



Investigation of factors affecting transactional distance in E-learning environment with artificial neural networks

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Received: 10 March 2022 / Accepted: 9 September 2022 / Published online: 17 October 2022
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Abstract

In this study, the factors affecting the transactional distance levels of university students who continue their courses with distance education in the 2020–2021 academic years due to the Covid pandemic process were examined. Factors that affect transactional distance are modeled with Artificial Neural Networks, one of the data mining methods. Research data were collected from a total of 1638 students, 546 males and 1092 females, studying at various universities in Turkey, by using the personal information form, the Transactional Distance Scale and the Social Anxiety Scale in E-Learning Environments. Students' transactional distance levels were included in the model as dependent variable and social anxiety and 17 variables, which were thought to be theoretically related to transactional distance, were included in the model as independent variables. The research data were analyzed using Multilayer Perceptron (MLP) Artificial Neural Networks and Radial Based Functions (RBF) Artificial Neural Networks methods. In addition, these methods are compared in terms of estimation performance. According to the results of the research, it has been seen that the MLP method predicts the model with lower errors than the RBF method. For this reason, the results of the MLP were taken into account in the study. As a result of the analyzes carried out with this method, quickness of the instructor to give feedback on messages is determined as the most effective variable on the transactional distance.

This study was adapted from the thesis study titled “investigation of the relationship of students' transactional distance perceptions with different variables by artificial neural networks”, completed by the first author under the supervision of the second author.

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Keywords Transactional distance · e-learning · Artificial neural networks

1 Introduction

The importance given to Distance Education (DE) is increasing with the changing world regularity and the emergence of various epidemic diseases. DE can be seen as a strong alternative to formal education in compulsory situations or when geographical distances may prevent education. DE is a form of education that occurs when students, teachers and resources are not in the same physical environment, but interact with each other at the same or different times (Simonson et al., 2019). Although distance education is a good tool in this aspect, it can have some negative effects if not taken care of. Since people are not in the same physical environment during distance education, they may not be able to affect each other as in face-to-face education. In this case, the motivation and sense of commitment of the learner may decrease with the increase in transactional distance which is a negative effect of distance education, and this may cause a decrease in interaction by affecting the desire to participate actively. According to Berge (2002) and Danesh et al. (2000), the primary goal of education is interaction. Garrison and Shale (1990) also agree that the interaction between student–teacher and student–student should be qualified in the structuring and analysis of knowledge. In this case, it can be said that the role of interaction is important in motivating the student in distance education, in transferring the information correctly by the instructor or in receiving the information without misunderstanding by the student.

The Transactional Distance Theory was developed by Michael C. Moore (1980) with the idea of removing the barriers to learning that occur due to the lack of stimulation in distance education. According to Moore (1980), this theory considers the distance between the learner and the instructor not only as a physical distance, but rather as an educational and psychological distance. Also, transactional distance refers to the lack of interaction or a special form of interaction between teacher and student due to their geographical separation (Gavriliş et al., 2020). Similarly, Moore and Kearsley (2011) describe this theory as a gap related to the communication and understanding between students and teachers who are physically distant.

Transactional Distance (TD) consists of two dimensions: distance (interaction) and autonomy (self-learning) (Horzum, 2011). Zhang (2003) defines interaction as elements' effect and reaction on each other. While the interaction represents the two-way interaction between student–teacher, student–student and student–content, the autonomy represents active participation of the student in determining learning activities, goals and evaluation criteria (Moore, 1972). However, later Hillman et al. (1994) included student–interface interaction, which is defined as the process of using necessary tools to complete a task, in the interaction dimension of TD.

The interaction dimension of TD is divided into two parts. The first part is the “dialogue”, the second one is the “structure”.

Dialogue is the student's communication with the teacher or another student and the students' interaction with each other by sharing information, thoughts and

feelings (Moore & Kearsley, 2011). In dialogue process, people can derive new meanings from the information which is shared mutually, derive this information with the meanings they infer, and make each other accept this information by creating disagreements in each other's minds. Dialogue includes student–teacher interaction and student–student interaction, which are the types of interaction that Moore stated (Moore, 1989). Student–teacher interaction is an interaction that takes shape according to the guidance of the teacher and the approach of the student and teacher to each other. On the other hand, student–student interaction can be considered as the interaction of students at the same grade level and taking the same course with each other.

