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Examining the empathy levels of medical students using CHAID analysis

Nesrin Hark Söylemez[1*]

Abstract

Background Empathy is a key factor in the medical field as it strengthens doctor-patient relationships, enhances communication, and leads to improved patient outcomes. This study aims to investigate the empathy levels of medical students, providing insights into the factors that influence these levels and using advanced analytical methods for accurate predictions.

Methods The study was conducted with 322 medical students from a public university in Turkey. A relational screening model was applied, using a "Personal Information Form" and an "Empathy Scale" to gather data. CHAID analysis was employed to identify the key predictors influencing empathy levels, whereas machine learning algorithms were utilized to classify and predict individuals' empathy levels.

Results The analysis revealed that 41.3% of students displayed high empathy, 44.7% moderate empathy, and 14.0% low empathy. Factors such as parental education, maternal occupation, and gender were significant in determining empathy levels, with gender being the most influential. The machine learning models achieved an 80.1% accuracy in predicting empathy levels.

Conclusions The findings indicate that targeted educational and social interventions, especially those addressing gender differences, could improve empathy in medical students, potentially leading to better patient care.

Trial registration Not applicable, as this study does not report results from a health care intervention involving human participants.

Keywords Empathy, Medical students, Decision tree, CHAID analysis, Machine learning algorithms

Introduction

Empathy is a complex and multifaceted psychological process that plays a critical role in understanding others and forming social bonds. It is a multidimensional concept defined as the ability to feel what another person is feeling, to imagine oneself in another's situation, or to envision oneself as the other person in that context [1]. This skill not only strengthens emotional connections but also significantly impacts various domains such as social cohesion, communication, and cooperation. Empathy allows individuals to better understand one another, resolve conflicts, develop a sense of social belonging, and enables them to coordinate their activities effectively in interpersonal interactions [2].

Empathy has been extensively studied in various medical disciplines such as psychology and neuroscience and is recognized as a fundamental component of human relationships and social interactions. Particularly in medical education, empathy is an indispensable element, playing a vital role in communication between physicians and their patients, as it fosters understanding and trust. For this reason, medical students require not only clinical knowledge and skills but also social and emotional competencies such as empathy to enhance interpersonal connections [3, 4]. Empathy, which plays an important role

*Correspondence:
Nesrin Hark Söylemez
nesrin_hark@hotmail.com
[1] Department of Educational Sciences, Dicle University, Diyarbakir, Turkey

in the educational process of medical students, is shaped by various factors. A review of the literature reveals that different studies have addressed the factors influencing empathy. Capdevilla-Gaudens et al. [5] stated that medical students' empathy scores are at the higher levels of the scale, and female have a higher percentage within the highest scoring group. Furthermore, Shi and Du [6] found that female students have higher levels of empathic concern compared to male students. This finding highlights the impact of gender on empathy, suggesting that social and cultural factors may also shape these relationships. Dyrbye et al. [7] expressed that positive student-faculty interactions are associated with higher empathy scores, and older female students generally score higher in empathy compared to younger male students. In another study, Silva and Junior [8] found that empathy levels were influenced by factors such as students' year of study and their parents' education level. These findings demonstrate that the factors shaping empathy are multidimensional. These factors provide us with insight into the developmental process of medical students' empathetic skills.

Empathy strengthens trust in doctor-patient relationships, promotes treatment adherence, and enhances patient satisfaction [9]. Additionally, empathetic communication is regarded as an ethical imperative in patient care and positively shapes physicians' professional identity [10]. Numerous studies in the literature support the idea that empathic doctor-patient communication positively influences clinical outcomes [11–14]. For example, a meta-analysis conducted by Roter et al. [12] found that empathic communication skills not only improved psychological treatment processes but also enhanced the effectiveness of pharmacological treatments. Additionally, Hojat et al. [14] demonstrated that physicians with higher levels of empathy are less prone to errors, directly influencing patient safety. Several studies have associated empathic doctor-patient communication with better outcomes in both psychological and pharmacological treatments [15, 16]. However, recent observations suggest an increasing number of physicians in medical schools struggling to establish empathic relationships with their patients, having difficulty understanding them, or even failing to make efforts in this regard [17]. One of the main reasons for this is the demanding medical curricula and the emotional burdens medical students face [5]. Some studies have emphasized that empathy levels decline over time, becoming more pronounced during clinical training years [18, 19]. This situation highlights the necessity of educational strategies aimed at increasing empathy during the clinical years. Examining general empathy levels in medical students will provide a deeper understanding of the emotional competencies that influence doctor-patient interactions and overall clinical outcomes, making a significant contribution to the existing literature.

Another limitation in the current research is the predominant focus on medical empathy, often measured through scales specifically designed for clinical contexts. While these studies provide valuable insights into the application of empathy in healthcare, they tend to overlook the evaluation of general empathy, which serves as the basis for developing medical empathy. Clinical empathy, a concept specifically measured by scales applied in doctor-patient relationships and clinical contexts, encompasses emotional and cognitive processes that form the foundation of this relationship [20, 21]. In this context, measuring general empathy levels is crucial for a comprehensive assessment of medical students' empathy skills. In this study, the Toronto Empathy Questionnaire (TEQ), which has proven validity and is reliable in capturing a multidimensional structure, was used to measure participants' general empathy levels. TEQ, by addressing empathy with both its emotional and cognitive components, facilitates understanding the key elements that enhance clinical empathy [21]. Thus, an attempt has been made to provide a more comprehensive view of the emotional and cognitive skills that shape empathic behaviors in medical practice. Despite its importance, there remains a lack of research employing general empathy scales to assess the empathy levels of medical students. Addressing this gap is essential for enhancing our understanding of empathy as a multidimensional construct and for developing more holistic strategies to cultivate this vital skill in medical education.

Medical students are expected to possess high levels of empathy, as this quality is crucial for doctors who will solve health problems and provide support to patients. Measuring and evaluating the empathy levels of medical students is important for supporting the development of these skills. Examining the empathy levels of future doctors using predictive models can help identify the variables affecting empathy and understand their significance.

