

## Pre-service teachers' use of eye-tracking data to diagnose students' misinterpretations in statistical graphs

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*This study explores how a pre-service mathematics teacher interprets eye-tracking data to diagnose students' reasoning when working with histograms. Using a qualitative case study design, the participant engaged with an eye-tracking vignette, featuring a student's gaze plot, answer, and cued recall explanation. The targeted error was frequency–value confusion, a common systematic error where students treat bar heights as measured values. Findings show that the participant initially relied on assumptions rather than the gaze data itself. Over time, her reasoning shifted to a more reflective analysis, integrating multiple data sources to better understand the student's thought process. She also identified the limitations of interpreting gaze data in isolation, especially when no clear pattern was evident. This study suggests that the use of eye-tracking data, when scaffolded through structured tasks, can enhance pre-service teachers' diagnostic skills in the interpretation of statistical graphs.*

### INTRODUCTION

Eye-tracking data can reveal students' visual search patterns, which are normally hidden and challenging for students to explain. This study explores how pre-service teachers can learn to diagnose students' understanding of statistical graphs and identify specific interpretation errors or strategies by analysing eye-tracking data (Abt et al., 2025; Boels et al., 2024; Schreiter & Vogel, 2023). For most teachers, analysing such data is new. While one study examined teachers interpreting eye-tracking data from reading comprehension tasks (Knoop-Van Campen et al., 2021), a gap remains in understanding how pre-service teachers analyse similar data in the context of graphical representations. This study focuses on the context of histograms, where students often make systematic errors.

Eye movements are frequent motor actions that support cognitive processes (Spivey & Dale, 2011). Gaze data offer insights into students' thinking, linking actions to specific concepts (e.g., Chumachemko et al., 2014) and revealing strategies used for answering. This helps identify correct strategies even with incorrect answers, or vice versa. This connection allows teachers to see how students engage with data representations, such as histograms, and pinpoint where conceptual difficulties arise.

Histograms are essential for visualizing both data and their distribution. However, students and teachers misinterpret histograms due to conceptual difficulties related to data (e.g., confusing frequency with measured values) and distribution (e.g., overemphasizing shape when comparing histograms) (Boels et al., 2019). An example of such a misinterpretation related to data can be seen in a student's gaze plot while interpreting a histogram (see Figure 1).

Figure 1 displays a gaze plot from a student solving a histogram interpretation task that involves estimating the mean. The student's eye movements indicate a common systematic error known as frequency–value confusion: interpreting the height of the bars as measured values rather than as frequencies. The gaze plot shows that the student's visual attention is focused on the top of bars and the y-axis (i.e., frequency), with minimal engagement with the x-axis, which represents the measured values (i.e., weight in kg). The scanpath suggests that the student attempted to visually equalize the bar heights by searching for a horizontal line where the bars appear to be of equal height, which is a strategy typically applied when interpreting case-value plots. A correct strategy for estimating the mean in a histogram involves integrating both the measured values and their frequencies to identify the balance point of the distribution. This process is typically reflected in vertical gaze movements between the bars and their corresponding x-axis values.

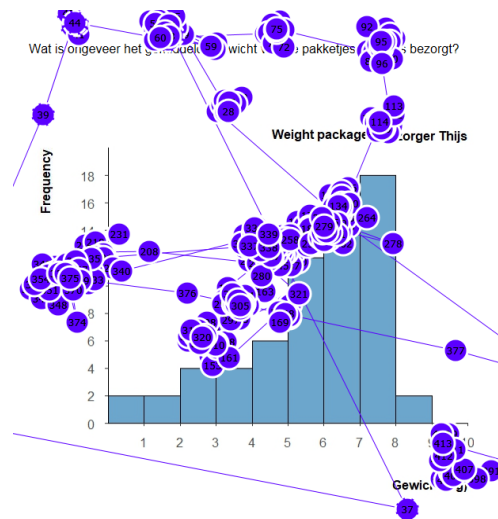


Figure 1. A gaze data image showing frequency-value confusion on a histogram

To support this aim, this study incorporates eye-tracking technology to improve pre-service teachers' diagnostic skills by analysing such complex visual-spatial data. We also designed vignettes using the Four-Component Instructional Design (4C/ID) model (Van Merriënboer & Kirschner, 2018) to guide pre-service teachers in analysing eye-tracking data to refine their diagnostic skills.

As part of the Eye Teach Stats project, which aims to support teachers in diagnosing systematic errors in students' interpretation of statistical graphs, this study explores how pre-service teachers use these vignettes to further develop these skills by interpreting eye-tracking data as complex spatial data with the following guiding research question: *How do pre-service teachers engage with students' eye-tracking data when diagnosing students' systematic errors in histogram interpretation?*

## METHOD

### *Research Design*

This study adopts a qualitative case study design to explore how a pre-service mathematics teacher engages with an eye-tracking vignette. A case study approach was selected to allow in-depth analysis of the participant's diagnostic thinking as it unfolds in response to eye-tracking data as complex spatial data.

