ROLE OF CONTEXT IN STATISTICS: INTERPRETING SOCIAL AND HISTORICAL EVENTS

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ABSTRACT

Recent educational reforms include a vision of integrating reflective practice and contextual consideration into statistics education. Yet, statistics courses are rarely taught in a way that connects the data-enriched world to the educational experiences of learners. This deficiency highlights the need for statistics teaching courses to be aligned with the endeavors to equip pre-service mathematics teachers (PMTs) with skills needed in a data-enriched world. The data for the case study reported in this paper were collected from a newly developed statistics teaching course implemented at a university in Turkey. The aim of the research was to explore how seven PMTs used their context knowledge of data to examine statistical information critically. Researchers collected and analyzed videos of classroom activities, PMTs' written work, and their written Google Blogger reflections. Results suggested the PMTs' evaluation of examined historical events shifted from an emphasis on personal knowledge and experiences to the use of statistical reasoning and contextual knowledge. Context helped them understand the story reflected in the data, revise their initial perceptions or understanding of the events under examination, and pose further statistical inquiry questions.

Keywords: Statistics education research; Teacher education; Statistical reasoning; TinkerPlots; Context; Pre-service mathematics teachers

1. INTRODUCTION

Given the importance of statistics in our changing world, the ability to analyze and interpret data as well as to make decisions based on data becomes crucial for the development of statistically competent citizens (Zieffler et al., 2018). Along with the needs of the evolving and changing world, we posit that Wells' (1903) century old prediction that "statistical thinking will one day be as necessary for efficient citizenship as the ability to read and write" (paraphrased by Wilks, 1951) has come true. Statistics provides a means of analyzing accumulated data on issues such as security, historical and cultural heritage, economy, people's welfare, social structure, and political matters that impact people's lives (D'Ambrosio, 2016; Skovsmose, 2013). When engaging in statistical inquiry, individuals should evaluate the issues critically by posing questions and accessing context knowledge of data.

Researchers have suggested that context-based statistics teaching through novel tasks is important for teaching statistics to students (e.g., Makar & Ben-Zvi, 2011; Wild et al., 2011). Correspondingly, recent educational reforms and curriculum revisions strongly emphasized the incorporation of novel statistical content into mathematics curricula (Lovett & Lee, 2017). In addition, studies involving

students emphasized the role of context in developing statistical reasoning (Makar & Ben-Zvi, 2011). An important issue for consideration is how pre-service teachers and in-service teachers accumulate learning from experiences grounded in context-based statistics teaching.

In teacher education programs, it is essential for pre-service mathematics teachers (PMTs) to engage in experiences in which they connect context knowledge of data with statistical information (Casey et al., 2021). Making the connection requires individuals to draw on evaluations of events from a statistical perspective and the ability to attach meaning to statistical data/information (Bargagliotti et al., 2020; Casey et al., 2021). It also entails reasoning about data, reasoning about representations of data, organizing and describing data statistically, establishing relationships between statistical concepts, interpreting statistical results, and the ability to explain statistical processes (Ben-Zvi & Garfield, 2004). Garfield (2003) stated that the primary goal of statistics education should be to create opportunities for students to produce reasoned descriptions, judgments, inferences, and opinions about data. A student who demonstrates data awareness will demonstrate statistical reasoning, as the student reasons with statistical ideas and attaches meaning to statistical information (DelMas, 2002). For students to be statistically competent, various educational experiences both within and beyond the classroom need to be offered (Garfield, 2003).

To enable students to engage in meaningful statistical investigation, statistics teaching courses should be carefully designed to provide future teachers of mathematics with activities that restructure their context knowledge of the data by examining it with critical lenses, posing questions (Bargagliotti et al., 2020; Casey et al., 2021), and engaging in contexts from multiple discipline areas (Bargagliotti et al., 2020). These activities should also be ones to which they can relate and for which they can use educational technology (Bargagliotti et al., 2020; Lee & Hollebrands, 2011). Research has shown, however, that a gap exists between the existing learning experiences of PMTs in statistics courses and the education that is offered by authentic context-based statistics education programs (da Ponte, 2011; D'Ambrosio, 2016; Lovett & Lee, 2017). This gap points to the need to align current teacher education programs with preparations intended to teach statistics to PMTs in this novel context that will prepare them for future teaching (Lovett & Lee, 2017).

One of the weaknesses of current teacher education programs is the insufficient support for the practical application of new ideas, with educators confident in the assumption that student-teachers will handle easily the learned knowledge when they return to class (da Ponte, 2011). In the case of university-level statistics teaching, the majority of courses are taught in a mostly procedural way and on the basis of a "paradigm of transmission of knowledge" (da Ponte, 2011, p. 7). In these courses, PMTs are trained on procedural calculations without a strong connection to insights on the real-world settings (Leavy, 2010). These courses are focused mainly on the manipulation of numbers and the carrying out of calculations instead of developing the skills needed to interpret data or make inferences based on data (D'Ambrosio, 2016). New reforms in statistics education, however, expect teachers to teach statistics in connection with multiple disciplinary areas and to examine data with a critical contextual lens. Such reforms also require "the capability of inferring, proposing hypotheses and drawing conclusions" (D'Ambrosio, 1999, p.133). In statistics education characterized by the aforementioned requirements, calculations and measurements are not essential concerns and priority is instead assigned to cultivating deep and critical reflection on social issues. This approach helps the learners to understand the role of statistics in the real world context (Ben-Zvi & Berger, 2016; Makar & Ben-Zvi, 2011; Tate, 1995).

In an effort to meet these expectations, we designed an authentic statistic teaching course in which PMTs engage with various real-world statistics tasks regarding influential historical events, thereby engaging them in an interdisciplinary learning environment that fosters access to contextual knowledge of data. Within this scope, this study was aimed at exploring how PMTs use contextual knowledge to critically examine the statistical data on major historical events. To this end, we sought answers to the following research questions:

1. How do PMTs use contextual knowledge of data to critically analyze the data of historical events?
2. How does use of context knowledge support PMTs to develop a comprehensive understanding of the events examined?

2.   ROLE OF CONTEXT IN STATISTICS

In novel statistics teaching and learning, students should engage in statistical investigation wherein context surrounding a phenomenon under examination and statistical knowledge are connected (Wild & Pfannkuch, 1999; Wild et al., 2011). This connection was explained by Cobb and Moore (1997) as follows: "Statistics requires a different kind of thinking, because data are not just numbers, they are numbers with a context" (p. 801). Adding to this insight, Garfield and Ben-Zvi (2008) stated that authentic context-based tasks should be used to create meaningful statistics learning experiences. Also, Ben-Zvi and Berger (2016) stated there is an increasing interest in exploring the role of context in developing statistical reasoning of students.