The aim of this study is to determine the empathy levels of medical students, reveal the relationships between the variables influencing empathy, and develop models that can predict empathy levels using machine learning techniques. While various statistical methods have been employed to explore empathy in medical education, this study is unique in applying CHAID analysis to uncover interaction patterns and subgroup structures that are often missed by traditional analyses. To achieve this goal, the current empathy levels were first evaluated, and then the relationships between the variables influencing empathy were revealed using CHAID (Chi-squared Automatic Interaction Detection) analysis. A literature review

indicates that there are no studies examining the empathy levels of medical students using CHAID analysis. CHAID is a decision tree algorithm based on chi-squared tests that identifies statistically significant relationships between variables [22]. By using CHAID, rule sets can be developed to classify outcomes, and groups can be formed based on predictive variables [23]. This allows for a better understanding of the factors influencing empathy levels. Additionally, machine learning techniques have been used in this study to develop models that can predict empathy levels. Measuring and assessing the empathy levels of future physicians with machine learning algorithms can provide valuable insights for improving educational processes. Therefore, this study aims to conduct an analysis that highlights the importance of educational and social strategies that promote empathy. By evaluating empathy skills in a multifaceted way, the study aims to contribute to the development of this critical competency. The findings will help make effective and efficient planning in medical education and contribute to filling an important gap in the literature.

Empathy

Rogers described empathy as the process of entering another person's perceptual world, understanding that person's inner structure along with its emotional components, and engaging in the thought process of "if I were that person" [24, 25]. Feshbach [26] interpreted empathy as an activity that involves the ability to recognize another individual's perspective and, at the same time, share the emotional response that person is experiencing. Wispé [27] defined empathy as "the effort to understand another self's positive and negative experiences in a nonjudgmental way by someone who knows themselves". Kohut [28] in his early writings on empathy, defined empathy as "vicarious introspection" and considered it one of the most important tools for exploring another person's inner world.

The ability to feel another person's emotions, thoughts, and experiences as if they were our own can be defined as empathy. Empathy is a fundamental component of an effective therapeutic relationship [29]. Empathy for medical students is not only a professional competency but also a fundamental part of effective patient care and ethical decision-making processes [30]. Defined as giving an emotional response that is appropriate to another's emotional state and independent of one's own situation, empathy is a complex, multidimensional concept with moral, cognitive, emotional, and behavioral components [31, 32]. Today, the most widely accepted approach posits that empathy has two sub-dimensions: cognitive and emotional [33, 34]. Cognitive empathy is the ability to understand and predict others' behaviors, particularly their epistemic mental states such as beliefs, knowledge, pretense, and expectations [35]. According to Hoffman [32], emotional empathy is an emotional response that is more appropriate to someone else's situation than one's own. Emotional empathy refers to an emotional response in one person that arises from and parallels the emotional state of another [35]. The development of emotional empathy in medical students is important for establishing a strong emotional connection with patients and ensuring effective communication, especially in sensitive situations [36]. The cognitive aspect of empathy involves the ability to effectively grasp distressing situations, recognize another person's emotions, and adopt that person's perspective. The emotional aspect of empathy requires an individual to experience an indirect emotional response to the emotions expressed by others [37]. The cognitive and affective dimensions of empathy complement each other and are said to be in constant interaction. The simultaneous development of these two dimensions in medical students ensures the integration of both technical skills and the human aspect in patient care [38].

Empathy is a complex psychological process influenced by both biological predispositions and environmental factors. Our genetic makeup, brain structure, and neurological functions provide the biological foundation that affects our capacity to understand and share others' emotions. However, environmental factors such as family environment, education, social interactions, and life experiences shape this biological foundation, significantly impacting our empathy skills. These environmental factors encompass all experiences, social interactions, and learning processes to which an individual is exposed from birth. They play a critical role in the development of empathy and continue to influence an individual's level of empathy throughout their life.

Empathy in medical domain

Empathy is considered one of the cornerstones of the medical profession and is one of the most critical factors in determining the quality of the relationship between a physician and a patient. This dynamic process reflects a physician's effort to deeply understand the patient's perspective, concerns, and experiences. Empathy in the medical context involves not only being sensitive to the patient's current emotions but also effectively communicating this understanding back to the patient [39]. Medically, empathy is understood as the non-judgmental recognition of a patient's inner world as a separate individual [20]. According to Jackson [40], empathy is a crucial element in healing. A physician with empathy is better able to understand their patient's problems and is more effective in addressing those issues [17].

In the field of healthcare, empathy has been examined under various terms, including clinical empathy and medical empathy. Medical empathy is defined as the ability to understand the patient's perspective and emotions, convey this understanding to the patient, and act therapeutically based on this understanding [31]. Physician empathy is characterized as a multidimensional construct encompassing cognitive (the ability to understand and reflect another's perspective), emotional (the subjective ability to perceive another's inner experiences and natural emotions), and behavioral (the ability to effectively communicate this understanding) components [41]. The cognitive aspect of physician empathy involves accurately understanding the patient's mental state (the ability to take another's perspective) and effectively communicating this perspective to patients. The emotional aspect of physician empathy is defined as the physician's ability to respond to and ameliorate the patient's emotional state [11].

Recent research in medical education increasingly emphasizes the importance of empathy skills in clinical practice and examines various intervention programs aimed at developing this skill among medical students. Targeted programs such as communication skills training [42], narrative-based medical practices [43], and role-playing or simulation-based activities [44] have been shown to be effective in enhancing students' levels of empathy. In addition, structured practices such as Balint group discussions, narrative workshops, and mindfulness-based training have been found to improve emotional awareness and strengthen empathic communication [19, 45]. Practices such as reflective writing and patient shadowing, which aim to foster perspective-taking and compassion, also contribute to this process [44, 46]. These findings support the growing pedagogical trend in medical curricula that approaches empathy as both a teachable and measurable competence.

Empathy plays a critical role in the communication between a physician and their patient. Studies have shown that empathy strengthens the communication between patient and physician [47, 48]. Empathetic communication supports the patient and creates a perception in the patient regarding the physician's clinical competence. When a patient feels that their physician understands their emotions, thoughts, and concerns, they are more likely to trust their physician and express themselves more comfortably [49]. In empathy between a patient and physician, it is not enough for the physician to understand the patient; the physician must also have the ability to reflect this understanding back to the patient. Because even if physicians accurately understand their patients' perspectives and emotions, they may not be perceived as sufficiently empathetic by their patients if they fail to convey this understanding [50].

