PEDAGOGICAL PERSPECTIVE | RESEARCH ARTICLE

Evaluation of statistics teaching practices: Development of a two-structure observation form

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ABSTRACT

Teachers' instructional practices play a crucial role in students' understanding and application of statistical concepts. This study aimed to design an observation form to evaluate the quality of statistics teaching in classrooms. The form was developed around two key structures emphasized in the literature: statistical knowledge for teaching and the statistical process. Statistical knowledge for teaching was addressed in five components (knowledge of content and students, knowledge of content and teaching, curriculum knowledge, key developmental understandings, and pedagogically powerful ideas). The statistical process was represented through four components (formulating statistical investigative questions, data collection, data analysis/representation, and interpret the results). The development of the form followed a three-phase process: preparation, implementation, and evaluation. In the preparation phase, relevant models and reports were reviewed, and a draft form was created based on expert feedback. In the implementation phase, the form was tested in two stages: a preliminary review of its aspects and a classroom application involving six hours of lessons covering all stages of the statistical process. Finally, in the evaluation phase, the form was revised and finalized. The results indicated that the form demonstrated both validity and usability. It is expected to serve as a valuable tool for future research on statistics education.

KEYWORDS: Observation form; Statistical knowledge for teaching; Statistical process

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1. Introduction

It is stated that statistics are increasingly evident in every aspect of our daily lives (Bargagliotti et al., 2020). In our society, which is in constant interaction with data (Engledowl & Tarr, 2020), there is a need to make effective data-driven decisions to keep pace with technological developments (Rodrigues & Ponte, 2020). In parallel with this need, training individuals equipped with statistical knowledge emerges as an important goal. In particular, the GAISE (Aliaga et al., 2005; Bargagliotti et al., 2020; Carver et al., 2016; Franklin et al., 2007) and SET (Franklin et al., 2015) reports list principles based on contemporary approaches for teaching statistics, and draw attention to the fact that training individuals who are equipped in terms of statistics and can transfer statistical knowledge to their lives is now an inevitable need.

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Considering the role and importance of statistics in our lives, there has been an increasing emphasis on improving the quality and quantity of statistics teaching practices in recent years (Batanero et al., 2011; Meletiou-Mavrotheris & Serradó, 2011; Pfannkuch & Ben-Zvi, 2011). Students are expected to be equipped with statistical knowledge and to have basic literacy skills for situations in their lives (Watson, 2006). While various factors are mentioned that affect students' development as individuals equipped in the field of statistics (Sproesser et al., 2014), it is emphasized that one of these factors is teachers (González et al., 2011). At this point, among the searches for learning opportunities offered to students, the question of what kinds of experiences they have in statistics education also becomes meaningful. Drawing attention to the importance of developing statistical knowledge and understanding in individuals also brings into focus questions about the quality of statistics education. In this context, there is a need not only for students but also for teachers to possess the necessary knowledge and skills to deliver more effective statistics instruction. Therefore, the role of teachers in the learning environment is directly related to the practices and approaches they include in their teaching.

It is recommended that statistics teaching should focus on statistical literacy and thinking, that real-life data should be used, that the statistical process should be experienced with active participation in the form of collect data, data organization, data analysis-representation and interpretation rather than the application of rules, formulas and procedures, and that conceptual understanding development in students should be ensured (Aliaga et al., 2005; Carver et al., 2016). In addition, studies have highlighted the importance of teachers considering the statistical process stages as a whole, which include creating statistical research questions, collecting data/evaluation, data analysis, and interpreting the results during the teaching process (Bargagliotti et al., 2020; Newton et al., 2011; Özmen, 2015). In addition, it is stated that teachers see themselves as inadequate and do not have the necessary equipment for teaching statistics (Batanero et al., 2011; Batanero et al., 2004; Gattuso & Ottaviani, 2011; Hill et al., 2004; Lovett & Lee, 2017; Wessels, 2011; Yeniçırak, 2020) and do not graduate from universities prepared and equipped for teaching statistics (Henriques & Ponte, 2014; Koparan, 2015; MacGillivray & Pereira-Mendoza, 2011; Yılmaz, 2019). International literature indicates that students' and teachers' statistical knowledge is not at the expected level and needs improvement (Callingham & Watson, 2017). Similarly, in the national literature, it is noted that teachers do not have sufficient knowledge about teaching statistics, that they have difficulties in teaching statistics subjects (Kaynar & Halat, 2012; Koparan, 2015; Ulusoy & Çakıroğlu, 2013; Yeniçırak, 2020), and that teachers need to enrich their statistics teaching (Akkoç & Yeşildere-İmre, 2015; Gürel, 2016; Koparan, 2015; Yılmaz, 2019).

The development of teachers' statistical knowledge and skills and the enrichment of statistics teaching with the statistical knowledge and skills required by the age are important initiatives, and it is noted that as a natural result of such an initiative, students' statistical knowledge and skills will also improve (Callingham et al., 2016; Callingham & Watson, 2017; Hay, 2010; Pierce & Chick, 2013; Yeniçırak, 2020). It is stated that students have various difficulties regarding statistics topics and concepts (Tishkovskaya & Lancaster, 2012; Zakari, 2020; Zieffler et al., 2008). It is thought that there is a strong connection between students' ability to overcome these difficulties and the teaching carried out by teachers. At this point, it is worth examining teachers' practices in teaching statistics. In other words, it is considered important how teachers' statistics teaching practices are in terms of the teaching recommendations and approaches that will add quality to statistics teaching expressed in the GAISE (Aliaga et al., 2005; Bargagliotti et al., 2020; Carver et al., 2016; Franklin et al., 2007) and SET (Franklin et al., 2015) reports, which are considered important in statistics teaching, what they do to overcome student difficulties, and what kind of teaching they do in terms of statistical process and statistical knowledge for teaching. Therefore, it is important to examine teachers' statistical teaching practices in terms of the teaching strategies and knowledge-skills outlined in reforms and reports on statistics education.