### *Participant*

The participant in this study was a pre-service mathematics teacher (female) from Türkiye. She had recently completed her teacher education program at a public university, qualifying to teach mathematics at the middle school level (grades 5–8, ages 10–14). She had no formal teaching experience beyond mandatory teaching practicum courses. As part of her undergraduate studies, she completed two courses related to statistics: one on inferential statistics and another on teaching statistics and probability. She had no prior experience working with or interpreting eye-tracking data and reported being unfamiliar with the concept of gaze data before the study. Her profile was representative of novice teachers entering the profession with limited classroom experience but some academic background in statistics education.

### *Data Collection Tool*

The vignette was constructed using the 4C/ID model (Van Merriënboer & Kirschner, 2018), consisting of: (1) a learning task, (2) supportive background information about histograms, (3) procedural information on gaze plots, and (4) a follow-up task. The central task asked the participant to evaluate a student's (Sophie's) answer to a histogram question: "What is approximately the mean weight of the packages that Thijs delivers?" The participant was provided with a histogram showing weight distribution and asked to interpret Sophie's answer ("The mean is about 8") through eye-tracking data and then the cued recall explanation to diagnose the student's systematic error. Figure 2 shows the

vignette page where the participant first encountered Sophie's gaze plot alongside her answer to the histogram question. The targeted error was *frequency-value confusion*, a common systematic error in which students treat the height of histogram bars (frequency) as if they were the values being measured. The vignette scaffolded the participant's gaze data through stepwise exposure to the student's answer and Sophie's verbal explanation, and a summary about the type of error that Sophie made.

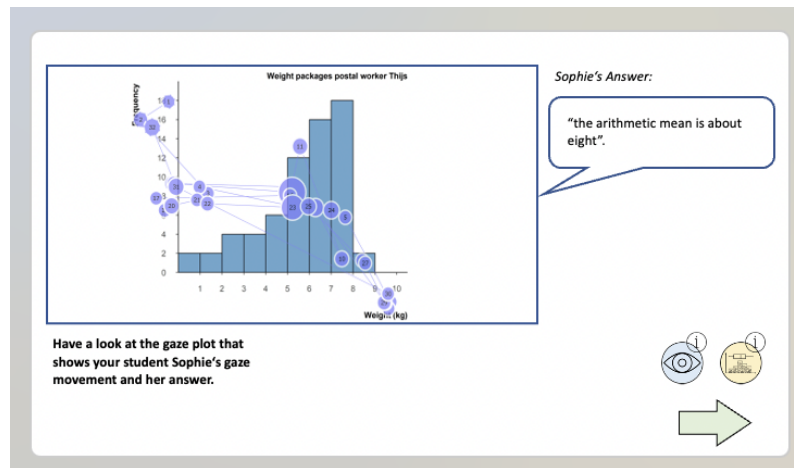


Figure 2. An exemplary page from the vignette showing frequency-value confusion on a histogram

The participant was asked to think aloud while working through the vignette, and her verbal reasoning was video recorded. After completing the vignette, she participated in a semi-structured interview focused on how she interpreted the gaze data, what influenced her judgments, and whether she encountered ambiguity or bias in the data. The aim was to conduct a detailed analysis of how their reasoning evolves as they progress through the vignettes.

#### Data Collection Procedure

The data collection involved the participant interacting with a prototype vignette that incorporated eye-tracking data from a real student. The session lasted approximately 75 minutes and consisted of two main parts: a think-aloud task and a follow-up semi-structured interview. During the think-aloud phase, the participant worked individually with an eye-tracking vignette, which included a histogram interpretation task, Sophie's gaze plot, her answer to the task, and her retrospective explanation (cued recall). The participant verbalized her thoughts throughout, without writing notes or being interrupted. Her screen and audio were recorded for later analysis. Afterwards, a follow-up interview was conducted to deepen insight into how the participant interpreted the gaze data and integrated it with the other elements of the vignette. The interview questions focused on: (a) the interpretability of eye-tracking data; (b) how the participant reasoned about the student's eye-tracking data and explanation; (c) the perceived reliability of different sources of information (e.g., gaze plot, student explanation, task response); and (d) the participant's overall confidence in diagnosing the student's error.

#### Data Analysis

The data were analysed qualitatively with a focus on how the participant engaged with the gaze data during the task. Transcripts of the think-aloud and interview sessions were automatically generated, and the researcher, who conducted the session, identified points where the participant interpreted, questioned, or reconsidered the gaze plots. Initial codes were derived from this process and grouped into broader categories. The resulting themes are still developing and reflect a preliminary phase of analysis.

## RESULTS

This section presents preliminary findings from one participant's engagement with student gaze data. The analysis focuses on how her interpretations shifted during the task, with emerging codes highlighting both initial assumptions and later reflections.