The structure, which is another dimension of the interaction, covers the student–content interaction, which is the interaction of the student with the content presented to the student during the education process, and the student–interface interaction, which is related to the presentation style of this content. Student–content interaction is one of the complementary features of education, and it is a type of interaction that more refers to in the interaction classification (Moore, 1989). Sabry and Baldwin (2003) examined this type of interaction from a broad perspective as student–knowledge interaction and emphasized it as the interaction of the student with the materials related to the course or not. On the other hand, student–interface interaction is a tool that provides interaction and communication between the user and the material that enables the user to reach the information they need. There is a mutual balance between structure and dialogue in distance education. If the dialogue increases, the structure decreases; if the structure increases, the dialogue decreases (Jonassen, 2004).

Moore (1980) states that there is a lack of stimulation in distance education and sees TD as the psychological distance that causes it. However, TD is not a psychological distance or gap that occurs by itself. There can be many factors that affect TD. Human psychology can be affected by external and internal factors (Aslan & Doğan, 2020). This effect can direct the human psychology and cause the person to create an unconscious infrastructure against various situations. TD is a key point in interpersonal interaction, and the fact that it is based on a psychological structure may mean that it can be affected by various factors, just like psychology. These factors can cause TD to decrease or increase in interpersonal interaction. In this study, what we need is to find the factors that affect TD in a good or bad way and to determine the importance of these factors in terms of affecting the TD level, and to develop a solution to eliminate the obstacles that TD creates in terms of education in the e-learning environment. TD is a barrier to education and training Moore (1980). At the same time, TD can cause weakening of interpersonal interaction. However, Berge (2002) and Danesh et al. (2000) state that the basic way of education is interaction. Therefore, the role of interaction in education is inevitable. Both the problems that may arise related to the interaction in the educational environment and the educational obstacles that may arise from TD meet the need to examine the factors affecting TD.

It is already known that interaction plays a key role in the sustainability of online learning and the completion of distance education (Ustun & Tracey, 2021; Yılmaz & Keser, 2017). According to studies conducted before the pandemic,

students could feel lonely due to the limited opportunity to interact with their classmates in distance education (Arkorful & Abaidoo, 2015). In this case, it can be said that the students already have a basic social disconnection related to distance education and accordingly, loneliness problems, and this loneliness may require the individual to develop a new interaction network and create a social presence in the lonely environment. Considering the negative situation that the pandemic period has created on students who have to quickly move away from face-to-face education, it is inevitable that students will feel even lonelier and be more reluctant to learn, as they enter a compulsory communication gap in distance education (Ustun, 2021).

On the other hand, how TD changes depending on individual variables has always been a popular research topic. Individual variables are internal teaching inputs for learners, and age, gender, education level, culture, and online learning experience were common learner characteristics (Kara, 2021). Accordingly, the potential for individual or environmental variables to affect TD provides an important way to measure the presence and effect of TD in the environment and to understand what effect transactional distance has according to which variable or factors.

In this study, it is aimed to determine or estimate the variables that are predicted, estimated or previously assumed to affect the TD in the e-learning environment by using artificial intelligence technologies with the data obtained from the individuals trained through e-learning. Accordingly, the main variable of this study is transactional distance, and auxiliary variables are perception of social anxiety in the e-learning environment, age, gender, science area, grade level, mother's education level, father's education level, family monthly income, number of siblings, possibility of access to the internet, more used tool when providing access to e-learning environment, e-learning format used by the instructor, Instructor's encouragement and guidance to applications outside the learning management system in order to enable students to interact and share, quickness (early reply, late reply, not responding) of the instructor to give feedback on messages, style (sincere, formal) of the instructor, type (operational, applied, theoretical) of course content, students' experience of distance education outside the Covid pandemic process, the instructor's application of measurement and evaluation methods. In this study, it was aimed to examine both the variables whose relationship with TD was tried to be determined statistically before, and the variables whose relationship with TD was not tried to be determined before. In this direction, throughout the study, it was aimed to contribute to the literature with the unique data of the study, and it was tried to be shown in the same cluster in other studies by making comparisons with the statistical results of the studies already done. In this direction, individuals who conduct research on TD are offered the opportunity to compare the statistical data of many sources related to TD from a single source. In addition, in this study, the presence of transactional distance in the e-learning environment has been analyzed with a large and diverse dataset and offers high accuracy rates.

