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Graph Literacy in the Classroom: Examining Mathematics Teachers' Instructional Practices

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Abstract

In this study, middle school mathematics teachers' graph-teaching practices were examined within the framework of graph literacy. A case study was conducted with six 7th-grade mathematics teachers in public schools, using classroom observations and semi-structured interviews analyzed through an 18-indicator graph literacy observation form. The findings revealed that teachers mainly focused on reading data within context, selecting appropriate graph types, and comparing data sets using graphs. In contrast, instructional practices involving changes to data and their graphical representations, physical resizing of graphs without changing the underlying data, and interchanging the horizontal and vertical axes were rarely observed. No practices corresponding to drawing attention to variation were observed. Interview findings also indicated that teachers emphasized students' difficulties with pie charts, ratios, and scaling. Overall, the observed practices concentrated on a limited subset of the graph literacy indicators, suggesting a need for professional development that supports a broader range of graph-teaching practices.

Introduction

In our world, which is increasingly surrounded by data (Engledowl & Tarr, 2020), making inferences and evaluations based on this data is essential for making informed decisions about our lives (Rodrigues & Ponte, 2020). As the importance of making effective data-driven decisions grows, so does the significance of statistics and statistical literacy (Martínez-Castro et al., 2023; National Council of Teachers of Mathematics, 2000). In parallel with the increasing importance of statistics, it becomes clear that students, regardless of their level of education, need to be equipped with statistical knowledge and skills to be statistically literate (Aliaga et al., 2005; Büscher, 2022; Cimpoeru & Roman, 2018; Sharma, 2017; Utomo, 2021). Studies on statistics education emphasize the importance of improving students' statistical knowledge and skills, particularly at the middle school level (Carvalho, 2008; Gal, 2019).

Statistical literacy is defined as the ability to understand and utilize statistical information (Budgett & Rose, 2017; Callingham & Watson, 2017). It involves organizing data, representing it in various forms, and critically interpreting these representations to draw conclusions (Ben-Zvi & Garfield, 2004; Franklin et al., 2007). The updated Pre-K–12 GAISE II report situates graphical representations within statistical investigations, emphasizing the interpretation of data in context and attention to variability (Bargagliotti et al., 2020). Among the various forms of data representation, graphs are especially important because they simplify complex information and enhance comprehension (Zucker et al., 2015). Graphs and other data visualizations are used in journalistic media to communicate quantitative information, requiring readers to interpret visual and numerical features and consider their meaning within context (Gal & Geiger, 2022; Wiik & Vos, 2024). Wiik (2025) examined journalistic data visualizations through visual-numeric literacy, highlighting the interconnected roles of decoding visual and numerical information, acting on that information, and reflecting on the trustworthiness of the data and their representations. Graphs are also used beyond mathematics, for example to communicate health-related statistical information and support informed decisions (Galesic & Garcia-Retamero, 2010). Therefore, developing skills in reading, creating, and interpreting graphs is crucial for students (Boote, 2014; Patahuddin & Lowrie, 2019).

Fry (1981) described graphical literacy as the ability to read and draw graphs. Graph literacy is understood in this study as a multidimensional construct encompassing reading and interpreting graphical information within context, comparing data, selecting and constructing appropriate graphical representations, understanding

scaling and variation, evaluating misleading graphs, and transforming between representations (Carver et al., 2016; Curcio, 1987; Friel et al., 2001; M. T. Gonzalez et al., 2011; Shah & Hoeffner, 2002). These skills are increasingly emphasized in educational curricula (Ministry of National Education, 2018, 2025). Research has documented difficulties in working with graphs among students, prospective teachers, and practicing teachers (Aoyama, 2007; Díaz-Levicoy et al., 2019; Friel et al., 2001; M. T. Gonzalez et al., 2011; Koleza & Kontogianni, 2016; Matuk et al., 2019; Rodríguez-Alveal & Aguerrea, 2025; Sharma, 2006; Uyanık & Özmen, 2026; Wu, 2004). Garcia-Mila et al. (2014) found that students in Grades 5–8 experienced difficulties in organizing and aggregating data and incorporating a second variable when constructing bar graphs. Çatman Aksoy and Işıksal Bostan (2021) found that many seventh-grade students could interpret average in the contexts presented through bar and line graphs but had difficulty interpreting variation. Sharma (2006) found that high school students struggled to make inferences from graphs. Matuk et al. (2019) observed that students often relied on personal interpretations rather than scientific reasoning, and Ozmen et al. (2020) reported difficulties in accessing information not explicitly presented in graphs. Arteaga et al. (2012) describe difficulties in graph interpretation and construction involving graph selection, scales, titles and labels, and the interpretation of represented information. Glazer (2011) emphasizes that graph interpretation is influenced by graph characteristics, content, and readers' prior knowledge, and that students need explicit guidance to develop this skill.

Addressing these challenges requires effective teaching strategies, as teachers' instructional methods significantly influence students' understanding (O. Gonzalez, 2014). Moreover, teachers' graph literacy and their graph-teaching practices are important for supporting students' conceptual understanding of graphs. For this improvement to occur, it is first necessary to assess and evaluate the current state of graph teaching.