When the literature on statistics and statistics teaching is examined, it is seen that studies on statistics and statistics teaching have been conducted to reveal theoretical frameworks related to the knowledge of teaching statistics (Burgess, 2006; 2007; Burrill & Pfannkuch, 2024; Godino et al., 2008; Godino et al., 2011; González, 2014; Groth, 2007; 2013; Silverman & Thompson, 2008), to improve teachers' knowledge of teaching statistics (Baker & Chick, 2006; Lee & Hollebrands, 2011; Souza et al., 2015; Wright et al., 2024), examining teachers' understanding of certain statistical concepts (mean, graph reading, change) (Callingham & Watson, 2011; González et al., 2011; Jacobbe & Carvalho, 2011; Sanchez et al., 2011; Watson et al., 2009), and determining teachers' and prospective teachers' knowledge of teaching statistics (Batur, 2021; Forgasz et al., 2024; Yılmaz, 2019). However, few studies have addressed the practicalities of teaching statistics to teachers. In these studies, it is generally seen that teaching practices are addressed in specific contexts such as examining the courses in terms of statistical/graph literacy, which is considered as the target for statistics teaching (Özmen, 2015; Uyanık, 2022), experiencing instructional practices related to the statistical process (Güven et al., 2015), and examining statistics teaching by focusing on the dimension of knowledge of teaching a particular statistic (Yeniçırak, 2020). On the other hand, studies on the stages of the statistical process, which range from the formulation of statistical research questions to the interpretation of results, are very limited (Pfannkuch, 2005). It is evident that in statistics teaching practices, statistical knowledge for teaching and the stages of the statistical process come to the fore. It is important to consider these two dimensions together, as they play complementary roles in achieving the ultimate goal of developing statistics education. In addition, there is a need to evaluate teachers' classroom practices in line with current approaches and suggestions in terms of statistics education. In this context, it is important to consider classroom teaching practices in terms of these two ideas, which are considered important in the curriculum for the development of statistics education. Upon examining the literature, the need to develop a structure that includes the components necessary to evaluate and develop teaching practices for statistics topics and concepts becomes apparent. In this sense, the need to develop an observation form to evaluate teachers' teaching practices in terms of two important structures for statistics teaching constitutes the scope of this study. In this context, the current study aimed to develop a structured observation form to evaluate the statistics teaching practices of secondary school mathematics teachers in terms of statistics teaching knowledge and the stages of the statistical process.

1.1. Theoretical Framework

1.1.1. Statistical Knowledge for Teaching

Statistical knowledge for teaching includes various information and components regarding how best to teach statistics (Groth, 2013). In this context, various models grounded in mathematics education have been proposed by researchers for teaching statistics, which cannot be considered completely independent of mathematics (Groth, 2007; 2013). Groth (2013), considering that the nature of mathematics and statistics is different, presented the statistical knowledge for teaching model and included the knowledge of content and teaching, content and student recognition knowledge, and curriculum knowledge components in the mathematics teaching knowledge models (Baki, 2012; Ball et al., 2008). The components in the model are presented in Figure 1.

Figure 1 ***Statistical knowledge for teaching model***

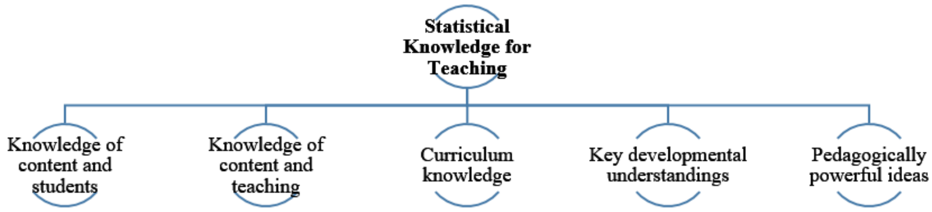


Figure source: (Groth, 2013)

When Figure 1 is examined, five components in the Groth (2013) model stand out. Knowledge of content and students includes information on organizing instruction to take into account students' understanding, possible errors, and misconceptions in statistics teaching, as well as on directing the flow of the instructional process in line with students' answers. Information on how to plan for more effective teaching of statistics subjects and learning outcomes is an important part of content and teaching knowledge. Curriculum knowledge includes information on subjects and learning outcomes related to statistics in the mathematics curriculum, and information on the grade level and order in which the subjects should be taught, taking into account the student level. Key developmental understandings are a component added to Groth's (2013) model of knowledge for teaching statistics and include the basic information needed to make sense of statistical knowledge. This information is presented as an important turning point for gaining knowledge and understanding of the field of statistics and its context. Groth (2013) states this component as an important mechanism in the development of field knowledge and defining cognitive substructures. For example, understanding the idea of "change" is important for understanding measures of spread such as standard deviation. Meanings related to change form the basis for understanding this concept. Finally, pedagogically powerful ideas refer to the activation of situations that support students' understanding of statistics-related information. Groth (2013) states that this component is also an element that will activate key developmental understandings. This component emphasizes providing in-depth understanding and explanations regarding statistical knowledge. For example, deciding which questions to ask students to understand a concept and explaining the answers from the most basic to the most advanced are important elements of this component. The Groth (2013) model is based on the idea that mathematics and statistics are inherently different fields and is developed as a synthesis of mathematics teaching knowledge models (Baki, 2012; Ball et al., 2008) that are frequently used in the literature. In the models of knowledge of teaching mathematics, Groth (2013) included the components of content and teaching knowledge, content and student knowledge, and curriculum knowledge. However, given the nature of statistics, it also included key developmental understandings and pedagogically powerful ideas prominent in the statistics education literature. In this study, which aims to evaluate teachers' statistics teaching practices, the Growth (2013) model was chosen to structure statistical knowledge for teaching, as it includes the theoretical framework related to mathematics teaching knowledge models and incorporates components suited to the nature of statistics.

1.1.2. Statistical Process

The statistical process is holistic, beginning with the formulation of a research question and continuing through the interpretation of the results. In the GAISE-I and II reports (Bargagliotti et al., 2020; Franklin et al., 2007), which include important instructional recommendations for teaching statistics, the statistical process is also expressed as a problem-solving process. The stages of the statistical process are schematized in Figure 2:

