__Original Research Article__

BEYOND THE BARS: EXPLORING PRE-SERVICE TEACHERS' UNDERSTANDING OF HISTOGRAM

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ABSTRACT

Aims: This study explored the ability of first-year pre-service mathematics teachers to interpret graphical representation, with an emphasis on histograms.
Study design: The descriptive survey design was employed as the methodological framework for the investigation.
Place and Duration of Study: Department of Mathematics Education, University of Education, Winneba, Ghana, during the 2022/2023 academic year.
Methodology: The purposive and convenient sampling techniques were used to sample 342 first-year pre-service mathematics teachers. This sample included 31.3% (107) trained teachers who have taught mathematics at the basic schools level. Females also formed 15.5% (53) of the sample. The test used as the instrument for collecting data was adapted from previous studies and classified into two skill types: statistical literacy (SL) and statistical reasoning (SR). Data was analyzed by computing the success rates for the items as well as assessing participants' valid justifications for their responses. This gave insight into the challenges participants encountered.
Results: Under statistical literacy items, findings revealed that for items which covered tasks like reading frequencies and identifying axes, success rates ranged from 45.6% (156)to 63.7% (218), whereas those which required identification of median of a categorical dataset in a bar chart and comparing modes of two histograms presented more complex situation with success rates around 26.0% (89). Under the statistical literacy items, only 12.1%(11) could provide valid justifications for their correct response on the item on identifyingthe median of a categorical dataset in a bar chart, and 28.1% (25)for the item on comparing modes of two histograms.On statistical reasoning items, moderate success rates were recorded for items requiring interpretation of information from a histograms with success rates ranging from 33.0% (113) to 56.1% (192). Challenges were encountered with matching given description to an appropriate histogram and comparing and contrasting distributions characteristics with success rates of 24.0% (82) and 0.6% (2) respectively. Under these statistical reasoning items, participants' lack of conceptual understanding was evident as either a zero conceptually sound justifications were recorded or an abysmally low one (5.3% (9) or 6.2% (7)), even for correct responses, with just a repetition of the choice of answer from the options.
Conclusion: Participants demonstrated moderate proficiency in basic statistical tasks, however, significant challenges were encountered with more complex tasks which required inferential reasoning. It was recommended that teachers integrate creative pedagogical approaches and interactive technologies that emphasize statistical reasoning into their teaching.

Keywords: Statistical Literacy, Statistical Reasoning, Graphical Representation, Pre-service Mathematics Teachers

1. INTRODUCTION

Graphical representations of data are essential components of descriptive statistics and are frequently employed to enhance statistical analysis of data. They function as vital instruments for presenting intricate statistical data in an understandable style. Tebabal and Kahssay (2011) contend that graphs are the most efficient means of succinctly depicting a functional connection.

Graphs can be perceived in two manners: firstly, as communicative instruments (information carriers) that describe a data set or a solution to a problem, and secondly as “tools for generating meaning”, serving as a lens for inquiry (Monk, 2003, as cited in Bleich et al., 2006, p. 23). According to Eshach (2014) in Radulović et al. (2022), graphs also serve as potent visual instruments for pattern recognition, enabling the identification of trends and the detection of nuanced variations in shape.

Of the many graphical representations, histograms effectively reveal the distribution of values within a data set, particularly the skewness and the presence of outliers. Despite its prevalence in several texts and media, research have consistently revealed widespread difficulties in understanding these representations where students are seen to misinterpret scales, axes, and shapes of distributions (Kaplan et al., 2014; Glazer, 2011; Radulović et al. (2022).

In today's information-rich world, where the cultivation of scientific inquiry abilities is essential, it is imperative for the educated public to be proficient in the representation and understanding of images and graphics (Lowrie & Diezmann, 2007). The ability to conceptualise and comprehend graphical representations like histogram is crucial in education and other occupations. And for pre-service teachers, misconceptions in these fundamental skills can influence their ability to teach these concepts negatively and as a result affect the statistical literacy of future generations (Meletiou & Lee, 2003; Sharma, 2013; Ngulube & Ogbonnaya, 2023).

Graphical representations of data serve as the foundation for statistical analysis extensively utilized in education, research and daily communication to simplify and convey complex information. The extensive use of graphical representations in media and daily life arises from the expectation of immediate transparency to the viewer. However, Dreyfus and Eisenberg (1990) have observed that comprehending graphical representations may not be as straightforward, as it's a complex skill to acquire. They opined that:

Reading a diagram is a learned skill; it doesn’t just happen by itself. To this point in time, graph reading and thinking visually have been taken to be serendipitous outcomes of the curriculum. But these skills are too important to be left to chance (Dreyfus & Eisenberg, 1990, p. 33).