Especially in the teaching of statistics (Burgess, 2011; Sorto & White, 2004), which differs from mathematics in some respects (Elfitra & Siregar, 2020), it is important to use real data sets in the classroom (Sharma, 2017) and to determine classroom practices that emphasize the meaning of basic statistical concepts (Konold & Higgins, 2003). Studies indicate that learning and teaching statistics are difficult (Tishkovskaya & Lancaster, 2012; Zakari, 2020; Zieffler et al., 2008). As a result, teachers face challenges in teaching statistics (Batanero et al., 2011; Ponte, 2011), and their knowledge of how to teach statistics is often insufficient (Burrill & Biehler, 2011; Connor, 2010; Umugiraneza et al., 2022). Given the place of graphs in the data-processing learning domain, examining teachers' graph-teaching practices can provide insights into how this content is addressed in classroom instruction. A review of the literature reveals that there is insufficient research on teachers' graph-teaching practices (M. T. Gonzalez & Pinto, 2008; M. T. Gonzalez et al., 2011). Examining how teachers teach graphs in the classroom is deemed important (Baki, 2018; Monteiro & Ainley, 2007). Furthermore, attention has been drawn to the significance of teachers' instructional practices that allow students to express their thoughts about graphs (Sorto, 2004).

Although research has examined students' graph comprehension and documented difficulties in interpreting and constructing graphs, less attention has been paid to how teachers address different aspects of graph literacy in classroom instruction. In particular, there is limited empirical evidence on which aspects teachers emphasize and which receive less attention in their graph-teaching practices. Examining these practices can help identify the learning opportunities offered to students and inform teacher education and professional development related to graph teaching. In this study, graph-teaching practices refer to teachers' instructional actions when addressing graph-related content, including the explanations they provide, the questions they ask, the examples they use, and the activities through which they engage students in working with graphs. These practices are examined in

relation to graph literacy indicators to identify which aspects of graph literacy teachers address and how they address them during classroom instruction. This study aims to examine middle school mathematics teachers' graph-teaching practices in the context of graph literacy. Specifically, the study addresses the following research question:

To what extent do middle school mathematics teachers' classroom practices on graph teaching reflect the graph literacy indicators identified in this study?

Graph Literacy and Indicators

In some problem-solving-oriented approaches to mathematics education, mathematical objects are often introduced through their role in solving specific problems (M. T. Gonzalez et al., 2011). However, such an approach may be insufficient for supporting students' understanding of the nature of graphs and for enabling meaningful interpretation of data representations (M. T. Gonzalez et al., 2011). Therefore, the teaching of graph concepts requires pedagogical considerations that differ from those typically emphasized in mathematics instruction. The observation form developed in this study operationalized the aspects of graph literacy outlined in the Introduction as indicators of teachers' classroom practices. The indicators and their supporting theoretical sources are presented in Appendix 1. The following recommendations concern teachers' knowledge of graphs and classroom approaches to supporting students' graph literacy. They informed the development of the observation indicators used in this study:

- Developing teachers' technical knowledge of how different types of statistical graphs are constructed (M. T. Gonzalez et al., 2011),
- Bringing real-life examples of graph usage into the classroom (Uyanik et al., 2023)
- Offering graph-reading experiences with contextualized knowledge (Monteiro & Ainley, 2007),
- Encouraging the use of graphs across different subject areas (Zucker et al., 2015),
- Engaging students in activities to determine which graph types are appropriate for representing particular data sets (Uyanık & Özmen, 2026),
- Highlighting the difficulties students may face when creating or reading graphs (Bruno & Espinel, 2009; Shaughnessy, 2007),
- Incorporating metacognitive instruction into graph-teaching activities (Kramarski, 2004),
- Facilitating transformations between different data representations (M. T. Gonzalez et al., 2011),
- Allowing students to discuss and reflect on matching different graphical representations of data (Aliaga et al., 2005),
- Providing students with opportunities to construct graphical representations of data (Carver et al., 2016),
- Investigating the situations that graphs can or cannot represent (Carver et al., 2016),
- Promoting metacognitive approaches to graph reading and interpretation (Shah & Hoeffner, 2002).

Research on difficulties in graph construction and interpretation also informed the inclusion of indicators concerning teachers' attention to potential student errors and difficulties (Bruno & Espinel, 2009; Shaughnessy, 2007). Based on these theoretical perspectives and recommendations, 18 graph literacy indicators were

developed to examine teachers' graph-teaching practices. The indicators and their theoretical foundations are presented in Appendix 1.

Methodology

In this case study, which evaluated middle school mathematics teachers' graph teaching in the context of graph literacy, a qualitative research method was adopted. The case was defined as the instructional practices related to graph literacy within seventh-grade mathematics teaching. The six participating teachers were considered within this shared instructional context rather than as six independent cases. This approach enabled the examination of commonalities and variations in how graph literacy indicators were reflected in classroom instruction.

Study Group

The sample of the study consisted of six 7th-grade mathematics teachers working in public schools in Edirne province. The participants included one female teacher (T3) and five male teachers (T1, T2, T4, T5, and T6). Seventh grade was selected because the curriculum applicable to the study included instruction on line, bar, and pie graphs. To ensure diversity, teachers with varying years of professional experience were included, grouped into three categories: 0–15 years, 16–25 years, and over 25 years. Participation was voluntary after teachers were informed about the study. Each teacher was assigned a code (T1–T6). Demographic information is presented in Table 1.