Figure 2 ***Statistical process stages***

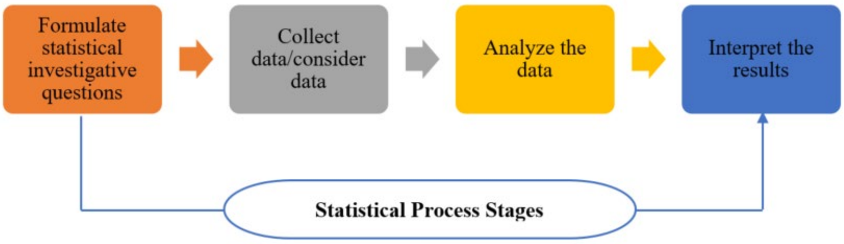
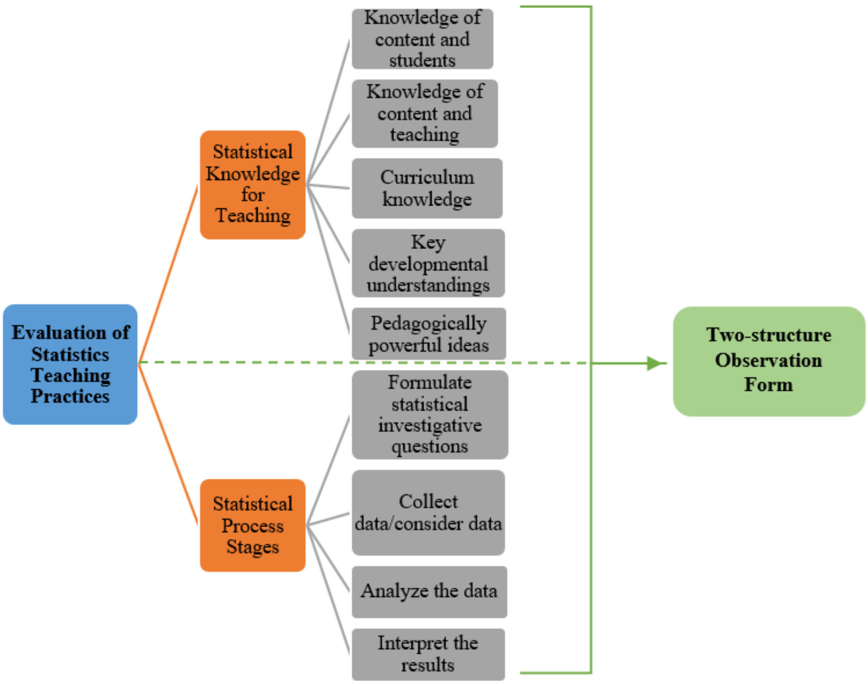


Figure source: (Bargagliotti et al., 2020)

When Figure 2 is examined, the statistical process in GAISE reports (Bargagliotti et al., 2020; Franklin et al., 2007) is explained in 4 stages: formulate statistical investigative questions, collect data/evaluation, analyze the data, and interpret the results. The first of these stages is to formulate statistical investigative questions. The statistical process will be shaped in line with these research questions. In this sense, the question/problem to be posed must have the characteristics of a statistical research question. Data collection/evaluation is the stage where data appropriate to the determined research question are collected. At this stage, it is necessary to select a population/sample that can answer the research question, determine the data collection methods, and collect and evaluate the data. Analyze the data is the stage where appropriate analysis methods and representation types are determined for the collected data. Analyzing the data involves organizing and classifying the collected data, displaying it using various representations (graphs, tables, etc.), and using measures of central tendency (arithmetic mean, median, mode) and dispersion (range, interquartile range, standard deviation, etc.) to summarize it. Interpreting the results is the stage where a decision is made by analyzing the data, taking into account variability, and relating it to its context.

In this study, two theoretical structures (statistical knowledge for teaching and statistical process) were used as a basis for determining teaching practices related to statistics, and this theoretical structure was schematized as in Figure 3 for the observation form developed.

Figure 3: ***Two theoretical structures in the evaluation of statistics teaching practices***



When Figure 3 is examined, two structured theoretical frameworks are evident, based on the observation form prepared to evaluate teachers' statistical teaching practices. In this context, the statistical process stages, which are emphasized in GAISE reports (Bargagliotti et al., 2020; Franklin et al., 2007) and highlighted as an important approach for statistics teaching (Güven et al., 2015; Newton et al., 2011; Topan, 2023), played an active role in the creation of the observation form that will be the basis for the evaluation of teaching.

2. Method

In the preparation of the observation form to be developed for the evaluation of statistics teaching, two theoretical constructs, the components of knowledge of teaching statistics and the stages of the statistical process, were taken as the basis.

2.1. Construct Validity of the Observation Form

To evaluate statistics teaching practices, an observation form was developed to capture two important structures emphasized in prominent models and reports in the literature: statistical knowledge for teaching (Groth, 2013) and the statistical process (Bargagliotti et al., 2020; Franklin et al., 2007). In revealing the construct validity of the observation form, the structure of statistical knowledge for teaching was addressed in 5 components (knowledge of content and students, knowledge of content and teaching, curriculum knowledge, key developmental understandings, pedagogically powerful ideas), which served as the basis for Groth's (2013) study. The statistical process structure is based on 4 components (formulating statistical investigative questions, collecting data, analyzing and representing data, and interpreting the results), as outlined in the GAISE-II report (Bargagliotti et al., 2020). In this context, aspects of these two structures and their related components were included when developing the observation form. The components and explanations associated with these two dimensions, which form the basis for the construct validity of the observation form, are summarized in Table 1.

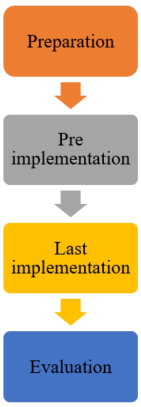
Table 1 ***Explanations regarding the knowledge component of teaching statistics and the stages of the statistical process***

Theoretical Idea	Component	Explanation
Statistical knowledge for teaching (Groth, 2013)	Knowledge of content and students	It includes information on organizing instruction to take into account students' understanding, potential errors, and misconceptions in teaching statistics, and on directing the flow of the teaching process in line with students' responses.
	Knowledge of content and teaching	Information on how to plan to teach statistics subjects and learning outcomes more effectively is important.
	Curriculum knowledge	Information on the subjects and learning outcomes related to statistics in the mathematics curriculum requires knowledge of the grade level and the order in which the subjects should be taught, taking into account the student level.
	Key developmental understandings	This component, which Groth (2013) added to the statistical knowledge for teaching model, refers to the basic information required to make sense of statistical knowledge in the field. This information is identified as an important turning point for gaining statistical subject-matter knowledge and understanding the context (Groth, 2013). Groth (2013) states this component as an important mechanism in defining cognitive substructures in the development of subject matter knowledge.