Comprehending graph is widely acknowledged as an essential component of statistical literacy (Bursal & Yetiş, 2020; Salcedo et al., 2022). It encompasses multiple elements, including graph features, content, and readers’ prior knowledge (Glazer, 2011). However, a common cognitive fallacy in graph interpretation is to perceive it iconically. This involves perceiving the graph as a literal representation of scenarios rather than an abstract quantitative information (Leinhardt et al., 1990 as cited in Glazer, 2011).

In Ghana, students have been found to encounter difficulties in interpreting and utilising information from various representations including histograms (Armah et al., 2016; Armah & Asiedu-Addo, 2014).The study of Ngulube and Ogbonnaya (2023) in South Africa revealed thatboth high school economics educators and pre-service teachers struggle with graph interpretation and plotting, and the pre-service teachers were also found to lack confidence in teaching using graphs.Likewise in Ethiopia, a significant number of ninth-graders were also identified with difficulties in basic graphical interpretations (Tebabal& Kahssay, 2011). Results are not different in the Western context like the United States and the United Kingdom, where studies identified comparable challenges among pupils in comprehending graphical material (Friel et al., 2001; Monteiro & Ainley, 2006).

The above studies highlight the fact that globally, students across different educational contexts have been found to encounter profound challenges in interpreting graphical data. These findings call for a need for improved pedagogical approaches to enhance statistical literacy among learners at different levels.

In Ghana, the significance of mathematics, and by extension, statistics, is well-recognized, being seen as vital for various aspects of societal development. As an integral part of mathematics, statistics is introduced to learners right from the basic level, progressing to more advanced concepts in senior high education (NaCCA, 2019). However, the instruction of graphical representation abilities has not progressed in accordance with the anticipated curriculum standards (Monteiro & Ainley, 2006). Students have been found to have challenges reading and using information from histograms and other representations like bar charts (Armah et. al, 2016; Armah & Asiedu-Addo, 2014).

In the educational realm, comprehending histograms is crucial as it underpins the cultivation of statistical literacy among students. Histograms facilitate educators in interpreting and elucidating intricate statistical concepts, including central tendency, variability, and skewness, with enhanced precision and efficacy. For pre-service teachers, proficiency in understanding histograms is not merely an academic obligation, but an essential ability vital for their effective instruction during training. It is a crucial ability for fostering informed decision-making and data-driven thinking in future generations. This is because there is evidence of high school teachers' pedagogical strategies impacting the low self-efficacy of pre-service teachers (Ngulube & Ogbonnaya, 2023).

Meletiou and Lee (2002) and Sharma (2013) emphasise the importance of histogram interpretation in promoting statistical reasoning, which consist of connecting basic concepts like measures of center, variability and distribution. Consequently, it is essential for pre-service teachers to possess a comprehensive understanding of histograms not just as an academic requirement, but also as a crucial skill to enhance statistical education and foster a numerate culture. Previous studies have highlighted various domains where misunderstandings commonly occur in the interpretation of histograms, illustrating the pervasive nature of these challenges. These include misinterpreting or misreading of the scales, confusion with bar charts, difficulties in comprehending the shape of distributions as well as the continuous nature of data (Kurt &Çakıroğlu, 2023; Sharma, 2013; Nikiforou&Meletiou-Mavrotheris, 2015; Whitaker & Jacobbe, 2017).

This current study builds on these previous findings to investigate Ghanaian pre-service mathematics teachers' ability to interpret graphical representations appropriately with a focus on histograms. It is the aim of the study to reveal the specific challenges encountered by these pre-service teachers and propose actionable insights and recommendations for the improvement on the pedagogy and the statistical literacy of upcoming educators in Ghana.

This will help in the long run to achieve the overall objective of building a statistically literate culture skillful at navigating the complexities of the modern data-driven world.

2. MATERIAL AND METHODS

A descriptive survey design was employed as the methodological framework for the investigation. The population comprised first-year pre-service teachers from the Department of Mathematics Education at the University of Education, Winneba, Ghana. The group was purposively sampled due to their exposure to the pre-tertiary core mathematics curriculum and elective mathematics, which encompassed advanced mathematical and statistical concepts. This group was expected to exhibit a more positive attitude and enhanced understanding of mathematics, and hence statistics, compared to individuals who solely studied core mathematics. The researcher had convenient access to this demographic as she is a senior lecturer in the department and instructs these students in an Introductory Probability and Statistics course.

The convenience sampling technique was employed to select 342 participants for the study. This was the number of students present during the administration of the study instrument. Among this sample, 31.3% are trained teachers who have taught mathematics in Ghanaian basic schools. Females constituted 15.5% of the sample.

The instrument utilised for the study was a ten (10) item test intended to investigate pre-service teachers' statistical literacy and reasoning skills assuring conformity with the Ghanaian senior high school (SHS) mathematics curriculum. The items were adapted from Kaplan et al. (2014), Delmas et al. (2005), and Whitaker and Jacobbe (2017). An exemplar of the test is provided in Appendix A. Five (5) of these items were multiple choice, each necessitating an explanation or justification of the selected response. The remaining items were open-ended, inviting participants' rationales for their responses.