Table 1
Demographic information of the teachers in the research group

Teacher Code	***Years of Professional Experience***	***Graduated Department***
T1	10	Mathematics Teacher Training
T2	11	Mathematics Teacher Training
T3	14	Mathematics Teacher Training
T4	16	Mathematics Teacher Training
T5	22	Mathematics
T6	43	Teacher Training School

Data Collection Tools

In this study, observations and interviews were used to evaluate teachers' graph teaching within the context of graph literacy. Information about the measurement tools is provided below:

Observation

The researcher conducted in-class observations to assess the teachers' graph-teaching practices in the classroom environment. During these observations, the lessons were videotaped to prevent data loss. A

literature-informed observation form was developed to analyze teachers' graph-teaching practices. The observation form was not used in real-time during the classroom observations. Instead, after transcribing the video recordings, the raw data were analyzed according to the observation form.

To create the observation form, studies on the evaluation of graph teaching and graph literacy were first reviewed. Based on these reviews, preliminary indicators were developed. These indicators were then sent to three academicians specializing in this field for feedback. In response to expert opinions, revisions were made to indicators that were unclear, redundant, or too broadly defined. Following this, the researcher conducted a pilot study with eight middle school mathematics teachers. After the pilot study, necessary adjustments were made, and the observation form was finalized. Once the form was completed, classroom observations were conducted with six teachers. The number of hours for each teacher's lessons is provided below:

Table 2
Information on Course Observations

Teacher Code	***Number of Observed Lessons***	***Learning Outcome***
T1	2	Constructs and interprets a line chart for data.
T2	4	Constructs and interprets a pie chart for a group of data.
T3	6	Shows data in bar, pie, or line charts and makes appropriate transformations between these representations.
T4	4	
T5	7	
T6	4	

Note. The three learning outcomes applied to all participating teachers. The numbers indicate the total lessons observed for each teacher across these outcomes, rather than the number of lessons devoted to each outcome separately.

All lessons in which the participating teachers taught the graph-related learning outcomes listed in Table 2 were observed, yielding 27 lessons in total. The number of observed lessons varied across teachers. Each lesson lasted 40 minutes.

Semi-structured Interviews

Semi-structured interviews were conducted after the classroom observations to gather demographic information about the teachers, provide further explanations of the observed practices, and explore teachers' reasons for their instructional actions. A general interview outline was prepared and refined based on feedback from an academic specializing in mathematics education with research experience in statistics teaching. The outline included questions about lesson planning, the selection and sequencing of examples, the use of everyday contexts, graph-type selection, students' difficulties, and intended learning goals. It was supplemented with teacher-specific questions about practices observed during the lessons; therefore, the interview content varied slightly across teachers. The interviews were audio-recorded with permission to prevent data loss.

Data Analysis

Data analysis is presented under three headings: analysis of observations, validity and reliability and analysis of interviews.

Analysis of Observations

The assessment of middle school teachers' graph teaching in the context of graph literacy involved a systematic analysis of classroom video recordings. The video data were analyzed using an observation form consisting of indicators related to graph literacy. The indicators were used to identify teachers' observable instructional actions related to graph literacy, rather than to assess students' attainment of graph literacy skills. Coding focused on how teachers addressed these aspects through explanations, questions, examples, and classroom activities. The resulting frequencies describe the occurrence of indicator-related practices; they do not, by themselves, measure instructional quality or student learning. For each teacher and each indicator, frequencies and percentages were calculated to describe instructional patterns.

Validity and Reliability

All classroom video recordings were transcribed verbatim to generate raw data for analysis. The use of video data enabled repeated and detailed examination of teachers' instructional practices. The observation form was grounded in the literature on graph literacy. In addition, examples illustrating how teachers' instructional statements were coded in relation to selected graph literacy indicators are presented in Table 3. Providing this sample analysis enhances the transparency of the coding process and supports the validity of the interpretations. Regarding reliability, 20% of the observation data were randomly selected and independently coded by a second researcher.

Inter-coder reliability was calculated using the Miles and Huberman (1994) formula (Number of agreements / [Number of agreements + Number of disagreements]). The inter-coder agreement was found to be 85%, indicating a high level of consistency. Following the comparison of coding results, the researcher reviewed the analyses and made final adjustments to eliminate any remaining coding inconsistencies.

Table 3

Sample Teacher Expressions and Explanations for Some Indicators

Indicators	***Sample Expressions Used by the Teacher During Teaching***	***Explanation***
Using graphs with examples from daily life and asking students to give examples	'Where do we see graphs in our daily lives, children? When we use the audience wildcard in the Who Wants to be a Millionaire contest, the distribution of the audience's answers is shown in the bar graph, teacher.'	In this context, it was evaluated within the scope of this indicator because the teacher enabled students to give examples of the use of graphs in daily life (media, press, trade, etc.).
Explaining the basic elements that make up graphs (axes, title, starting point, data, etc.)	'What does the horizontal bar show us and what does the vertical bar show us? I intersect the horizontal one and the vertical one. When I look at the horizontal one, I can see the years, and the vertical one is the height, and I can see the height in 2013.'	In this context, it was evaluated within the scope of this indicator because the teacher made explanations to the students about axes, one of the basic elements of graphs.
Drawing attention to errors related to graphs	'If I don't take the angle measurements and equivalently show them, that is, if I show 90 degrees as an obtuse angle, or if I show a pie segment smaller than a pie segment corresponding to an angle of 120 degrees, this will be a misleading graph in the pie graph.'	In this context, this indicator was evaluated within the scope of this indicator due to the teacher's work on what kind of errors can be made in a graph used during the lesson (such as scaling, naming, and correct use of data).
Having students construct graphs after making changes to the data and interpret how these changes affect the graphical representations	'There is 5° between class B and class A, would it make sense if one was 50° and the other 100°? Would I have to minimize between 10° and 50° or what?'	The teacher was evaluated under this indicator because the classroom discussion focused on how hypothetical changes in numerical values could affect the graphical representation and its interpretation.