In this study, the selection of the factors whose relationship with TD is tried to be analyzed was made by referring to the literature reviews and the opinions

of the faculty members who have improved themselves in the field. The reason why social anxiety was chosen among these factors is that many studies have been conducted on social anxiety in the e-learning environment. The main purpose of these studies is to try to find the social interaction between individuals who are not physically in the same environment. TD targets interpersonal interaction, so it is tried to find out whether the high or low level of social interaction between individuals who are not in the same environment will affect the level of TD by looking at the relationship between TD and the sub-factors of social anxiety.

The choice of age, another factor whose relationship with TD was tried to be analyzed, was based on the literature review. Moore (1989) and Ashong and Commander (2012) suggested that younger students are more affected by student–student interaction or pairwise group interaction. In addition, Huang (2002), Jung (2006), Horzum (2007), Ekwunife-Orakwue and Teng (2014), Kinyanjui (2016), Akpınar (2019), Force (2004), and Vasiloudis et al. (2015) considered the age factor in their studies on TD and interaction. All these situations have caused us to consider it important to examine the effect of the age factor on TD. Another factor whose relationship with TD is tried to be analyzed is grade level. Özkaya (2013) and Vasiloudis et al. (2015) giving importance to the grade level factor in their views on TD and the fact that the grade level is effective in the study of Küçükoğlu and Erdoğan (2008) caused us to consider the grade level factor important in our study. Among the factors whose relationship with TD was tried to be analyzed, the selection of the factors of mother and father education levels was made with the influence of both the suggestions of the researchers working in the field and some studies in the literature. Moore (1980) sees TD as an obstacle to education and this obstacle affects student failure. Horzum (2007) emphasized that TD is affected by the motivation factor. Aksu and Güzeller (2016) and Ünal and Turabik (2016) found that there is a relationship between motivation and student achievement. Related to this, Anıl (2009) and Karabay et al. (2015) found that father's education level has an effect on student success and Dursun and Dede (2004), Gürsakar (2009), Savaş et al. (2010) and Karabay (2013) stated that father's education level has an effect on student success. All this relationship showed that it is important to examine these factors. Another factor whose relationship with TD is tried to be analyzed is the possibility of access to the internet. The studies and opinions of Sandoe (2005), Karakuş and Yelken (2020) and Akpınar (2019) on the possibility of access to the internet can have an effect on TD show that the effect of this factor on TD is to be examined. Another factor whose relationship with TD is tried to be analyzed is Instructor's encouragement and guidance to applications. Horzum (2011) observed that this factor was effective on TD, and Bayır (2014) observed that students' chatting and messaging via e-mail affected TD, indicating that it is important to examine the effect of this factor on TD. Another factor whose relationship with TD is tried to be analyzed is quickness of the instructor to give feedback on messages. Wheeler (2007) and Moore and Kearsley (1996) argue that rapid feedback can be effective on TD. In addition, the relationship

we established between the terms social presence, student satisfaction, feelings of isolation, students' misunderstandings and timely responses based on the studies (Barbour & Reeves, 2013; Argyle & Dean, 1965; Gunawardena & Zittle, 1997; Wheeler, 2007; Tallman, 1994; Burgess, 2006; Saba and Shearer, 1994; Burgess, 2006; Moore & Kearsley, 1996; Northrup, 2005; Pettazzoni, 2008; Denton et al., 2008), and the fact that the TD level can be affected by this relationship is of great importance in the selection of this factor for analysis. This relationship can be seen in more detail in the discussion and conclusion section. Another factor whose relationship with TD is tried to be analyzed is style of the instructor. Wengrowicz (2014) and Moore (1993) observe that style of the instructor is related to TD. In addition, Çakmak and Aktan (2016) emphasized that various facts about the teacher's style are important in the communicative interaction between the teacher and the student, indicating that it is important to analyze the style of the instructor's relationship with TD. Another factor whose relationship with TD is being analyzed is instructor's application of measurement and evaluation methods. Moore (1973) stated that this factor had an effect on TD, and Tezci and Dikici (2002), Gömleksiz and Ayhan (2010), Burgess (2006), Kayri and Ceberut (2013), Van den Berg et al. (2006), Özan and Yurdabakan (2008) and Moore (1993)'s studies on the relationship between students and teachers, the theoretical knowledge levels of students, the relationship we have established between the terms student satisfaction, time consuming and communication skills, and the fact that this relationship can affect TD instructor's Indicates that it is important to analyze the application of measurement and evaluation methods factor. On the other hand, while it was decided to analyze the gender factor inspired by the studies of Herman and Kirkup (2017), Horzum (2011) and Bolliger and Halupa (2018) on TD, science area, family monthly income, number of siblings, more used tool (smart phone, tablet computer, computer, smart tv) when providing access to e learning environment, e-learning format used by the instructor (Synchronous, Asynchronous, Both), type (operational, applied, theoretical) of course content, students' experience of Distance education outside the Covid pandemic process factors were considered important for the research according to the opinions of experts in the field. However, since these factors were not found to be important in the analyzes we made with the artificial neural network technique, these factors will not be discussed much in this study.

