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Enhancing Statistical Literacy in Data Representation: The Impact of Problem-Posing Intervention*

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Abstract

Statistical literacy includes the components of data collection, data analysis, data representation, and drawing inferences from data. This study aims to investigate the impact of a teaching environment based on problem-posing activities on middle school students' statistical literacy, specifically on the data representation component. The study was conducted with 32 seventh-grade students in a middle school in Turkey. 17 students were in the experimental group, and 15 were in the control group. In the study, a mixed-methods research design was adopted, wherein quantitative data were collected using a quasi-experimental method. In the experimental group, teaching was conducted using problem-posing activities, while the control group continued with the teacher's ongoing teaching method. A test was developed to determine the students' statistical competency in the data representation component of statistical literacy. Interview questions were also developed to assess the students' levels of statistical literacy. The students who participated in the interviews were selected based on the results of a prediction test administered to both groups before the intervention. Validity and reliability studies for the tests, as well as the analysis of the answers given by the students, were conducted using the Rasch model. The raw scores obtained from the tests were first converted into linear measures. Subsequently, frequencies, percentage distributions, independent t-test, and ANCOVA analyses were performed. The findings of the study indicated that there was a statistically significant difference in favor of the experimental group students in terms of the data representation component of statistical literacy. Additionally, the interview results revealed that students in the experimental group demonstrated high-level performance in statistical literacy. Based on these results, it is recommended that learning environments offer experiences based on problem-posing activities in the context of statistical processes, to support the development of students' statistical competencies and improve their statistical literacy levels.

Keywords: Problem-posing, middle-school mathematics, statistical literacy, data representation

Veri Temsilinde İstatistiksel Okuryazarlığı Geliştirme: Problem Kurma Temelli Bir Müdahelenin Etkisi

Öz

İstatistik okuryazarlık, veriyi toplama, analiz etme, temsil etme ve veriden çıkarım yapma bileşenlerini içermektedir. Bu çalışma, problem kurma etkinlikleri temelinde yapılan bir öğretim sürecinin ortaokul öğrencilerinin istatistik okuryazarlık bileşenlerinden veri temsiline etkisini incelemeyi amaçlamaktadır. Çalışma, Türkiye'deki bir ortaokulda öğrenim gören 32 yedinci sınıf öğrencisiyle yürütülmüştür. Bu öğrencilerden 17'si deney grubunda, 15'i ise kontrol grubunda yer almıştır. Çalışmada, karma yöntem araştırma deseni tercih edilmiş olup, nicel veriler yarı deneysel bir yöntemle toplanmıştır. İstatistiksel süreci temel alan problem kurma etkinlikleriyle istatistik öğretiminin yapıldığı deney grubunun aksine, kontrol grubunda öğretmenin süre gelen öğretim yöntemi uygulanmıştır. Öğrencilerin istatistiksel yeterliğini ölçmek amacıyla istatistik okuryazarlığın veri temsili bileşenine odaklanan bir test geliştirilmiştir. İstatistik okuryazarlık düzeylerini tespit etmek için ise mülakat soruları hazırlanmıştır. Mülakatlara katılacak öğrenciler, uygulama öncesinde her iki gruba uygulanan yordama testinin sonuçlarına göre seçilmiştir. Testlerin geçerlik ve güvenirliğinin incelenmesi ile öğrencilerin sergiledikleri performansların analizi Rasch Kuramı temelinde gerçekleştirilmiştir. Testlerin uygulanmasıyla erişilen ham puanların öncelikle lineer puanlara dönüşümü yapılmıştır. Daha sonra bu puanların frekansları ve yüzde dağılımları ile birlikte bağımsız *t*-testi ve ANCOVA analizleri yapılmıştır. Çalışma sonunda elde edilen bulgular veri temsili bileşeninde istatistiksel yeterlilik açısından deney grubu öğrencileri lehine anlamlı farklılık olduğunu ortaya koymuştur. Gerçekleştirilen mülakatlar deney grubundaki öğrencilerin istatistik okuryazarlık düzeyi bakımından üst seviyede performans sergilediğini ortaya koymuştur. Araştırmanın sonuçları doğrultusunda, öğrencilerin istatistiksel yeterliliğinin gelişimini desteklemek ve istatistiksel okuryazarlık düzeylerini artırmak amacıyla, öğretim sürecinin istatistiksel süreç temelinde yapılandırılmış problem kurma etkinliklerine dayalı deneyimler sunması tavsiye edilmektedir.

Anahtar kelimeler: Problem kurma etkinlikleri, ortaokul matematik öğretimi, istatistik okuryazarlığı, veri temsili

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INTRODUCTION

In the digital age, individuals are constantly exposed to vast amounts of information through digital systems, mobile devices, social media, newspapers, and other communication platforms. The ability to read, interpret, and draw conclusions from the data provided by these sources has become not only a critical life skill but a civic necessity. Indeed, individuals' decisions—ranging from personal health choices to evaluating political claims—often rely on accurate data interpretation (Hamre, 2014). Therefore, acquiring competencies such as collecting, organizing, analyzing, representing, and interpreting data is central to becoming a statistically literate individual (Koparan & Akıncı, 2015; Watson & Callingham, 2003). Statistical literacy enables individuals to make informed judgments in a wide array of domains, including economics, health, education, and daily life (Batanero et al., 2011; Garfield & Ben-Zvi, 2008).

Given the increasing emphasis on statistical reasoning in modern curricula, educational systems worldwide have sought to embed statistical literacy into mathematics instruction. The National Council of Teachers of Mathematics (NCTM, 2000) has emphasized key focal areas in statistics education, including data visualization, quantitative literacy, and statistical inference. In Turkey, significant steps have been taken to integrate these concepts into the national curriculum. The Ministry of National Education (MoNE, 2005; 2013; 2018; 2024) has emphasized the role of data processing and statistical interpretation in developing mathematically literate citizens. Particularly, the Turkey Century Maarif Model (MoNE, 2024) highlights statistical literacy as a fundamental component of middle school mathematics education.

Middle school is a critical period for cognitive development and the acquisition of foundational skills. Eccles (1999) emphasized that ages 6–14 represent a stage of rapid cognitive growth, making this a key window for developing statistical reasoning. However, despite curricular innovations, existing instructional approaches have often been criticized for emphasizing procedural computations over meaningful understanding and interpretation of data (Shaughnessy, 2007; Sharma, 2017; Watson, 2006). Students are frequently unable to make connections between statistical concepts and real-life contexts or reason effectively with data. This shortcoming highlights the need for innovative instructional models that provide students with opportunities to engage deeply with statistical ideas. This gap is further highlighted by the observation that statistics courses are often 'rarely taught in a way that connects the data-enriched world to the educational experiences of learners'. Instruction frequently remains 'mostly procedural' and disconnected from real-world settings. In response, recent reforms emphasize the value of authentic, context-based tasks where learners examine data through a 'critical contextual lens' and prioritize the 'cultivating [of] deep and critical reflection on social issues' (Yilmaz et al., 2023).

One promising approach is the use of problem-posing-based learning environments. Such environments invite students to actively construct problems related to given data sets, thereby promoting inquiry, critical thinking, and conceptual understanding (Silver & Cai, 2005; Xie & Masingila, 2017). Research shows that problem-posing activities can enhance motivation, sharpen creativity, foster understanding of mathematical concepts and encourage flexible thinking (Baumanns & Rott, 2021; Cankoy & Darbaz, 2010). However, few studies have examined how such pedagogical strategies impact statistical literacy, particularly in terms of students' ability to represent and interpret data.