Contextual knowledge should be an integral part of statistical investigations. Contextual knowledge is defined as "the source of meaning and basis for interpretation of obtained results" and the situational context from which data are collected (Gal, 2002). Engel et al. (2016) suggested that statistical teaching should incorporate context and its critical examination into educational programs in addition to the use of statistical knowledge. In a similar vein, Langrall (2010) asserted that engaging in statistical inference and investigation requires individuals "to interact with data rather than merely apply arithmetical procedures to act on data. Knowledge of the data context can encourage and support such interactions" (p. 6). This interaction was described by Pfannkuch (2011) as typified by "social and data-based argumentation skills" (p. 27).

During statistical investigations, students can use their knowledge and experience of a task context to pose research questions and formulate hypotheses (Watson, 2008; Yilmaz et al., 2017). In addition, context knowledge can be used to support the inferences made from data analyses (Ben-Zvi & Berger, 2016; Gil & Ben-Zvi, 2011; Langrall, 2010; Makar, 2013). Students can also engage in statistical investigations to explore the social structure of phenomena under examinations. All these require a sound context knowledge of data. If a person engages such investigation without sufficient context knowledge, "it becomes more difficult to imagine why a difference between groups can occur, what alternative interpretations may exist for reported findings about an association detected between certain variables, or how a study could go wrong" (Gal, 2002, p. 15). For instance, Langrall (2010) conducted a study in which students were asked to "determine whether sodas have more caffeine than other drinks" (p. 4). She found that students who did not have a contextual knowledge regarding the amount of caffeine in particular drinks struggled with exploring and interpreting data, eventually making informal statistical inferences.

In the process of statistical investigations, students become engaged in various contextual tasks by relating their knowledge of the situation and experiences with the data to make further statistical claims (Makar & Rubin, 2009; Pfannkuch, 2011). In such interaction between context knowledge and data, one can negotiate their beliefs and views about the situation under examination (Ben-Zvi & Berger, 2016; Yilmaz et al., 2017). Using real-world tasks and data is a first step to initiate such statistical investigation. Making sense of the data in relation to context and going beyond the data, however, are not easy tasks for students (Konold & Higgins, 2003). Thus, pre-service teachers and teachers should acquire experience of engaging in statistical investigations that help them to reason about the data by considering their real-life knowledge, experience, and context knowledge of the data.

Although many researchers (e.g., Gil & Ben-Zvi, 2011; Langrall, 2010; Langrall et al. 2011; Makar, 2013) worked with students to explore the connection between context and statistical investigations by using real-world tasks, data, and scenarios, we encountered only a few studies (e.g., Monteiro & Ainley, 2007; Arteaga et al., 2015) in our review, conducted with pre-service teachers who will teach statistics to students in the future. In addition, the studies we encountered were mainly focused on pre-service teachers' critical reading ability of graphs representing real world data. Although the context of the data is a part of the reading skills, these studies did not use a multidisciplinary statistic learning approach to access context knowledge. Also, the studies did not focus on active engagement in the phases of statistical investigations (e.g., posing research questions, creating hypotheses, data analysis, interpretation and making inferences), which requires the use of context knowledge of data.

In one study, Chick and Pierce (2012) worked with pre-service teachers (PSTs) and asked them to create statistics lesson plans using a given real-world data set. They examined the statistical literacy hierarchy level of the lesson plans. The higher level requires "critical, questioning engagement with context …, showing appreciation of uncertainty in making predictions" (Chick & Pierce, 2012, p. 344). Since critical engagement with context was essential, some of the participants designed lessons

involving an interdisciplinary approach. The Chick and Pierce (2012) study, however, did not capitalize on the multidisciplinary nature of statistics education even though they used the real-world context in the lessons designed. The study focused on lesson planning tasks within a workshop rather than focusing on a long-term intervention with PSTs. Thus, in this study, researchers aimed to examine how context-based statistics tasks in the newly designed statistics teaching course enable PMTs to use contextual knowledge of data to explore social, historical, and political aspects of the events under examination through engaging in a multidisciplinary learning environment.

3.   METHOD

In this study, the case study method was utilized. This method is a detailed examination of a single case in a specific domain (Yin, 2003), designed to answer the question "what are the characteristics of this particular entity, phenomenon, person, or setting?" (Ary et al., 2010, p. 389). According to Yin (2003), a case study focuses on the "how" and "why" questions to explain the phenomenon in detail. Case studies typically include multiple sources of data collected over time to provide a rich holistic description of the context (Ary et al., 2010). This method was used in this study for a few reasons. First, a limited number of studies examining how PMTs use context knowledge of data as they engage in statistical investigation. Second, only a few novel statistics education courses (Lovett & Lee, 2017) have been developed for PMTs to meet the expectations of current reforms in the statistics education field. Thus, conducting a case study enabled the researchers to deeply examine how this novel context-based statistics education course supported PMTs to use context knowledge in critical statistical examination of the major historical events.

3.1. PROCEDURE

Seven pre-service secondary mathematics teachers participated in the study voluntarily. All PMTs were in their last year of study in a mathematics education undergraduate (tertiary level) program in Turkey. They took two courses on teaching mathematics prior to this study. They learned about how to teach basic descriptive statistics in two weeks of the second course. Also, they took a mathematical statistics course. The course content covered descriptive statistics, *t*-tests, ANOVA, and correlation. The mathematical statistics course did not focus on the teaching and learning of these contents.

During the time of the study, the PMTs were enrolled in an elective teaching statistics and probability course. This teaching statistics and probability course was offered for the first time in the Department of Mathematics Education. The study was conducted as a part of this course for six weeks. The researcher-teacher (R-T) and a mathematics teacher with a master's degree met with the PMTs for three hours per week.

Each week, the activities were implemented in two stages. In the first stage, the PMTs engaged in statistical investigation**.** They posed research questions and hypotheses, then analyzed event data using *TinkerPlots*[TM] software (https://www.TinkerPlots.com). Then, they interpreted statistical results and reflected on connections between the statistical results and context knowledge of the data. In the second stage, the PMTs were asked to answer reflection questions about the tasks implemented. Reflections were recorded on a Google Blogger platform (https://www.blogger.com/about/).

Tasks. Three tasks were utilized in the study. The tasks were designed by the first two authors. Revisions and refinements were then made to the tasks based on the feedback of the third author of this study and one independent mathematics educator.