Analysis of Semi-Structured Interviews

In this study, semi-structured interviews were conducted with teachers in addition to classroom observations. The interviews were recorded using a voice recorder, and the interview data were later transcribed and transferred to a computer. The interview transcripts were examined in relation to the graph literacy indicators identified in classroom observations. Teachers' statements about their instructional priorities and decisions were compared with their observed classroom practices to provide additional context for interpreting the findings. Thus, the interview data were used to support and elaborate on the observation-based analysis rather than to evaluate instructional practices independently. For example, T3's interview statements about graphs helping to organize and make sense of data were examined in relation to I1 (emphasizing the importance of graphs) and compared with her classroom explanations related to the same indicator.

Findings

Statistics for each teacher were calculated reflecting the graph literacy indicators of the graph teaching practices used by middle school mathematics teachers in their lessons.

Table 4 presents the indicators and the frequency distribution of the practices the teachers employed during their lessons.

Table 4

Frequency and Percentage Distributions of Teachers' Inclusion of Graph Literacy Indicators in Graph Teaching

		Teachers													
		T1		***T2***		***T3***		***T4***		***T5***		***T6***		***Total***	
CODE	**INDICATORS**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**	**f**	**%**
I1	Emphasizing the importance of graphs	4	12	0	0	6	7	1	2	0	0	1	2	12	3
I2	Using graphs with examples from daily life and asking students to give examples	4	12	3	4	3	4	1	2	6	9	3	6	20	6
I3	Enabling students to think and discuss in which situations it is appropriate to use a graph type	1	3	0	0	4	5	8	15	6	9	4	8	23	7
I4	Explaining the basic elements that make up graphs (axes, title, starting point, data, etc.)	1	3	5	7	10	12	4	7	6	9	4	8	30	8
I5	Drawing attention to the importance of scaling	1	3	3	4	6	7	4	7	1	2	1	2	16	5
I6	Using graphs and asking questions to make inferences from graphs	1	3	3	4	1	1	1	2	3	5	0	0	9	3
I7	Relating readings across data to context and asking questions	4	12	13	19	23	28	7	13	9	14	14	26	70	20

Note. I1–I18 are defined in Appendix 1. Frequencies count indicator occurrences in the observed lessons. Teacher-column percentages use each teacher's total frequency; Total-column percentages use all 353 occurrences; Total-row percentages show each teacher's share of these occurrences. The final row reports the mean indicator frequency per observed lesson, calculated by dividing each teacher's total indicator frequency by the number of lessons observed for that teacher. Percentages may not sum to 100% due to rounding. Teachers differed in the number of observed lessons; frequencies do not measure teaching quality.

		Teachers													
		T1		***T2***		***T3***		***T4***		***T5***		***T6***		***Total***	
I8	Enabling them to compare data sets on a graph	5	15	9	13	4	5	3	6	9	14	6	11	36	10
I9	Providing examples of incorrect use of graphs and enabling them to interpret them	0	0	4	6	4	5	1	2	0	0	0	0	9	3
I10	Drawing attention to errors related to graphs	0	0	5	7	2	2	7	13	0	0	2	4	16	5
I11	Engaging students in activities involving the range, mode, median, and arithmetic mean of data sets using graphs	0	0	2	3	1	1	2	4	3	5	1	2	9	3
I12	Having students construct graphs after making changes to the data and interpret how these changes affect the graphical representations	0	0	0	0	0	0	2	4	0	0	0	0	2	1
I13	Demonstrating that physical changes to a graph (e.g., zooming in or out) do not change the underlying data	0	0	2	3	0	0	1	2	0	0	0	0	3	1

Note. I1–I18 are defined in Appendix 1. Frequencies count indicator occurrences in the observed lessons. Teacher-column percentages use each teacher's total frequency; Total-column percentages use all 353 occurrences; Total-row percentages show each teacher's share of these occurrences. The final row reports the mean indicator frequency per observed lesson, calculated by dividing each teacher's total indicator frequency by the number of lessons observed for that teacher. Percentages may not sum to 100% due to rounding. Teachers differed in the number of observed lessons; frequencies do not measure teaching quality.

		Teachers													
		T1		***T2***		***T3***		***T4***		***T5***		***T6***		***Total***	
I14	Making instructional statements about the most appropriate type of graph to represent a data set	12	36	12	18	7	9	8	15	14	22	10	19	63	18
I15	Emphasizing the transformation between graphs drawn in a given context and emphasizing which of these transformations is more appropriate	0	0	1	1	3	4	4	7	5	8	4	8	17	5
I16	Emphasizing that the same data can be represented by interchanging what is shown on the horizontal and vertical axes, where appropriate	0	0	1	1	0	0	0	0	3	5	2	4	6	2
I17	Asking questions to lead to an answer through a graph	0	0	4	6	7	9	0	0	0	0	1	2	12	3
I18	Drawing attention to variation in the graph	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total	33	9	67	19	81	23	54	15	65	18	53	15	353	
	Mean indicator frequency per observed lesson	16.5		16.75		13.5		13.5		9.29		13.25			

Note. I1–I18 are defined in Appendix 1. Frequencies count indicator occurrences in the observed lessons. Teacher-column percentages use each teacher's total frequency; Total-column percentages use all 353 occurrences; Total-row percentages show each teacher's share of these occurrences. The final row reports the mean indicator frequency per observed lesson, calculated by dividing each teacher's total indicator frequency by the number of lessons observed for that teacher. Percentages may not sum to 100% due to rounding. Teachers differed in the number of observed lessons; frequencies do not measure teaching quality.