1.1 Purpose of the research

It is thought that the TD may increase if the student–teacher, student–student and student-content interaction in distance education is weak and if the student cannot develop the sense of anxiety about interacting on his own. The increase in TD may create deficiencies in the education of the student in the e-learning process, as well as may affect him in terms of interacting. In this study, the level of TD in e-learning environments is examined in terms of the variables:

- perception of social anxiety in the e-learning environment
- age
- gender
- science area
- grade level
- mother's education level
- father's education level
- family monthly income
- number of siblings
- possibility of access to the internet
- more used tool (smart phone, tablet computer, computer, smart tv) when providing access to e-learning environment
- e-learning format used by the instructor (Synchronous, Asynchronous, Both)
- Instructor's encouragement and guidance to applications (Whatsap, Messenger, e-mail vb.) outside the learning management system in order to enable students to interact and share
- quickness (early reply, late reply, not responding) of the instructor to give feedback on messages
- style (sincere, formal) of the instructor
- type (operational, applied, theoretical) of course content
- students' experience of distance education outside the Covid pandemic process
- the instructor's application of measurement and evaluation methods such as self-assessment and peer assessment, portfolio etc. apart from the exam (classical exam)

It has been tried to analyze whether these variables affect the TD or not with Artificial Neural Networks, one of the data mining methods. This study aims to enable the development of hypotheses to reduce the TD by looking at the level of influence of these variables on TD.

In this study, our main aim is to question the existence of Transactional Distance, which is stated as a negative phenomenon by experts and which can prevent human interactions, in the e-learning environment and to analyze the factors that may affect this existence. The findings obtained in this process will contribute to the literature statistically. Apart from this, the analysis of these findings using the artificial neural network technique, which is an artificial intelligence estimation technique, differs from the analysis methods in the literature in terms of determining the effect levels of the transactional distance and the factors affecting it. Another point that makes this study different is that studies that try to determine the factors affecting transactional distance in the literature always try to associate similar popular factors with transactional distance. However, in this study, even the factors that are not popular and even not associated with transactional distance were tried to be analyzed by taking data from the sample in the study with expert opinions and suggestions contrary to the other studies carried out on transactional distance in the literature. Moreover, both multilayer artificial neural network and radial functions

artificial neural network analysis techniques of artificial neural networks were used while performing this analysis. In order to get the most accurate predictive result, even these methods were compared among themselves and it was decided which technique's data would be used according to their accuracy percentages. In this direction, the factors that the method determined as the most important have been discussed throughout the study. Another importance of this study is that social anxiety, which has become a popular topic in the e-learning environment, is tried to be analyzed by associating even the sub-factors of both variables one by one in order to determine whether there is a relationship between transactional distance, which is a cognitive and psychological gap, and in the e-learning environment.

2 Method

In this study, relational survey model and descriptive research method were used. Relational survey model is a research method that examines the interaction between multiple variables with the cause-and-effect method (Karasar, 2006). In this study descriptive research method is chosen because it is a method used to broadly describe and interpret a situation, an event or a problem (Büyüköztürk et al., 2015). Transactional distance is a problem for students' education because it can prevent communication between people and cause difficulty on concentrating.

2.1 Study group

In this study process, the target group from which the data were taken represents a large universe. Therefore, we decided that the most suitable sampling technique for the population structure of this study is the Simple Random Sampling technique, which is one of the probabilistic learning methods. The simple sampling technique is a sampling technique that gives an equal chance of being selected to combinations of samples of different sizes n , which can be selected independently from an X sized population (Serper & Aytaç, 1988). Simple random sampling technique is the selection of a sample of n size by giving equal chance to all possible samples that can be selected from a finite-sized population, without replacing or adding the selected sample unit (Karakulah, 2006). In order to use this sampling method, the information about the problems must be addressed homogeneous according to the universe, and in this sampling method, every possible combination of the elements in the universe has an equal probability of being included in the sample (Kerlinger & Lee, 1999). The universe of this research consists of university students who take courses through distance education due to the Covid-19 pandemic process in the 2020–2021 academic year. The sample of our research consists of 1638 undergraduate students, 546 males and 1092 females, studying at various

universities in Turkey and continuing their education through distance education due to the Covid-19 pandemic.

