

The Importance of Statistical Literacy in Mathematics Teacher Education

Nadia Naqvi

nadianaqvi.irc@gmail.com

NED University of Engineering and Technology <https://orcid.org/0009-0000-9557-8929>

Research Article

Keywords: Statistical literacy, Statistics Education, Pre-service Statistics Teacher Education, Mathematics Education

Posted Date: October 12th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-11287857/v1>

License:   This work is licensed under a Creative Commons Attribution 4.0 International License.
[Read Full License](#)

Additional Declarations: The authors declare no competing interests.

Abstract

One of the major challenges in Statistics Education is to promote statistical literacy and foster critical attitudes toward the use of statistical data in society. The preparation of teachers who will teach Statistics is especially significant in terms of pedagogical approaches based on statistical literacy. Statistical literacy is characterized by two components: cognitive (statistical and mathematical knowledge) and dispositional (beliefs, attitudes, and critical thinking). However, Mathematics teacher education programmes often do not explicitly address statistical literacy as an object of study. This article discusses findings from a research study that investigated how pre-service Mathematics teachers understood statistical literacy within a teacher education course designed to explore different dimensions of statistical literacy. The present discussion focuses specifically on data obtained through semi-structured interviews. The findings indicate that, when working with data related to meaningful and socially relevant issues, the participants were able to engage effectively in data interpretation. They expressed their own views about the information rather than limiting their responses to purely mathematical answers. The analysis also suggests that deficiencies in statistical and/or mathematical knowledge sometimes restricted the participants' interpretations; however, these limitations did not prevent them from developing elements of statistical literacy.

1. Introduction

Statistics Education, as a field of research, is concerned with issues related to the teaching and learning of concepts and procedures associated with Statistics, Probability, and Combinatorics. In Latin America, researchers and educators have increasingly taken on the challenge of promoting statistical literacy at different levels of education, including both basic education and higher education.

Within the educational context, Statistics Education has an important role in supporting the development of statistical knowledge from the early years of schooling. The report on Statistical Education of Teachers (SET) suggests that students need to be introduced to the idea of data at an early age. This means understanding that data are not simply numbers, categories, sounds, or images. Rather, data exist within a context, vary from one situation to another, and can be used to answer questions about the world around us.

The growing emphasis on statistical literacy is mainly associated with the need to develop people's ability to deal with the different forms in which statistical information and messages are represented in everyday life.

The era of technological advancement is very fast, and has altered the perception and understanding of the world. In addition to this technological development, it is essential to train people to comprehend the information that is constantly conveyed to them, especially statistical messages presented in different languages and different representations. As such, the democratization of technology can only be complete if society possesses knowledge and skills to comprehend and critically assess information it accesses.

Making decisions and engaging in public debate in democratic societies relies a lot on arguments backed by evidence. Meanwhile, however, misinformation has become more prevalent.

Such information is often incorrectly described simply as "fake news", although misinformation and deliberately fabricated information are not necessarily the same thing. The production and dissemination of false or misleading information can pose serious threats to society. This problem becomes even more significant when large sections of the population have limited educational opportunities and consequently have difficulty critically analyzing the information presented to them.

There is therefore a growing need for a culture of knowledge that enables people to understand this new environment of producing, communicating, and consuming information. Introduced the concept of statistical culture in response to the need for citizens to interpret, critically evaluate, and communicate statistical information and messages in society. Similarly, Ben-Zvi and Garfield (2004) argued that such abilities should form an important part of educational programmes so that students can appropriately evaluate evidence and claims based on data.

From this perspective, the development of a statistical culture depends not only on the inclusion of statistical content but also on how that content is taught, beginning in the early years of education. As Batanero (2019) points out, simply including a topic in a curriculum does not automatically guarantee that it will be taught or learned appropriately.