### *Making assumptions before engaging with gaze data*

At the beginning of the task, the participant saw the student's answer (8) alongside the gaze plot. Without analysing the gaze pattern in any detail, she immediately made a connection between the answer and what she assumed the student had looked at: *Eight. Because the frequency of eight is higher, I think it could be eight.* This interpretation appears to rely more on the answer itself than on the actual gaze data. The participant did not yet engage with the gaze plot as meaningful evidence, but instead assumed that the student had focused on the tallest bar, because it matched the answer. This assumption became more evident during the interview, where the participant referred to the number 32 on the gaze plot by saying: "I said I had looked at these sixteen parts (referring to the frequency 16 on the y-axis) 32 times (referring to the number of the fixation in the sequence)". Although she did refer to the gaze data, her interpretation of it was filtered through her own assumptions, treating the number 32 not as a sequence marker, but as a literal count of attention. By doing this, she used the gaze plot to support what she already believed, rather than questioning what it might actually show. In this early moment, gaze data functioned less as a source of insight and more as a background image used to justify a guess. This illustrates how initial reasoning can be shaped by expectations and visual assumptions, rather than by careful analysis of the data.

### *Revisiting gaze data considering new information*

As more information was introduced during the vignette, particularly the student's explanation and the error description, the participant began to interpret the gaze data in more reflective ways. Unlike earlier moments when she relied on visual assumptions, she now used the gaze plot together with the explanation to reevaluate her understanding of the student's reasoning. She reported that the student's explanation alone was vague but became meaningful when aligned with where the student had looked. In this sense, gaze data and explanation worked together, each clarifying the other. This phase also showed a shift from treating the gaze plot as confirmatory evidence to engaging with it analytically. The participant began to compare her own reasoning with the student's and noticed conceptual differences, particularly around the axes. She realised that, while she had relied on the x-axis midpoint to find her answer, the student appeared to be aligning bar heights instead, effectively reasoning with the y-axis. This moment reflected a growing awareness of graph conventions. Overall, the participant's engagement with gaze data evolved from a simple matching strategy to a more interpretive use that included triangulating across data sources, questioning assumptions, and noticing representational nuances.

### *Recognising the limits of gaze-only evidence*

In the final part of the vignette, the participant reviewed six anonymous gaze plots of the same histogram as a follow-up task and attempted to identify students who made the same systematic errors without access to their explanations. In several cases, she confidently matched the plots to what she had earlier identified as Sophie's approach. These included gaze data consistent with frequency–value confusion. Her ability to recognise these patterns was partly informed by her own approach to solving the question. She had arrived at the correct answer by identifying where the values on the x-axis (representing package weights) were most concentrated, estimating a balance point rather than relying on precise calculation. This gave her a sense of alignment with students who showed a similar gaze. Matching these plots reinforced her confidence in the use of gaze data as a reliable tool for interpreting reasoning. However, this confidence was challenged by one student whose gaze plot showed no clear direction. Fixations were scattered across the graph, appearing on labels, the title, and multiple non-adjacent bars. The participant described this case as confusing and said she would return to it later. When she did, she remained uncertain. Unlike Sophie's more horizontal scanpath or the participant's own approach, this student's gaze did not follow any recognisable structure, making it difficult to infer their thinking. Importantly, the participant also recognised the limitations of gaze-based evidence. As she progressed through the task, she began to realise that gaze data was not always easy to interpret. When

the gaze pattern seemed clear, it helped her understand how the student might be reasoning. But when the data looked scattered or came without a clear explanation, it became much harder to tell what the student's reasoning was. This shift illustrates an emerging awareness that the usefulness of gaze data depends on how well it aligns with the context, and that interpretation is not always straightforward.

## CONCLUSION AND IMPLICATIONS

This study explored how a pre-service teacher engaged with student gaze data while working through a vignette. Preliminary results traced how her reasoning evolved from early, assumption-based judgments to more reflective and comparative interpretations. Over time, she revised her thinking, used multiple sources of information, and began to identify the frequency–value confusion systematic error. This development is consistent with prior findings by Knoop-van Campen et al. (2021), who found that while teachers can use gaze data to identify reading strategies, they may also interpret it as evidence of less directly observable constructs, such as motivation or concentration. In addition, the participant described gaze data as especially helpful when explanations were vague and emphasised its potential use in classroom settings and teacher education.

Beyond this single case, the study raises broader considerations for teacher education. Pre-service teachers bring diverse perspectives, shaped by their own experiences and expectations, which may influence how they interpret gaze data. Such variation can reveal how personal biases shape diagnostic reasoning and highlight the need for structured opportunities to reflect on the interpretation of such complex visual data. Over time, and through repeated engagement with vignettes, they may develop a more systematic approach, learning to treat gaze data not as definitive evidence, but as one component within a broader diagnostic process. As their interpretations become more nuanced and accurate, these insights may inform teacher education programs by highlighting how gaze data can support pre-service teachers in identifying students' reasoning strategies and potential errors when interpreting complex spatial data.

At the same time, the study has some limitations. The findings are based on one participant and represent an early stage of analysis with emerging themes. Another limitation is that the study used only one form of gaze data, static gaze plots. Other types of gaze data, such as gaze videos or heatmaps, were not included and might offer different insights into students' reasoning or help triangulate interpretations more effectively. Despite these limitations, this case highlights how eye-tracking data, when used alongside verbal explanations and contextual cues, can be a valuable resource in developing teachers' diagnostic skills.

## ACKNOWLEDGEMENTS

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