The Importance of the Study

This study addresses a critical gap in the literature by investigating whether instructional environments based on problem-posing strategies can effectively enhance students' statistical literacy, particularly their competencies in the data representation component. Given that statistical literacy is essential for functioning effectively in modern society and that middle school represents a vital period for its development, identifying effective pedagogical strategies is both timely and necessary. By exploring how a problem-posing-based approach influences students' ability to understand and use data representations, this research contributes valuable insights to the field of mathematics education.

Theoretical Framework

This study is grounded in two complementary theoretical perspectives: statistical literacy and problem-posing approach in mathematics education.

Statistical literacy is conceptualized as a hierarchical and multidimensional construct that goes beyond basic numeracy. It involves the ability to understand, critically evaluate, and communicate about data encountered in various real-world contexts (Gal, 2002). Recognizing that data are not just numbers but 'numbers with a context', statistical literacy is an interpretive process that requires engaging with this context as the 'source of meaning' and the 'story reflected in the data', thereby enabling a critical examination of data-based claims and their social or

historical implications (Yılmaz et al., 2023). Statistical literacy also encompasses key processes such as collecting, analyzing, representing, and drawing inferences from data, each of which plays a crucial role in enabling individuals to interact meaningfully with statistical information. Watson and Callingham (2003) propose a six-level hierarchy of statistical literacy, ranging from idiosyncratic understanding to integrated, critical, and mathematically informed reasoning. These levels reflect progressive capacities to interpret complex data, make inferences, and critique representations. According to this model, statistical literacy comprises four interrelated components: (1) understanding the context in which data are generated, (2) interpreting and evaluating statistical messages, (3) communicating statistical information effectively, and (4) making evidence-based decisions using statistical reasoning (Watson & Callingham, 2003). These components work in tandem to enable individuals to move beyond surface-level comprehension and engage critically with statistical content in real-world contexts. Among these components, data representation plays a pivotal role, serving as a bridge between raw information and meaningful interpretation. Students' ability to select appropriate graphical formats, transform between different representations, and critique misleading visuals is essential for full participation in data-informed contexts.

Moreover, statistical literacy is increasingly viewed as both a cognitive and socio-cultural competency. According to Ben-Zvi and Garfield (2004), statistical literacy must be developed in ways that consider context, real-world applications, and students' prior knowledge. The teaching of statistics should emphasize exploratory data analysis, argumentation, and reasoning over rote calculation. These ideas resonate with constructivist approaches to learning, which posit that students build new knowledge by engaging with problems that are meaningful and relevant.

The second theoretical basis for this study is problem-posing pedagogy, which originates from the constructivist tradition and emphasizes students' active role in generating mathematical content (Silver, 1994; Silver & Cai, 2005). Problem-posing requires learners to construct their own problems, either freely, semi-structured, or based on given data. This process demands not only creativity but also a deep understanding of mathematical concepts. When applied to statistical contexts, problem-posing helps students make connections between abstract data representations and real-life scenarios.

Several scholars have demonstrated that problem-posing contributes to the development of both mathematical thinking and representational fluency. For instance, English (1997) found that students engaged in problem-posing tasks displayed enhanced ability to transfer knowledge across contexts. Similarly, Cai and Hwang (2002) found a strong link between students' problem-posing performance, such as posing more varied or complex problems, and their success in mathematical problem solving. In the realm of statistics, this approach encourages learners to question assumptions, interpret data critically, and generate hypotheses—all of which are integral to statistical literacy.

Combining these frameworks, the present study views problem-posing not only as a pedagogical method but also as a tool to facilitate the development of statistical literacy. When students generate and solve problems using authentic data, they engage in a recursive cycle of data analysis, representation, and interpretation. This active engagement promotes deeper understanding, encourages critical evaluation of graphical information, and builds a foundation for lifelong data literacy skills (Watson & Callingham, 2003; Gal, 2002).

Purpose of the Study and Research Question

The purpose of this study is to investigate the effect of a learning environment that incorporates problem-posing activities based on the statistical process on students' competency and literacy levels with respect to data representation component of statistical literacy. It seeks to determine whether students who engage in problem-posing activities demonstrate both improved performance in statistical competency and deeper conceptual levels of statistical literacy regarding data representation, compared to those taught through traditional methods. This study is derived from a broader doctoral dissertation, which examined the intervention's effect on all four components of statistical literacy (data collection, data representation, data analysis, and data inference), as well as students' attitudes toward statistics. The scope of the present article, however, is intentionally limited to reporting the findings related *only* to the data representation component, addressing one of the sub-problems of the original dissertation. The central research question guiding this study is as follows: To what extent does a learning environment that incorporates problem-posing activities within the framework of the statistical process affect middle school students' competencies and statistical literacy levels with respect to data representation component of statistical literacy?

METHOD

Research Design

This study employed a mixed-methods intervention design to examine the effect of a teaching environment enriched with problem-posing activities on middle school students' statistical literacy levels and statistical competencies with respect to the data representation component of statistical literacy. The quantitative component of the study was based on a quasi-experimental design (Creswell & Creswell, 2017). Two intact seventh-grade classes were selected; one intact class was randomly assigned to the experimental group condition, and the other to the control group condition. Both groups were administered the same instruments before and after the instructional intervention, ensuring comparability.

In parallel with the quantitative procedures, a qualitative component was incorporated to gain a deeper understanding of students' development in statistical literacy. This component included semi-structured interviews with a subset of students from both groups, conducted after the implementation. The interview data allowed the researchers to examine how students interpreted and represented data, providing insight into their reasoning processes and supporting the interpretation of quantitative findings. Thus, the integration of quantitative and qualitative data provided a more comprehensive understanding of the impact of the instructional intervention.

Study Group

The study was conducted in two separate classes at a public school, with the first author serving as the mathematics teacher for both instructional groups. To manage potential researcher expectancy effects and ensure impartiality, a clear differentiation between the instructional plans was maintained. The control group strictly followed the teacher's established, ongoing teaching method, while the experimental group received the structured problem-posing intervention. The researcher utilized detailed field notes throughout the process to document adherence to the distinct instructional plans for both groups and to ensure that instructional elements, such as time allocation and teacher enthusiasm, remained consistent.

The control group consisted of 15 students (8 girls and 7 boys), and the experimental group consisted of 17 students (11 girls and 6 boys). The selection of 7th-grade students was based on their prior experience with basic statistical knowledge, allowing them to provide the necessary feedback for the component of statistical literacy required for this study. Prior to the 7th grade, students had been introduced to foundational statistical concepts. This background included formulating research questions, the process of data collection, representing data via frequency tables and bar charts, and calculating descriptive statistics such as the arithmetic mean and range.

The selection of students for interviews was guided by their performance on the Prediction test, which is detailed in the subsequent section, specifically using their logit scores obtained from a Rasch analysis. Following the Prediction test, these logit scores were aggregated to determine an overall average and standard deviation. To ensure the interview sample was representative of the score distribution, a stratified selection process was employed. As approximately 68% of scores are expected to lie within one standard deviation of the mean, four out of six students from each group were selected from this central range. The remaining two students were chosen from the regions of the score distribution above and below one standard deviation. This method aimed to ensure that the selected students represented the full spectrum of performance and were balanced between the two groups.