Purpose of the study and research questions

The purpose of this study is to analyze the genel empathy levels of medical students using CHAID analysis and to develop a predictive model utilizing machine learning algorithms. The Toronto Empathy Questionnaire is used as the data collection tool to assess these empathy levels. Accordingly, the research seeks answers to the following sub-problems:

1. What are the results of the two-step cluster analysis of the empathy scale scores of medical students?
2. What is the order of importance of the predictor variables that have a significant effect on the empathy levels of medical students?
3. How is the decision tree obtained through CHAID analysis for the empathy levels of medical students?
4. What are the rule sets derived from CHAID analysis regarding the empathy levels of medical students?
5. What are the results related to the prediction of medical students' empathy levels using machine learning methods?

Methodology

Research design

A correlational survey model is adopted in this study. In a correlational survey model, the relationship presented indicates that a portion of the change observed in one variable may be attributed to another variable [51]. Correlational studies are employed to identify relationships between two or more variables and to determine the effects of these relationships on causality [52].

Participants

The participants of this study consist of 322 medical students studying at a public university in Turkiye during the fall semester of the 2023–2024 academic year, who volunteered to participate in the study. The study employed a convenience sampling method, and data were collected through an online survey. General information about the participants is provided in Table 1.

The sample size used in this study is considered sufficient to ensure the reliability of the analyses. The literature suggests that a sample size greater than 200 is generally sufficient to ensure adequate statistical power for data analysis [53, 54]. Additionally, a sample of 300 cases has also been suggested [55].

In decision tree models, the adequacy of the sample size is evaluated based on factors such as the number of variables, the number of terminal nodes, and the depth of the tree. These factors influence the complexity of

Table 1 General information about the participants of the study

Variable	Value	f	%
Gender			
	Female	148	46.0
	Male	174	54.0
Age			
	18–21	59	18.3
	22–25	230	71.4
	26 and over	33	71.4
Grade			
	3	85	26.4
	4	141	43.8
	5	42	13.0
	6	54	16.8
Marital Status			
	Married	5	1.6
	Single	316	98.1
	Other	1	0.3
Number of Siblings			
	None	2	0.6
	1–3	129	40.1
	4 and more	191	59.3
Graduation			
	Regular High School	24	7.5
	Anatolian High School	151	46.9
	Science High School	141	43.8
	Vocational High School	6	1.9
GPA			
	0–60	5	1.6
	61–70	103	32.0
	71–80	148	46.0
	81–90	51	15.8
	91–100	15	4.7
Daily Internet Usage Time			
	0–1 Hours	13	4.0
	1–3 Hours	81	25.2
	3–5 Hours	117	36.3
	Over 5 Hours	111	34.5
Primary Purpose of Internet Use			
	Gaming	15	3.7
	Chatting	20	6.2
	Research	46	13.4
	Social Networks	193	59.9
	Music/Movie	46	14.3
	Other	5	1.6
Mother's Level of Education			
	Illiterate	87	27.0
	Literate	45	14.0
	Elementary School	58	18.0
	Middle School	29	9.0
	High School	37	11.5
	University	66	20.5
Father's Level of Education			
	Literate	43	13.4
	Elementary School	69	21.4
	Middle School	23	7.1
	High School	61	18.9
	University	126	39.1
Mother's Occupation			
	Civil Servant	43	13.4
	Worker	4	1.2
	Self Employed	14	4.3
	Housewife	246	76.4
	Other	15	4.7
Father's Occupation			
	Civil Servant	112	34.8
	Worker	48	14.9
	Self Employed	77	23.9
	Unemployed	47	14.6
	Other	38	11.8
Family Income Status			
	Income Equals Expenditure	150	36.6
	Income Exceeds Expenditure	73	22.7
	Income is Less Than Expenditure	99	30.7
Living With Elderly			
	Yes	117	55.0
	No	145	45.0
Predominantly Resided Settlement Area			
	Rural	38	11.8
	Urban	284	88.2
	Total	322	100

the model and the statistical power required to detect meaningful relationships. For robust decision trees, it is essential that each terminal node contains enough observations to avoid overfitting and ensure the model's generalizability [56]. In current study, a decision tree with a depth of 4 was created using 5 variables, resulting in a total of 9 terminal nodes. Each terminal node contains a sufficient number of observations, averaging 35, which ensures reliable interpretation and eliminates the risk of overfitting.

Data collection tool

The Turkish version of the Toronto Empathy Questionnaire (TEQ) was used to measure the general empathy levels of the participants. Originally developed by Spreng et al. [21], the TEQ was adapted and tested for reliability and validity by Totan et al. [57] on Turkish university students. The reliability of the scale was examined using test-retest and Cronbach's internal consistency methods.

For the test-retest study, a correlation of 0.73 was found between the two applications. The Cronbach's internal consistency coefficient of the questionnaire was 0.79.

The Turkish TEQ consists of 13 questions that test empathy. The survey questions are scored between 1 and 5 (1: not at all appropriate, 2: not appropriate, 3: somewhat appropriate, 4: appropriate, and 5: completely appropriate). The items numbered 1, 3, 5, 7, 8, 9, 11, and 12 in the scale are reverse-scored. The total score ranges from 13 to 65, with higher scores indicating higher levels of empathy.

The primary aim of the study is to assess the empathy levels of medical students in a general sense; therefore, a more general empathy scale has been used instead of one specific to medical empathy. This approach offers the opportunity to address empathy not only in a medical context but also in a broader human and social context. Furthermore, the TEQ is widely accepted in the literature for its measurement validity and reliability. Some items from the scale are as follows:

- Other people's misfortunes do not disturb me a great deal.
- I can tell when others are sad even when they do not say anything.
- I do not feel sympathy for people who cause their own serious illnesses.
- I am not really interested in how other people feel.

Data analysis

The data obtained from medical students were first subjected to a two-step cluster analysis to divide the dependent variable into homogeneous subgroups. Afterward, CHAID analysis was performed to identify the predictor variables and their order of importance.

The key feature of decision trees is their method of recursively dividing a target variable based on the values of input variables or predictors. This process creates partitions and resulting subsets of data, known as leaves or nodes. These subsets become more homogenous in terms of the target variable within each leaf or node, while being increasingly different from each other across different leaves or nodes at each level of the tree [58]. In decision trees, classification is performed using the feature values of the samples. Each node in the decision tree represents a feature of the classified sample [59].