The introduction of Statistics into basic education has stimulated considerable research, particularly in Pakistan, following the implementation of the National Curriculum Parameters in the late 1990s. Since then, several researchers have investigated the statistical preparation of future Mathematics teachers (Lopes, 2013; Pamplona, 2012; Costa & Pamplona, 2011; Costa & Nacarato, 2011; Pamplona & Carvalho, 2009). Their findings have repeatedly indicated weaknesses in the statistical preparation provided to pre-service Mathematics teachers.

One of the problems identified by these studies is that, within Mathematics teacher education programmes, Statistics is frequently treated as a branch of applied Mathematics. Such an approach often places considerable emphasis on mathematical calculations, theorem-based demonstrations, and the application of algorithms.

A direct consequence of this approach is highlighted by **Batanero (2011)**, who observed that Statistics in many school curricula had traditionally been reduced to formula-based instruction. Such teaching can result in students entering higher education without sufficient statistical understanding and can contribute to statistical illiteracy among adults. This type of statistical instruction, which gives priority to mathematical techniques and procedures, overlooks the non-deterministic nature of Statistics. It may also fail to encourage students to think critically about the many phenomena that form part of their everyday lives, particularly social phenomena.

Considering these issues, and recognizing the important role that Mathematics graduates will play in promoting statistical literacy among students in basic education, the general objective of the research was to analyze pre-service Mathematics teachers' understandings of statistical literacy within the context of a teacher education course that explored critical dimensions of statistical literacy.

Several tools were used to collect data for this purpose. Among them was a semi-structured interview, and the present article focuses specifically on the findings obtained through this tool. The interview analysis reported here forms part of a doctoral research project conducted in Pakistan.

2. Theoretical Perspectives

The main educational objective of Statistics should be to help students understand the world in which they live. In Pakistan, Statistics is generally included within Mathematics education and is therefore usually taught by Mathematics teachers. A serious issue with teaching Statistics, however, is the failure to acknowledge its epistemological distinctiveness from Mathematics. While Mathematics is usually thought of as a subject where everything is determined and certain, Statistics has a great deal to do with uncertainty, variability, and phenomena that can't be predicted with absolute certainty. If only taught as an extension of Mathematics, however, students may have restricted chances to build up an adequate understanding of statistical concepts and reasoning. For this reason, Statistics education within Mathematics teacher education programmes should give greater importance to the contexts in which statistical information is produced and interpreted. Moore (1990) emphasized the importance of understanding "numbers in context", meaning that statistical numbers should not be interpreted independently of the situations from which they originate. Similarly, Gal (2019) argues that statistical learning should be connected to meaningful situations that are relevant to students' real lives. From this perspective, statistical education should focus more strongly on fundamental statistical ideas and less on calculations and procedural techniques. Nevertheless, statistical instruction in Pakistan has traditionally placed considerable emphasis on technical and procedural aspects. The Statistics course offered to future Mathematics teachers should therefore contribute to the development of statistical literacy. Its purpose should not be limited to teaching basic statistical terminology or formal statistical procedures. Rather, it should contribute to the future teachers' general competence in comprehending the use of Statistics to structure, describe, communicate and, in some cases, influence social and economic life. Critical Mathematics Education is also closely linked with the principles of Statistical Literacy. Critical skills allow people to interpret and investigate social, political and economic events. Statistics is important in this process as it is used to convert data into information and messages that can affect the decisions of individuals, institutions and society. **Gal's (2002)** definition of statistical literacy is a quite general definition that extends beyond the capacity to conduct statistical procedures. Statistical literacy involves the ability to critically evaluate statistical information, discuss it, communicate an understanding of statistical messages, and express informed opinions and judgments. According to Gal's (2002) model, statistical literacy consists of both cognitive and dispositional elements. The cognitive elements include:

- literacy skills;
- statistical knowledge;
- mathematical knowledge;
- contextual knowledge; and
- critical skills.

The dispositional elements include:

- beliefs;
- Attitudes; and
- a critical stance.

These elements do not operate independently. Rather, they interact when individuals interpret, evaluate, and communicate statistical information encountered in everyday life.