The Instructional Process in the Experimental and Control Groups

Instruction for the study was administered to both groups over a four-week period, encompassing a total of seven weekly lesson hours (five regular mathematics lessons and two elective mathematics lessons). The instructional process for the control group ran concurrently with the experimental group. It consisted of the teacher-researcher's conventional teaching methods, implemented *without any intervention*. This traditional approach proceeded along two parallel dimensions, differentiated by their instructional context. The first dimension comprised the formal mathematics lessons within the regular classroom setting. This context was characterized by a teacher-centered approach, where instruction typically began with a class discussion to activate students' prior knowledge and explore real-world applications of the topic. Following this introduction, the teacher delivered theoretical information pertinent to the learning outcome, explaining and writing definitions and rules on the board. In this direct-instruction model, students' initial exposure to the content was through this theoretical presentation. To reinforce learning, the teacher provided and solved basic examples in detail. Subsequently, students were assigned similar examples to solve, with the teacher re-explaining any areas of difficulty. The question-and-answer technique was frequently utilized throughout these sessions. The second parallel dimension consisted of the elective mathematics lessons. This supportive context was dedicated entirely to practice and reinforcement. During these sessions, students solved additional problems and completed relevant exercises from the textbook. The

process involved a collective review of any misunderstanding, incorrectly answered, or skipped questions. Finally, homework was assigned either from the textbook or provided by the teacher.

For the experimental group, the elective lessons were conducted in an environment separate from the regular classroom, which was more conducive to group work. This setting was defined as the "problem-posing club." Prior to the intervention, the experimental group underwent a two-week orientation phase. This phase was designed to familiarize students with problem-posing activities, using exercises related to ratios, proportions, and percentages.

Following this orientation, the main intervention unfolded along two parallel dimensions, which were clearly differentiated by their instructional context and activity type. The first dimension consisted of the formal mathematics lessons in the regular classroom, which followed the prescribed curriculum outcomes. In this setting, the intervention primarily involved *structured problem-posing* activities (e.g., based on provided data or graphs), designed to help students adapt to the new process and content. The second parallel dimension was the problem-posing club. In this supportive context, *semi-structured problem-posing* activities were utilized. These activities were inspired by the in-class sessions but granted students greater responsibility and creative freedom (e.g., collecting their own data, completing incomplete graphs).

The pedagogical foundation in both contexts was collaborative learning within fixed, heterogeneously grouped teams of three. The activity cycle followed a systematic structure: groups formulated a problem, randomly exchanged their problem with another group, and then solved the problem they received. Upon completion, the group that originally posed the problem evaluated the solution and provided peer feedback. Any misconceptions or errors identified were addressed under the guidance of the researcher-facilitator. Throughout the process, the researcher adopted the role of a facilitator, observing the groups, taking field notes, and intervening when necessary. Each activity concluded with a general evaluation session focused on assessing the quality of the posed problems (e.g., solvability, linguistic clarity, level-appropriateness) and reinforcing conceptual understanding. This model was designed to cover specific statistics learning outcomes (line graphs, measures of central tendency, pie charts, and graph conversions) and to integrate components of statistical literacy (data collection, representation, analysis, and inference). Within this framework, four activities were designed for each of the four curriculum outcomes, resulting in a total of 16 activities during the main intervention. These activities were distributed symmetrically between the two contexts: 8 activities were implemented in the formal classroom, and 8 were implemented in the problem-posing club.

Data Collection Tools

To examine the effects of the statistics literacy-focused, problem-posing teaching design, this study utilized several data collection tools. The primary goal was to assess two distinct outcomes related to the data representation component: (1) students' conceptual levels of statistical literacy, and (2) their test performance in statistical competencies. The main data collection instruments included a Prediction Test, a Data Representation Component Test, and semi-structured interviews. To triangulate the findings and provide a richer context, these were supplemented by in-class observations, video recordings, and researchers' field notes. The instructional activities implemented in this study, along with the data collection instruments, are available in the appendices of the first author's doctoral thesis, which was supervised by the second author and is open access at the Council of Higher Education National Thesis Center (https://tez.yok.gov.tr).

Prediction Test

Given that the 7th-grade data representation topics under investigation were new to the participants, a conventional pre-test using the post-intervention instruments was deemed inappropriate. Consequently, to establish a more valid baseline and to statistically control for initial differences between the groups, a Prediction Test (PT) was developed. This instrument was specifically designed not to measure knowledge of the 7th-grade content itself, but rather the foundational, prerequisite knowledge from earlier grades that the literature identifies as critical for learning the targeted content.

The scores obtained from the PT served a crucial dual purpose in this study. First, they provided a quantitative basis for the stratified selection of participants for the subsequent semi-structured interviews. Second, the scores were used as a covariate in the final analysis of covariance, a procedure that statistically accounts for any pre-existing differences in foundational knowledge between the experimental and control groups, thereby allowing for a more robust and precise inference about the teaching design’s true impact.

Data Representation Component Test

Following the implementation of the two different teaching designs, the Data Representation Component Test (DRCT) was administered at both the experimental and control groups. The primary purpose of this test was to quantitatively measure and compare the statistical competencies of the groups, specifically concerning the Data Representation Component (DRC) of statistical literacy. The test consisted of 9 questions developed in alignment with the learning outcomes of the MoNE (2018) and the competencies described in the GAISE (Franklin et al., 2007) and GAISE II (Bargagliotti et al., 2020) reports for this age group.

Validity and Reliability of the Tests

Table 1 presents the reliability and discrimination indices for persons and items, the mean fit indices, and the range of item point-measure correlation values from the measurements conducted with the PT and DRCT.

Table 1. Findings Related to the Reliability and Validity Indicators of PT and DRCT

	Persons				Items				
Test	ri	si	mii	moi	ri	si	mii	moi	pmci
PT	.74	1.69	1.01	0.80	.88	2.68	1.00	0.79	(0.33,0.84)
DRCT	.71	1.57	0.99	0.78	.89	2.80	0.98	0.75	(0.41,0.88)

ri: reliability index; si: separation index; mii: mean of infit indeces; moi: mean of outfit indeces; pmci: point-measure correlation interval

Given the thresholds for these indices proposed by Boone et al. (2014), the measurements from both tests are reasonably valid and reliable.

Validity and Reliability of Qualitative Data

To ensure the trustworthiness of the qualitative data obtained from the interviews, the researchers implemented several measures to enhance validity and reliability (Yıldırım & Şimşek, 2013). To establish the internal validity and content relevance of the interview protocol, the questions prepared by the researchers were first subjected to expert review. Feedback was obtained from three subject matter experts: two academics and one mathematics teacher with 12 years of experience. Following the expert review, the questions were pilot-tested with a separate group of students to confirm their clarity and comprehensibility.

During the data collection phase, participant validation was employed. The interviewing researcher frequently repeated or summarized students' answers, allowing them to confirm the accuracy of the interpretation or correct any misunderstandings. Furthermore, all findings related to student performance are presented with direct quotations from the verbatim transcripts, allowing readers to assess the interpretations.