The items were categorised into two groups according to the paradigm established by Delmas et al. (2005): Statistical Literacy (SL) and Statistical Reasoning (SR).

- Under statistical literacy, items measured the understanding and utilisation of fundamental statistical concepts and tools. Examples included reading frequencies, recognizing and comprehending scales used, identifying shapes of distributions, and differentiating between graph types.
- Similarly, under statistical reasoning, items assessed higher-order thinking skills, employing basic statistical concepts like center, spread and shape to comprehend and interpret statistical information. This included recognizing a graph from a variable's description, matching two different graphs representing the same data, demonstrating understanding underlying causes for a data shape, and articulating rational justification.

The categorization of test items is summarised in Table (1).

Table 1: Test Item Categorizationby Skill Type

Item No.	Task Description	Skill Assessed	Type
1 – 3	Read frequencies and interpret axes	Statistical Literacy	Open-Ended
4	Match histogram to a description	Statistical Reasoning	Multiple Choice

5	Interpret graphical representations	Statistical Reasoning	Multiple Choice
6	Analyze medians and qualitative variables	Statistical Literacy	Multiple Choice
7 – 8	Interpret histograms considering axes	Statistical Reasoning	Multiple Choice
9	Identify and compare modes of distributions	Statistical Literacy	Open-Ended
10	Analyzing and contrasting distributions characteristics.	Statistical Reasoning	Open-Ended

The test was administered to students prior to addressing the subject of "graphical representations of data" in their curriculum. This was to guarantee the absence of interference with the knowledge acquired at the SHS level. No time limit was imposed during the test to allow participants to provide reflective responses.

Responses of participants were categorized and analysed according to the skill types measured:

- Statistical Literacy: participants' responses were assessed for precision in reading frequencies, interpreting axes, identifying and comparing centers.
- Statistical Reasoning: participants' responses were assessed based on their ability to connect concepts and give valid justifications.

The number of correct responses for items were noted and success rates computed. Also, participants' number of valid justification on the responses were summarized. This gave insight into the common challenges participants faced.

In this study participation was voluntary. The purpose of the study was explained to participants and their confidentiality was assured.

3. RESULTS AND DISCUSSION

The results on the test varied widely. This showed the different levels of mastery in statistical literacy and reasoning. The success rates and correct justifications gives insight into the areas of strength and challenges of students. This is summarized in Table (2).

It can be seen from Table (2) that performance on the statistical literacy items showed moderate proficiency. Thesuccess rates for the first three items which covered tasks like reading frequencies and identifying axes reveals that while participants find basic statistical and straightforward tasks more accessible, there is still much room for improvement. This is consistent with findings Uyanik et al. (2023) who also observed middle school teachers to be more successful in reading data in graphical representations. It is also consistent with findings of Delmas et al. (2005), Friel et al. (2001), and Kaplan et al. (2014) who highlight the need for deeper engagement with even straightforward or fundamental statistical tasks to build a strong conceptual base.

Item 6 presented a more complex situation for participants when they had to identify the accurate statement on the median of a qualitative dataset in a bar chart. This challenging scenario seem to stem from conceptual misunderstandings and the misapplication of visual conventions in the representation. In this, though participants might have a conception of the median as the item in the center of a data set, they overlook the notion of the type or measurement level of the data and thus mistaking categorical data for a numerical one. This echoes with the findings of Kaplan et al. (2014), where even after an intervention, students still thought the median could be found from this bar chart of a categorical data. The same conclusion can be inferred from the findings of Cooper and Shore (2008)who observed that participants often calculate the median incorrectly, treating frequencies on the vertical axis as data points rather than understanding the median as a central value in the horizontal distribution. It is worth noting that for this item while a low correct justification rate was recorded, as many as 56.0% of participants who answered correctly gave justifications with no statistical basis indicating their lack of understanding of the concept involved. A considerable proportion of them (31.9%) also could not provide any justification for their correct response. This implied that majority of those who even answered correctly just guessed from the options provided.

A similar challenging and complex situation was faced by participants in items 9 in comparing the modes of two histograms with a success rate of 26.0%. This observed difficulty is consistent with the findings of Kaplan et al. (2014) who reported that participants often misidentifying the mode when comparing histograms as a result of an overemphasis on bar height without considering the relationship between frequency and bin grouping. As such, subtle differences in bin widths or scales overlooked, leads to incorrect conclusions as noted by Cooper and Shore (2008). The fact that an even a smaller proportion (28.1%) could explain their reasoning highlights the challenges pre service teachers face with comparative tasks, as discussed by Glazer (2011). These observations emphasize the need for targeted instructional strategies to enhance students' analytical reasoning in comparing statistical measures across different graphical contexts.