In the present research, particular attention is given to two dimensions of Gal's model: critical skills, which constitute a cognitive element, and critical stance, which represents a dispositional element. When individuals encounter statistical information, they need to ask questions about how the information was produced. For example, they may need to consider the source of the data, how the sample was selected, whether the sample adequately represents the population, how the data were collected, and whether graphs and tables accurately represent the information.

In this sense, critical skills involve questioning the procedures and information presented in statistical investigations. The critical approach, however, is assessing the outcomes of an investigation and assuming a stance on the basis of the outcomes.

The acquisition of these skills is especially relevant because people often find themselves in situations where they have to deal with statistical information in newspapers, on TV, on social networks, on websites, in advertisements, etc. People who just read numbers and don't ask questions about how and what they came from can fall for misinterpretations.

The ideology of certainty is also relevant with regards to this perspective as discussed by Skovsmose (2007, 2013). Ideology of certainty is when mathematical and numerical information is believed to be objective and unquestionable.

This attitude can have a negative impact on the development of a critical understanding of Statistics. All statistical information comes with conditions, assumptions, data collection methods, variability and uncertainty. So, it is important to not take statistical results as gospel. In critical statistical literacy, people should be able to ask questions about numerical information and not take it for granted. Building this skill can assist individuals understand that statistical outcomes are created with specific data, procedures, contexts, and interpretations. Therefore, statistical literacy should not only encompass the knowledge of how to compute statistical measures but also have to include an understanding of

statistical information, its context, questioning the methods used to generate it, and forming informed attitudes to the conclusions drawn. This is an important point of view for future Mathematics teachers. Teachers must have adequate statistical knowledge to be able to inform their students to go beyond mere calculation and interpret and analyze statistical data with meaning. Therefore, opportunities for pre-service teachers to experience Statistics in real-life and socially relevant contexts should be provided in Mathematics teacher education programmes.

3. Methodology

This study adopted a qualitative research approach. The research involved nine students enrolled in a Mathematics teacher education programme at a public university in Pakistan. The participants were identified as L1 to L9 in order to preserve their anonymity.

Most of the participants were male and their ages ranged from 20 to 23 years. Five participants were enrolled in the seventh semester of the programme, while four had not yet completed the Statistics course. Participants L7 and L9 were in the final year of their degree programme.

The participants were selected through convenience sampling. An invitation was sent by email to approximately 30 students enrolled in the Mathematics teacher education programme. Ten students initially responded to the invitation, but one subsequently withdrew from the study. Consequently, nine students participated in the research.

Individual semi-structured interviews were conducted with the participants. Each interview lasted approximately 30 minutes, and a total of seven interview sessions were conducted.

The interview protocol was developed on the basis of **Gal's (2002)** statistical literacy model. The questions were organized into three main blocks. The first block addressed the participants' academic backgrounds and experiences. The second block included activities involving the interpretation of graphs and tables. The third block explored the participants' opinions and reflections concerning the activities involving statistical representations.

The complete interview consisted of 19 questions related to statistical representations. Because of the space limitations of the article, the present study discusses ten of these questions.

The activities used during the interviews were based on controversial and socially relevant topics reported in the media, particularly information concerning homicide and violence against women. The use of such topics was intended to provide participants with authentic contexts in which statistical information could be interpreted and critically discussed.

3.1 Activity 1 Interpreting Homicide Rate Data

The first activity was a graph depicting the homicide rates in Pakistan the period 2005–2015. The participants were asked questions concerning the conclusions that could be drawn from the graph,

variations in homicide rates, comparisons between regions, and possible predictions for the year 2030. They were also asked what additional information they considered necessary for a better understanding of the data. The graph combined bars and lines. The bars represented the national homicide rate, while the lines represented the rates for different Pakistan regions. The information was obtained from the Atlas da **Violência 2017** (Cerqueira et al., 2017). An important aspect of the activity was that the measurement unit for the rates—per 100,000 inhabitants—was deliberately omitted. This omission was intended to encourage participants to question the information presented in the graph and to identify information that would be necessary for an appropriate interpretation.