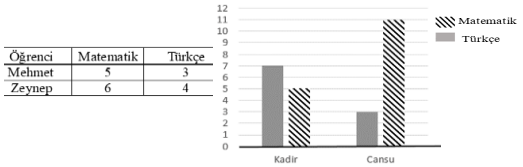
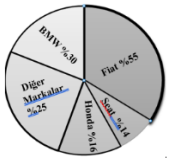
External validity (transferability) was addressed through two primary methods. First, data triangulation was achieved by supplementing the interview data with findings from in-class observations and video recordings. Second, the methodology section provides a "thick description" of the research context, including the study's model, the participant selection process, data collection and analysis procedures, and the researchers' roles, allowing readers to judge the applicability of the findings to other contexts.

Semi-structured Interviews

To gain a deeper, qualitative understanding of students' levels of DRC of statistical literacy, semi-structured interviews were conducted. Participants were selected from both groups based on a purposeful sampling strategy that aimed to capture a range of abilities. The interviews focused on the data representation component, with questions designed to elicit students' reasoning about representing data using tables and graphs, completing missing information, and transitioning between different representations. Students' responses were analyzed and categorized into levels based on the framework and indicators proposed by Watson and Callingham (2003). To ensure confidentiality, all student participants were assigned pseudonyms. The questions asked to the students during the interview, along with the indicators of their proficiency level based on their potential answers, are presented in Table 2.

Table 2. Interview Questions and Proficiency Level Indicators

No	Interview questions	Potential answers indicating levels
1		A student is considered to have achieved Level 1 proficiency in the DRC upon correctly answering part a) of the problem. Proficiency is evaluated at Level 2 if the student also provides a correct answer for part b).

	a) According to the data in the graph, what was the total value of imports in 2011? b) According to the data in the graph, in which year was the difference between the export and import values the smallest?	
2	Four friends each study for 20 hours in one week outside of school, keeping a promise, they made. The table below shows the hours Mehmet and Zeynep spent on Mathematics and Turkish. The column graph below shows the hours Kadir and Cansu spent on the same subjects.  a) Represent Mehmet and Zeynep's study times for Mathematics and Turkish on the column graph using the data provided in the table. Also, fill in any missing information on the column graph. b) Which of these four friends spent the most time studying subjects other than Mathematics and Turkish?	If a student fails to accurately transfer the data from the table to the column graph and does not complete the graph's missing elements, but successfully answers the question in part b), they will be assessed as having Level 3 proficiency in the DRC.
3	The newspaper article below presents a pie chart showing the distribution of all cars sold in a one-year period by brand, along with an associated statement. **Honda Araç Satışında Bu Yıl da Lider!**  Is the information presented in the graph consistent with the accompanying statement? Are there any elements that could be considered inappropriate?	The assessment criteria for this problem require the student to recognize multiple flaws. Consequently, a student who points out some of these flaws is deemed to have Level 4 proficiency in the DRC. A student who points out all of them is considered to have reached Level 5.
4	The pie chart provided represents the distribution of a team's wins by month. Given that the team achieved 8 wins in December, construct a line graph to represent its number of wins by month. 	A student is deemed to have Level 6 proficiency in the DRC if they are able to create a complete graph that includes correctly labeled axes and maintains the proportional accuracy of the data set.

Data Analysis

Analysis of the PT

The test was administered to all students before the intervention, and their responses were scored based on a correct/incorrect rubric. Subsequently, the raw scores obtained by the students were converted into measures (logits) using Rasch analysis. Following this transformation, an independent *t*-test was performed on these logit scores to determine if a significant difference existed between the mean scores of the two groups.

Analysis of the DRCT

After the intervention the DRCT administered both experimental and control groups. The students' raw scores were subsequently transformed into linear measures through the application of Rasch analysis. A one-way ANCOVA was performed on the adjusted scores of both groups to compare their performance on the test. Pearson correlation coefficients were calculated to determine the relationship between the PT scores and DRCT scores. Covariance assumptions, such as the homogeneity of regression slopes, were tested before analysis.

Analysis of Interviews

Semi-structured interviews were conducted with 12 students (six from the experimental group and six from the control group) to assess their statistical literacy levels. The interviews were transcribed and analyzed qualitatively. Through this analysis, the statistical literacy levels of the interviewed students with respect to the DRC were determined based on the criteria proposed by Watson and Callingham (2003).

FINDINGS

In this section of the study, the findings obtained through the analysis of the data related to students' statistical literacy and statistical competency, based on the data representation component of statistical literacy, are presented under the relevant headings.

Findings from the PT

The results of the independent samples *t*-test performed to determine whether there was a significant difference between the mean PT measures of the two groups are presented in Table 3.

Table 3. Analysis of Group Equivalence on the Prediction Test

Group	***n***	***M***	***SD***	***t***	***p***
Control	15	0.77	1.46	-0.95	.35
Experimental	17	1.38	2.08		

As seen in Table 3, although the average PT scores of the students in the experimental group are higher than those of the control group, the difference is not statistically significant ($t(30) = -0.95$, $p > 0.05$). Therefore, before the main study, the two groups of students are considered equivalent in terms of their prior knowledge of topics considered to affect the learning of statistical concepts at the 7th-grade level.

Findings Regarding Students' Statistical Competencies

The DRCT was administered to both the experimental and control groups in the week following the completion of the teaching intervention. To determine whether the two different teaching processes created any differences in students' statistical competencies in the data representation component of statistical literacy, a one-way ANCOVA was performed on the students' adjusted scores from the DRCT. The PT scores of the students were used as a covariate. Before the analysis, Pearson's correlation coefficient was calculated to determine whether there was any relationship between the PT and DRCT scores. The obtained coefficient indicates a statistically significant positive relationship between the two variables ($r = .54$, $n = 32$, $p < .01$). The coefficient shows that the two variables share 29% common variance, indicating a strong relationship between them (Lakens, 2013).

Before performing the ANCOVA, the assumption of homogeneity of regression slopes was tested. The results indicated that the interaction effect between the group variable and the PT scores was not statistically significant ($p = .20 > .05$). The descriptive statistics of the raw and adjusted scores from both groups on the DRCT are presented in Table 4.

Table 4. Descriptive Statistics for the DRCT by Group

		DRCT measure		Adjusted DRCT measure	
Group	*n*	*M*	*SD*	M_d	*SE*
Control	15	0.55	2.30	0.39	0.44
Experimental	17	2.02	2.66	1.73	0.42
Total	32	1.01	2.65		

M_d: Adjusted DRCT measure mean

According to the descriptive statistics obtained, the mean score of the experimental group students is higher than that of the control group students. The results of ANCOVA conducted to determine whether this difference is statistically significant are presented in Table 5.

Table 5. ANCOVA Results for Adjusted Scores Obtained from DRCT

Source of Variance	**Sum of Squares**	***df***	**Mean Square**	***F***	***p***	**Effect Size (eta squared)**
PT	102.7	1	102.7	35.22	< 0.001	.55
Group	13.86	1	13.86	4.75	0.03	.14
Error	84.57	29	2.92			
Total	256.44	31				

The results of the covariance analysis demonstrated a statistically significant difference between the groups regarding their DRCT scores after controlling for the effect of their PT scores, [$F(1, 29) = 4.75$, $p < .05$]. The computed effect size ($\eta^2 = .14$) indicates that 14% of the variance in the dependent variable is explained by the group variable, suggesting a large effect according to current guidelines for interpreting effect sizes (Lakens, 2013)

To provide a more detailed examination of the student performance distribution on the DRCT, the relationship between participant ability and item difficulty was co-calibrated and mapped. As presented in Figure 1, this person-item map illustrates the distribution of participant ability measures relative to the item difficulty measures, both located on a shared logit continuum. Individual items are plotted according to their calibrated

difficulty measure, with corresponding item numbers indicated. Concurrently, participant frequencies are displayed as aggregated counts within designated ability intervals along the same scale.