In the first task, PMTs were asked to analyze Gallipoli 57th Infantry Regiment data (Sayılır, 2015) about soldiers who were killed in World War I. In the second task, they worked on Southeastern Anatolia Project (GAP; Ministry of Industry and Technology, 2018) data. GAP is a (Turkish) regional development project. In the third task, the PMTs analyzed Hiroshima and Nagasaki bombing data (Atomic Bomb Museum, 2006; Hsu et al., 2013). All the tasks have historical importance both in national and international context. The implementation of each task lasted 2 weeks. The task details (description of task context, statistical concepts covered and reflection focus) are provided in Appendix A.

Implementation of each task proceeded in four phases (Table 1) followed by an online post-reflection Phase (5) using Google Blogger.

Table 1. Phases of the study implementation

Phase number	Phase name	Example
1	Discussion on contextual knowledge	What do you know about Hiroshima and Nagasaki atomic bombing?
2	Creating research question and formulating hypothesis	What can we analyze with the variables given in the data set? State your hypothesis.
3	Analysis	Has the prevalence of cancer diseases tended to change with respect to years? Explain how.
4	Accept/reject hypothesis and conceptual discussion	A person claims that after exposure to radiation, women have more severe health problems than men. Is it true?
5	Post-reflection: Reflect on and synthesize statical results and contextual knowledge	Are there any other events like this [refers to the atomic bombings] in human history? If so, what are the similarities and differences between their effects and the bombing that we have investigated?

In each task, the PMTs used *TinkerPlots*™ educational software to explore the data. *TinkerPlots*™ is one of the dynamic statistics software developed for use by students as a data visualization and modeling tool (Konold & Miller, 2005). *TinkerPlots*™ was designed for the collection, organization, analysis, representation, and interpretation of data to enhance the development of statistical reasoning of students. The aim of using *TinkerPlots*™ in this study was to provide opportunities for the PMTs to explore real data and to use their ability to create different statistical representations, to enable them to improve their visualization and thinking skills, concepts and understanding (Khairiree & Kurusatian, 2009). Another aim was for the software to support the PMTs in hypothesis testing, seeing the aggregate view of data, and exploring how a variable affects different analyses (Rubin, 2007).

3.2. DATA COLLECTION AND ANALYSIS

Video of all classroom activities, the PMTs' computer screen recordings while working with *TinkerPlots*™, written work on the activity sheets, and Google Blogger entries were collected. These data sources were used for triangulation in which "researchers search for convergence among multiple and different sources of information to form themes or categories in a study" (Creswell & Miller, 2000, p. 126).

To collect videos of classroom activities, two video cameras, one at the back and the other at the front of the classroom, were used. Video recordings of classroom activities and screen works enabled us to access detailed audio and visual data (Bottorff, 1994) about the PMTs' engagement in statistical investigations and use of context knowledge in the investigation process. The video-data enabled us to reexamine the data and triangulate the video-data with other data sources.

Data analysis. The video data were analyzed by means of the Analytical Model (Powell et al., 2003). Researchers independently described data content to address the aim of the study and defined critical events. The critical events were those in which the PMTs used context knowledge of the data in the statistical investigation process. Those events were transcribed and coded. In order to code the PMTs' use of context knowledge, we referred to categories from Langrall et al. (2011). In their study, Langrall et al. (2011) aimed to explore middle school children use of contextual knowledge as they engaged in statistical investigations. They found that students used context knowledge in five different ways.

The first use, called "bring new insight," in which "students draw on context knowledge to provide new insight or additional information to the task at hand" (Langrall et al., 2011, p. 57). This use was observed in three patterns: 1) recognizing additional data, 2) informing analyses, and 3) stating opinions. In the first pattern, students recognized additional information not included in the data set that could be significant for their analysis. Since the data were not available, students could not include them

in their analysis. In the second pattern, students' insights about context influenced the way they interacted and analyzed the data. Sometimes students acted upon these insights in their analysis and other times did not. In the third pattern, students shared their beliefs and ideas about aspects of data and this influenced the way students interpreted the data or drew conclusions.

The second use of context knowledge was "explain the data," in which students explain "why the data are the way they are" (Langrall et al., 2011, p. 58) by using context knowledge. This way of use was observed in two patterns: 1) reporting the story behind the data, and 2) rationalizing data. In the first pattern, students used context knowledge to explain aspects of the data or analysis results that were not specifically stated in the information provided. In the second, students tried to justify what they saw in the data using their context knowledge.

The third use of context knowledge was called "identify useful data" in which students rely on their context knowledge to identify the useful information in the data set for their statistical analysis. The fourth was called " Justify or qualify a claim" in which students try to justify or support their initial claims using context knowledge. This way of use was observed in three patterns: 1) stating opinion as support, 2) making logical arguments, and 3) appending claim with qualifier. In the first pattern, students shared personal opinions to support their claims. In the second, students developed a logical argument to support their claim. The third happens in the form of "a qualifying statement that modified a claim more than it served to justify." (Langrall et al., 2011, p. 61). The fifth and final use of context knowledge was called "state facts irrelevant to analysis" in which students shared irrelevant facts that could be related to data yet did not contribute to the analysis of the data or were irrelevant to the analysis.

Content analysis was used to analyze the PMTs' written works and reflections from the blogger platform using the Langrall et al. (2011) categories. Some of the critical events were coded under more than one category in the instance of use of context knowledge. The main categories and related sub-categories are shown in Table 2. The frequency (f) of occurrences of the instances are noted.

Table 2. Categories for analysis

Categories	Ways to Use Context Knowledge	Example
C1. Bring new insight ($f = 23$)	a) Recognizing additional data ($f = 15$) b) Informing analysis ($f = 8$) c) Stating opinion (f = 0)	a) We don't know other factors such as underlying health condition or age of the people to understand more what contributes the cancer rate over the years. b) In the world, number of women is more and number of men is fewer. If that was the case for this data [Hiroshima and Nagasaki delayed symptoms]. If we see more sickness in few number of men, this could show men get more sick.
C2. Explain the data ($f = 19$)	a) Reporting story behind data ($f = 11$) b) Rationalizing data ($f = 8$)	a) It was surprising to see few soldiers joined the 57th Regiment from Istanbul, closest big city to Gallipoli. I researched Istanbul was under England control back in that time, that makes sense. b) Political instability, safety concerns could be the reason why we did not see decrease in immigration rate in GAP region.
C3. Identify useful data	In all cases the PMTs used context knowledge of data.	
C4. Justify or qualify a claim ($f = 16$)	a) Stating opinion as support ($f = 7$) b) Making logical argument ($f = 9$) c) Appending claim with qualifier ($f = 0$)	a) I hypothesized that more soldiers could die in winter months since weather would be cold and they could get sick too. b) If there are enough job opportunities, people will not immigrate to find jobs in other places. Immigration rate will increase if there are not enough jobs in GAP region.
C5. State facts irrelevant to analysis ($f = 0$)		

The critical events were coded independently by two researchers. Coding consistency was found to be 84%. The instances of disagreements were discussed with the third author of the study and revisions made to the coding when the authors reached a consensus. The instances authors could not reach a consensus were discussed with an independent mathematics educator to facilitate a resolution.