Teachers most frequently used practices related to relating readings across data to context and asking questions (I7), selecting the most appropriate graph type (I14) and comparing datasets through graphs (I8). In contrast, indicators such as having students construct graphs after making changes to the data and interpret how these changes affect the graphical representations (I12), demonstrating that physical changes to a graph (e.g., zooming in or out) do not change the underlying data (I13), and emphasizing that the same data can be represented by interchanging what is shown on the horizontal and vertical axes, where appropriate (I16), were among the least frequently observed. Furthermore, indicator I18, which involves drawing attention to variation, was not used at all. Of the 353 indicator occurrences identified across the observed lessons, T3 accounted for the largest share (23%) and T1 for the smallest (9%). These shares reflect total frequencies across differing numbers of observed lessons rather than frequencies per lesson (see Table 4). The extent to which teachers incorporate indicators into their lessons directly affects the degree to which their teaching can be evaluated in terms of graph literacy. However, it is important for teachers to use a variety of indicator-related practices to support graph literacy. Repeatedly focusing on a single indicator may limit the diversity of graph-teaching practices, even when that indicator occurs frequently. Practices corresponding to I1, which concerns emphasizing the importance of graphs, were observed on 12 occasions. Six of these were used by T3, four by T1 and one each by T4 and T6. This indicator was not present in the lessons of T2 or T5. I1 emphasizes why graphs are necessary in daily life and how they contribute to it. Below is a section from T3's lesson notes related to I1.

T3: For example, there may be a province or neighborhood where people with similar opinions live. We cannot just survey that neighborhood and say all of Turkey thinks this way. We collect the data and then analyze it. One method we use here is graphing, drawing graphs. Why do we use graphs?

Student: To see the data properly.

T3: Could we also write the data in a table if there were a lot of data? But what would happen then? There would be confusion, right? I mean, our job would be more difficult, wouldn't it? There's really only one reason why we draw graphs—to make our work easier, to understand the information better, and to grasp it more quickly.

T3 emphasized that graphs are important tools for organizing data. She highlighted how disorganized data in a table can lead to confusion and hinder understanding. T3 also pointed out that graphs are crucial for organizing data collected from appropriate samples. These explanations align with the scope of I1. When asked in an interview about her primary goals in teaching graphs, T3's responses echoed her in-class statements. A portion of the interview is provided below:

R: What are the ideas and understandings you primarily aim to develop in your students when teaching graphs?

T3: First of all, visual materials allow us to see all kinds of information about the data without getting lost in it, and that makes our work easier. We use graphs because they simplify things. […]

T3's interview response was consistent with her observed emphasis on the importance of graphs (I1). Her stated rationale for using graphs—to make information easier to understand—complemented her classroom explanations about organizing data.

Regarding I2, which involves using graphs with daily life examples, teachers included this indicator 20 times: 6 by T5, 4 by T1, 3 each by T2, T3, and T6, and 1 by T4. An excerpt from T5's statements about I2 is provided below.

T5: What can we do with the line graph?

Student: How much sales are made on different days.

T5: Yes, your friend made a very good point. He touched on a logical point—how much sales were made on weekdays. Now think about the line graph in daily life. We see it in advertisements, etc. You've seen the line graph in news programs on television. Where else do you see it?

Student: Teacher, when the dollar increases in value in the news.

T5: Yes, we see it in economy programs, for example. What else?

Student: Teacher, in job finding rates.

T5: Yes. What else?

Student: The weather, teacher.

T5: The weather is a good example—increases and decreases in temperature. Let's add that to the list.

Student: Traffic accidents.

T5: Yes, if we look at it year by year, we can use it for traffic accidents as well.

T5 asked students to give examples of where they encounter graphs in their daily lives. In doing so, he guided the formation of knowledge about situations where students might use different types of graphs. Additionally, the teacher enriched the students' examples by providing further real-world examples of how graphs are used in daily life. T5's interview responses were consistent with his observed classroom practices. An excerpt from T5's interview is presented below:

R: How do you choose the examples you use in the lesson for these outcomes? Are there any factors you take into account when selecting these examples? If so, what are they?

T5: I start by engaging with the children. I continue by asking questions and getting answers from them in a way that suits their level. I try to gather data with questions like their favorite team or favorite food and create graphs with them. I make sure to capture the child's attention and ensure the examples come from their own life.

R: Do you include real-life examples or problems with real data in your lessons? If so, for what purposes?

T5: Yes, it helps the child remember and retain the information.

T5's interview response provided a rationale for his observed use of daily-life examples (I2): attracting students' attention and supporting retention. In the observed lesson, this approach was reflected in his questions inviting students to identify situations in which they encountered graphs.

Practices corresponding to I5 (drawing attention to the importance of scaling) included explanations about the consequences of incorrect scaling, the meaning of graph intervals, and how the interpretation of the same data set changes with different scales. An example question from T2 is provided below.

T2’s question related to I5

T2 aimed to explain how the interpretation of the data in the graph would change with different scaling by using this question (Fig. 1). T2's explanations are provided below:

T2: What does it say? It shows that the difference between the k and l values is significant. Where is it?

Student: 1.