2.2 Data collection tools used in the research

In this study, personal information form, Transactional Distance Scale (Yılmaz & Keser, 2015) and Social Anxiety Scale in E-Learning Environment (Keskin et al., 2020) were used as data collection tools.

2.2.1 Transactional distance scale

This scale was developed by Zhang (2003) to measure the TD level and adapted to Turkish culture by Yılmaz and Keser (Yılmaz & Keser, 2015). Validity and reliability analyze of the scale were performed by the authors who carried out the adaptation study. Accordingly, it has been determined that it is a reliable and valid measurement tool in measuring TD in the online environment. The scale consists of five factors in total. These are student-interface interaction, student-content interaction, student-teacher interaction, student-student interaction and student-environment interaction. Higher levels of these interactions mean lower TD. In this case, it is known that a high transaction distance is a negative situation, and a low transaction distance is a positive situation. Since it is focused on interpersonal interaction in the research, the student-interface interaction and student-content interaction factors of the TD scale were not used. For this reason, the reliability analysis of the scale was performed again. The scores obtained from this scale were converted into discrete scores by clustering.

The Cronbach’s Alpha coefficients given in Table 1 vary between 0.84 and 0.92 for the sub-factors.

In the scale used in the research, perceptions regarding student-teacher interaction are included in items 1–6, perceptions regarding student-student interaction in items 7–17, and perceptions regarding student-environment interaction in items 18–24. Items 2 and 23 in the scale were reverse scored.

Table 1 Cronbach’s Alpha coefficient results of the transactional distance scale and its factors

	Alpha value in this study	Alpha value in the scale study
Transactional distance scale	0,93	0,92
Student-interface interaction	–	0,82
Student-content interaction	–	0,82
Student-teacher interaction	0,85	0,91
Student-student interaction	0,92	0,95
Student-environment interaction	0,84	0,87

2.2.2 Social anxiety scale in the E-learning environment

This scale was developed by Keskin et al. (2020) to measure the social anxiety levels of students in the e-learning environment. The validity and reliability analyze of the scale were carried out by the authors of the scale and it was determined that it is a reliable and valid measurement tool in measuring social anxiety in the e-learning environment. The scale consists of six factors in total. These are negative evaluation in discussion pages, somatic symptoms in discussion pages, avoidance of interaction in discussion pages, negative evaluation in communication with the instructor, somatic symptoms in communication with the instructor, and avoidance of interaction in communication with the instructor. Since this study focused on interpersonal interaction, somatic symptoms in discussion pages and somatic symptoms in communication with the instructor factors of the social anxiety scale in e-learning were not used because they focused on the somatic symptoms of anxiety like sweating and fever. For this reason, the reliability analysis of the scale was performed again. The scores obtained from this scale were converted into discrete scores by clustering (Table 2).

In the scale used in the research, perceptions regarding negative evaluation in discussion pages is included in 1–9 items, perceptions regarding avoidance of interaction in discussion pages is included in 10–19 items, perceptions regarding negative evaluation in communication with the instructor is included in 20–28 items and perceptions regarding avoidance of interaction in communication with the instructor is included in 29–38 items. There is no reverse scored item in the scale.

2.3 Data analysis method

In this study, Data Mining was preferred in the analysis of the data, since the large amount of data was used, and the Artificial Neural Networks (ANN) method, which can predict, classify and correlate data, was used to see the effect of independent variables on the dependent variable. ANN is a data

Table 2 Cronbach's Alpha coefficient results of the social anxiety scale and its factors

	Alpha value in this study	Alpha value in the adaptation study
<i>Social Anxiety</i>	0,97	0,92
Negative evaluation in discussion pages	0,91	0,95
Somatic symptoms in discussion pages	–	0,92
Avoidance of interaction in discussion pages	0,92	0,95
Negative evaluation in communication with the instructor	0,95	0,97
Somatic symptoms in communication with the instructor	–	0,93
Avoidance of interaction in communication with the instructor	0,95	0,97

mining method. it is a software that try to imitate the human brain's abilities such as remembering, learning, producing and generalizing and model the learning style of the brain mathematically (Öztürk and Şahin 2018; Kabalcı, 2014). In this study, analysis was made with Multilayer Perceptron (MLP) Artificial Neural Network and Radial Based Functions (RBF) Artificial Neural Network models of ANN method.