In the statistical reasoning items, pre-service teachers were faced with moderate to challenging situations. Yet for items where moderate success rates were recorded, their justifications exposed their lack of understanding of the concepts involved.

Item 4 which required pre-service teachers to match a given description to an appropriate histogram was challenging. The low rate of 24.0% recorded for this item is in sharp contrast with a higher rate (71.3%) reported by Delmas et al. (2005) on same item. Though the same concept of skewness was tested in item 5, a comparatively elevated success rate of 56.1% was found. However, participants' lack of conceptual understanding was evident as a zero conceptually sound justification was recorded for both items 4 and 5. In item 5, participants were just repeating the responses in the options provided as justifications (item 5). This is troubling and reveals a phenomena of superficial comprehension lacking profound conceptual knowledge. It must be noted that in the case of Delmas et al. (2005), participants were not required to justify their responses.

In items 7 and 8 pre-service teachers were required state whether the erroneous descriptions of a histogram were true or false and justify their responses. The erroneously descriptions included a time component.Where participants' concentration were not on what the axes represented but just on the position of the tall bars. Though moderate success rates were also recorded for both items, abysmally low justifications (5.3% and 6.2%) were observed. Just as was reported for items 4 and 5, the low justifications (even for moderate success rates) demonstrate the lack of conceptual understanding of the pre-service teachers. In the case of Kaplan et al. (2014), majority (about two-thirds) were able to answer these items without justification.

The same challenge was observed in item 10 when they had to compare and contrast distributions characteristics. These two items recorded success rates of 24.0% and 0.6% respectively. The success rate of 0.6% for item 10 leaves much to be desired. This aligns with the findings of Whitaker and Jacobbe (2017) where 50.27% of participants scores zero (0) on this item and only 3.16% scored 4. Similarly, they observed a low success rate for open ended items that fell under reasoning category. This points to participants' overreliance on shallow or surface-level knowledge than a robust engagement with the fundamental basic concepts. The findings clearly show a significant gap in reasoning, the ability to interpret histogram shapes effectively, as well as connecting visual data with textual or conceptual information, critical skills in statistical reasoning.

Table 2. Summary of Success Rates and Justifications for Test Items

Item No.	Task Description	Skill Assessed	Success Rate (%)	Correct Justification (%)
1	Read frequency from a histogram	SL	45.6	N/A
2	Interpret total frequency	SL	54.4	N/A
3	Identify axis meaning	SL	63.7	N/A
4	Match histogram to a description	SR	24.0	0.0
5	Interpret a graph - distribution shape	SR	56.1	0.0
6	Analyze qualitative variable (median)	SL	26.6	12.1
7	Interpret histograms considering axes	SR	33.0	6.2
8	Interpret histograms considering axes	SR	49.7	5.3
9	Compare modes across distributions	SL	26.0	28.1
10	Analyzing and contrasting distributions characteristics.	SR	0.6	N/A

4. CONCLUSIONS AND RECOMMENDATIONS

In summary, the findings suggest that although pre-service mathematics teachers exhibit moderate success in straightforward and fundamental tasks, their comprehension diminishes with increasing complexity, especially in tasks necessitating justification or inferential reasoning. This pattern aligns with the findings of studies who identified the widespread existence of misconceptions and challenges in reading and interpreting statistical data and graphs (Uyanik et al., 2023; Muñoz et al., 2020; Meletiou& Lee, 2002; Wu, 2004).

Findings also reveal pre-service mathematics teachers have a challenge matching histograms to a description.This is largely due to their inability to interpreting the concept of skewness or shape of the representation. This confirms the observations in previous studies where students have been reported to misinterpret skewness when compare histograms (Boels et al., 2019;Boelset al., 2024).

Findings further suggest that pre-service teachers do not place emphasis on what the axes represent when reading information or interpreting histograms, leading to incorrect conclusions (Kaplan et al., 2018; Boels et al., 2019;Boelset al., 2024).

These findings call for an urgent necessity for improved teaching methodologies emphasising profound conceptual comprehension, critical analysis, and practical application. The integration of creative pedagogical methods and technology, as emphasised by Kaplan et al. (2014) and Whitaker and Jacobbe (2017), provide promising avenues for improving student engagement and understanding. Continuous research and novel teaching approaches remain essential to tackle these enduring difficulties and enhance students' statistical literacy comprehensively in this data – driven world.

It is therefore recommended that mathematics educatorsdevelop their lessons with a focuson conceptual understanding of statistical concepts, using real world datasets to demonstrate the relevance of histograms in interpreting practical scenarios to ensure contextualization of statistical concepts. Mathematics educators must also incorporate pedagogical approaches like the inquiry-based, collaborative and problem-based learning to encourage critical thinking, real-world application, and collaboration.