Theoretical Idea	Component	Explanation
	Pedagogically powerful ideas	It is meant to activate situations that will support the understanding of information about statistics and facilitate students' understanding. Groth (2013) states that this component is also an element that will activate key developmental understandings. This component emphasizes providing in-depth understanding and explanations about statistical information.
	Formulate statistical investigative questions	The first stage of the statistical process is to pose a statistical research question. How the statistical process will proceed will be shaped by this research question. In this sense, the question/problem to be posed must have the characteristics of a statistical research question.
Statistical Process (Bargagliotti et al., 2020)	Collect data	This is the stage where data appropriate to the determined research question is collected. At this stage, it is necessary to select a population/sample that can answer the research question, determine the data collection methods, and collect and evaluate the data.
	Analyze the data	This is the stage where the collected data is analyzed according to appropriate analysis methods, and the variability in the distributions is explained. Analyze the data, which includes organizing and classifying the collected data, displaying it with various representations (graphs, tables, etc.), and using central tendency and measures of dispersion to represent the data.
	Interpret the results	The results obtained from analyzing the data are interpreted by taking into account the variability and relating it to the context in which it is located, and a decision is made.

A preparation-implementation-evaluation process (pre-implementation–last implementation) was followed in the development of the two structured observation forms based on the two theoretical ideas summarized in Table 1. The observation form development process is schematized as in Figure 4.

Figure 4 ***Observation form development process***



When Figure 4 is examined, the first preparation work was done in the process of developing the observation form. The preparation work covers the process of creating the draft observation form, which forms the basis for the next implementation stage. This stage also includes studies on construct validity. The second stage is the implementation stage, consisting of two sub-stages and includes the usability, validity, and reliability studies of the observation form aspects with the help of pre-post analyses. After the completion of the last implementation stage, the findings obtained were examined, and the evaluation stage was started. As a result of this stage, the two-structure observation form was finalized.

In the preparation phase, the emphasis in the literature on statistical knowledge for teaching and statistical process, and the expected teaching behaviors for these structures were examined, and the first draft of the observation form was created in line with the opinions and reviews of the project researchers. The draft form consists of a total of 53 aspects, 25 in the statistical knowledge for teaching structure and 28 in the statistical process structure. After the draft form was finalized, the first stage, the preparation stage, was completed by obtaining opinions from 6 faculty members who are experts (experts' fields of study are statistics education, teacher education, pedagogical content knowledge, and noticing skills) in the field for content validity. The feedback from the experts was collected under the titles of being observable in the classroom, the aspects being independent of each other, the expressions being clear and understandable, and being appropriate in terms of language and expression. While creating the observation form, care was taken to ensure that the roots of the observation form aspects were independent of each other in order to avoid repetition and to be able to determine different elements during the observation. The aspects were revised in line with expert opinions, taking care not to repeat each other in terms of scope and expression. Experts evaluated the observation form within the framework of the criteria of "appropriate", "improvable", and "not appropriate" regarding the aspects. As a result of the examinations made by a total of 6 experts in line with the evaluation criteria, the items coded as 'improvable' and 'not appropriate' were re-examined. After the feedback from the experts, the scope validity rates of the aspects were calculated using the Lawshe (1975) technique. The Lawshe (1975) technique was used to examine whether the items in the observation form provided content validity. In this technique, the aspects are graded into three categories: "the item measures the targeted structure", "the item is related to the structure but unnecessary," and "the item does not measure the targeted structure," and a formula is presented to calculate the content validity rate. According to this formula, the content validity rate is obtained by subtracting 1 from the ratio of the number of experts (Ne) stating the 'appropriate' or 'necessary' opinion regarding each item to half of the total number of experts (N) (KGO = Ne/(N/2)-1). As a result of the calculation, the content validity ratio can take a value between -1 and +1. The critical values of the content validity ratios change according to the number of experts, and the critical value was determined as 0.99 according to the number of experts used in the study (6 experts) (Lawshe, 1975). In the last case, the evaluations of a total of 6 experts and the values obtained from the Lawshe technique were evaluated together, the relevant aspects were removed, and changes were made to the relevant items.

When the expert opinions and Lawshe technique results are considered together, the number of aspects in the sub-dimensions of curriculum, key developmental understandings and pedagogically powerful ideas under the statistical knowledge for teaching dimension in the observation form remained the same. Some aspects under the knowledge of content and student were combined and new aspects were added, increasing the number of aspects of this component by 1. One aspect was removed from knowledge of content and teaching component, and it was decided to add 1 aspect to the key developmental understandings dimension. In the last case, the number of aspects under the knowledge of content and teaching dimension decreased by 2. On the other hand, there was no change in the number of aspects in the dimensions of formulate statistical investigative questions, data collection and data analysis-representation under the statistical process stages dimension, only some aspects were improved in terms of meaning and grammar. In addition, 1 aspect was removed from the dimension of interpreting the results. As a result, there were a total of 51 aspects in the observation form, which was finalized in line with the expert opinions and Lawshe technique results. In the dimension of statistical knowledge for teaching, 1 aspect was added to the knowledge of content and students component, 2 aspects were removed from the knowledge of content and teaching component as a result of the merger; in the dimension of statistical process stages, 1 aspect was removed from interpret the results component. With the arrangements made after expert opinions, the observation form was finalized with 51 aspects (statistical knowledge for teaching 24, statistical process 27).

The second stage of the observation form development process, the implementation stage, was carried out in two sub-stages. In the first stage, preliminary analyses were conducted as a pre implementation to examine the usefulness of the aspects in the observation form and their inclusion in statistics teaching. Within the scope of the pre implementation, a statistics teaching conducted for two class hours was analyzed in line with the observation form. After these analyses, studies were conducted on the scope of the aspects and what kind of behaviors they measured. In the second phase of the implementation, six-hour lessons covering all stages of the statistical process were analyzed with the help of the observation form. The classroom observations were conducted by a researcher with experience in statistics education; relevant field notes were taken during the observations, and the transcribed lessons were subsequently prepared for coding. The selection of the lessons was determined by ensuring a variety of topics and being related to graphs, research questions, collect data and analyze the data. The selection of the lessons in which these topics were covered was influenced by the idea that the diversity of the aspects in the observation form for the structure created in line with the statistical process stages and that they would include topics based on different stages in order to see their functionality was effective. Within the scope of the needs analysis, information on the analyzed lessons—including teacher, teaching experience, school achievement level, lesson duration, grade level, and learning outcomes—is presented in Table 2.