3.3. RESEARCHER ROLE

Unluer (2012) postulated that social researchers, especially those employing qualitative methodology, should make their roles as researchers clear to the best of their abilities to ensure credibility of their research. As such, qualitative research brings advantages (Smyth & Holian, 2008) and challenges (DeLyser, 2001) for the researcher who has an emic stance. To clarify, the emic stance might help researchers to tell and judge the truth (Bonner &Tolhurst, 2002). It is also likely, however, for qualitative researchers to experience a problem of familiarity, which may lead to a loss of objectivity or introduction of bias (DeLyser, 2001), in addition to the role duality (Gerrish, 1997). In the current study, one of the researchers had an emic stance, which is why it was of utmost importance to accommodate the four criteria for trustworthiness: credibility, transferability, dependability, and confirmability, as suggested by Lincoln and Guba (1985). To overcome such challenges due to the emic stance and to provide trustworthiness and credibility of the study, we utilized data triangulation, peer-debriefing, and thick description strategies to ensure the credibility of the findings (Lincoln & Guba, 1985). Also, the data collection and analysis processes were audited by one of the researchers, who adopted an etic stance.

4.   FINDINGS

The findings of this study suggest that PMTs used context knowledge in different ways as they engaged with the context-based tasks namely, bringing new insights, explaining data, identifying useful information, and justifying a claim. The following sections report on each critical use of context knowledge.

4.1. BRINGING NEW INSIGHT

The PMTs used context knowledge when they brought new insight or additional information regarding the task being examined particularly in their data interpretations. This critical use of context knowledge was coded 23 times within the course of this study, which accounts for 40% of context knowledge use occurrences.

In the second task (GAP project), R-T asked the PMTs, "What do you know about the GAP project?" before they examined the project data. Six out of seven PMTs responded it was about water and agriculture. They were not aware of other goals of the GAP project. Although this was the case, as PMTs worked on different data sets (e.g., health, education) generated by the GAP project, they became more familiar with the project goals. Then, they brought their personal insights into the process of statistical interpretation and inferences. For instance, the PMTs worked on the following research question: "Which factors can be related to infant mortality rate in the GAP region? Explain your reasons." The PMTs analyzed several variables including number of hospitals, the population of each city in the GAP region, number of obstetricians etc. In this task, *TinkerPlots*[TM] allowed the PMTs to explore these different variables in the data set dynamically. They assigned different variables to the graphs and observed how different variables influence their analysis results. In addition, *TinkerPlots*[TM] allowed the PMTs to define new variables (e.g., number of obstetricians per birth) and explore how its data influence their analysis. In one instance, they analyzed the relationship between the number of obstetricians and the number of infant mortalities. They constructed two scatterplots (Figure 1). Then they calculated and interpreted the correlation coefficient (e.g., direction and strength).
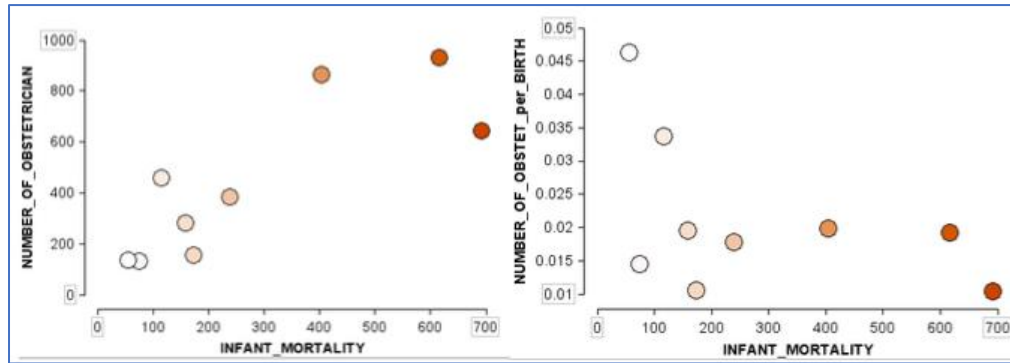
Figure 1. Infant mortality and number of obstetricians.

The discussion took place as follows:

R-T:	What is the relationship between the number of obstetricians and infant mortality?
PMT4:	Increasing.
R-T:	What do you mean?
PMT7:	Just like that relationship (PMT pointed at the direction, the relationship with her hand at the graph represented above on the left).
R-T:	What does this relationship tell us?
PMT7:	Direct proportion.
R-T:	... If there is a direct proportion, what does this tell us?
PMT7:	If there is a direct proportion, as the number [of] obstetricians increases, the number of baby deaths also increases. This does not make sense.
R-T:	Well, then which variables should we take into consideration?
PMTs 3 & 6:	The number of obstetricians per delivery.
PMT7:	There is an inverse proportion here.
R-T:	What does this tell us?
PMT2:	As the number of obstetricians increases, fewer deaths happen. …. [correlation concept discussion with the whole class]
R-T:	Why? The number of obstetricians did not give us a reasonable analysis.
PMT7:	This assumes that all obstetricians give care only for all those babies that were dead.
PMT3:	The issue is not only the babies. Obstetricians also have some other duties.

This conversation shows that the PMTs initially analyzed the relationship between the number of obstetricians and infant mortality in the GAP region. They were surprised to see a positive correlation between the number of obstetricians and infant mortality. Then, they started to question this result and took into consideration that if mortality rate is the same, more births means more deaths. This is why the PMTs defined a new variable called the number of obstetricians per delivery and created the new graph shown in Figure 1 (graph on the right). However, they did not define a variable that shows mortality rate in their analysis. This context-based insight informed the data analysis. The instance of *informing analysis* was coded eight times throughout the study.

Although PMTs found a negative correlation, the PMTs read the statistical result with careful lenses. PMT1 suggested other factors can also contribute to the mortality rate such as socio-economic status of the family. PMT3 stated a different opinion as, "The issue is not only about babies. Obstetricians also have some other duties." These PMTs pointed out *additional information* should be carefully considered to interpret the correlation they found. Similarly, PMT2 also stated that other factors such as the number of doctors may also affect mortality rates. PMT3 added "the obstetrician is not only responsible for the baby during birth, but also after the birth. Although the number of obstetricians is high in some cities, the mortality rate may also be high. Since, there might be more babies in that city and obstetricians may have more babies to take care of." Based on this discussion, all PMTs concluded that they should cautiously interpret the analysis results due to other external variables at the end of the classroom discussion. They shared their opinions on why they need to consider other factors that could also contribute to the mortality rate in the classroom discussion. Such instances of *recognizing additional data* and *their opinion on the influence of such data* were coded 15 times throughout the

study. Unlike in the classroom discussion, five out of the seven PMTs did not discuss possible external variables that could be related to infant mortality in their written responses prior to classroom discussion. The change in PMTs' caution in interpreting statistical results by considering external variables as result of classroom discussion showed the contribution of this course.