The use of interactive softwares like Excel, SPSS, and apps like Geogebra must be introduced into the curriculum to help students to interact with data and explore the effects of changing variables on histogram shapes and distributions. It is also recommended that teachers introduce gamified learning Apps like Kahoot to increase engagement and encourage critical thinking. Teachers should as well incorporate error analysis in their teaching to provide opportunities for students to analyse errors in histogram interpretation. Last but not the least, teachers can help students develop a self-assessment checklist for histogram interpretation to be used after analysing a histogram.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

REFERENCES

[1] Tebabal, A., & Kahssay, G. (2011). The effects of student-centered approach in improving students' graphical interpretation skills and conceptual understanding of kinematical motion. *Latin-American Journal of Physics Education, 5*(2), 374-375. https://www.researchgate.net/publication/267217869

[2] Bleich, L., Ledford, S. D., Orrill, C. H., & Polly, D. (2006). An analysis of the use of graphical representation in participants' solutions. *The Mathematics Educator, 16*(1), 22–34. http://math.coe.uga.edu/tme/issues/v16n1/tmev16n1_final.pdf#page=24

[3] Radulović, B., Zajkov, O., Gegovska-Zajkova, S., Stojanović, M., &Sliško, J. (2022). A Cross-Country comparison of students' graphs understanding and perceived mental effort. *Mathematics*, *10*(14), 2428. https://doi.org/10.3390/math10142428

[4] Kaplan, J. J., Gabrosek, J. G., Curtiss, P., & Malone, C. (2014). Investigating student understanding of histograms. *Journal of Statistics Education, 22*(2), 1–30. https://doi.org/10.1080/10691898.2014.11889701

[5] Glazer, N. (2011). Challenges with graph interpretation: A review of the literature. *Studies in Science Education, 47*(2), 183–210. https://doi.org/10.1080/03057267.2011.605307

[6] Lowrie, T., & Diezmann, C. M. (2007). Middle school students' interpretation of graphing tasks: Difficulties within a graphical language. *In Rosihan Ali, D (Ed.) Proceedings of the 4th East Asia Regional Conference on Mathematics Education 2007*. Universiti Sains Malaysia, Malaysia, Penang, (pp. 611-617).

[7] Meletiou, M., & Lee, C. (2002). Student understanding of histograms: a stumbling stone to the development of intuitions about variation. *Proceedings of the Sixth International Conference on Teaching Statistics: Developing a Statistically Literate Society,*January 2002, (pp. 1-4).

[8] Sharma, S. (2013). Assessıng students' understandıng of tables and graphs: implıcatıons for teachıng and research. *International Journal of Educational Research and Technology-IJERT, 4*(4), 51–70. www.soeagra.com/ijert/ijert.htm

[9] Ngulube, B., & Ogbonnaya, I. C. (2023). Applying Bandura's Theory of Self-Efficacy to assess the perceptions of Pre-service Economics teachers concerning teaching using graphs. *International Journal of Research in Business and Social Science12*(8), 517-525. https://doi.org/10.20525/ijrbs.v12i8.2813

[10] Dreyfus, T., & Eisenberg, T. (1990). On difficulties with diagrams: Theoretical issues. *In G. Booker, P. Cobb & T. N. de Mendicuti, Proceedings of the 14th Psychology of Mathematics Education Conference* (Vol. 1, pp. 27-33). Oaxtepec, Mexico.

[11] Bursal, M., &Yetiş, S. (2020). Middle school students' graph skills and affective states about graphs. *International Journal of Research in Education and Science, 6*(4), 692–704. https://doi.org/10.46328/ijres.v6i4.1136

[12] Salcedo, A., González, J., LIra, A. S, & González, J. (2022). Statistical literacy of citizens: The interpretation of statistical graphs. *Bridging the Gap: Empowering and Educating Today's Learners in Statistics. Proceedings of the Eleventh International Conference on Teaching Statistics.*https://doi.org/10.52041/iase.icots11.t7a1

[13] Armah, G., Asiedu-Addo, S. K., Owusu-Ansah N. A. (2016). An Investigation on the Conceptual Understanding of the Standard Deviation of Fresh Undergraduate Students. *ASIO Journal of Chemistry, Physics, Mathematics & Applied Sciences, 1*(3), 1 – 9. http://albertscience.com/asset/images/uploads/14690835803732.pdf

[14] Armah, G., & Asiedu-Addo, S. K. (2014). Ghanaian Students' Knowledge of Averages after Senior High Education. *Researchjournali's Journal of Mathematics, 1*(4), 1 - 12.

http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.683.6171&rep=rep1&type=pdf

[15] Friel, S. N., Curcio, F. R., & Bright, G. W. (2001). Making sense of graphs: Critical factors influencing comprehension and instructional implications. *Journal for Research in Mathematics Education, 32*(2), 124–158. https://doi.org/10.2307/749671

[16] Monteiro, C., & Ainley, J. (2006). Student teachers interpreting media graphs. *In A. Rossman & B. Chance (Eds.), Proceedings of the Seventh International Conference on Teaching Statistics.* Salvador, Brazil: International Statistical Institute and International Association for Statistical Education. www.stat.auckland.ac.nz/~iase/publications.