T2: Isn’t it at 1? But when we look at the values, we see that it isn’t. This is a deceptive tactic. The truth of the graph should be like 2. In other words, the difference between the units should be equal so that we can interpret it more easily. It seems as if the difference in the first graph is too large. But actually, the difference (points to the 2nd graph) is only this much. When we look at the whole, starting from zero, the difference is actually tiny, but when drawn like the first graph, it seems like there’s a huge difference. So, they used a deceptive tactic.

T2 demonstrated to students that the same data can lead to different interpretations when presented on different scales, emphasizing that equal intervals between units make graphs easier to interpret. These explanations were considered within the scope of I5. In the interview, T2 explained the reason for emphasizing scaling as follows:

R: During the lesson, you included examples that emphasized the importance of scaling in graphs. Is there a reason for this?

T2: Statistics are very important, but they’re particularly important in these visuals. There needs to be something proportional. […] To prevent misinterpretations, scaling is crucial. It might be a small difference, but it looks much bigger if the scaling is incorrect.

During the interview, T2 emphasized that equal intervals in graphs are crucial for accurate interpretation, which aligns with his lesson explanations.

I7 was the most frequently used indicator (see Table 4). Practices corresponding to this indicator included selecting familiar data sets for graph construction and relating data readings to context through interpretations and questions. An example from T6’s lesson is presented below.

T6’s question related to I7

T6 aimed to explain the relationship between percentages and proportions to the students using this question (Fig. 2). T6's explanations are provided below:

T6: […] How do we calculate that?

Student: If we say 10 banknotes correspond to 30 degrees, then how many banknotes correspond to 90 degrees? We get 30.

T6: It has to be 3 times as much, so there will be 30.

Student: What is the total value of the 10 TL banknotes? If 30 degrees corresponds to 10 banknotes, then 120 degrees is four times 30 degrees, so there are 40 banknotes, giving a total of 400 TL.

T6: Which type of banknote has the highest total value?

Student: There were 10 banknotes of 100 TL, so that makes 1,000 TL. Then there were 40 banknotes of 10 TL, which makes 400 TL. Then 30 banknotes of 50 TL, which makes 1,500 TL. And finally, 40 banknotes of 5 TL, which makes 200 TL. So the 50 TL banknotes have the highest total value.

This question uses a pie graph to show how banknotes of different values are distributed. Students need to recognize that, although a 100 TL banknote has a higher face value than a 10 TL banknote, the total value depends on the quantity of banknotes. Recognizing this relationship requires connecting the data, which is why the question was evaluated within the scope of I7.

Interview explanations about student difficulties were consistent with the lesson statements of T2, T3, and T4, who frequently addressed such errors and organized activities to resolve them. Although no practices corresponding to I10 were identified in T1's and T5's observed lessons, both teachers highlighted student difficulties in their interviews. Excerpts from the interviews are presented below.

T1: We find that students struggle more with misconceptions in pie graphs. The use of ratio and proportion in pie graphs sometimes presents limitations for some students. Before transforming a pie graph, we revisit the topic of ratio and proportion and guide them on how to use it correctly.

T2: They face difficulties because the pie graph involves too many mathematical operations. Students struggle with understanding which type of graph to use and how to interpret it. There can be proportional mistakes related to the relationship between size and magnitude. These issues can be addressed with daily life examples or by practicing more math calculations. For example, if they have a problem with ratio and proportion, they can work on it more.

T3: When drawing a graph, students think it's enough to draw the axes with equal spacing, scale them, and just place the points. With a pie graph, if there is a problem with proportion, they also struggle there. When the slices of a pie graph are 30, 60, and 90 degrees, they directly say x, 2x, 3x, which comes from memorizing proportionality rules. They tend to skip over it. Some students also have problems measuring angles when creating a pie graph. It's important to explain how to measure an angle again, show them how to do it, and provide examples so they can understand the error and how to avoid misinterpreting it. The goal is for students to recognize and correct their own mistakes.

T5: I notice that they struggle with determining the type of graph, transformations, and mathematical operations. However, they don't face much difficulty with interpretation. The problematic area is addressed by solving questions related to it, and they are guided with examples.

In the interview excerpts, T1, T2, and T3 highlighted difficulties with pie graphs and proportional reasoning; T3 also discussed scaling and angle measurement. T2 and T5 highlighted difficulties with selecting the appropriate graph type, while T5 also mentioned transformations and mathematical operations. They believed that including examples of these common errors in their lessons was important.

Conclusion, Discussion and Recommendations

I7, which concerns relating data readings to context and asking questions, was the most frequently observed indicator in teachers' classroom practices. Within the scope of this indicator, teachers associated data with context while interpreting it, made comments by selecting situations familiar to students when creating data sets, and asked questions that involved interpreting data relationships. Additionally, teachers drew attention to this indicator by making various interpretations using data. In their interviews, teachers emphasized the importance of obtaining data sets from students and making comments on these data sets to ensure active student participation and to motivate students during the lesson. This suggests that they prefer to use such practices in the classroom. Research on prospective teachers has identified difficulties in interpreting graphs and connecting the results of data analysis to the problem context (Arteaga et al., 2015; M. T. Gonzalez et al., 2011). Difficulties in graph interpretation have also been reported among practicing middle school mathematics teachers (Uyanik et al., 2023).