The reason for choosing the CHAID decision tree algorithm in this study is to take advantage of its benefits, which allow for the quick and clear understanding of complex relationships and interactions. CHAID comprehensively investigates the independent variables that show the most differentiation in the dependent variable. It uses a systematic algorithm to identify the strongest relationship among these variables [60, 61]. CHAID analysis stands out as a superior method compared to traditional regression models in identifying interactions between variables and classifying groups. Regression analyses are typically used to understand linear relationships and main effects; however, they may be limited in capturing complex interactions and multiple group differences [62, 63]. CHAID analysis is particularly powerful in identifying interactions among multiple variables and demonstrating how these interactions form distinct groups.

When using the CHAID algorithm, the predicted (dependent) variable, empathy levels, was utilized as a three-class categorical variable: low, medium, and high. As independent variables, the predictive factors with the greatest impact on students' empathy levels, namely gender, mothers level of education, fathers level of education, and mother's occupation.

Machine learning algorithms used in classification

There are existing studies that utilize machine learning in analyzing the education of medical students, particularly in predicting various behavioral and cognitive outcomes [64–66]. A variety of machine learning algorithms were utilized in this study, including random forest, AdaBoost, decision tree, and Multi-Layer Perceptron (MLP), to predict the empathy levels of medical students. These algorithms were chosen based on their distinct advantages in handling different types of data patterns and predictive tasks. Random forest and decision tree were included due to their interpretability and ability to capture non-linear relationships. Decision tree was selected for its simplicity and high interpretability, allowing clear insights into the structure of the predictive model [58]. Random forest, on the other hand, was included to enhance predictive accuracy and reduce overfitting by aggregating the results of multiple decision trees trained on different data subsets [67]. AdaBoost was included because of its robustness in improving the accuracy of weak learners through boosting and its proven performance in similar prediction tasks. Compared to other ensemble techniques such as Gradient Boosting or XGBoost, AdaBoost was preferred due to its computational efficiency and simpler hyperparameter tuning in the context of the dataset used [68]. MLP, as a neural network-based model, was incorporated to capture complex, non-linear patterns that traditional tree-based methods might overlook. As the fundamental form of feedforward neural networks, it offers a balance between modeling capacity and relatively low computational complexity, making it suitable for structured data

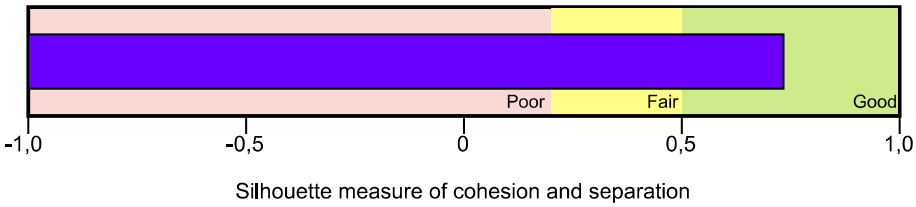

Fig. 1 Cluster quality

[69]. By employing a diverse set of algorithms, the study aimed to balance interpretability, robustness, and predictive accuracy in assessing empathy levels.

Metrics used in the study

Precision, recall, F1-score, and accuracy metrics are employed in this study. These metrics are calculated using the counts of TP (True Positive), representing correctly predicted positive classes, TN (True Negative), representing correctly predicted negative classes, FP (False Positive), representing incorrectly predicted positive classes, and FN (False Negative), representing incorrectly predicted negative classes.

Softwares used in the study

SPSS Modeler software is used in the decision tree modeling phase of this study. Python (v3.10) was used for the implementation of machine learning algorithms. The machine learning concepts were realized using the Scikit-learn library (v1.2.2). Correlation matrices are plotted using the Seaborn library (v0.12.2).

Findings

In this section, the findings obtained from the analysis of the research data are presented.

Results of the two-step cluster analysis of the empathy scale scores of medical students

The results of the cluster quality analysis for the two-step clustering of the average scores on the empathy scale are presented in Fig. 1 and Table 2.

The clustering performed in this study indicates that the cluster structures have strong evidence and fall into the "good" category (Average Silhouette = 0.7).

Examining Table 2, it is observed that the average scores for medical students are as follows: 3.31 for 45 students (14%) in the first cluster (low level), 4.05 for 144 students (44.7%) in the second cluster (medium level), and 4.63 for 133 students (41.3%) in the third cluster (high level). Consequently, a three-category dependent variable has been established. These results indicate that a significant majority, approximately 86%, of the medical students exhibit empathy levels at or above the medium level.

Importance ranking of predictor variables affecting medical students' empathy levels

Predictor importance refers to the process of determining which variables have the most significant impact on the model's predictions. Variables with high importance provide the most relevant information for predicting the target outcome, helping the model make more accurate and meaningful predictions. On the other hand, variables with low importance can unnecessarily increase the model's complexity and potentially lead to statistical errors. An initial CHAID analysis was performed to assess predictor importance. Mother's level of education was found to be the variable with most impact on students' empathy levels. Mother's level of education, gender, father's level of education, and mother's occupation were selected for conducting the actual CHAID analysis. By identifying and focusing on the most influential predictors, the model's clarity and accuracy were improved. The importance ranking of predictor variables that significantly affect the empathy levels of medical students is shown in Fig. 2.

Decision tree obtained from CHAID analysis for medical students' empathy levels

The decision tree algorithm for students' empathy levels is presented in Fig. 3.

In this study, CHAID analysis was applied to examine the empathy levels of medical students. The root node of the decision tree represents the entire student sample and provides a general distribution of empathy levels. In this node, it is observed that 41.30% of the students have high, 44.72% have medium, and 13.98% have low empathy levels.

The variable that best explains students' empathy levels is gender. A significant majority, 58.11%, of students

Table 2 Results of the two-step clustering analysis for the empathy scale of medical students

Clusters	N	x̄	ss	%
1 st Cluster (Low level)	45	3,31	,261	14
2nd Clusters (Medium level)	144	4,05	,157	44,7
3rd Cluster (High level)	133	4,63	,197	41,3