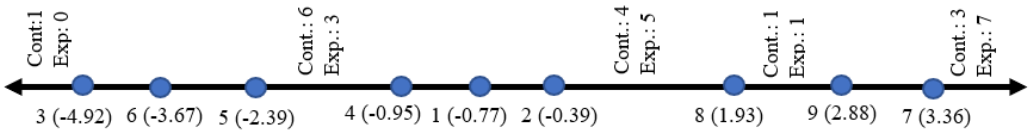


Figure 1. Person-Item Map for the DRCT

As seen in the distribution depicted in Figure 1, the most difficult item on the DRCT was item 7, while the easiest was item 3. The ability measures of seven students in the experimental group exceeded the difficulty measure of the most difficult item, whereas this was the case for three students in the control group. Furthermore, one student in the control group exhibited an ability measure lower than the difficulty measure of the easiest item, while no students in the experimental group were located in this range.

Qualitative Findings on Students' Statistical Literacy Levels in DRC

To qualitatively assess the statistical literacy levels of students in the experimental and control groups concerning the DRC, semi-structured interviews were conducted. These interviews included tasks designed to elicit students' reasoning processes. The tasks, detailed in Table 2, involved reading data from a column graph, completing missing data in the column graph, identifying inconsistencies in a newspaper article and its corresponding pie chart, and transferring data from a pie chart to a line graph using proportional reasoning. Excerpts from the dialogues with students, exemplifying the different literacy levels identified, are presented in this section.

The analysis of the first interview question, which aimed to determine statistical literacy levels for the DRC, established that Deniz, a student in the control group, possessed Level 1 statistical literacy. An excerpt from the interview on this first question, which points to this conclusion, is as follows:

Researcher: What do the data represented in the graph indicate?

Deniz: They represent Turkey's import-export figures in the food sector over certain years.

Researcher: What is the import amount the year 2011?

Deniz: 4.9 billion dollars.

Researcher: How did you determine that?

Deniz: Because the import column corresponds to 4.9 billion dollars in 2011.

This dialogue indicates that Deniz can read a specific, explicit value directly from the bar graph. This foundational skill of data extraction aligns with Level 1 in the DRC. The subsequent segment of the interview demonstrates that Deniz did not exhibit performance characteristics of Level 2, the Informal Level, in the DRC:

Researcher: In which year was the difference between imports and exports the smallest?

Deniz: I will need to do some calculations.

Researcher: What result did you find?

Deniz: I couldn't reach a conclusion.

Researcher: Why couldn't you find the result?

Deniz: There are two different values, and they are getting mixed up. Also, since the numbers include decimals, I couldn't determine the exact result.

During the continuation of the interview with Deniz regarding the first interview question on the DRC, it was observed that he was unable to reach a conclusion using the given values in a bar graph, made errors in his calculations, and failed to provide the correct answer. For these reasons, Deniz is considered to have not performed at Level 2, the Informal Level, in the data representation component.

In contrast to Deniz, who was unable to correctly interpret the second part of the first interview question, Şamil, a student from the control group, demonstrated a successful performance. A segment of the interview indicating this conclusion is as follows:

Researcher: In which year was the difference between imports and exports the smallest?

Şamil: I need to perform calculations for each year to determine that.

Researcher: What result did you find?

Şamil: When I subtracted the import and export values for each year, I found that the smallest difference occurred in 2009.

Şamil's responses to the first interview question indicate that he performed at Level 2. However, an excerpt from the dialogue regarding the second interview question shows that he did not demonstrate Level 3 performance. The relevant segment of the interview with Şamil is as follows:

Researcher: Is there any missing information in the given bar graph?

Şamil: Two people are shown in the table, and two people are represented in the graph. I think nothing is missing.

Researcher: What is shown in the table and the graph?

Şamil: Mathematics and Turkish courses.

Researcher: What aspect of Mathematics and Turkish courses is represented?

Şamil: The number of hours allocated to them.

Researcher: Can you also represent the individuals shown in the table in the graph?

Şamil: (Struggles and attempts to represent them separately) This is all I could do.

Researcher: Is there still any missing information in the graph?

Şamil: No, now all four people are represented in the graph.

Researcher: Is it clear what the graph represents?

Şamil: Yes, it clearly shows the number of hours allocated to Mathematics and Turkish.

Researcher: Are all missing elements in the graph now complete?

Şamil: Yes, I have completed all the missing parts.

Researcher: Which of these individuals has allocated the most time to subjects other than Mathematics and Turkish?

Şamil: Cansu.

Researcher: How did you reach that conclusion?

Şamil: Because, as seen in the graph, Cansu has spent the most time on Mathematics and Turkish, with 14 hours.

Researcher: But the question was about who allocated the most time to subjects other than Mathematics and Turkish.

Şamil: I wouldn't know that.

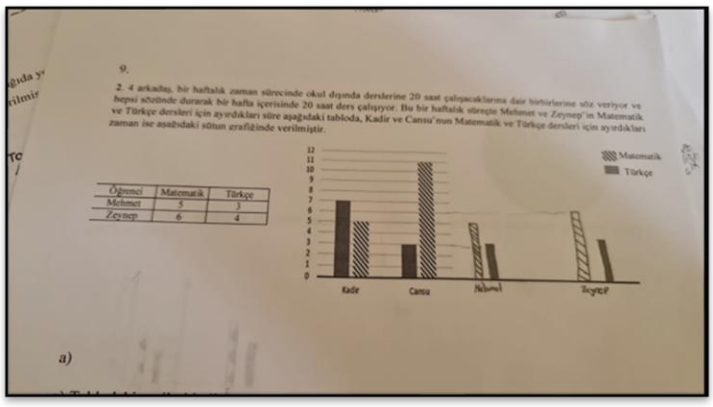


Figure 2. The Bar Graph Created by Şamil in Response to the Second Interview Question

As seen in Figure 2, during the interview with Şamil, it was observed that in response to a question requiring the creation of a graph to represent data, he was unable to label the axes and did not fully depict the relationship between the variables. Additionally, he failed to identify the missing elements in the graph. When faced with a problem that required performing calculations using the given data, he simply pointed to the relevant data in the table or graph instead of conducting the necessary computations. It was noted that he did not go beyond basic statistical operations when reading and interpreting the graph. Therefore, Şamil is considered to have demonstrated Level 2 performance in the DRC.

While Şamil merely pointed to the same data in the table or graph in response to the researcher's questions about the second interview question, Zeynep, from the control group, provided interpretative comments on the given graph. A segment of the interview conducted with Zeynep is as follows:

Researcher: Is there anything missing in the given bar graph?

Zeynep: Everything seems complete for now. I don't see anything missing.

Researcher: How many people's data are included here?

Zeynep: Four people.

Researcher: How many people's data are shown in the graph?

Zeynep: Two people's.

Researcher: Did you find a missing element?

Zeynep: Yes, I need to represent the other two people with bars as well.

Researcher: How will you represent them?

Zeynep: I will show them like the others. I will draw up to the corresponding value.

Researcher: Is there anything else missing in the graph?