In addition to considering external variables while interpreting the statistical results, the R-T asked the PMTs about the difference between causation and correlation. After the whole class discussion, the PMTs concluded that the existence of a relationship does not necessarily mean causation. They acknowledged they had only looked at the existing data without manipulating the variables. Thus, it was hard to tell whether the number of obstetricians per birth alone causes an increase or decrease in infant mortality rate. This discussion also helped PMT7 to understand the difference between direct proportion and positive correlation.

Based on the analysis, the PMTs were surprised by the number of dead babies in the region and concluded the project did not fully realize its objectives when mortality rate was considered. They concluded, however, that population and west-east region comparison was another important factor in evaluating whether the project reached its objective or not. PMT4 pointed out "we can check the infant mortality rate for another city in the west, to see whether the GAP project helped the GAP region to close the gap between the west and southeastern part of Turkey." This response of PMT4 was also an example of looking for additional data to make an inference about whether the project reached its goals pertaining to infant death rate. All these findings indicated that the PMTs began to question the data at hand with a critical lens and enhanced their knowledge about the project with the support of statistical analysis and context knowledge.

4.2. EXPLAINING THE DATA

Explaining the data as use of context knowledge was mostly observed when the PMTs tried to explain the results when the data analysis contradicted their initial hypotheses. In order to explain the story behind the statistical results, they researched sources from different discipline areas (e.g., history, politics, geography) regarding the context of events under examination. This instance was coded 19 times in the study and accounted for 32% of context knowledge use occurrences. All PMTs at least once tried to explain what they had seen in the data. The use of *TinkerPlots*[TM] allowed the PMTs to test their hypothesis through constructing various statistical representations (e.g., dot graph, bar graph) and using statistical analysis tools (e.g., mean, correlation coefficient).

In the Gallipoli task, all the PMTs hypothesized the average age of the soldiers in the 57th Regiment to be around 18–20 years. To test their hypotheses, all PMTs (*n* = 7) created a dot plot using T *TinkerPlots*[TM] as shown in Figure 2.
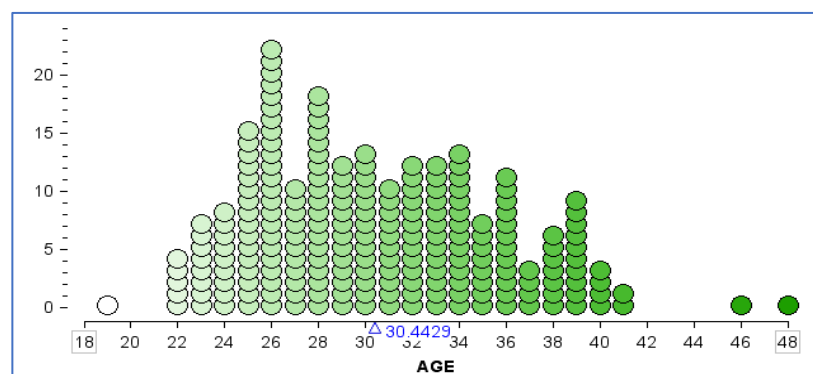

Figure 2. Age distribution of soldiers in the 57th Regiment; the mean age of the soldiers is denoted by the △ symbol. The numerical value of the mean is shown in blue text.

As seen in Figure 2, the PMTs used the mean tool to show the mean age as 30.44 years. Reaching this statistical result was a big "aha" moment for each PMT. All PMTs rejected their hypothesis and felt the need to search for answers for why such differences occurred between their initial guesses and the statistical results. PMT7 stated, "Before analyzing the Gallipoli 57th Regiment data, we

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hypothesized that the mean age of soldiers was 20. However, it turned out to be 30 after our analysis." Six out of the seven PMTs also wrote differences between their initial hypothesis and statistical result in their written responses prior to classroom discussion. For instance, PMT2 wrote, "My hypothesis was mean age of the soldiers was 18–20 years old, however; I found out the mean age was 30.44," in response to, "Please compare your hypothesis and the result of data analysis." See Figure 3.

1. Dersin başında var olan öngörüleriniz ile veri analizi sonucunda elde ettiğiniz bulguları karşılaştırın.

Öngörüm; yaş ortalamasının 18-20 yaş aralığında olmasıydı fakat yaş ortalamasının 30,44 olduğunu öğrendim.
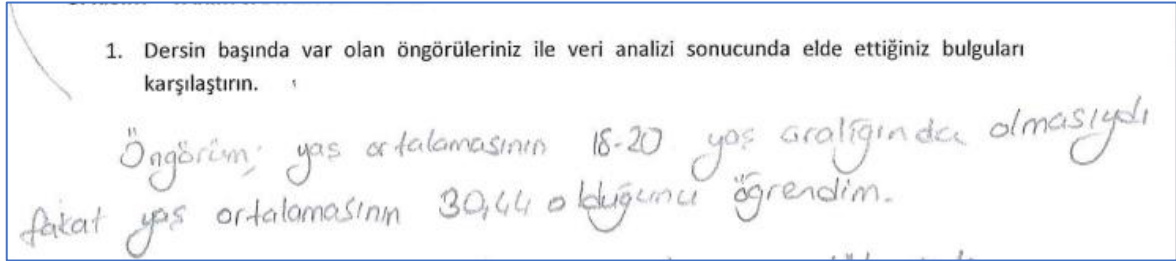
Figure 3. Comparison of hypothesis and statistical result.

Then, all PMTs searched for the possible reason behind this result. Such instances ($n = 11$) were coded under the *reporting story behind data.*

> PMT7: We all needed to read the history of Gallipoli-57th Regiment (1915–1916). We questioned our hypothesis. We all have noticed that the 57th Regiment sample mainly consisted of experienced soldiers coming from the northwest side of Turkey following Balkan Wars (1912–1913). Our data is not enough to completely analyze Gallipoli.

As seen in the response above, PMT7 found an article online about the soldiers who were in 57th Regiment and found they also battled in Balkan Wars. Then, she used this information to explain why the average age of the soldiers was higher than what they hypothesized. In addition, PMT7 and all other PMTs stated they could only make informal statistical inferences cautiously about the Ottoman soldiers battled in Gallipoli since the 57th Regiment was just a sample from all the soldiers in Gallipoli War.