[17] NaCCA, Ministry of Education (2019). *Mathematics Curriculum for Primary Schools*. NaCCA, Accra.

[18] Kurt, K., &Çakıroğlu, E. (2023). Prospective mathematics teachers' TPACK development in graphical data displays: A microteaching lesson study. *International Journal of Mathematical Education in Science and Technology*, DOI: 10.1080/0020739X.2023.2246970

[19] Nikiforou, M. A., &Meletiou-Mavrotheris, M. (2015). Graph reading and interpretation: An investigation of introductory statistics college students' knowledge. *H. Oliveira, A. Henriques, A.P. Canavarro, C. Monteiro, C. Carvalho, J. P. da Ponte, R. T. Ferreira, & S. Colaço (Eds), Proceedings of the International Conference on International Conference Turning data into knowledge: New opportunities for statistics education* Lisbon, Portugal: Instituto de Educação da Universidade de Lisboa, 124.

[20] Whitaker, D., &Jacobbe, T. (2017). Students' understanding of bar graphs and histograms: Results from the LOCUS assessments. *Journal of Statistics Education, 25*(2), 90–102. https://doi.org/10.1080/10691898.2017.1321974

[21] Delmas, R., Garfield, J., & Ooms, A. (2005). Using assessment items to study students' difficulty reading and interpreting graphical representations of distributions. *Proceedings of the Fourth International Research Forum on Statistical Reasoning, Literacy, and Reasoning*, January 2005, 1–17.

[22] Uyanik, S., Elbir, D., &Ozmen, Z. M. (2023). Determining the graphical literacy levels of the middle school mathematics teachers. *Pedagogical Research*, *8*(2), em0158. https://doi.org/10.29333/pr/13003

[23] Cooper, L. L., & Shore, F. S. (2008). Students' misconceptions in interpreting center and variability of data represented via histograms and stem-and-leaf plots. *Journal of Statistics Education, 16*(2), 324–326. https://doi.org/10.1080/10691898.2008.11889559

[24] Muñoz, D. E., Esparza, A. C. M., Ciprés, M. C., & Macías, M. G. M. (2020). Comprehension of statistical graphs and tables by primary school teachers-in-training. *Zetetiké*, *28*, 1-17, e020007. https://doi.org/10.20396/zet.v28i0.8656854

[25] Wu, Y. (2004). Singapore secondary school students' understanding of statistical graphs. *Proceedings of the 10th International Congress on Mathematical Education*, (pp. 1–7).

26] Boels, L., Bakker, A., Van Dooren, W., &Drijvers, P. (2019). Conceptual difficulties when interpreting histograms: A review. Educational Research Review, 28, Article 100291. https://doi.org/10.1016/j.edurev.2019.10029

[27] Boels, L., Bakker, A., Van Dooren, W., &Drijvers, P. (2024). Secondary school students' strategies when interpreting histograms and case-value plots: an eye-tracking study. *Educational Studies in Mathematics*. https://doi.org/10.1007/s10649-024-10351-3

[28] Kaplan, J. J., Lyford, A., & Jennings, J. K. (2018). Effects of question stem on student descriptions of histograms. *Statistics Education Research Journal, 17*(1), 85–102. http://www.stat.auckland.ac.nz/serj

APPENDIX A - TEST

Dear participant,

I want to show my appreciation for your willingness to take part in this test, which is being conducted for research purposes only, and your responses will play a vital role in this.

Kindly note that participation in this test is entirely voluntary. As such, you are free to choose whether to participate or not, and you can decide to withdraw at any point without any consequences. Additionally, it must be noted that this test will not form part of your assessment for the course, so you are encouraged to be as honest and as frank as possible in your responses.

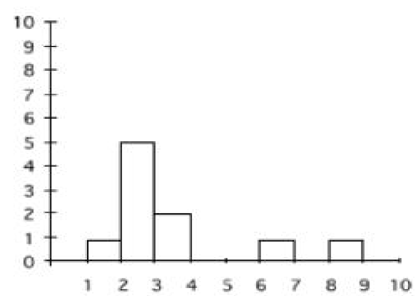
You are not required to write your name or index number on the test paper. This is to ensure confidentiality and anonymity. No time limitis set for this test, as a result, you are encouraged to take your time to answer all questions to the best of your ability.

Thank you for your time and effort.

