provides a detailed breakdown of each step of the teaching statistics process and the frequencies detected in the designed numeracy activities.

Table 3

Frequencies of Statistics Teaching Step Processes in the Numeracy Activities

Step	N	%
Formulating questions	15	16.5%
Collecting and recording data	31	34.1%
Organising and representing data	29	31.9%
Analysing and interpreting data	16	17.6%
Total activities designed	36	100%

Table 3 shows that the majority of PSTs (N=31 [34.1%]) incorporated collecting and recording data in their designed numeracy activities. This finding aligns with Gough's (2007) argument that creating and interpreting data tables and graphs are fundamental mathematical concepts found in many areas of science. However, it is important to note that PSTs must also acquire the necessary skills and strategies for teaching statistics (e.g., Bargagliotti et al., 2020; Franklin et al., 2007) across different curriculum areas. Teacher education programs have a responsibility to cultivate PSTs' competencies, skills, and confidence in teaching numeracy across diverse curriculum areas.

Conclusion

The importance of statistical literacy has been widely recognised in the literature. According to the Australian Curriculum, Assessment and Reporting Authority (2019), statistical literacy is essential for interpreting and making sense of the world around us. Developing PSTs' skills in designing statistically rich activities across multiple curriculum areas is vital for students' numeracy skill development in schools. This is particularly important given the increasing emphasis on data-driven decision-making in society (Day, 2013).

This study was conducted at an Australian University's School of Education and involved final-year Pre-Service Teachers (PSTs) preparing to teach Foundation to Year 6 students. The study aimed to investigate the PSTs' skills in designing numeracy tasks that focused on the statistics strand of the Australian curriculum. The study's results are consistent with previous research that has found that PSTs tend to focus on a limited range of curriculum areas when designing numeracy activities (Geiger et al., 2015; Koellner et al., 2009). This limited focus can reduce students' confidence and opportunities to use their numeracy skills in complex contexts. Therefore, PSTs need to develop their skills in designing numeracy activities that incorporate a broader range of curriculum areas.

The study also highlights the importance of including all the steps for teaching statistics when designing numeracy activities. As noted by Booker et al. (2021) and Reys et al. (2022), steps such as formulating questions, analysing and interpreting data, and making conclusions are essential in enabling students to proceed to the other steps of solving statistical problems, including collecting and analysing data. Therefore, PSTs need to receive more training and support to develop their skills and confidence in designing numeracy activities that incorporate all the steps for teaching statistics across different curriculum areas.

Moreover, designing numeracy activities across curriculum areas that require students to analyse data and draw conclusions can help students develop critical thinking and problem-solving skills (Sabbag et al., 2018). Therefore, PSTs need to develop their skills in designing numeracy activities that promote these skills.

Although the study's findings are insightful, its small sample size limits the generalizability of the results. Future research could benefit from larger samples and more detailed analyses of PSTs-designed numeracy activities. However, the study's findings provide valuable insights into how PSTs can incorporate statistical concepts into numeracy activities across different curriculum areas and year levels. These findings have relevance for researchers and policymakers interested in developing PSTs' skills in integrating statistics across the curriculum and enhancing students' overall numeracy experiences in schools.

Overall, this study highlights the need for PSTs to develop their skills in designing numeracy activities that incorporate statistical concepts across a broader range of curriculum areas. The study's findings suggest that PSTs need more training and support to develop their confidence and skills in teaching statistics and numeracy across curriculum areas. By doing so, PSTs can help students develop critical thinking and problem-solving skills, which are essential for success in today's data-driven society.

References

Australian Curriculum, Assessment and Reporting Authority. (2019). *The Australian curriculum*. ACARA. https://www.australiancurriculum.edu.au/

Bargagliotti, A., Franklin, C., Arnold, P., Gould, R., Johnson, S., Perez, L., & Spangler, D. A. (2020). *Pre-K-12 guidelines for assessment and instruction in statistics education II (GAISE II)*. American Statistical Association. https://www.amstat.org/asa/fles/pdfs/ GAISE/GAISEIIPreK-12_Full.pdf

Bennison, A. (2015). Supporting teachers to embed numeracy across the curriculum: A sociocultural approach. *International Journal on Mathematics Education, 47*(4), 561–573. https://doi.org/10.1007/s11858-015-0706-3

Booker, G., Bond, D., Sparrow, L., & Swan, P. (2020). *Teaching primary mathematics (6th ed)*. Pearson Higher Education.