3.2 Activity 2 Analysis and Interpretation of Female Homicide Rate Trends (2003–2013)

The second activity was a graph of the female homicide rate over the 11-year period from 2003 to 2013. In this instance the rates were per 100,000 people. The participants were asked to discuss their analysis of information given in the graph, probable decrease or increase in the rates and possible explanations for the observed trends. They were also asked what type of information they would need to determine the rate and what they might want to know about the source and reliability of the data given in the graph. The activities were intended to prompt the participants to think not just about numbers but the context, source, structure and interpretation of statistical information.

4. Data Analysis

Interviews were recorded and then transcribed for analysis. Initially, the researchers carried out a preliminary or "floating" reading of the transcripts in order to identify meaningful excerpts and recurring patterns in the participants' responses. The analytical categories are the result of the comparison that was carried on between the theoretical literature and the empirical data gathered in the interviews. The categories were therefore developed through a process of interaction between the theoretical perspectives and participants' responses.

Two broad categories were established.

The first category comprised knowledge elements, such as:

- Statistical knowledge;
- Mathematical knowledge;
- Contextual knowledge; and
- Critical skills.

The second category involved dispositional elements, especially:

- Critical stance; and
- Certainty.

The categories were drawn from **Gal's (2002)** model of statistical literacy with the main focus on the dimensions presented.

5. Results and Discussion

The 19 interview questions generated a total of 176 responses. Due to the limitations of space, ten questions were selected for detailed analysis in the article. The distribution of the responses according to the analytical categories is presented below:

Category	Frequency	Percentage
Statistical knowledge	50	28.4%
Mathematical knowledge	21	12.0%
Contextual knowledge	16	9.1%
Critical skills	13	7.4%
Critical stance	15	8.5%
Certainty	0	0.0%

The knowledge elements—statistical knowledge, mathematical knowledge, contextual knowledge, and critical skills—accounted for approximately 56.9% of all responses. Statistical and mathematical knowledge together represented 40.4%, while contextual knowledge and critical skills represented 16.5%. Critical stance accounted for 8.5% of the responses.

Approximately 43.1% of the responses were evasive, incomplete, or consisted of only one word or a very brief answer.

The analysis demonstrated that participants used different cognitive elements when interpreting statistical information. They also incorporated their own opinions and experiences into their responses instead of restricting themselves to purely mathematical answers.

5.1 Statistical Knowledge

Statistical knowledge was the most frequently identified category, accounting for 50 responses, or 28.4% of the total. Many participants demonstrated an awareness of statistical variation when discussing the graphs. Their responses indicated that they could identify increases, decreases, and differences in the values presented. However, the participants' statistical interpretations were not always sufficiently developed. In several cases, participants recognized a pattern in the data but did not provide a detailed statistical explanation for that pattern.

This suggests that participants possessed some elements of statistical knowledge but did not always have sufficient conceptual understanding to provide more elaborate interpretations.

5.2 Contextual Knowledge

Contextual knowledge received 16 responses, covering 9.1% of the items.

The general knowledge of participants and their personal experiences of Pakistani society were often used to interpret the statistical information. The social context of homicide and violence was particularly relevant to their interpretations.

But not all conclusions were necessarily accurate based on contextual knowledge. Participant L4, for instance, proposed that the homicide rate should be high in the big city Karachi.

This answer shows that some contextual knowledge has been applied, but the argument is not necessarily consistent with the given statistical information. Large population or large city does not necessarily mean a higher homicide rate if rates are standardized by population size.

As illustrated in this example, contextual knowledge can affect the interpretation of statistics, and it can also have misconceptions.

5.3 Mathematical Knowledge

Mathematical knowledge appeared in 21 responses, representing 12.0% of the total.

Some participants experienced difficulties in interpreting the statistical rates presented in the activities. In particular, there was evidence of confusion between a rate and concepts such as a mean or an index.

Some participants were unable to explain how the homicide rate was calculated. Three out of nine respondents identified specifically that he did not know how the rate was determined.