Teachers frequently provided instructional explanations about representing a data set with the most appropriate graph type. It is thought that the inclusion of separate outcomes for each graph type at the 7th-grade level in the curriculum may influence this. In addition, teachers stated in their interviews that for students to decide on the appropriate graphical representation, they should first define each graph type and then make appropriate choices among them. In their interviews, T2 and T5 reported that students experienced difficulties in selecting the appropriate graph type. These concerns may drive the emphasis on practices related to selecting the appropriate graph type during lessons. However, teachers generally relied on similar examples without presenting different contexts. In other words, teachers mainly explained graph types using similar and limited contexts, such as line graphs for time-dependent data like exchange rates, pie graphs to display election vote distribution, and bar graphs to compare student scores. Arteaga et al. (2012) describe students' difficulties in selecting graphical representations appropriate to the type of variable and the problem being investigated. More specifically, Ozmen et al. (2020) found that some eighth-grade students used the same graph type for different contexts, indicating difficulties in selecting a representation appropriate to the given context. Therefore, it is thought that providing such explanations may help students overcome difficulties in determining the correct graph type.

Of the 353 indicator occurrences identified in the observed lessons, 70 (20%) involved relating data readings to context and asking questions (I7), while 63 (18%) involved instructional explanations about the most appropriate graph type for representing a data set (I14). Considering that the observation form included 18 indicators, these findings suggest that classroom practices tended to foreground a limited set of indicators. This pattern may indicate that certain aspects of graph teaching—particularly those supporting students' conceptual understanding and active engagement—were less visible in the observed lessons.

Teachers did not provide explanations addressing variation in graphs. It is important for students to explain and recognize the central role of variation in statistics (Carver et al., 2016; Sanchez et al., 2011). Carver et al. (2016) emphasized that variation is also fundamental to understanding statistical relationships and making inferences. Sanchez et al. (2011) noted that variation is linked to many core statistical concepts. Indeed, studies indicate that students have intuitive ideas about variation (Reading & Shaughnessy, 2004). It is important to reveal such intuitive ideas through data representations. Peters and Stokes-Levine (2019) showed how professional development involving critical reflection, multiple representations, and discussion supported teachers' understanding of measures of variation. Although range is the only measure of spread included in the middle school curriculum, opportunities to discuss variation are not limited to formal measures of spread. Teachers can also draw students' attention to how values vary within a data set and how this variation is represented in graphs.

Therefore, the absence of observed practices corresponding to I18 cannot be explained solely by the exclusion of standard deviation and variance from the curriculum.

This study also revealed that teachers provided limited explanations and examples for the indicator that draws attention to situations where students may have difficulties with graphs. Although T1 and T5 acknowledged students' graph-related difficulties in their interviews, no practices corresponding to I10 were identified in their observed lessons. This suggests that awareness of student difficulties does not necessarily translate into classroom practices that explicitly address them. It is important for teachers to address situations that may lead to student misconceptions during their teaching practices. Similarly, Williams and Ryan (2000) noted that in-class practices to overcome students' misconceptions and errors, which are crucial for effective teaching, should be incorporated into teachers' lessons. Ijeh (2012) pointed out that teachers need to be aware of student difficulties to foster meaningful learning. For this reason, the explanations, questions, and interpretive examples that teachers include in their lessons will be important for helping students overcome these mistakes. Indeed, the literature indicates that pre-service teachers and teachers often struggle to identify students' errors (Daiga, 2018; Estrella et al., 2015; Sorto, 2004). However, the present findings describe teachers' graph-literacy-related practices in the observed lessons, rather than directly assessing their knowledge of individual graph types or student misconceptions. Limited attention to particular indicators therefore points to aspects that could be strengthened in classroom instruction, but does not by itself establish a lack of teacher knowledge.

Differences in the number of observed lessons should be considered when interpreting frequency counts across teachers. Higher total frequencies may reflect a wider range of observed indicators or repeated attention to a limited set of indicators, and should therefore not be interpreted as evidence of broader or higher-quality instruction.

The findings contribute to the literature in several ways. First, while previous studies have primarily focused on students' graph literacy levels or teachers' knowledge of graphs, this study provides evidence regarding how graph literacy is enacted in authentic classroom settings. Second, the findings reveal that teachers tend to concentrate on a limited number of graph literacy indicators, whereas indicators related to variation, scaling, transformations between representations, and data modification receive considerably less attention. Finally, the study offers an observation framework consisting of 18 graph literacy indicators that may be useful for future research and professional development programs aimed at improving graph teaching. In teacher education and professional development, the indicators could be used to guide reflection on lesson excerpts and the design of graph-related activities. For example, teachers could examine which indicators their instruction addresses and plan activities involving aspects that received limited attention in this study, such as variation, data modification, and transformations between appropriate graphical representations.

Technological applications are highly valuable in teaching graphs, as they save time in drawing graphs, allow for easy manipulation of data, and enable conversion between different types of graphs. Teachers can be introduced to applications such as Excel and TinkerPlots, which facilitate graph-related tasks, and they can be encouraged to integrate these tools into their lessons through professional development activities focused on graph-related topics. Considering the prevalence of graphs in the age of technology, it has become essential for teachers to integrate technology into their teaching when designing learning environments. Accordingly, future studies could explore how technology-integrated teaching enhances students' graph literacy skills by examining the role of different technological tools and instructional designs.

Declarations

Ethics approval:

Ethical approval was obtained from the Ethics Committee of Trabzon University Rectorate on February 15, 2022 (document no. E-81614018-000-2200007496).

Consent to participate:

Informed consent was obtained from all participants included in the study.