Brown, M., Askew, M., Baker, D., Denvir, H., & Millett, A. (2002). Is the national numeracy strategy research-based? *British Journal of Educational Studies, 46*(4), 362–385. https://doi.org/10.1111/1467-8527.00090

Carter, M. G., Klenowski, V., & Chalmers, C. (2015). Challenges in embedding numeracy throughout the curriculum in three Queensland secondary schools. *The Australian Educational Researcher, 42*(5), 595–611. https://doi.org/10.1007/s13384-015-0188-x

Ford, K. (2018). Persisting gaps: Labor market outcomes and numeracy skill levels of first-generation and multi-generation college graduates in the United States. *Research in Social Stratification and Mobility, 56*(2018), 21–27. https://doi.org/10.1016/j.rssm.2018.06.003.

Forgasz, H. Leder, G., & Hall, J. (2017). Numeracy across the curriculum in Australian schools: Teacher education students' and practising teachers' views and understandings of numeracy. *Numeracy, 10*(2), 1–23. http://doi.org/10.5038/1936-4660.10.2.2

Franklin, C., Kader, G., Mewborn, D., Moreno, J., Peck, R., Perry, M., & Scheafer, R. (2007). *Guidelines for assessment and instruction in statistics education (GAISE) report: A pre-K-12 curriculum framework*. American Statistical Association. http://www.amstat. org/education/gaise/

Geiger, V., Forgasz, H., & Goos, M. (2015). A critical orientation to numeracy across the curriculum. *International Journal on Mathematics Education, 47*(4), 611–624. https://doi.org/10.1007/s11858-014-0648-1

Goos, M., Geiger, V., & Dole, S. (2013). Designing rich numeracy tasks. In C. Margolinas (Ed.), *Task design in mathematics education: Proceedings of ICMI Study 22* (pp. 589–598). Oxford.

Gough, J. (2007). Make your school's numeracy-across-the-curriculum policy. *Australian Mathematics Teacher, 63*(3), 31–39. http://hdl.handle.net/10536/DRO/DU:30007800

Koellner, K., Wallace, F. H., & Swackhamer, L. (2009). Integrating literature to support mathematics learning in middle school. *Middle School Journal, 41*(2), 30–39. https://doi.org/10.1080/00940771.2009.11461710

Mathieson, R., & Homer, M. (2021). "I was told it would help with my Psychology": Do post-16 core maths qualifications in England support other subjects? *Research in Mathematics Education*, 1–19. https://doi.org/10.1080/14794802.2021.1959391

Neill, W. A. (2001). The essentials of numeracy. *Paper presented at the New Zealand Association of Researchers in Education Conference* (pp. 6–9). Available at https://www.nzcer.org.nz/system/files/10604.pdf

Reys, R., Rogers, A., Bragg, L., Cooke, A., Fanshawe, M., & Gronow, M. (2022). *Helping children learn mathematics* (4th ed.). John Wiley & Sons.

Sabbag, A., Garfield, J., & Zieffler, A. (2018). Assessing statistical literacy and statistical reasoning: The REALI instrument. *Statistics Education Research Journal, 17*(2), 141–160. https://doi.org/10.52041/serj.v17i2.163

Thornton, S., & Hogan, J. (2004). Orientations to numeracy: Teachers' confidence and disposition to use mathematics across the curriculum. In M. J. Hoines, & A. B. Fuglestad (Eds.), *Proceedings of the 28th conference of the International Group for the Psychology of Mathematics Education* (Vol. 4, pp. 315–320). PME.

Usiskin, Z., & Hall, K. (2015). The relationships between statistics and other subjects in the K–12 curriculum. *Chance, 28*(3), 4–18. https://doi.org/10.1080/09332480.2015.1099361

Watson, J., & Callingham, R. (2020). COVID-19 and the need for statistical literacy. *Australian Mathematics Education Journal, 2*(2), 16–21. https://search.informit.org/doi/10.3316/informit.287208637600347

Watson, J., & Smith, C. (2022). Statistics education at a time of global disruption and crises: A growing challenge for the curriculum, classroom and beyond. *Curriculum Perspectives*, *42*(2), 171–179. https://doi.org/10.1007/s41297-022-00167-7