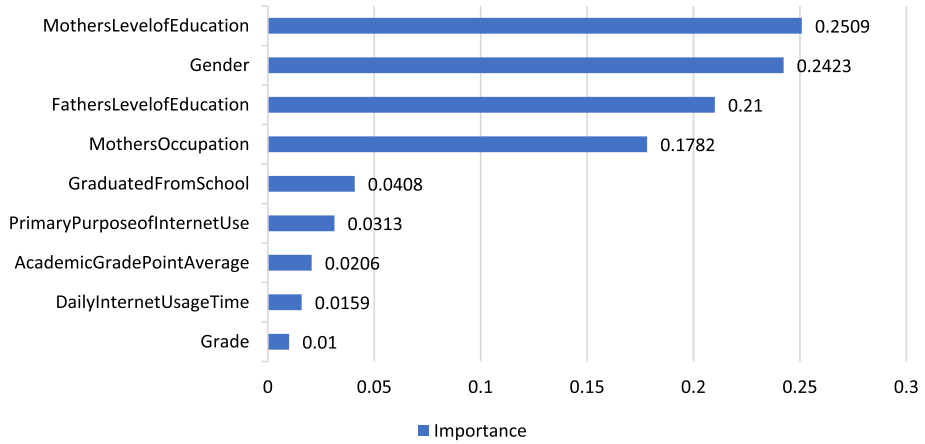

Fig. 2 The ranking of predictor variables based on their significant impact on medical students' empathy levels

identifying as female have high empathy levels. The variable that best explains the cluster of students identifying as female is mother's occupation. For students whose mother's occupation is classified as civil servant, worker, housewife, or other, a majority of 60.14% have been found to have high empathy levels. For students whose mother's occupation is classified as self-employed, a majority of 80.00% have been found to have low empathy levels.

For students identifying as female and whose mother's occupation is civil servant, worker, housewife, or other, the variable mother's level of education best explains the empathy levels. Among students with mother's level of education classified as illiterate, literate, middle school graduate, or high school graduate, 73.75% have high empathy levels. Students whose mother's level of education is elementary school graduate or university graduate show a 50.79% rate of medium empathy levels.

Among students identifying as male, 52.87% have been found to have medium empathy levels. The variable that best explains the cluster of students identifying as male is father's level of education. For students whose father's level of education is classified as literate or high school graduate, 40.91% have medium empathy levels. Students whose father's level of education is classified as elementary school graduate or middle school graduate have been found to have high empathy levels, with 44.44% in this category. For students whose father's level of education is classified as university graduate, 69.74% have been found to have medium empathy levels.

The variable that best explains the cluster of students identifying as male and whose father's level of education is classified as literate or high school graduate is mother's level of education. Under this cluster, 48.57% of students whose mother's level of education is classified as illiterate, elementary school graduate, middle school graduate, or high school graduate have been found to have low empathy levels, while all students whose mother's level of education is classified as literate or university graduate have been found to have medium empathy levels.

The variable that best explains the cluster of students identifying as male with a father's level of education of university graduate is mother's occupation. Under this cluster, among students whose mother's occupation is classified as civil servant, worker, self-employed, or housewife, 73.24% have been found to have medium empathy levels, while 80.00% of those whose mother's occupation is classified as other have been found to have low empathy levels.

The variable that best explains the cluster of students identifying as male with a father's level of education of university graduate and mother's occupation as civil servant, worker, self-employed, or housewife is mother's level of education. Under this cluster, among students whose mother's level of education is classified as illiterate, middle school graduate, or high school graduate, 50.00% have been found to have medium empathy levels, while 85.11% of those whose mother's level of education is classified as literate, elementary school graduate, or university graduate have also been found to have medium empathy levels.

Rule sets from CHAID analysis on medical students' empathy levels

The rule sets presented in Fig. 4, derived from the CHAID analysis, highlight the factors influencing medical students' empathy levels. These rules outline the probabilities of students exhibiting specific empathy levels under various conditions.

The rule sets can be interpreted as follows: Female students are more likely to have higher empathy levels compared to male students (RS1). Female students whose mothers are employed as civil servants, workers, housewives, or in other roles are more likely to exhibit higher