Table 2 ***Information on the lessons analyzed within the scope of the needs analysis***

Teacher	Teaching Experience	School Achievement Level	Duration	Grade Level	Learning Outcomes
T1	8-16 years	Medium Level	2 hours	Grade 7	M.7.4.1.1. Constructs and interprets line graphs related to data. M.7.4.1.3. Constructs and interprets circle graphs related to a data set.
T2	0-8 years	Low Level	2 hours	Grade 5	M.5.3.1.1. Formulates research questions requiring data collection. M.5.3.1.2. Collects data related to research questions and represents them using frequency tables and bar graphs.
T3	16+ years	High Level	2 hours	Grade 7	M.7.4.1.2. Determines and interprets the mean, median, and mode of a data set.

The analyses were conducted simultaneously by three researchers. As a result of the analyses conducted by the three researchers, the differences between the codes were discussed in meetings and a consensus was reached and then the necessary arrangements and changes were made in the observation form. After these reviews by three researchers, the second part of the implementation phase was completed and the evaluation phase was started.

The arrangements and changes made during the evaluation phase were grouped under three themes: combination, removal and regulation aspects. Combination covers the changes and arrangements made when it was observed that some aspects covered each other while the observations made for the needs analysis were analyzed in line with the observation form. Under the combination theme, 6 aspects were merged into 3 aspects by merging them in pairs. As a result of the analysis, the observability of the 7 aspects in classroom practices was discussed and it was decided to remove these aspects from the form in line with the operability criteria. Finally, all aspects in the observation form were re-examined and 16 aspects were edited in terms of grammar and meaning. For example, in the knowledge of content and students component of the statistical knowledge for teaching dimension, the aspect "Addressing the subject with multiple approaches that will enable students at different levels to understand" was edited as "Supporting the topic with different explanations to facilitate the understanding of students at varying levels" in order to be more understandable.

3. Findings

The observation form development process consisted of four phases: preparation, implementation (pre-last), and evaluation. The first phase, the preparation phase, was completed after the expert opinions were obtained. After receiving expert opinions for the scope and construct validity of the observation form, the implementation phase of the development process was started. The implementation phase consists of two sub-phases. In the first part of the implementation phase, a preliminary analysis was carried out to reveal the validity of the observation form. As a result of the preliminary analyses conducted by three researchers over 2 lesson hours, 7 aspects out of a total of 51 were deemed appropriate to be removed, and 7 aspects were edited in terms of language and meaning. In this context, the researchers conducted repeated analyses using the observation form for observations made within the scope of the needs analysis (6 lesson hours). Following analyses by three researchers, the differences between the codes were discussed in online meetings, and a consensus was reached. In this direction, the necessary arrangements and changes were made in the observation form. These arrangements and changes were grouped under three themes: combination, removal, and regulation indicators. Table 3 includes the themes and explanations of the arrangements made.

Table 3 ***Changes made to the observation form as a result of the needs analysis***

Theme	Explanation	Number of Changed Aspects
Combination	While the data regarding the observed lessons were being analyzed in line with the observation form, it was observed that some aspects covered each other. Therefore, it was foreseen that there might be confusion in the coding. It was decided to combine such aspects by making appropriate arrangements.	6
Removal	In the meetings held on the analysis, the situations regarding the availability of some aspects in classroom applications were also discussed. In this context, it was decided as an important criterion to examine the availability (operability) of the aspects in statistics teaching.	7
Regulation	In the analyses, all aspects in the observation form were re-examined in terms of grammar and meaning and edited in order to ensure that	16

Theme	Explanation	Number of Changed Aspects
	different researchers could derive the same meaning from the relevant aspect and to increase the reliability of the coding.	

As a result of the analyses conducted for the second stage of the implementation section, at the end of the process that started with 51 aspects, it was decided to combine 6 aspect pairs, remove 7 aspects and make arrangements in 16 aspect expressions. For example, in the key developmental understandings dimension, two aspects were included: “Stating expressions such as change, representation, center as important ideas in statistics teaching” and “Emphasizing the big ideas of statistics teaching (change, center, representation, randomness, etc.) within the subject”. In the online meetings, based on the course analyses, it was decided that the two aspects could be under the same roof in terms of emphasizing and indicating important ideas such as change, center, and representation, and even that they should be combined because they were repetitive. In the last case, the two aspects mentioned were combined under a single aspect as “Framing the big ideas of statistics instruction (such as variation, center, representation, randomness) as key concepts.” As an example for this aspect, the following statement was made in the lesson of T3, which covered the concepts of arithmetic mean and range:

> “....There is an average question about the graph, those questions are good questions, those types of questions will help us a lot in the 8th grade next year. Let’s see, it says, the weekly temperature change of a city, look at the change, children said look at the change, what is the name of the graph?”

When T3’s statement was examined, it was seen that it fell within the scope of both aspects, that the two aspects could not be distinguished in such examples and that there was no significant difference in terms of scope. It was determined that both aspects were within the same scope in terms of reinforcing the expression or idea of change. Based on such examples, it was decided to combine these two aspects.

In the observation form, there are two aspects in the dimension of pedagogically powerful ideas: “Asking questions to ensure conceptual understanding in the teaching process” and “Asking questions and producing strategies that can eliminate students’ mistakes about statistics”. It was prioritized that the statements in both aspects be separated from those related to the KCS (knowledge of content and students) component, and that they focus on the deep consideration of conceptual understanding within the dimension of pedagogically powerful ideas. Based on this idea, they were combined into a single aspect: “Posing critical questions during instruction to promote conceptual understanding and address students’ errors related to statistics”. In the online meetings held, it was decided to combine these aspects into a single aspect, given that both focused on asking questions and that conceptual understanding could be developed during the teaching process, while possible errors could be eliminated.

The idea of considering the two aspects in the KCS dimension, “Revealing possible errors and misconceptions that may develop in students” and “Asking critical questions to determine students’ difficulties regarding the subject or concepts”, within the scope of a single aspect, emerged. Since both aspects involve determining students’ errors, misconceptions, and difficulties and serve the same purpose, they were combined. For example, the following statement was made in the lesson of teacher T1 on arithmetic mean and range:

> "...Children, can we say that the arithmetic mean is 17 by looking at the numbers in this table without finding the arithmetic mean?"

When the relevant statement in the analysis example is examined, it is seen that this question is asked by the teacher to determine the difficulties of the students regarding the subject or concept (calculation of arithmetic mean, conceptual understanding of the relevant procedure) and to deepen it, therefore the teacher also aims to reveal the errors and misconceptions that may develop in the students in this process. Therefore, it is thought that such statements contain both aspects in a natural structure. In this context, it was decided to combine the two aspects in the KCS component into "Posing questions aimed at revealing potential misconceptions and difficulties that may arise among students," and to consolidate them under a single aspect.