Zeynep: No, there isn't. These two people were missing, and after adding them, everything is complete.

Researcher: What does the graph represent? Shouldn't the axes be labeled?
Zeynep: We already know what it represents. I don't think repetition is necessary.

Researcher: Which of these individuals has allocated the most time to subjects other than Mathematics and Turkish?
Zeynep: Mehmet.

Researcher: How did you reach this conclusion?

Zeynep: I looked at both the individuals in the graph and those in the table. The graphs represent the study time for Mathematics and Turkish. The remaining time must be allocated to other subjects. So, Mehmet, who spent 12 hours on other subjects, has dedicated more time than the others.

When Zeynep was asked to create a graph to represent the data, she did not label the axes, name what the graph represented, or fully illustrate the relationship between the variables. However, when asked what the graphically represented situation indicated, she was able to make a single interpretation and repeated the data from the table. For this reason, Zeynep's performance in the DRC is considered to be at level 3.

Melisa, from the control group, transferred the study hours of four friends during a week from the table into a bar graph and correctly answered the questions about the data. The graph, in which Melisa completed the missing elements, is shown in Figure 3.

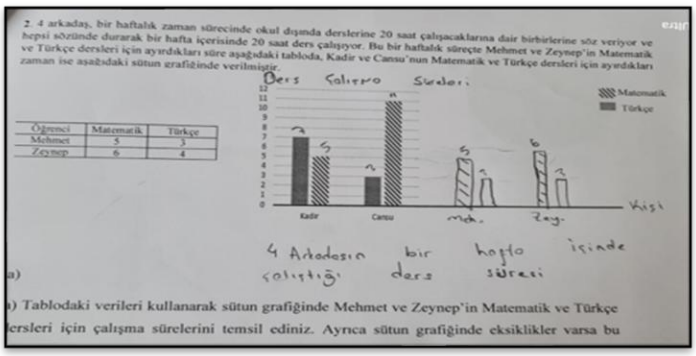


Figure 3. Bar graph created by Melisa within the scope of the second interview question**.**

To determine Melisa's level of statistical literacy with respect to DRC, the third interview question was posed. In this question, a newspaper article and a pie chart related to this article were presented, and she was asked to identify inconsistencies and inaccuracies in the graph. A segment of the interview with Melisa is as follows:

Researcher: What does the given pie chart represent?

Melisa: It shows the distribution of cars sold in a year according to their brands.

Researcher: What did you understand from the newspaper article?

Melisa: That Honda car was sold the most.

Researcher: Is there any inconsistency or inaccuracy in the graph compared to this article? Melisa: Yes, there is. The article states that Honda is the leader, but the graph shows Fiat as the most sold brand. The correct information should be that Fiat is the leader.

Researcher: Can you identify any other inconsistencies or inaccuracies in the graph? Melisa: Yes, there is. The graph states that "Other brands" account for 25% and BMW accounts for 30%, but BMW's section appears smaller. There is a visual inconsistency.

Researcher: Are there any other inconsistencies or inaccuracies?

Melisa: I don't see any others. These are all the inconsistencies and inaccuracies.

Melisa was able to identify some of the errors and inaccuracies in the pie chart related to the newspaper article on car sales. However, she failed to notice that the Fiat brand, which was shown as 55%, meaning more than half, was visually represented as less than half. Additionally, she did not recognize that the total percentages in the graph added up to 140% instead of 100%, which is another inconsistency. Since she did not identify all the errors, her interpretation of the graph remained partial. Given that she created representations that only partially reflected the relationships between variables, Melisa's performance in the DRC is evaluated at Level 4.

Yusuf, from the experimental group, identified the inconsistencies and inaccuracies that Melisa failed to notice. A segment of the interview with Yusuf, showing that he detected the errors Melisa overlooked in the third interview question, is as follows:

Researcher: What does the given pie chart represent?

Yusuf: It shows the distribution of car sales by brand in a year.

Researcher: What did you understand from the newspaper article?

Yusuf: That Honda is the leader in sales, meaning the most Honda cars were sold.

Researcher: Is there any inconsistency or inaccuracy in the graph compared to this article? Yusuf: Absolutely. The article claims that Honda is the leader, but the graph shows Fiat as the most sold brand.

Researcher: Can you identify any other inconsistencies or inaccuracies in the graph? Yusuf: Yes, there is. The graph states that "Other brands" account for 25% and BMW accounts for 30%, but BMW's section appears smaller.

Researcher: Are there any other inconsistencies or inaccuracies?

Yusuf: Yes, there is. The total percentage in the graph should be 100%, but here, it adds up to 140%.

Researcher: Any other inconsistencies or inaccuracies?

Yusuf: It says Fiat accounts for 55%. A percentage of 55% means it should take up more than half of the pie chart, but here, it takes up less than half.

Researcher: Any other inconsistencies or inaccuracies?

Yusuf: I don't see any more inconsistencies or inaccuracies, but I think there is a missing element.

Researcher: What is that missing element?

Yusuf: The title of the pie chart. The chart should have a title explaining what it represents.

From this dialogue, it is evident that Yusuf was able to detect all the errors and inaccuracies in the newspaper article and the related pie chart. He successfully identified the inconsistencies that Melisa, who performed at Level 4, failed to notice—such as the incorrect visual representation of Fiat's 55% share and the total percentage exceeding 100%. Additionally, he pointed out the missing title as another issue.

Following this discussion, Yusuf was presented with the fourth interview question, which involved a pie chart displaying the number of victories of a sports team by month. He was asked how these values could be represented in a line graph. A segment of this interview with Yusuf is as follows:

Researcher: What does the given pie chart represent?

Yusuf: It shows the number of victories of a team by month.

Researcher: Can you represent the data in the pie chart as a line graph?

Yusuf: Yes, I can.

Researcher: How will you do it?

Yusuf: All the values are given December: 80, January: 90, February: 40, March: 120, and April: 30. I will plot these values in a line graph.

Researcher: Are these numbers the actual victory counts for each month?

Yusuf: Not exactly, but they are related to the number of victories, right?

Researcher: But the chart says December had 8 victories. Can you determine the other months based on this?

Yusuf: I can't find it out right now, but it doesn't stop me from drawing the graph.

Researcher: How will you draw the graph?

Yusuf: I will label the vertical axis as the number of victories and use the values from the pie chart. I will label the horizontal axis with the months. I will also write the title of the graph. Then, I will plot a dot for each month's victory count and connect them with a line.

Researcher: If you were to summarize what is represented in the graph, what would you say?
Yusuf: I have no comment.

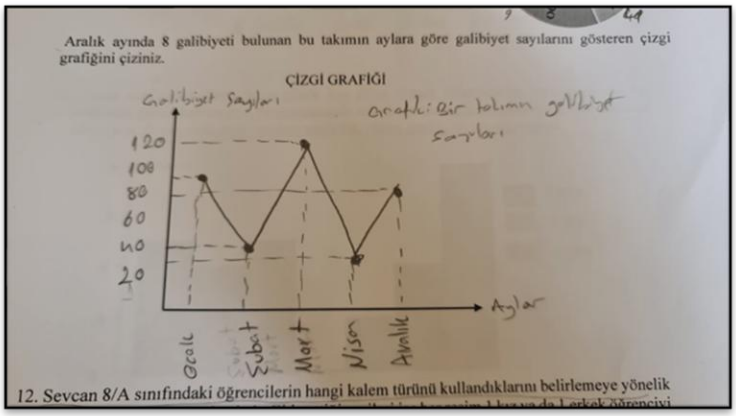


Figure 4. Yusuf's line graph created in the fourth interview question

In the interview where Yusuf was asked to transfer the data from a graph showing a team's number of victories by month into a line graph, it was observed that he did not engage in proportional reasoning. As seen in Figure 4, he was unable to determine the number of victories other months based on the given 8 victories for December. Instead, he created the line graph according to the central angles in the pie chart. Therefore, while Yusuf identified all the errors in the newspaper article and the corresponding pie chart and interpreted the graph completely, he did not engage in proportional reasoning in the final interview question and was unable to summarize the situation represented by the graph. As a result, Yusuf's performance in the DRC is evaluated at Level 5.