In this study, learning in ANN models was realized with supervised learning which is a subcategory of machine learning and artificial intelligence. Supervised learning is a form of learning used in artificial neural networks. With this learning, the most appropriate value of the weight values of the network is found. Learning is provided for the output that is likely to correspond to certain input patterns with supervised learning, and the same nodes correspond to more general pattern classes by making changes in the weight values (Kutlu & Badur, 2009). Some of the continuous variables used in the study were transformed into a categorical structure with Two-Step Cluster Analysis. Two-Step Cluster Analysis is a scalable and multivariate cluster analysis method, and it is often preferred because it can process categorical and continuous variables in large data sets, decide on the most appropriate cluster number, and successfully extract non-conforming observations (Rundle-Thiele et al., 2015).

Before the TD was analyzed with MLP and RBF, it was tested whether there was a multicollinearity problem among the variables included in the analysis. In multicollinearity test, Variance inflation Factor (VIF) and Tolerance values of multicollinearity are taken into account. If the VIF value is greater than 10 or the tolerance value is less than 0.1, it is understood that there is a problem of multicollinearity between the variables (Keller et al., 2012).

2.3.1 Multilayer perceptron (MLP) artificial neural networks training

After the net input of each variable in the output layer is calculated by adding the threshold value to the weighted input values, this value is processed again with the activation function to determine the output values. Then the output values of the network are compared with the expected output values and the error value is calculated. Therefore, the number of neurons in the output layer must match the number of outputs in the data set. Back propagation algorithm is applied for the MLP and the rules are defined in the following equations (Beale & Jackson, 1990). First, the weight and threshold values are randomly determined, and the input value (X_i), weight (W_i), activation function (f) and dependent variable (Y_{pj}) are defined as follows to calculate the actual outputs.

$$Y_{pj} = f \left[\sum_{i=0}^{n-1} w_i x_i \right]$$

After the calculations are made, it passes as input to the next layer and the results of the last layer are determined by O_{pj} values. After the weights are set, it starts from the output layer and the process continues backwards.

$$w_{ij}(t+1) = w_{ij}(t) + \eta \delta_{pj} o_{pj}$$

$W_{ij}(t)$ represents the weights from the i 'th node to the j 'th node in time t , η represent gain, O_{pj} represents the error term for event p at node j . The following equation is applied for the output units.

$$\delta_{pj} = k o_{pj} (1 - o_{pj}) (t_{pj} - o_{pj})$$

The following equation applies for hidden units.

$$\delta_{pj} = k o_{pj} (1 - o_{pj}) \sum_k \delta_{pk} w_{jk}$$

2.3.2 Radial basis function (RBF) artificial neural networks training

The design of the RBF consists of three parts: calculating its width (σ), setting its center (μ_i), and setting the weights (ω). First, the input vector ($(\vec{x})$) is defined as the input layer and the output of the hidden layer is calculated. Then the output vector of the network is calculated and compared with the expected output. If there is a difference, the weight vector is adjusted. These steps are applied for each vector and repeated until the error becomes zero (Pislaru & Shebani, 2014). The width is fixed according to the spread of the centers. h represents the number of centers, d represents the maximum distances between the selected centers (Kayri, 2015). It is shown in the equation below.

$$\phi_i = e^{\left(\frac{h}{d^2} \|x - \mu_i\|^2\right)}, i=1,2,\dots,h$$

$$\sigma = \frac{d}{\sqrt{2h}}$$

Output of networks belonging to radial base networks for input $(\vec{x})$ (Wu et al., 2012).

$$y_i(\vec{x}) = \sum_{k=1}^h w_{ki} \phi(\|\vec{x} - \vec{c}_k\|), i = 1, \dots, j_3$$

Here $(\vec{x})$ represents i 'th output, $\phi_i(x)$ represents the radial basis function, w_{ki} represents the weight connections between the i 'th output unit and the k 'th hidden units, $\| \cdot \|$ represents Euclidean norm, and J represents layer. RBF $\phi(\cdot)$ is chosen as the Gaussian function.