In the CT (knowledge of content and teaching) component, it was decided to remove the aspect of "Presenting a context appropriate to the nature of the subject" from the observation form, considering that it is included in aspects such as "Drawing attention to the production of research problems appropriate to the context of the subject" in the SRQ (formulating statistical research questions) component, "Interpreting the obtained results in an appropriate context" in the IR (interpret the results) component, and that it better represents the practices related to the statistical process and its stages rather than the structure of teaching knowledge. Another aspect removed from the observation form is as follows.

The aspect of "Drawing attention to the importance of collecting data appropriate to the research problem" in the data representation dimension, "Drawing attention to the importance of selecting a sample appropriate to the problem context and collect data" and "Ensuring that students decide on the appropriate collect data method (questionnaire, measurement, database, etc.)" under the data representation stage in the observation form were discussed as including applications for this aspect, and the relevant aspect was removed from the observation form in order to avoid situations involving repetition between the aspects.

In the process of removing an aspect, the fact that the aspect was not directly encountered in the courses where the needs analysis was conducted did not factor into this decision. In deciding to remove an aspect, it was considered that the applications related to this aspect may fall within the scope of another aspect, or that it is difficult to encounter the relevant aspect in the applications used in the classroom environment. As an example of this process; although the aspect of "Using technological tools to highlight conceptual understanding in analyze the data" in the analyze the data-representation dimension of the observation form was never encountered in the analysis of the lesson observations made within the scope of the needs analysis, it was not removed from the observation form because it was an aspect that could emerge in future observations. Therefore, while the researchers decided to remove the aspects from the observation form, they did not rely solely on whether the aspects were observed in the analyses of the 6 lesson hours.

In the KCS component, discussions were held on expressing the aspect "Addressing the subject with multiple approaches that will enable students at different levels to understand" more clearly. In this context, it was decided to organize it as "Supporting the topic with different explanations to facilitate the understanding of students at varying levels". Given that the expression of approach may limit the aspect, a change in this direction was deemed appropriate to address instructional explanations more broadly.

It was considered to add the expression "drawing" to the aspect "Drawing attention to the basic elements of graphs (scaling, axis name, graph title, etc.)" in the data analysis-representation dimension. After this arrangement, the relevant aspect was arranged as “Drawing attention to the basic elements of graphs (scaling, axis name, graph title, drawing, etc.)”. It was decided to add the expression drawing to this aspect as a result of the analyses. For example, the following expression was used in T2’s lesson on frequency table and column chart:

> “...So what was I doing after that? I was creating the column chart according to these tables, I could make comments according to the heights of those columns in the column charts...”

When the teacher’s statement was examined, it was seen that he emphasized the basic elements of the graphs as well as the drawing of the graph. It was determined that the teacher actually emphasized drawing the graph as a basis for teaching graphs, highlighting the heights of the columns in the bar graph. In order to include the emphasis regarding the drawing of the graph in the scope of this aspect, it was decided to include the expression “drawing” in the relevant aspect. In this context, after the second stage of the implementation process for developing the observation form, changes, additions, and removals were made to relevant aspects, and the evaluation stage was initiated in the studies to give the observation form its final form.

In the evaluation phase, the observation form with two structures was finalized, including 41 aspects: 17 for the statistical process structure of the observation form and 24 for the statistical knowledge-for-teaching structure. In the final version of the observation form, 3 aspects were included in the formulate statistical investigative questions stage, 7 in the collect data stage, 10 in the data analysis and representation stage, and 4 in the interpretation stage of the results for the statistical process structure. For the statistical knowledge for teaching structure, 2 aspects were included in the curriculum knowledge component, 4 in the content and student recognition component, 6 in the knowledge of content and teaching component, 2 in the key developmental understanding component, and 3 in the pedagogically powerful ideas.

4. Discussion

The aim of the present study was to develop a two-structure observation form to evaluate the statistics teaching practices of secondary school mathematics teachers. In line with this purpose, the theoretical framework of the study in developing the observation form was formed based on the components of statistical knowledge for teaching and statistical process stages that are prominent in the literature. At the end of the process, a two-structure observation form was developed that included the dimensions of statistical knowledge for teaching and statistical process stages. There are 17 aspects in the statistical knowledge for teaching dimension and 24 aspects in the statistical process stages dimension. When the literature is examined, although there are studies on teachers’ statistics teaching practices (Batur, 2021; Chick & Pierce, 2008; Estrella et al., 2015; Henriques & Ponte, 2014; Jacobbe, 2007; Kuzle & Biehler, 2015; González, 2014; Verbisck et al., 2022), it is seen that these studies usually focus on a specific dimension or are addressed in terms of a single structure. In this context, the development of an observation form based on the theoretical structure for the evaluation of statistics teaching and whose validity and reliability studies have been conducted is considered as an important output. Although observation forms have been developed in studies to examine statistics teaching (Özmen, 2015; Uyanık, 2022; Yeniçırak, 2020), it is seen that they focus on a specific dimension or subject. Considering that the “Statistical research process” is included as a theme (learning area) in the new mathematics curriculum published within the scope of the Turkey Century Education Model (Ministry of National Education [MoNE], 2024), the importance and necessity of considering the statistical process as a whole, not a single dimension, comes to the fore once again. In the studies conducted, it is emphasized that this process should be experienced holistically (Newton et al., 2011; Özmen, 2015; Topan, 2019; Watson, 2006). Accordingly, it is expected that the application practices to be carried out in statistics education will serve the determined themes simultaneously. As a matter of fact, the observation form developed within the scope of this study differs from the literature in terms of being created based on two theoretical structures, being developed in line with the reforms and reports regarding statistics education, and revealing the validity of the content and construct.