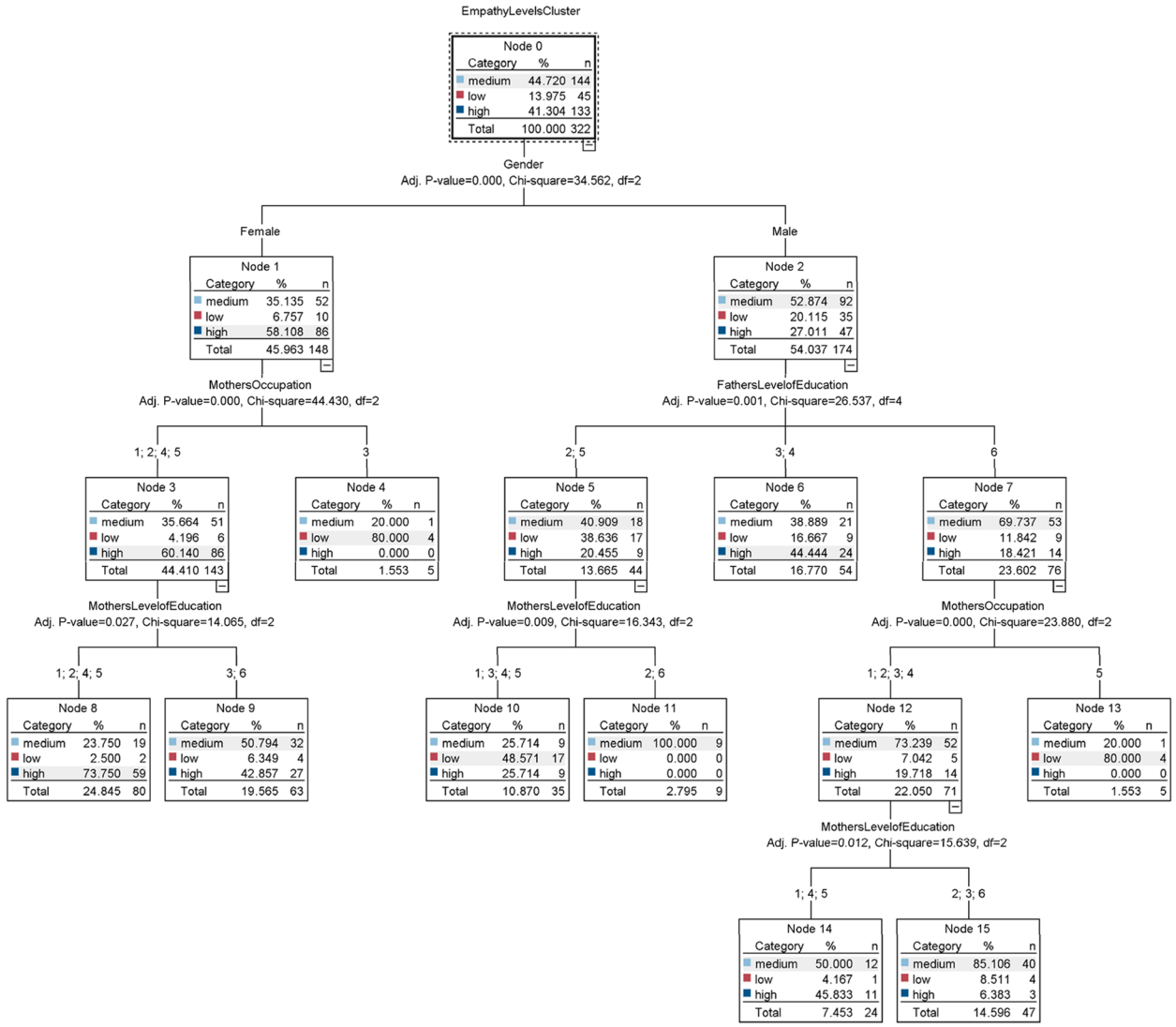

Fig. 3 Decision tree obtained from CHAID analysis of students' empathy levels. *****Education levels were recoded as 1: Illiterate, 2: Literate, 3: Elementary School Graduate, 4: Middle School Graduate, 5: High School Graduate, 6: University Graduate. *Occupation categories were recoded as 1: Civil Servant, 2: Worker, 3: Self-Employed, 4: Housewife, 5: Other

empathy levels (RS2). On the other hand, female students whose mothers are self-employed have a higher probability of having lower empathy levels (RS3). Male students generally have a medium level of empathy (RS4). Male students with fathers who are literate or high school graduates tend to have medium empathy levels (RS5). However, male students with fathers who have completed elementary or middle school are more likely to have high empathy levels (RS6). Finally, male students whose fathers are university graduates generally have medium empathy levels (RS7).

Prediction results of medical students' empathy levels using machine learning methods

One of the aims of the study is to predict medical students' empathy levels using machine learning methods. Within this scope, classification algorithms including random forest, decision tree, AdaBoost and MLP were employed. The following parameters are used as input for the classification algorithms: gender, age, grade, marital status, number of siblings, graduation, GPA, daily internet usage time, primary purpose of internet use, mother's level of education, father's level of education, mother's occupation, father's occupation, family income status,

living with elderly, and residence. The target variable is defined as empathy levels of medical students.

Experiments were conducted using the fivefold cross-validation method. In this approach, the dataset was randomly divided into five equal subsets. In each iteration, 80% of the data were used for training and 20% for testing. This procedure was repeated five times, with each subset serving as the test set once. This method helps prevent overfitting by ensuring that all observations are used for both training and testing across different iterations, thereby providing a more reliable estimate of the model's generalization performance. The findings related to the prediction of computational thinking skills using machine learning methods are presented in Table 3. Accuracy was the primary metric for evaluating model performances, and the results include the accuracy of each fold, along with the mean accuracy and standard deviations across folds. Furthermore, to aid in the proper interpretation of classification performance, average precision, recall, and F1 score metrics of all folds are also included.

It is found that the random forest algorithm to have the highest performance, achieving a mean accuracy of 0.801. Following this, decision tree, AdaBoost, and MLP algorithms achieved mean accuracies of 0.778, 0.770, and 0.739, respectively. The parameters used for different machine learning algorithms employed in the study are provided in Table 4.

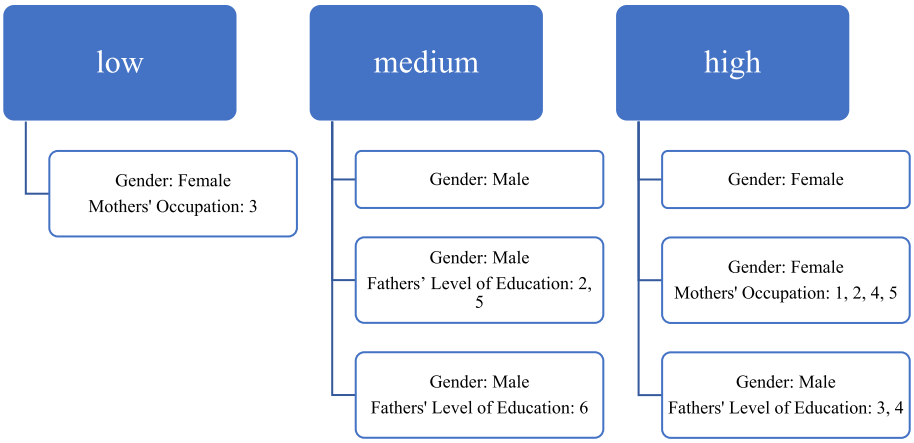

Fig. 4 Rule sets obtained through CHAID analysis. *Education levels were recoded as 1: Illiterate, 2: Literate, 3: Elementary School Graduate, 4: Middle School Graduate, 5: High School Graduate, 6: University Graduate. *Occupation categories were recoded as 1: Civil Servant, 2: Worker, 3: Self-Employed, 4: Housewife, 5: Other

Table 3 Performance evaluation of machine learning algorithms

Algorithm	Accuracy (%)							Precision	Recall	F1 Score
	Fold1	Fold2	Fold3	Fold4	Fold5	Mean	Std			
Random forest	0,808	0,827	0,784	0,725	0,863	0,801	0,046	0,808	0,656	0,724
Decision tree	0,846	0,769	0,784	0,745	0,745	0,778	0,037	0,774	0,750	0,762
AdaBoost	0,788	0,808	0,745	0,725	0,784	0,770	0,030	0,828	0,750	0,787
MLP	0,692	0,750	0,725	0,784	0,745	0,739	0,030	0,640	0,500	0,561

Table 4 Parameter configurations for used machine learning models

Random forest	Decision tree	AdaBoost	MLP
criterion: gini max depth: 15 min samples leaf: 1 min samples split: 2 n estimators: 50	criterion: gini max depth: 10 min samples leaf: 1 min samples split: 2 splitter: best	max depth: 2 learning rate: 1.0 n estimators: 150	activation: relu alpha: 0.0001 hidden layer: (100, 100) solver: adam

Discussion

Empathy, at the core of doctor-patient communication, is not only a social skill but also a fundamental component of providing effective and efficient healthcare. Numerous studies have shown that empathy is directly related to positive patient outcomes. This not only enhances the quality of healthcare services but also supports patient satisfaction and treatment adherence. As demonstrated by Hojat et al. [14], an empathetic doctor-patient relationship offers several advantages, including increased mutual trust and the development of more accurate diagnoses and treatment plans. This can result in significant cost savings for both the patient's well-being and the healthcare system. Findings by Nightingale [70] also support this view, showing that empathetic doctors tend to avoid unnecessary tests and procedures, thereby reducing costs and performing fewer invasive interventions.