Another example for explaining the story behind the data was coded when analyzing which month the 57th Regiment had more martyrs. PMT7 stated that the number of dead soldiers during spring months was higher, especially in April and May, then this number decreased towards Fall (See the bar graph created by PMTs in Figure 4).
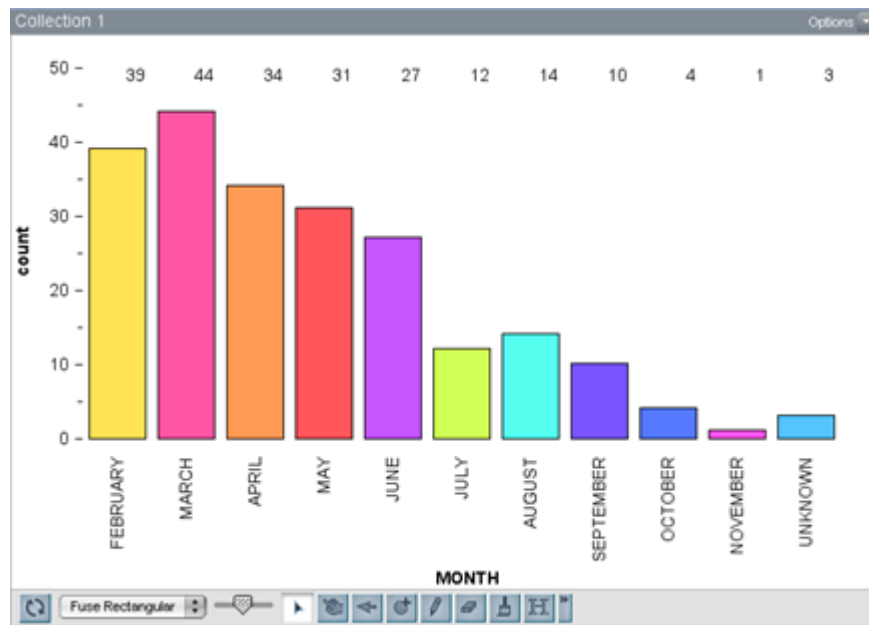

Figure 4. Number of soldiers died per month.

The R-T then asked about possible reasons for this trend and the ensuing conversation was as follows:

PMT7:   It may be due to weather conditions.
R-T: How do you establish a connection between the two?
PMT7:   Since Gallipoli is an island-shaped region, there was an invasion from the sea. In winter, it is hard to attack the region from the sea.

Following this interaction, R-T asked PMTs to research the 57th Regiment, sea attack and land invasions suggested by PMT7. Before PMTs started their search, PMT2 stated that troops were sent to Gallipoli by land. He did not know why, but he remembered that the 57th Regiment had battled on land. The PMTs found that after 18 March 1915, the Allies started to rely on land invasion in the Gallipoli War. The 57th Regiment played a critical role in stopping the Allies on the 25th of April (Atabey, 2015). The PMTs realized the land invasion started in the spring and the 57th Regiment played a significant role in stopping the Allies. Thus, the PMTs indicated this could be the possible underlying reason for the number of deaths being higher during spring (109 out of 219). Then, the PMTs started to ask why the number was low in the fall (15 out of 219) and August (14 out of 219). Initially, none of the PMTs could explain the possible underlying reasons. Then, PMT7 found an online source and shared her research findings with her peers:

PMT7:   On August 13, 1915, Hüseyin Avni, the commander of the 57th Regiment, died with his boots on, fighting in the battle. Major Hayri Bey, who was appointed the commander after Hüseyin Avni, moved the regiment to the district of Keşan. Soon after that, the 57th Regiment was sent to Galicia as part of the 19th Infantry Division of the Ottoman Turkish Army.
R-T: What does this information tell us? How can this information be related to the data we examined?
PMT7:   Since the death rate was too high [as a result of land invasion], [thus then] this Regiment [moved to Keşan] and combined with the new division.
R-T: When did this Regiment combine with the new division [19th Regiment] and sent to Keşan?
PMT7:   On August 15th, 1915.
R-T: What happened in August?
PMT2   There was a decrease in the number of soldiers [died]. [PMT referred to the bar graph that shows number of died soldiers on different months]
R-T: We may see a partial reflection of this [the contextual knowledge provided by PMT7] in our data. Why did I say "partial"?
PMT7:   Because we only analyzed data on 219 soldiers, not all [the soldiers in 57th Regiment].
Other PMTs: [Approved by nodding their heads]

These instances show that PMTs explained the possible reasons behind the statistical result related to the number of martyrs per month by using historical context knowledge. In addition, PMTs also realized they did not analyze the data from all soldiers in the 57th Regiment. Thus, they were cautious about making generalizations based on the data. Analysis of PMTs' written Google Blogger reflections showed a similar trend as in the classroom discussion. Six out of the seven PMTs pointed out that although Gallipoli 57th Regiment data helped them understand some characteristics of the war, it was not enough to understand the whole war. Figure 5 shows an example blogger entry by PMT4.

> 57.alayı analiz ettiğimizde görüyoruz ki savaşa katılanların yaş oratalaması tahmin ettiğimiz kadar genç değil. bir diğer gerçek alayda hayatta kalan kimsenin olmaması. Bu savaşın gerçek yüzünü gözler önüne sermekte. Elde ettiğimiz bulgulara bakarak savaşa en çok Balıkesir ve Bursadan katılım olduğunu gördük bu o zaman ki iç karışıklıkları anlamamızı sağladı . Ama sadece 57. alaya bakarak Çanakkale muharebesini yorumlayamayız savaşın diğer alaylardaki yansımasına da bakmamız gereklidir.

Figure 5. Google Blogger entry: Generalization reflection.

The second type of use of context knowledge to explain data was rationalizing the data. The PMTs provided justifications for what they saw in the data. For example, when PMTs analyzed the GAP project data to see whether it achieved its objective regarding the unemployment rate, they examined the relationship between unemployment rate and number of immigrants (Figure 6.). They created scatterplots and found a positive correlation between unemployment rate and the number of immigrants. Also, they analyzed the net migration and employment opportunities over time (between 2008 and 2015) in the GAP project region.
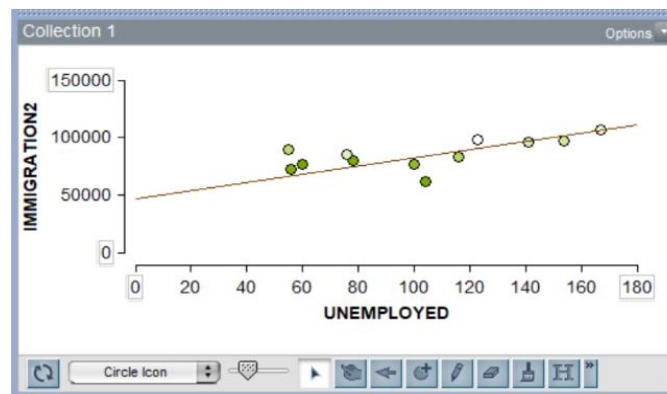

Figure 6. Relationship between unemployment rate and number of emigrants.