In the development of the observation form, six aspects were combined in total. For example, in the key developmental understanding dimension two aspects were combined under a single aspect as "Framing the big ideas of statistics instruction (such as variation, center, representation, randomness) as key concepts". Burrill and Biehler (2011) have indicated familiarity with basic statistical terms and concepts as one of the aspects of statistical literacy. While it is argued that the two biggest ideas in statistics education are distribution and inference, at this point, it emphasizes that teachers need to develop both their content knowledge and their pedagogical content knowledge of statistics (Shaughnessy, 2019). It is crucial for teachers to know, define, and make sense of these ideas that constitute the identity of statistics (Garfield & Ben-Zvi, 2008). This is because the big ideas have a special place in forming the conceptual foundations of statistics-related topics and strengthening teachers' content knowledge (Sorto, 2004). Thus, it is clear that understanding the big ideas in statistics is important and necessary. The other two aspects in the dimension of pedagogically powerful ideas were combined under a single aspect as "Posing critical questions during instruction to promote conceptual understanding and address students' errors related statistics." It is emphasized that it is quite important for teachers to identify the fundamental ideas that form the core of the subject (Batanero & Borovknic, 2016). At this point, it is considered important for teachers to expand their teaching knowledge based on a deep conceptual understanding of statistics (Batur, 2021). Indeed, studies have revealed teachers' inadequacies in supporting students' awareness of their own mistakes (Groth, 2014; Vermette & Savard, 2019; Watson et al., 2008b). These teachers have significant shortcomings in terms of what types of questions to ask students and how to create cognitive conflict in them without directly giving the answer (Watson et al., 2008b). At this point, it is essential for teachers to ensure that students think actively in statistics teaching. In doing so, they should be able to evaluate the strengths and weaknesses of methods that facilitate students' learning of statistics and deepen their understanding, and select the most appropriate ones for their teaching (Ijeh, 2012). It is also recommended that ideas be addressed in relation to each other rather than independently for a conceptual understanding of statistics (Pfannkuch & Ben-Zvi, 2011). As a matter of fact, some aspects in the observation form have been combined to ensure that the targeted situations can be observed in a clear, precise, and understandable manner. On the other hand, seven aspects have been removed entirely from the observation form. For instance, in the CT component, the aspect "Presenting a context appropriate to the nature of the subject" was removed, considering that it is included in the SRQ ("Drawing attention to the production of research problems appropriate to the context of the subject") and IR ("Interpreting the obtained results in an appropriate context") components, and better represents the teaching practices in these components. The researchers have emphasized the importance of context-based statistics education (Bargagliotti et al., 2020; Casey et al., 2021; Makar & Ben-Zvi, 2011; Yılmaz et al., 2023). Students who participate in tasks across various contexts in the statistical process could make advanced statistical interpretations (Pfannkuch, 2011). It has been highlighted that "contextual information should be an integral part of statistical investigations" and each statistical investigation phase has to use of context knowledge (Yılmaz et al., 2023). Therefore, context-related aspects have been included in the statistical process component (IR and SRQ) of the observation form. In addition, the aspect of "Drawing attention to the importance of collecting data appropriate to the research problem" in the data representation dimension was removed from the observation form in order to avoid situations involving repetition between the aspects under the same dimension.

In developing the observation form, the instructional objectives from studies in the literature were also taken into consideration. While the importance of using technology for teaching statistics is emphasized in the studies conducted (Carver et al., 2016; Cobb & McClain, 2004; Kuzle & Biehler, 2015; Henriques & Ponte, 2014), it is noteworthy that the use of technology is not directly considered as a basic element in teaching statistics (Özmen, 2015; Uyanık, 2022; Yeniçırak, 2020). From this perspective, the fact that the observation form developed also highlights teachers' integration of technology into their statistics teaching practices constitutes an important output. At this point, the aspect "Using technological tools to highlight conceptual understanding in analyze the data" was included in the two-structure observation form. On the other hand, although this aspect was not encountered in the observations made in the first stage, it was not removed from the observation form considering the importance of technology in providing conceptual understanding in teaching statistics. Indeed, in the GAISE-II report (Carver et al., 2016), this aspect was presented directly as an instructional recommendation and was considered as an important initiative for the development of statistics teaching. Boz (2017) also stated that it was a limitation that behaviors that could not occur in a single lesson and could not be observed in the classroom were not included in the observation form. This indicates that the observation form developed was comprehensive and was not limited to a single lesson. In addition, the use of real data is emphasized in statistics teaching (Carver et al., 2016; Franklin et al., 2007; Watson, 2006), and it is emphasized that information in sources such as newspaper news, articles, and reports should be included in statistics teaching in order to be understood and interpreted statistically (Garfield, 1999; Reston, 2005; Schield, 2006). At this point, it is stated that in order for students to work with real data, they will need basic statistical information as well as interactive classroom applications for analyzing and evaluating this information (Topan, 2019). In this context, the detailed inclusion of components that will help monitor the applications to be made step by step while working with real data in the observation form developed is considered as an important output. In addition, the aspects included in the observation form, such as "Drawing attention to the importance of selecting a sample appropriate for the context of the problem and collect data", enable students to reason on many issues such as the reality and credibility of data in various sources such as newspapers, news, etc. in daily life, and the appropriateness of collect data processes. It is thought that such aspects in the observation form will also contribute to the achievement of important goals for statistics education, such as the development of researcher identity in real life (Rumsey, 2002). From this perspective, it is revealed that the observation form developed is also important in terms of including recommendations for achieving the goals considered important for statistics education and teaching. It is also a guide for teachers in terms of including aspects that can be included in teaching practices as well as in the evaluation of statistics teaching. In this way, it will contribute to the achievement of the ultimate goal of "statistical literacy for everyone" (Bargagliotti et al., 2020).

Lastly in the development of the observation form, sixteen aspect expressions were revised. For instance, the aspect "Addressing the subject with multiple approaches that will enable students at different levels to understand" was decided to organize as "Supporting the topic with different explanations to facilitate the understanding of students at varying levels". This revision aimed to address instructional explanations in a broader scope. The role of the teacher is to provide guided learning support in a structure that allows learners to learn by thinking for themselves to the extent that they need (Lajoie, 2005; Masters & Yelland, 2002). Leinhardt and Steele (2005) argued that instructional explanations that take students' prior knowledge into account are effective, thereby enabling the information conveyed to be consistently retained in students' minds. When providing different instructional explanations to students at different levels, relevant student characteristics should be considered, such as skills, cognitive abilities, personality traits, learning styles, areas of interest, and motivation levels (Wittwer & Renkl, 2008). Based on these characteristics, it can be said that it is important and necessary for teachers to include different explanations in their lessons. The studies reveal that instructional explanations can be effectively combined with learners' cognitive activities, while also demonstrating that teachers' instructional support is a truly important element in constructivist learning environments (Hardy et al., 2006; Klahr & Nigam, 2004). Indeed, if students have basic knowledge, they can construct knowledge on their own. However, under these conditions, presenting instructional explanations may hinder or complicate active processing in some students and may have detrimental effects on students' knowledge construction process (Wittwer & Renkl, 2008). On the contrary, providing additional explanations to help students develop their knowledge may be beneficial for students who have limited knowledge on a subject (Brusilovsky, 2001).