In this study, 41.30% of medical students were evaluated as having high, 44.72% as having medium, and 13.978% as having low levels of empathy. According to these results, 86.02% of medical students demonstrate a moderate or high level of empathy. This finding suggests that medical education generally has a positive impact on fostering empathy. However, considering the proportion of students with low empathy levels, developing targeted training programs to support these individuals would be beneficial. Empathy is an indispensable part of medical education because it is necessary for doctors to understand their patients' emotional worlds and communicate effectively with them. Similar findings have been reported by Ardenhgi et al. [71], who suggested that medical students' empathy levels could be rated as medium to high. Another study found that the empathy level score for resident doctors was 73.1 ± 8.9 [17]. In another study by Teke et al. [72], the average empathy level score for doctors was found to be 79.37. However, Demir Karabulut et al. [73] found that students at a foundation university's medical school had empathy scores below the medium level. Another study found that medical students had low affective and cognitive empathy scores [74]. These differences may arise because empathy's affective, cognitive, and behavioral dimensions interact in complex ways, and empathy levels are influenced by numerous variables such as age, gender, and cultural background. Additionally, different research methods (survey, observation, experimental study, etc.) and different empathy measurement tools may have been used, leading to varying results.

In this study, the factors affecting the empathy levels of medical students were examined using CHAID analysis. CHAID analysis is an effective decision tree algorithm used to identify statistically significant relationships and classify data [22]. By examining the interactions between dependent and independent variables, the data was divided into meaningful subgroups. As a result of the analysis, factors influencing the students' empathy levels were identified. The findings suggest that CHAID analysis is a valuable tool in creating strategies for developing empathy skills. In the decision tree generated by the study, each node specifies the number and percentage of students classified into high, medium, and low empathy levels based on the relevant variables. These numerical values are crucial for understanding which variables have a more dominant impact on empathy levels in the decision tree and how these variables explain the differences in empathy among student groups. This analysis provides a detailed insight into the factors determining medical students' empathy levels.

The study found that female students have higher empathy levels compared to male students. This finding aligns with many studies in the literature. Maximiano-Barreto et al. [75] showed that female gender, being married, having siblings, and having children are associated with higher empathy levels. Numerous studies indicate that gender differences favor women concerning attitudes that value empathy and humanitarian qualities [76, 77]. Regarding individual factors affecting empathy development in health professions, findings from many studies show that women are generally more empathetic than men and score higher on empathy measures [78].

These findings support the general belief that women are typically more sensitive to emotional cues and better at understanding others' emotional states [30, 79]. This can be explained by a combination of factors such as biological differences, social learning experiences, and cultural expectations. For example, women's typically greater involvement in caregiving roles and the encouragement of empathy in family life may contribute to the development of their empathy skills. Additionally, societal expectations regarding gender roles may also shape women's empathy abilities. However, this is a generalization and does not imply that all women and men behave in the same way. Indeed, a different study found no statistically significant difference in empathy levels between male and female resident doctors [17]. An Italian study on empathy levels among doctors also found no significant difference based on gender [80]. These differing findings indicate that empathy is influenced by many variables and that gender is not the sole determining factor. Variables such as age, culture, education level, and familial factors also impact empathy

levels. Individual differences, personality traits, and life experiences are also significant factors affecting empathy levels.

It is important to consider that the mechanisms of gender differences in empathy are not solely social. Studies have shown that gender differences play a significant role in the neural mechanisms underlying emotional processes [81]. Another study shows that in women, the interaction between verbal working memory and negative emotion is associated with relative hyperactivation in emotion-related areas, whereas in men, regions associated with cognitive control and cognition are activated [82]. These neurological differences may explain why women are better at recognizing and responding to others'emotional states.

Additionally, although men are neurologically less sensitive to emotional cues, they can develop cognitive empathy, such as understanding others'perspectives; this involves understanding others'emotions without experiencing emotional empathy [83]. Research also indicates that societal norms may limit men's expression of emotional empathy, reinforcing the differences in empathetic responses between genders [84]. Therefore, both social learning experiences and neurological tendencies interact as factors shaping the empathy differences between genders.

Empathy is shaped not only by genetic predispositions but also by environmental factors such as family environment and education [37]. Early childhood family bonds significantly shape individuals' social relationships later in life [85]. This study confirms this situation. It is found that the education level of mothers, the profession of mothers, and the fathers' education levels are important factors determining children's empathy levels. This finding indicates that parents' education levels and professional roles affect empathy development in their children through the social learning opportunities and modeling they provide. This finding is consistent with previous research showing that parental education levels can affect children's cognitive and emotional development [86–88].

This study shows that the occupation of mothers affects students' empathy levels. Daughters of mothers working as civil servants, workers, housewives, or in other professions have higher empathy levels. In contrast, daughters of self-employed mothers have lower empathy levels. The higher empathy levels of daughters whose mothers are civil servants, workers, or housewives may be interpreted as these professions providing more social interaction and requiring more empathy. Conversely, the lower empathy levels of children of self-employed mothers may be attributed to the more individualistic and competitive nature of this profession, which may limit time spent with children. Individuals' relationships and experiences with their parents can influence the development of their empathy skills.

According to the study results, a complex relationship was observed between the education level of fathers and empathy levels in male children. The fact that children with fathers who are elementary or middle school graduates exhibit higher levels of empathy can be interpreted as these fathers having warmer and more supportive relationships with their children. However, the observation that children with university-educated fathers have medium levels of empathy suggests that a higher level of education is not always associated with higher empathy. This indicates that, in addition to education level, other factors such as fathers' parenting styles, professional lives, and personality traits may also play a significant role in the development of empathy.