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Author Contribution

S.U. collected and analyzed the data and drafted the manuscript. Z.M.Ö. supervised the study and critically reviewed the manuscript. Both authors reviewed and approved the final version.

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Data availability:

The raw classroom observation and teacher interview data are not publicly available to protect participant confidentiality. Anonymized excerpts supporting the findings are included in the article.

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Figures

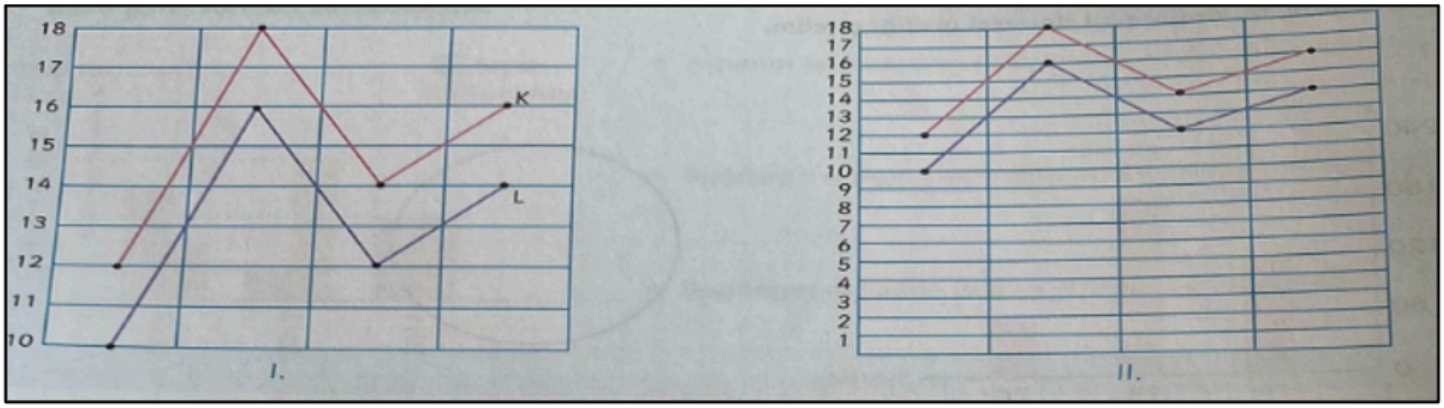

Figure 1

An example question from T2 is provided.

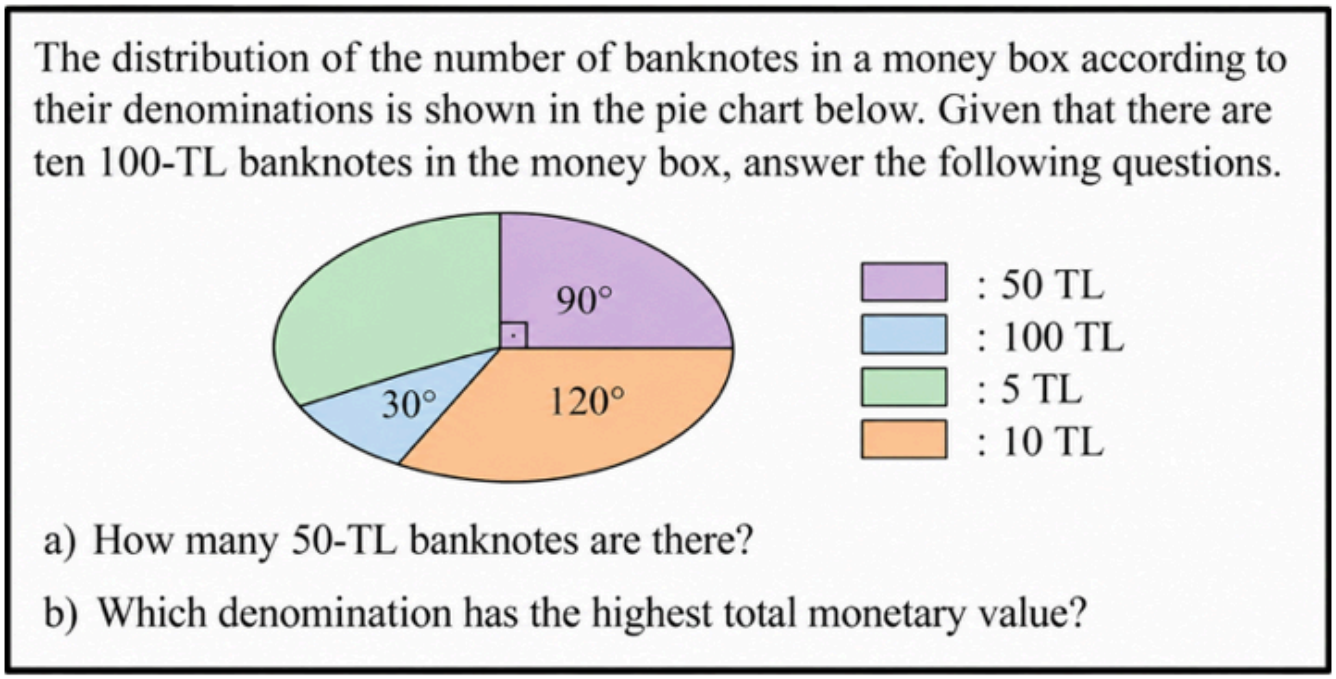

Figure 2

An example from T6's lesson is presented.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Appendix1.docx