It is thought that the observation form, which is created by using statistical knowledge for teaching and statistical process stages together, will provide an opportunity to deeply evaluate statistics teaching practices such as teachers' verbal expressions during the teaching process, assignments in the classroom, and use of different course resources. In addition to having a good level of statistical knowledge (Aliaga et al., 2005; NCTM, 2000), teachers need to be able to make the best representations and explanations on the subject, recognize the difficulties experienced by students, and determine and implement appropriate strategies to overcome them (Yeniçırak, 2020). At this point, the aspect of "Supporting the topic with different explanations to facilitate the understanding of students at varying levels" was included in the two-structure observation form. It is stated that in-class observations focus on teaching skills, teaching methods, use of teaching tools, evaluation of students' learning steps and teacher-student interaction (Rizvi, 2010). With teacher-student interaction, meaningful learning of students will occur, information exchange will increase, interest in learning will be felt and mutual respect between teachers and students will be realized (Abdullah et al., 2012). It can be said that this situation also points to the functionality of the aspect of "Posing questions aimed at revealing potential misconceptions and difficulties that may arise among students" in the observation form. Considering the stated focal points, it is thought that the developed form will provide teachers with the opportunity to monitor and improve themselves regarding the statistical knowledge for teaching and the stages of the statistical process.

It is stated that classroom observations are very important at this point, as the quality of teachers' classroom practices must be determined in order for students to learn effectively (Bruns et al., 2018). In fact, studies have shown that teachers have very limited knowledge of the meanings of statistical concepts (González, 2014; Watson et al., 2008). In the literature, it is pointed out that improving teachers' teaching knowledge is important in order to increase the effectiveness of statistics teaching (Batur, 2021; Groth, 2007; Simon, 2006; Silverman & Thompson, 2008; Watson et al., 2009). It is stated that teachers should give importance to extracting meaning from data, examining variability (Pfannkuch & Wild, 2008), focusing on the meaning of basic statistical concepts, and understanding and developing students' reasoning processes (Garfield & Everson, 2009; Pfannkuch & Ben-Zvi, 2011). The increase in teachers' statistical competence will also be reflected in their teaching of statistics. At this point, the importance and necessity of the aspect "Framing the big ideas of statistics instruction (such as variation, center, representation, randomness) as key concepts" in the observation form also comes to the fore.

4.1. Limitations and Future Directions

While the current study offers valuable insights into statistical education, several limitations should be acknowledged. Firstly, while developing the observation form, the statistical learning outcomes in the current mathematics curriculum are quite limited, and they predominantly focus on operation-based content, such as calculating averages. This situation may have limited observation of the effectiveness of certain aspects of the observation process, such as the use of technology in teaching statistics. In the new mathematics curriculum (MoNE, 2024), the statistical process is also addressed as a separate learning area, and it is recommended that students experience all stages of this process holistically. It can be said that aspects of the observation form grounded in statistical thinking and literacy will play an important role in teachers' development of classroom applications of the new curriculum. Secondly, classroom observations were conducted during two class periods by three different mathematics teachers in the 5th and 7th grades. To comprehensively observe all middle school statistical learning outcomes, observations can also be conducted across all grades. Also, observing more teachers' lessons will yield more comprehensive results regarding all aspects included in the observation form. Lastly, the schools where classroom observations were conducted were selected to include one school from different achievement level (low, medium, high). It is possible to select more schools from each achievement level, and a broader range of schools could be selected by considering different variables such as socioeconomic status and region (e.g., village, city center).

It can be said that the developed observation form will contribute to studies on statistics in the literature by providing important aspect descriptions, and will serve as a guide that teachers can draw on while directing their teaching. In the literature, classroom observations are widely recognized as an important tool for improving teachers' professional development (Haep et al., 2016; Hong et al., 2020; Lam, 2001). Regular follow-ups during this development process can also help detect variables that are sometimes neglected in the teaching process, among others. Thus, it will make a significant contribution to identifying and improving missing/faulty points in the teaching process. Since statistical processes are considered problem-solving in GAISE reports (Bargagliotti et al., 2020; Franklin et al., 2007), it is important to carefully monitor each stage of this process. It is stated that in current education, teachers mostly focus on the results of the problem-solving process and ignore students' activities during it, so the examination of teacher behaviors at each step of problem-solving can be conducted using observation charts (Yıldız & Güven, 2017). It is also stated that these observations can be used for consultancy purposes for the development of teaching to identify, evaluate, and improve the current situation (Hong et al., 2020). At this point, it is thought that the developed observation form will serve as a guide for teachers in their professional development processes.

4.2. Conclusion

After the changes and arrangements made during the evaluation phase, the observation form was finalized. After the evaluation phase, the observation form was completed with a total of 41 aspects, 17 in the statistical knowledge for teaching dimension and 24 in the statistical process dimension. It is expected that the observation form, whose validity and usability have been established, will serve as an important data tool in future studies on statistics teaching. In addition, it is anticipated that it will take its place in the literature as an important guide for identifying observed and unobserved behaviors and for shaping teaching by analyzing teachers' statistical teaching using this form.

5. Declarations

5.1. Conflict of interest

The authors declare that they have no known competing financial interests, institutional affiliations, or personal relationships that could have appeared to influence the work reported in this paper.

5.2. Funding

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5.3. Author contributions (CRediT)

Zeynep Medine Özmen: Conceptualization; Methodology; Investigation; Data Collection and Analysis; Writing—review & editing

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5.4. Data availability statement

Data are available from the corresponding author upon reasonable request.

5.5. Ethics approval

This study was approved by the Trabzon University Social and Humanities Scientific Research and Publication Ethics Committee (Approval Number: E-81614018-000-73; Approval Date: 20.01.2021). Informed consent/assent was obtained from all participants.

5.6. Use of artificial intelligence (AI) tools

GPT-5 was employed only for translation and language correction. However, all data collection, analysis, and interpretation were conducted and validated entirely by the authors. All AI-generated content was reviewed for scientific accuracy, ethical compliance, and source reliability by the author(s), who assume full responsibility.

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