Zehra, from the experimental group, demonstrated proportional reasoning and successfully summarized the graph in response to the question about the distribution of a team's victories by month, where Yusuf failed to do so. A segment of the interview with Zehra regarding this question is as follows:

Researcher: What does the given pie chart represent?

Zehra: It shows the number of victories of a team by month.

Researcher: How would you represent the data in the pie chart as a line graph?

Zehra: The number of victories for December is given. From this, I can determine the other months.

Researcher: How would you find them?

Zehra: By using ratio and proportion.

Researcher: What do you mean?

Zehra: December's angle is 80 degrees, and the number of victories is 8, meaning it is 10 times the number of victories. From this, I can determine the victory counts of other months.

Researcher: How would you display the victory counts in a line graph?

Zehra: In the line graph, I would place the victory counts on the vertical axis and the months on the horizontal axis. I would also include the title of the graph. I would plot a point for each month's number of victories and connect them with a line.

Researcher: Will you place the numbers randomly?

Zehra: No, I arranged them at equal intervals. I wrote them in ascending order.

Researcher: If you were to summarize the situation represented in both graphs, what would you say?
Zehra: The graphs show the number of victories and the months.

Researcher: If you were to summarize the situation represented in the line graph, what would you say?
Zehra: The number of victories fluctuated, increasing and decreasing at different times. The team showed an inconsistent performance. Additionally, it can be observed that the team performed very well in March.

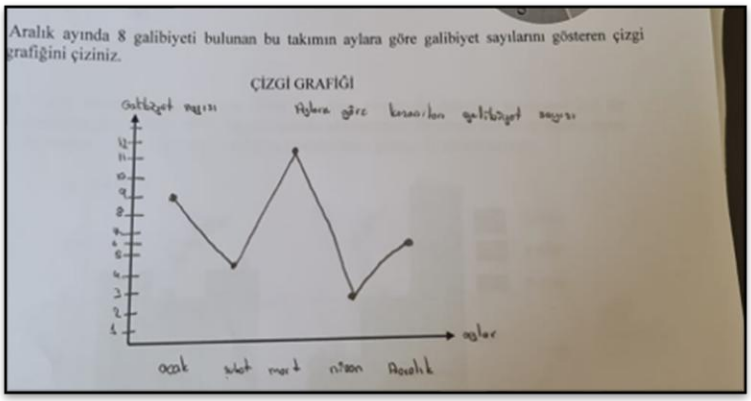


Figure 5. Line graph created by Zehra in the fourth interview question

As understood from the dialogue and Figure 5, Zehra successfully completed the line graph through proportional reasoning. Consequently, in the DRC, Zehra demonstrated the ability to construct an appropriate graphical representation that illustrates the relationship between two variables and interpret how these variables change relative to each other. Additionally, she was able to identify errors in a graphical representation. Moreover, Zehra displayed proficiency in reading and interpreting data within a graphical representation. She also provided a summary statement based on the data group depicted in the graph. Furthermore, she performed proportional calculations using the data within a representation tool. Therefore, Zehra's performance in the DRC is evaluated at Level 6.

Through interviews, it was determined that students at all levels were present in assessing their statistical literacy levels concerning the DRC. The statistical literacy levels of each student in both groups, along with the DRCT measures, are presented in Table 6.

Table 6. DRC Levels and Measures of Interview Students

	Experimental Group						Control Group					
	Yusuf	Zehranur	İlayda	Zehra	Miraç	Yunus	Zeynep	Deniz	Şamil	Furkan	Melisa	Melek
Level	5	6	6	6	5	6	3	1	2	3	4	5
Measure	-1,08	3,52	0,99	2,21	5,04	5.05	-0,1	-1,08	-1,08	-1,08	3,52	3,52

Table 6 presents the statistical literacy levels and corresponding DRCT measures for the students who participated in the interviews. The data highlights a notable divergence between the quantitative test scores (DRCT measure) and the qualitative literacy levels determined through the interviews. For instance, although control group students Deniz, Şamil, and Furkan all achieved an identical DRCT score (-1.08), the interviews revealed that they possessed different statistical literacy levels. A similar discrepancy was observed with Melek and Melisa (control group), who also shared the same DRCT score (3.52) but were ultimately assessed at distinct literacy levels.

DISCUSSION & CONCLUSION

This study investigated the impact of instructional practices enriched with problem-posing activities on seventh-grade students' statistical literacy, specifically in the domain of data representation. Statistical literacy, a critical competency in 21st-century education, encompasses not only the ability to read and interpret data but also the capacity to represent and reason with it meaningfully (Gal, 2002; Garfield & Ben-Zvi, 2008). As one of the few experimental studies conducted in the context of Turkish middle school mathematics curricula that integrates

structured problem-posing pedagogy with statistical content, this research offers original findings and practical insights. The results provide compelling evidence that instructional environments centered on problem-posing foster deeper understanding, higher-order thinking, and more sophisticated skills in data representation compared to conventional teaching methods, a finding that is consistent with previous research (Silver & Cai, 2005; Sharma, 2017).

Students in the experimental group, who participated in both regular and extracurricular problem-posing activities, consistently outperformed their peers in the control group across multiple aspects of DRC. As revealed in the DRCT, they demonstrated enhanced competencies in producing, interpreting, and transforming various graphical forms—such as bar charts, line graphs, pie charts, and frequency tables. These improvements were particularly evident in items requiring multiple representations and transformation between different types of graphs. For instance, Item 7, one of the most challenging DRCT questions that involved constructing a pie chart with missing information, revealed a significant performance gap: while only 18% of control group students exceeded the item's difficulty threshold, 44% of experimental group students surpassed it. Moreover, 10 out of 17 students in the experimental group answered it correctly, compared to just one in the control group. This result not only demonstrates the effectiveness of problem-posing instruction in fostering representational fluency but also highlights students' ability to engage with ambiguity and apply proportional reasoning—two skills critical to statistical literacy (Watson & Callingham, 2003; Koparan, 2012).

The interviews conducted after the DRCT administration confirmed these findings and added depth to the interpretation. According to the statistical literacy model by Watson and Callingham (2003), students in the experimental group achieved Levels 5 and 6, indicative of critical and mathematical engagement with data. These levels reflect students' ability to analyze complex representations, critique data displays, and synthesize conclusions based on proportional reasoning and evidence. In contrast, most students in the control group remained within Levels 1 to 3, characterized by basic reading without analytical depth. This finding empirically supports the critique that conventional instruction often remains 'mostly procedural' and disconnected from real-world settings, failing to connect 'the data-enriched world to the educational experiences of learners' (Yilmaz et al., 2023). These contrasting performance levels underscore a key result of this study: learning environments that empower students to generate, interpret, and justify data representations lead to more meaningful learning outcomes.