The scale used in the study focuses on the affective dimension of empathy. However, the findings of this study appear to align with those of previous studies that also assess cognitive empathy. Despite the tool used in this study focusing solely on affective empathy, the alignment of the findings with prior research incorporating cognitive empathy can be explained by the potential relationship between affective and cognitive empathy. The literature suggests that these two dimensions of empathy may function in a complementary or interconnected manner. For instance, Decety and Jackson [89] propose that while affective and cognitive empathy rely on different processes, the empathy mechanism may integrate these two components. Additionally, Shamay-Tsoory [90] highlights that affective empathy might facilitate cognitive empathy. In this context, the findings of this study, which focuses on measuring affective empathy, may indirectly reflect outcomes related to cognitive empathy. Furthermore, it has been emphasized in the literature that different instruments tend to measure overlapping aspects of the empathy construct [91]. Therefore, the consistency of the findings with the literature might stem from the interrelation of the different dimensions of empathy.

The algorithms used in this study achieved prediction accuracies ranging from 73.9% to 80.1%, indicating a reliable level of performance. The highest accuracy was obtained with the Random Forest algorithm (accuracy = 80.1%; precision = 0.808, recall = 0.656, f1-score = 0.724). This can be attributed to the nature of the dataset, which primarily consists of categorical and ordinal independent variables (e.g., gender, marital status, number of siblings, graduation status, parental education and occupation, family income status, and primary purpose of internet use). Decision tree-based models,

such as random forest and decision dree, are particularly well-suited for handling such variables as they create rule-based splits that effectively capture categorical distinctions. Furthermore, random forest's ensemble learning approach enhances model robustness by reducing overfitting through the aggregation of multiple decision trees, while its feature selection capability ensures that the most informative predictors contribute to the final decision-making process.

In contrast, the inferior performance of AdaBoost and MLP can be explained by their inherent limitations with categorical data. AdaBoost, which relies on iterative weighting mechanisms, may struggle with potential class imbalances and complex interactions, leading to cumulative errors. Similarly, MLP models, which generally perform better with large datasets containing continuous variables, may have been less effective due to the categorical nature of the dataset and the absence of highly nonlinear relationships. It could be said that tree-based models may have an advantage in this context.

Inherently, bias is one of the major drawbacks of machine learning algorithms, as they are prone to certain biases, such as overfitting and feature importance. Overfitting occurs when the model learns patterns too specific to the training data, which reduces its ability to generalize to new data, leading to high variance and unreliable predictions. Similarly, feature importance can cause models to place undue weight on variables that may correlate with the target but lack true causal significance, potentially leading to misleading conclusions. These biases can increase the margin of error, reduce model interpretability, and affect fairness in decision-making. Addressing them requires careful feature selection, regularization, and model validation to ensure robustness and fairness.

Given the reliability and high accuracy of these results, educational institutions can leverage such predictive models to identify student empathy levels earlier, enabling the development of strategies tailored to individual developmental needs. Using the developed prediction models, it is aimed to plan strategies to enhance empathy skills among medical students.

Conclusion

Healthcare sector is one of the fields where interpersonal communication is crucial, thus high levels of empathy are expected from physicians. This study shows that medical students generally have high levels of empathy. The findings indicate that empathy is a complex construct influenced by both genetic predispositions and environmental factors. In our study, variables such as parental education levels, mother's occupation, and gender have been found to have significant effects on empathy levels.

The finding that women generally have higher empathy levels than men is consistent with previous research and is supported in our study as well. This can be explained by various factors, including women's biological structures, social learning experiences, and cultural expectations. However, it should be noted that this is a generalization and may not apply to every individual.

It is found that the effect of parental education levels on children's empathy levels is noteworthy. This finding indicates that parents' educational levels affect empathy development through the social learning opportunities and modeling they provide to their children.

The impact of the mother's occupation on empathy levels is another important point emphasized in our study. It was observed that children of mothers working in professions that require social interaction and empathy have higher empathy levels.

The predictive models developed using machine learning algorithms can estimate the empathy levels of medical students with a certain degree of accuracy. These models can be used in the future to plan and evaluate interventions aimed at improving students' empathy skills in medical schools.

In conclusion, this study reveals multiple factors affecting the empathy levels of medical students. The findings suggest that empathy training should be an integral part of medical education and that such training should be tailored considering students' personal characteristics and family backgrounds.

Limitations and future directions

This study has several limitations. The research was conducted on a relatively small sample. Studies with larger samples may provide more generalizable results about medical students' empathy levels. The research only examined medical students in Turkey. Further research is needed to examine the empathy levels of medical students in different countries. Future studies could test the generalizability of these findings with research conducted in different cultures and socioeconomic levels. Different studies could help us better understand the relationships between mother's occupation, parental education levels, and medical students' empathy levels. Additionally, researchers should investigate other factors that could affect empathy levels (e.g., personality traits, family environment). Future research could explore the effects of different dimensions of empathy (cognitive, emotional, behavioral), cultural differences, socioeconomic status, and longitudinal studies to examine changes in empathy development over time.

Appendix A

Table 5 The Turkish Toronto Empathy Questionnaire

1.	Diğer insanların başına gelen talihsizlikler beni çok etkilemez.
2.	Birisine saygısızca davranıldığını görmek, beni üzer.
3.	Yakınımdaki bir insan mutlu olduğunda bundan etkilenmem.
4.	İnsanların daha iyi hissetmesini sağlamaktan mutluluk duyarım
5.	Bir arkadaşım sorunları hakkında konuşmaya başladığında konuyu değiştirmeye çalışırım.
6.	İnsanlar üzgün olduklarında hiçbir şey söylemeseler bile onların üzgün olduklarını anlayabilirim.
7.	Sağlıklarına özen göstermeyip ciddi hastalıklara yakalanan insanlara acımam.
8.	Birisi ağladığında sinir olurum.
9.	Başka insanların nasıl hissettikleri beni gerçekten alakadar etmez.
10.	Üzgün bir insan gördüğümde ona yardım etmek için güçlü bir istek duyarım.
11.	Birisine haksızca davranıldığını gördüğümde, ona acımam.
12.	İnsanların mutluluktan dolayı ağlamasını saçma bulurum.
13.	Birisinin kullanıldığını gördüğümde, onu koruma isteği hissederim.

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Authors' contributions
N. H. S. contributed to the all stages of this study.

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Data availability
The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate
Approval for the current study was obtained from the Dicle University Social Sciences Ethics Committee, with the ethical assessment decision dated 17.02.2023 and documented under the number 17.02.2023–53 and ensured compliance with all ethical standards and guidelines of Declaration of Helsinki. Information about the aim of the research was shared with all participants. Participation was voluntary and participants could choose not to participate in the research without repercussion. Informed consent obtained from participant.

Consent for publication
Informed consent obtained from participant.

Competing interests
The authors declare no competing interests.

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