The matrix form for the set of N pattern pairs $\left\{ (\vec{x}_p, \vec{y}_p) | p = 1, \dots, N \right\}$ is shown in the equation below.

$$Y = W^T \phi$$

The width between the Euclidean distance measure and the vector X and C can be selected (Pislaru & Shebani, 2014).

$$E_{dist} = \sqrt{\sum_{i=1}^n X_i - c_j}$$

In this equation, n represents the vector size and E_{dist} represents Euclidean distance. In order to reduce the training errors in RBF, the error function given below is tried to be minimized (Neruda & Kudova, 2005).

$$E = \frac{1}{2} \sum_{t=1}^k \sum_{j=1}^p e_j^2(t)$$

Neuron deviations in the output layer are modeled by additional neurons with a constant activation function of $\phi_O(r) = 1$.

2.3.3 Measuring performance in artificial neural networks

In ANN, Mean Square Error (MSE), Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Relative Absolute Error (RAE) and Root Relative Square Error (RRSE) criteria are used to test the performance of the network architecture. These criteria are shown in the equations below (Kayri, 2015; Kayri et al., 2017).

$$\begin{aligned} MSE &= \frac{1}{N} \sum_{i=1}^N (P_i - O_i) \\ RMSE &= \sqrt{\frac{1}{N} \sum_{i=1}^N (P_i - O_i)^2} \\ MAE &= \frac{1}{N} \sum_{i=1}^N |P_i - O_i| \\ RAE &= \frac{\sum_{j=1}^n P_{ij} - O_i}{\sum_{j=1}^n |O_j - \bar{O}|} \\ RRSE &= \sqrt{\frac{\sum_{i=1}^N (P_i - O_i)^2}{\sum_{j=1}^n (|O_j - \bar{O}|)^2}} \end{aligned}$$

In these equations, P_i represents the predicted value, O_i represents the observed value, P_M represents the mean of the predicted value, and N represents the sample number. MSE, RMSE, and MAE values must be zero. However, since it is impossible to reach these values, the state of reaching the most appropriate level of the network architecture is interpreted by how close the desired value is.

3 Results

Descriptive statistics of independent variables are given in the tables below (Table 3).

Table 3 Distribution of participants according to independent variables

Independent variable	Categories	Frequency	%
Gender	Male	546	33.3
	Female	1092	66.7
Science area	Education	277	16.9
	Science and Engineering	160	9.8
	Health	642	39.2
	Liberal arts	559	34.1
Grade level	Preparatory class	150	9.2
	1	626	38.2
	2	516	31.5
	3	149	9.1
	4	145	8.9
	5	39	2.4
	6	13	0.8
Mother education level	Didn't finish primary school	813	49.6
	Primary school	519	31.7
	Middle School	143	8.7
	High school	104	6.3
	Technical / Vocational High School	7	0.4
	University	46	2.8
Father education level	Master/PhD	6	0.4
	Didn't finish primary school	211	12.9
	Primary school	611	37.3
	Middle School	314	19.2
	High school	281	17.2
	Technical / Vocational High School	37	2.3
	University	164	10.0
Family's monthly earnings	Master/PhD	20	1.2
	0 ↔ 1500	470	28.7
	1501 ↔ 3000	700	42.7
	3001 ↔ 4500	223	13.6
	4501 ↔ 6000	142	8.7
Number of siblings	6001 ↔ 7500	103	6.3
	Between 1 and 3 Siblings	435	26.6
	Between 4 and 6 Siblings	723	44.1
	Between 7 and 9 Siblings	359	21.9
	10 and above	121	7.4
Possibility of access to the internet	Unlimited internet	491	30.0
	Limited internet	940	57.4
	No internet access	207	12.6
More used tool when providing access to e-learning environment	Smart Phone	1344	82.1
	Tablet	17	1.0
	Computer	270	16.5
	Smart TV	7	0.4

Table 3 (continued)

Independent variable	Categories	Frequency	%
E-learning format used by the instructor	Synchronous	950	58.0
	Asynchronous	30	1.8
	Both	658	40.2
Instructor encourages and guides to applications (Whatsap, Messenger, e-mail vb.) outside the learning management system in order to enable students to interact and share	Yes	1078	65.8
	No	560	34.2
Quickness of the instructor to give feedback on messages	Early reply	1024	62.5
	Not responding	468	28.6
	Early reply	146	8.9
Style of the instructor	Sincere	1028	62.8
	Formal	610	37.2
Type of course content	Operational	456	27.8
	Applied	264	16.1
	Theoretical	918	56.0
Student have any experience of distance education outside the Covid pandemic process	Yes	212	12.9
	No	1426	87.1
Instructor applies measurement and evaluation methods such as self-assessment and peer assessment, portfolio etc. apart from the exam (classical exam)	Yes	563	34.4
	No	1075	65.6
Age Category	17 to 20	826	50.4
	21 to 24	611	37.3
	25 to 28	109	6.7
	29 to 32	42	2.6
	33 to 36	21	1.3
	37 to 40	22	1.3
	41 to 44	5	0.3
	45 to 48	2	0.1

As can be seen in Table 4, the general perceptions of TD of the participants were at an average level with a score of 79.1 in the range of 0 to 120. Their general perceptions of student–teacher interaction were at a high level with a score of 22.2 in the range of 0 to 30. Their general perceptions of student–student interaction were at an average level with a score of 35,6 in the range of 0 to 55. Their general perceptions of student–environment interaction were at an average level with a score of 21.3 in the range of 0 to 35.