A major reason for this success lies in the pedagogical structure of the problem-posing activities. Students were not only asked to solve problems but to create them using given or collected data, choose appropriate graphs, and explain their choices. This recursive process encouraged metacognition and self-regulation, prompting students to evaluate the clarity, effectiveness, and correctness of their visualizations. This process effectively created the 'authentic context-based tasks' advocated for in literature. While Yilmaz et al. (2023) used historical events to foster critical inquiry, the present study demonstrates that problem-posing pedagogy achieves a similar outcome; it compels students to use context to 'understand the story reflected in the data', 'revise their initial perceptions', and 'pose further statistical inquiry questions'. The experimental group's high performance at Levels 5 and 6 suggests they developed the 'critical contextual lens' that traditional methods often miss (Yilmaz et al., 2023). These habits of mind were supported through collaboration, where students provided peer feedback, revised graphs, and engaged in dialogue that promoted critical reasoning, a mechanism consistent with the value of peer interaction highlighted by Cobb & McClain (2004).

A significant and original finding of this study is the increased attention to graphical quality and communicative accuracy observed in the experimental group. Students consistently labeled axes correctly, selected meaningful titles, used consistent scaling, and avoided distortions. This awareness reflects a more sophisticated understanding of graphs not merely as decorative elements but as functional tools for communication. This aspect was reinforced through the structure of the activities: students were often asked to critique each other's work or present their graphs for peer analysis. Such practices helped solidify high standards of visual clarity and analytical rigor, an outcome that aligns with the emphasis placed on using critical, peer-driven analysis to build representational skill.

Another key dimension was the development of proportional reasoning skills, which are foundational to understanding statistical relationships. The experimental group engaged in tasks requiring ratios, percentages, and comparisons between parts and wholes, particularly in activities involving pie chart construction and data transformation. These findings align with literature emphasizing the centrality of proportional reasoning to mathematical problem-solving (Arican & Kiymaz, 2022). For example, in the "7A Ne Yapmış" activity, students interpreted central angles within pie charts to solve and construct their own data-based questions. Their success on these tasks—and corresponding DRCT items—suggests a meaningful internalization of these concepts.

Moreover, students' metacognitive awareness emerged as a defining outcome. In interviews and classroom observations, students in the experimental group were more likely to question the appropriateness of a chosen graph, recognize misleading representations, and suggest alternative visual strategies. This critical engagement went beyond test-based competencies, reflecting a genuine shift in thinking patterns. These observations support Gal's (2002) assertion that statistical literacy includes interpretive and evaluative components, not merely procedural ones.

Importantly, the internal coherence between test results, activity performance, and interview data strengthens the validity of the study's conclusions. For example, the experimental group's strong performance in Item 1 (a pie chart interpretation task) and Items 2, 4, 8, and 9 (bar and line graph interpretation) corresponded with classroom activities that emphasized those representations. In the "Seçim Zamanı" and "Çiftlikteki Hayvanlarım" activities, students actively converted between chart types, practiced labeling, and discussed the representational choices that best fit given contexts. These internal connections between instruction, student performance, and assessment outcomes reinforce the claim that the problem-posing environment led to measurable learning gains.

Furthermore, the collaborative aspect of the problem-posing activities amplified learning. Students worked in triads, discussed representational strategies, and critiqued each other's work. These peer interactions fostered collective responsibility, helped correct misconceptions, and elevated the quality of the final products. This collaborative culture was particularly evident in the students' ability to refine visualizations based on constructive feedback.

Finally, this study's contribution lies in its integration of authentic, context-rich activities with structured pedagogical scaffolds, resulting in a significant impact on students' statistical literacy. The contrast between the experimental and control groups was not just quantitative but qualitative. While control group students often replicated visuals from textbooks without critique, experimental group students questioned, analyzed, and synthesized information to create meaningful representations. This cognitive and pedagogical transformation speaks to the potential of problem-posing as a high-impact instructional approach in statistical education.

In conclusion, the study provides robust and original evidence that a problem-posing-based instructional model significantly enhances students' statistical literacy, especially in the data representation domain. The results demonstrate that students exposed to such environments reach higher levels of cognitive functioning, develop proportional reasoning, and engage critically with data. Importantly, these outcomes are not only observed in test results but also reinforced by students' behaviors during learning activities and interviews. The findings highlight the transformative power of shifting from passive, teacher-centered instruction to active, student-driven inquiry. In an era where data is abundant and often manipulated, equipping students with the ability to create, evaluate, and communicate data through visual means is more than a curricular goal—it is a democratic and societal imperative.

Recommendations

Based on the findings of this study, several practical and research-oriented recommendations can be made. First, the integration of problem-posing activities into middle school statistics instruction appears to enhance students' ability to represent and interpret data more critically. Therefore, teachers and curriculum developers may consider incorporating structured problem-posing opportunities into regular classroom practice, especially within topics related to data representation and analysis. These activities do not need to replace existing methods but can complement them to promote student engagement and deeper learning.

Given the observed improvements in students' graphical literacy and proportional reasoning, teacher training programs may also include modules that introduce educators to the pedagogical design and implementation of problem-posing tasks. Such training may help teachers facilitate student-centered discussions and guide students in constructing, critiquing, and revising data representations.

For future research, this study highlights the value of combining quantitative outcomes with qualitative insights. Researchers could extend this work by exploring the long-term effects of problem-posing activities on different components of statistical literacy, such as data interpretation or informal inference. Comparative studies across different grade levels or educational settings may also help determine the generalizability of the current findings. Finally, further investigation into students' cognitive and metacognitive processes during problem construction and graph interpretation could offer richer explanations for the effectiveness of this instructional approach.

Limitations

The primary limitation is the small sample size, which consisted of 32 students from a single public school. This restricts the statistical power of the analyses and, more importantly, limits the external validity or generalizability of the findings. The results, while significant, may not be representative of the broader population of seventh-grade students in different schools or socio-economic contexts. A second significant limitation is the role of the researcher. The first author served as the mathematics teacher for both the experimental and control groups. This design introduces potential for researcher bias or expectancy effects. The researcher's awareness of the study's hypotheses and which group was the experimental group could have unconsciously influenced the instructional delivery, enthusiasm, or interaction with students, despite efforts to maintain objectivity. This study was intentionally focused on the data representation component of statistical literacy. Consequently, the findings demonstrating the effectiveness of the problem-posing approach cannot be generalized to *all* components of statistical literacy, such as data collection, data analysis, or statistical inference. The DRCT was administered "in the week following the completion of the teaching intervention". This design effectively measures the immediate impact of the teaching experiment but does not provide evidence of the long-term retention of these skills. It remains unknown whether the observed gains in the experimental group would persist over several months.

Statements of Publication Ethics

This study was conducted with the approval decision taken at the Ethics Committee for Educational Sciences (Number. 2022-4/2.23) of Trabzon University, dated 22.04.2022.

Researchers' Contribution Rate

Authors	Literature review	Method	Data Collection	Data Analysis	Results	Conclusion
Author 1	☒	☐	☒	☐	☒	☒
Author 2	☐	☒	☐	☒	☐	☒

Conflict of Interest

The author(s) declare that there is no conflict of interest with any institution or person within the scope of the study.

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