Best regards,
Course Instructor

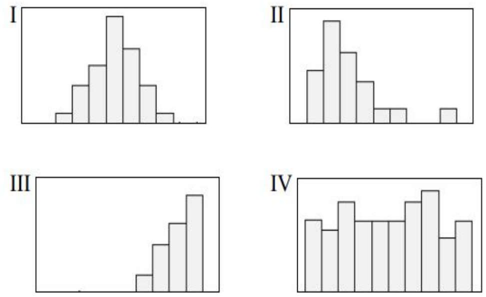
Please tick to indicate your sex: Male: [ ] Female: [ ]
Are you a professional teacher? Yes: [ ] No: [ ]

Here is a histogram for a set of test scores from a 10-item makeup quiz given to a group of students who were absent on the day the quiz was given. Use it to answer questions 1 to 3



1. How many people received scores higher than 4? …………………………..
2. How many people took the test and have scores represented in the graph? …………………………………..
3. What do the numbers on the vertical axis represent? ……………………………………

In question 4 match the description to the appropriate histogram below

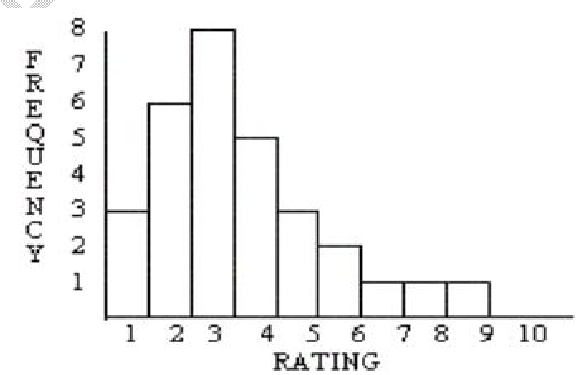


4. Which of the histograms best describes a set of quiz scores where the quiz was very easy?

   A. I
   B. II
   C. III
   D. IV
   E. I cannot determine it

   Explain your answer:
   ....
   ....

   One of the items on the student survey for an introductory statistics course was "rate your aptitude to succeed in this class on a scale of 1 to 10" where 1 = lowest aptitude and 10 = highest aptitude. The instructor examined the data for men and women separately. Below is the distribution of this variable for the 30 women in the class. Use it to answer question 5.

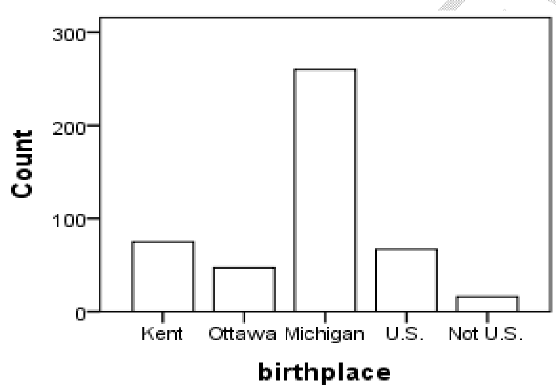


5. How would you interpret the women's perceptions regarding their success in the class?

A. A majority of women in the class do not feel that they will succeed in statistics although a few feel confident about succeeding.
B. The women in the class see themselves as having lower aptitude for statistics than the men in the class.
C. If you remove the three women with the highest ratings, then the result will show an approximately normal distribution.
D. I cannot interpret

Explain your answer:…………………………………………………………………..……………
……………………………………………………………………………………………
…………………………………………………………………………….

The following graph shows the birthplace of students in a large introductory statistics course. Use it to answer question 6.

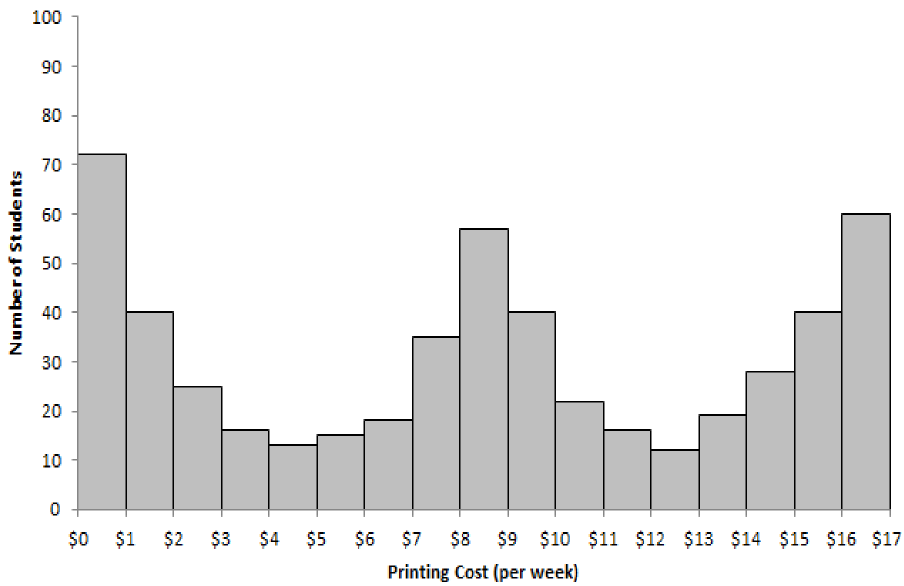


6. Which of the following is true?

A. The median is Michigan.
B. The median cannot be told from the graph, but could be if more information were given.
C. The median cannot be found for this information even if we had the birthplace for each individual student.
D. The median is 150
E. I have no idea.