Participant L9 came closest to giving a suitable definition, saying that the rate was the number of women killed amongst 100,000 people.

Understanding rates is particularly important when interpreting social and economic indicators. A lack of mathematical understanding can therefore restrict individuals' ability to interpret statistical information appropriately.

The findings indicate that mathematical knowledge and statistical knowledge are closely connected. Difficulties with basic mathematical concepts may consequently limit the development of more sophisticated statistical interpretations.

5.4 Critical Skills

Critical skills were identified in 13 responses, corresponding to 7.4% of the total.

One example of critical thinking involved questioning the source of the statistical information. Participant L3 demonstrated an awareness that information should not simply be accepted without

considering where it originated.

Critical skills are important because statistical information is produced through particular procedures. Understanding who collected the data, how the sample was selected, what variables were considered, and how the information was represented can influence the interpretation of statistical results.

Although some participants demonstrated elements of critical questioning, these responses were relatively limited in comparison with responses involving statistical and mathematical knowledge.

5.5 Critical Stance

Critical stance appeared in 15 responses, representing 8.5% of the total.

Participants sometimes expressed their own positions regarding the social issues represented in the graphs. Their responses demonstrated that they were not merely processing the numerical information but were also attempting to interpret the social meaning of the data.

For example, participants expressed opinions concerning violence in Pakistan and the possible reasons for the patterns presented in the graphs.

However, their critical positions were not always supported by detailed statistical or mathematical reasoning. In many cases, participants expressed an opinion without providing sufficient justification based on the data.

It is suggested that the relatively low frequency of critical stance, may have something to do with the traditional approach to teaching Statistics in Mathematics teacher education programme. If statistical education focuses exclusively on the calculations of formulas and procedures with no context, students may not have many chances to make critical interpretations of statistical information.

5.6 Certainty

It is interesting that no responses were put in the certainty category. The analysis shows zero cases, which's 0.0%. This finding suggests that participants did not clearly show an unquestioning belief in the certainty of numerical information during the interview. The participants did not seem to hold certainty. However the lack of responses, in this category should not automatically be seen as proof that participants have fully developed statistical perspectives. The participants' knowledge of statistics and mathematics may still have shaped how deep their interpretations were.

6. Discussion

The research shows that the participants were able to interact with statistical information differently. In case when the information was associated with socially relevant topics – homicides and violence against women, the participants did not limit themselves to the use of the mathematical formulas only.

On the contrary, participants quite often added their personal opinions, social context knowledge and knowledge about social issues to their answers.

It is an essential feature of statistical literacy because the process of interpreting statistical information requires much more efforts than just recognizing numerical patterns. People should take into account the social context in which the data were obtained, the meaning of statistical measurements and possible consequences of the data.

At the same time, some shortcomings in the statistical and mathematical knowledge of the participants were found during the process of research. These shortcomings sometimes hindered participants in providing more detailed answers.

Thus, the results of the study imply that statistical and mathematical knowledge are significant aspects of statistical literacy; however, they do not ensure this process alone. Context knowledge and critical skills also play a role in interpreting statistical information.

Moreover, the results of the research highlight the significance of the provision of authentic statistical situations for future teachers.

Working with socially relevant and realistic data helps pre-service teachers develop their critical skills and ability to interpret data and form opinions. From this perspective, statistical literacy can help in developing citizenship. The use of statistical information becomes wider and wider while discussing public health, violence, education, economy, politics and other issues of the social life.

7. Conclusion

The analysis of the interviews revealed both difficulties and possibilities regarding the development of statistical literacy among pre-service Mathematics teachers.

The participants demonstrated knowledge of several statistical and mathematical concepts; however, their understanding was often superficial, and they were not always able to provide detailed justification for their interpretations and opinions.

The results indicate that different forms of knowledge interact during the interpretation of statistical information. In particular, contextual knowledge and critical skills appeared to be related to participants' ability to make sense of the data. The prior knowledge that participants had about the world also affected their interpretation of the statistical data that was presented to them in the activities. This emphasizes the need to consider prior knowledge of the learners in teaching statistics.