They found that the number of people migrating to other cities from the cities in the Gap region were not reduced as the employment opportunities were not changing dramatically. Based on their analysis, the PMTs concluded that the GAP project had not achieved its objectives in the classroom discussion. Similarly, analysis of the PMTs' Google Blogger reflections showed that all PMTs elaborated on why the GAP project had not achieved its objective. For instance:

PMT2:   The GAP project had not achieved its goal when we compared the number of immigrants received and given as well as baby deaths with respect to years…. Political instability in the region may also be a reason for failure.

PMT4:   I do not think the GAP project reached its goal. When we examined the data of 2008–2013–2014–2015 years for the region, we saw that net migration was in the negative direction [refers to each year the people immigrate from the region more when compared to number of immigrants received to the region]. When we examined baby deaths in the same way, we could not observe a consistent decrease. If the project had been successful, infant mortality and immigration rates would decline over time. I think political instability is the biggest reason why the GAP could not reach its goals. This instability damaged the economy and the region itself, [thus this led to] prolonging the completion of the project.

These written reflections are evidence that the PMTs considered historical and political conditions in the region as a context knowledge to understand and interpret the data results to infer whether the project achieved its objectives over time.

4.2. IDENTIFYING USEFUL DATA

As Langrall et al. (2011) suggested, in our findings identification of useful data was also implicit in the way PMTs interpreted and made sense of the data in each task. For all tasks, the PMTs found presented data would be helpful to investigate the research questions. They also pointed out the need for additional data as another way of using context knowledge of data. We realized that since the PMTs were not that familiar with the GAP project, they stated that the presented data helped them understand the scope of the project. Initially, all PMTs thought GAP had to do with only water and agriculture, yet through analyzing the data they deepened their knowledge about the project's scope (e.g., healthcare quality, employment rate, and immigration etc.). In the process of statistical investigation, they still identified useful data to make sense of project objectives and scope. Thus, in all instances of context knowledge of data use, the PMTs also identified the useful data for their statistical analysis.

4.3. JUSTIFYING A CLAIM

This category was observed mostly when PMTs tried to justify their initial hypothesis about research questions. This instance was observed 16 times throughout the study and accounted for 28 % of use of context knowledge occurrences.

The first instance of justifying the claim was coded when PMT1 hypothesized that "more soldiers joined from Bursa and Balıkesir" (two of the cities in the same geographical region and close to Çanakkale city in which the Gallipoli battle happened). She used her historical knowledge of the era and made a logical argument to justify her claim. She stated, "There were wars in different regions of Ottoman Empire including the east, I think more soldiers joined from Bursa and Balıkesir." Then, all PMTs created a bar graph to see the city distribution. They found that most of the soldiers came from Balıkesir, followed by Bursa.

The second instance was observed when PMTs engaged with the third task of Hiroshima and Nagasaki. When discussing the long term and short-term effects of radiation on human health, the PMTs analyzed the data for cancer types detected in randomly selected survivors ($n = 175$) of atomic bombings between the years 1946–1954. They expected to see more cases for acute leukemia right after the bombings since acute cancer could be developed rapidly as result of intense exposure to the radiation after bombings. They stated chronic cancer could develop over time. One PMT justified this claim as "chronic illnesses like that, slowly progressed." Then, the PMTs concluded that the number of acute leukemia cancer cases had increased dramatically between the years 1946 to 1950 ($f = 1$ to $f = 25$) from the data analysis. The number of chronic cancers increased comparatively slowly over the years with a slight decrease in 1954 and 1955. The graph created by PMTs is shown in Figure 7.
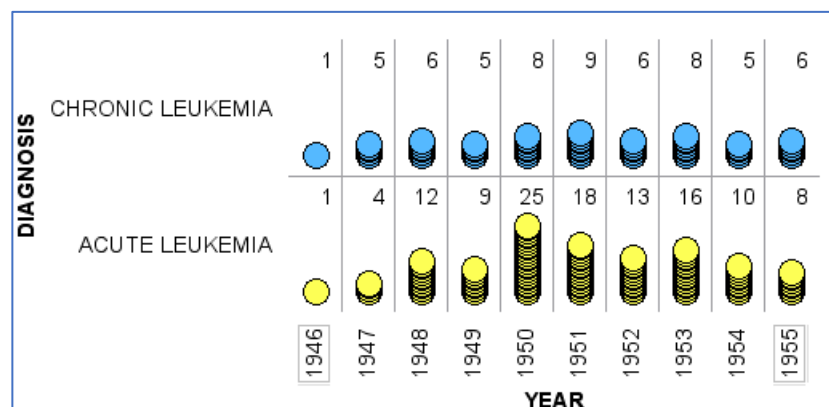

Figure 7. The chronic and acute leukemia distribution with respect to years.

PMT6 *shared her opinion* on why they see such a difference in the prevalence of the acute versus chronic leukemia cases between the years 1946–1954. She stated that acute leukemia could be triggered by a great exposure to the radiation when the atomic bomb hit the ground and that might be the reason why we saw more acute cases right after the bombings. She also suggested that acute leukemia could

be seen among the people who were most impacted by the radiation. "The chronic leukemia could have developed slowly as it is named and might have developed among the ones who were not exposed to radiation that much of the ones who were close to the explosion area." Five other PMTs also reflected on the impact of the bombing based on the distance to the explosion area (effects on the cities and countries nearby) and emission (sea versus earth-emission rate of radiation).

In conclusion, the findings of the study suggested that the PMTs used context knowledge in various ways. They used it to bring their personal insights into the process of making statistical interpretation and inferences. They asked why and how questions more and started to question the knowledge they had picked up through informal conversations in their lives by connecting statistical information and context. Beyond that PMTs provided justification for their claims and statistical results. In addition, it was seen that they could make inferences considering limitations of the given data set and its context.