Explain your answer: …………………………………………………………………….
……………………………………………………………………………………………..
……………………………………………………………………………………………..

The histogram below shows the printing cost (per week) for students at a nearby college. Use it to answer questions 7 and 8.



7. In the graph, there appear to be three times during the semester (beginning/middle/end) in which students spend a lot of money on printing at this college.

    A. True
    B. False

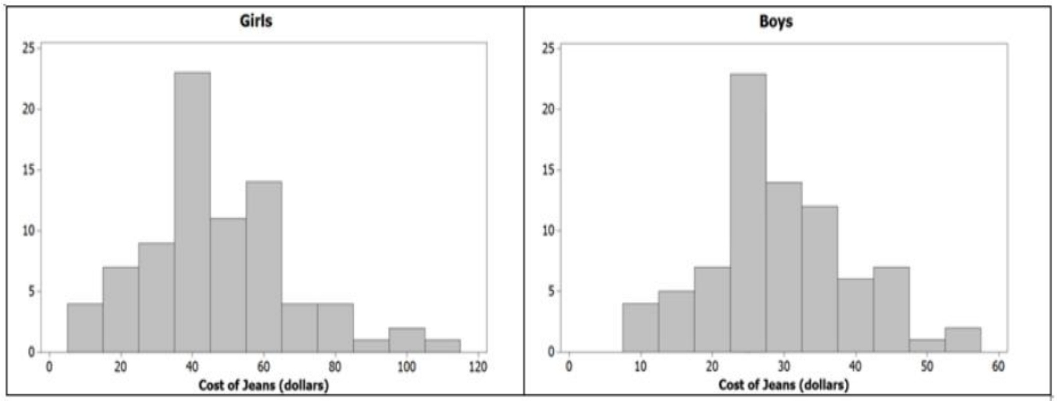
    Explain your answer: ………………………………………………………………
    ……………………………………………………………………………………..
    ………………………………………………………………………………………

8. This histogram suggests that students tend to spend the most on printing at the beginning of the semester.

    A. True
    B. False

    Explain your answer:………………………………………………………………
    ………………………………………………………………………………………
    ………………………………………………………………………………………

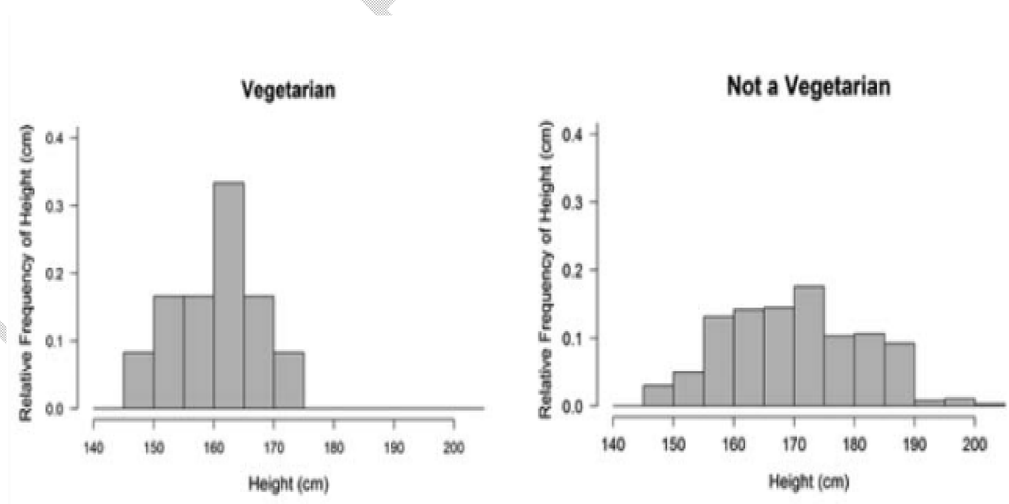
9. The following two graphs represent the amount of money spent on a pair of jeans,one
    for a sample of high school girls, and the other for a sample of high school boys.



Which group has the larger mode? …………………………………………………….

Explain your answer:………………………………………………………………….……………
……………………………………………………………………………….
……………………………………………………………………………………………

10. **A random sample of 411 high school students was selected in order to compare the heights, in centimeters (cm), of vegetarians and non-vegetarians. The relative frequency histograms below show the distributions of height for the 15 students who said they were vegetarians and for the 396 students who said they were not vegetarians.**



Write two sentences comparing the distributions of heights for the vegetarians and non-vegetarians.