The application of authentic contexts that involved homicide and violence against women was especially crucial.

These contexts encouraged participants to connect statistical information with real social issues. Such information can be understood as civic statistics, because it concerns issues that directly affect citizens and can contribute to discussions about social and economic development and people's well-being.

The participants' difficulties with more complex analyses were partly associated with insufficient mathematical and statistical knowledge. Despite this, the interviews also revealed the possibility of gaining an understanding that statistical interpretations are not always associated with the need to come up with an exact numerical answer.

Quite often, the process of statistical interpretation is linked to the ability of a person to make a judgment, give an opinion about something, assess evidence, and think about the social context of information given.

Thus, the programs of Mathematics teacher education should not only equip future teachers with the relevant knowledge of statistics and mathematics but also with the contextual knowledge, critical abilities, and a critical perspective.

Declarations

Participant Consent: Informed consent was obtained from all participants before their participation in the study. The participants were informed about the purpose of the study, and their participation was voluntary.

References

1. Batanero C (2019) Thirty years of stochastics education research: Reflections and challenges. *Actas del Tercer Congreso Internacional Virtual de Educación Estadística*. Universidad de Granada
2. Batanero C, Burrill G, Reading C (eds) (2011) *Teaching statistics in school mathematics: Challenges for teaching and teacher education: A joint ICMI/IASE study*. Springer. <https://doi.org/10.1007/978-94-007-1131-0>
3. Ben-Zvi D, Garfield J (2004) Statistical literacy, reasoning, and thinking: Goals, definitions, and challenges. In D. Ben-Zvi & J. Garfield (Eds.), *The challenge of developing statistical literacy, reasoning, and thinking* (pp. 3–15). Springer. https://doi.org/10.1007/1-4020-2278-6_1
4. Cerqueira D, de Lima RS, Bueno S, Valencia LI, Hanashiro O, Machado PHG, Lima A (2017) dos S. *Atlas da violência 2017*. Instituto de Pesquisa Econômica Aplicada & Fórum Brasileiro de Segurança Pública
5. Costa A, Nacarato AM (2011) A estocástica na formação do professor de matemática: Percepções de professores e de formadores, vol 24. *Boletim de Educação Matemática, Bolema*, pp 367–386. 39
6. Costa WNG, Pamplona AS (2011) Entrecruzando fronteiras: A educação estatística na formação de professores de matemática, vol 24. *Boletim de Educação Matemática, Bolema*, pp 897–911. 40

7. Gal I (2002) Adults' statistical literacy: Meanings, components, responsibilities. *Int Stat Rev* 70(1):1–25. <https://doi.org/10.1111/j.1751-5823.2002.tb00336.x>
8. Gal I (2019) Understanding statistical literacy: About knowledge of contexts and models. *Actas del Tercer Congreso Internacional Virtual de Educación Estadística*. Universidad de Granada
9. Lopes CE (2013) Educação estatística no curso de licenciatura em matemática. *Bolema: Bol de Educação Matemática* 27(47):901–915. <https://doi.org/10.1590/S0103-636X2013000400010>
10. Moore DS (1990) Uncertainty. In: Steen LA (ed) *On the shoulders of giants: New approaches to numeracy*. National Academy, pp 95–137
11. Pamplona AS (2012) A formação estatística e pedagógica do professor de matemática. *Zetetiké* 20(1):91–105. <https://doi.org/10.20396/zet.v20i37.8646637>
12. Pamplona AS, Carvalho DL (2009) O ensino de estatística na licenciatura em matemática: A inserção do licenciando na comunidade de prática dos professores de matemática, vol 22. *Boletim de Educação Matemática, Bolema*, pp 47–60. 32
13. Skovsmose O (2007) Mathematical literacy and globalisation. In: Valero P, Skovsmose O (eds) *Education policies: Globalisation, citizenship and democracy*. Sense
14. Skovsmose O (2013) *Towards a critical mathematics education*. Sense