5.   DISCUSSION

Students should be educated to become individuals who can better act on data (Langrall, 2010), interpret reported statistical results, and make statistical inferences. This can be achieved not only by talking about mathematical relations in statistical courses, but also by working on examples enriched in the social and cultural contexts of real life (Makar, 2013) as well as by building data-related skills (Horton, 2015). This study contributes to the literature on how novel statistics learning experience supports pre-service mathematics teachers' use of context knowledge of data as they engage in statistical investigations with an interdisciplinary approach. The results of the study suggest PMTs used context knowledge of data in various forms namely, bringing new insights, explaining the data, identifying useful information, justifying a claim. Their future students' would benefit from these experiences of learning statistics connected to a data-enriched world instead of merely relying on computation of statistical measures.

As Gil and Ben-Zvi (2011) suggested, the PMTs started to create more connections between the data and context knowledge either in their statistical interpretations, inferences, or claims as they engaged with various activities throughout the study. Also, in some instances, it resulted in bringing new insights to the analysis by pointing out the limitations of the data and stating additional data that could inform the analysis.

The result of the study suggested that the instances of tension between their initial claims and data result yielded in efforts to *explain the data* (Langrall et al., 2011; Makar et al., 2011). These tensions led PMTs to go beyond the data and search for context knowledge of data from different disciplines (Langrall, 2010) to reveal the story behind the data. Further, they engaged in socio-political and cultural discussions. Accessing such context knowledge also provided opportunities to PMTs to improve their knowledge of various disciplines of history, geography, and sociology. This is further evidence that teaching and learning of statistics promotes interdisciplinary learning. Also, as Gill and Ben-Zvi (2011) stated, the PMTs had the opportunity to reflect on their personal beliefs and views about the country and the world they live in and events that had been long forgotten. It is not only a critical reading of the past data that was important, but also potential for this raised consciousness in shaping the future through engaging context-based data investigation activities.

In the study, PMTs' views, prior knowledge, and beliefs about the events shaped how they reasoned about the data (Watson, 2008). In some cases, PMTs' views, prior knowledge, and beliefs restricted how they hypothesized about the event under examination (Pfannkuch & Rubick, 2002). When they saw the data result, however, they did not insist on their initial claims, instead they asked why and how questions (Wild & Pfannkuch, 1999). Then, they reasoned about additional context information that would be considered in the interpretation of statistical results. Similar to Langrall et al.'s (2011) study, in the instances of the PMTs being more knowledgeable about the task context, they used their prior knowledge to *justify their claims*. They used context knowledge to hypothesize possible relationships that exist within the data.

In all statistical analyses, the PMTs identified the useful data within the existing data set. In making informal inferences, parallel with the existing studies' findings with students (Langrall et al., 2011; Makar & Rubin, 2009), the PMTs used context knowledge when they made generalizations. They identified the limitations of the sample, recognized the influence of external variables, and used the context knowledge to explain why they made cautious inferences from sample to population.

Different from Langrall et al. (2011)'s study with middle schoolers, we did not code any instance for sharing irrelevant facts about the analysis context knowledge use. One possible reason for this difference was we worked with senior PMTs who may have had more highly developed socio-political views compared to middle school students. Another reason could be in the cultural context of Turkey, people talk about historical events and politics daily. that might help PMTs share ideas that are relevant to analysis.

The results of this study also showed that using open-ended tasks in which PMTs have the ownership of posing research questions that they would like to investigate, allowed the PMTs to create connections between data and context as they engaged meaningfully in statistical investigations. Further, the dynamic nature of the *TinkerPlots*^TM software gave PMTs flexibility to explore answers to the research questions by constructing different statistical representations and exploring the influence different data on their analysis. The PMTs tested their hypothesis, identified the trends in data and decided to what extent they would need contextual knowledge to explain the trends in the data (Rubin, 2007).

Although this study showed how PMTs used context knowledge of data in engaging interdisciplinary statistical tasks, there are a few limitations to be considered while interpreting the study results. The first limitation is that this study was conducted with a limited number of PMTs. The second limitation is the study participants were purposefully selected and not a random sample. Having a purposeful sample, however, created the opportunity for researchers to examine deeply how such novel statistics teaching courses support PMTs to use context knowledge of data in addition to statistics knowledge, to critically examine the real-world events and develop an understanding of social, historical, and political aspects of the events. There is, however, a need for further studies to examine how such novel statistics teaching courses support PMTs to learn and teach statistics that meet the demands of a data-enriched world and new curriculum revisions.

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Task	Brief description of task context	Data files and statistical concepts*	Reflection focus
Gallipoli 57th Regiment	57th Infantry Regiment was the first Turkish soldiers to resist the Allied landing at Gallipoli Campaign during World War I. (Uyar, 2016). PMTs watched the documentary "Revealing Gallipoli (2005)" co-produced by December Films Pty Ltd. and Turkish Radio & Television.	*One TinkerPlots file* Data of 219 soldiers in the 57th Regiment. The file included the soldiers' names, age of death, month and year of death, hometown, and the region of the hometown. *Topics Covered* Bar and pie graphs, dot plots, measures of central tendency, range.	Understanding war conditions and the story of the soldiers of the 57th Regiment at that time by looking at data and contextual knowledge.
Southeastern Anatolia Project (GAP)	The project includes nine provinces located in the southeastern region of Turkey. Project aims to "improve the level of income and quality of life quality of local population by utilizing region's resources; eliminating development disparities existing between the region and other parts of the country, and contributing to national economic development and social stability by enhancing productivity and employment opportunities in the region" (Ministry of Industry and Technology, 2018).	*Two TinkerPlots Files* One was on immigration, workforce, employment, and unemployment in cities in the GAP region for the years of project implementation. Second one shows the possible variables (e.g., # of obstetricians, number of hospital) related to death rates of newborn babies per city between the years of 2002–2015. *Topics Covered* Scatter plot, correlation	In the project website, it is stated that GAP project "… is the one most effectively implemented among regional development plans and programmes developed so far." (Ministry of Industry and Technology, 2018). Whether the GAP project achieved its objectives were discussed in a statistical and socio-political context.
Hiroshima and Nagasaki	The two atomic bombings over the Japanese cities of Hiroshima and Nagasaki on August 6 and 9, 1945. Prior to the task implementation, class watched the documentary titled "24 Hours After Hiroshima (2010)" produced by the National Geographic.	*Two TinkerPlots Files* The first file includes data on chronic vs. acute leukemia incidence among atomic-bomb survivors between 1946 and 1955. The second file includes data on the delayed symptoms (e.g., dyspepsia, headache) of the atomic bomb based on the gender. *Topics Covered* Line graph and box plot, and correlation.	The delayed effects of the explosion of the atomic bomb on the people living in the region were discussed in a statistical context.

* Each task includes posing research questions, formulating hypotheses and informal statistical inference, generalization and determining the limitations of data as statistical focus.