Table 4 Descriptive statistics of the transactional distance scale

	Minimum	Maximum	Average	Std.
Transactional Distance perception	0	120	79,1	18,1
Perceptions of Student–Teacher Interaction	0	30	22,2	5,1
Perceptions of Student–Student Interaction	0	55	35,6	9,9
Perceptions of Student–Environment Interaction	0	35	21,3	6,3

As can be seen in Table 5, the general perception of social anxiety in the e-learning environment of the participants were at an average level with a score of 134,4 in the range of 0 to 266. Their general perceptions of negative evaluation on discussion pages were at an average level with a score of 33,4 in the range of 0 to 63. Their general perceptions of Avoidance of interaction on discussion pages were at an average level with a score of 35,8 in the range of 0 to 70. Their general perceptions of negative evaluation in communication with the instructor were at an average level with a score of 32,8 in the range of 0 to 63. Their general perception of Avoidance of interaction in communication with the instructor were at an average level with a score of 32,4 in the range of 0 to 70.

Table 5 Descriptive statistics of social anxiety scale in e-learning environment

	Minimum	Maximum	Average	Std.
Perception of Social Anxiety in the E-Learning Environment	0	266	134,4	57,2
Perception of Negative Evaluation on Discussion Pages	0	63	33,4	14,5
Perception of Avoidance of interaction on Discussion Pages	0	70	35,8	16,3
Perception of Negative Evaluation in Communication with the Instructor	0	63	32,8	16
Perception of Avoidance of interaction in Communication with the Instructor	0	70	32,4	17,4

3.1 Application of multilayer perceptron artificial neural networks and radial based functions artificial neural network

In this study, it was observed that the VIF values varied between 1.029 and 1.585 and the tolerance values varied between 0.631 and 0.972. Therefore, it has been understood that there is no multicollinearity problem between the variables used in the research. First of all, clustering analysis was applied to the TD grand total score and social anxiety total score and converted into a categorical data structure. First of all, clustering analysis was applied to the total score of TD and total score of social anxiety and transformed into a categorical data structure. The MLP method was first applied to the data set. In the two-stage clustering method, Bayesian Information clustering criterion (BIC) was used to divide the heterogeneous dependent variable into homogeneous subgroups. According to this criterion, our sample group was divided into 2 different clusters. In Tables 6 and 7, Average, frequency and percentage distributions of each cluster are given. SPSS Modeler 18.0 program was used for the analysis of MLP and RBF methods.

Table 6 Transactional distance cluster distribution

		Average	N	%
Cluster	1	93,92	794	48,5
	2	65,17	844	51,5
	Total		1638	100,0

Table 7 Social anxiety cluster distribution

		Average	N	%
Cluster	1	91,54	907	55,4
	2	187,20	731	44,6
	Total		1638	100,0

The classification rates of the effect of 18 independent variables on the TD dependent variable according to the MLP and RBF models used in the study are shown in Tables 8 and 9.

It is seen that in Table 8, correct classification rate of the effect of 18 independent variables on the TD dependent variable is 73.1% and the rate of misclassification is 26.9% according to MLP model. In the MLP model, Hyperbolic Tangent is used as the hidden layer activation function and Softmax is used for the output layer.

Table 8 Correct classification rate according to MLP model

Method	MLP
The dependent variable	Transactional Distance
Number of independent variables	18
Correct Classification Rate	%73,1
Incorrect Classification Rate	%26,9

It is seen that in Table 9, correct classification rate of the effect of 18 independent variables on the TD dependent variable is 70,6% and the rate of misclassification is 29,4% according to RBF model. In the RBF model, Softmax is used as the hidden layer activation function and Identity is used for the output layer.

Table 9 Correct classification rate according to RBF model

Method	RBF
The dependent variable	Transactional Distance
Number of independent variables	18
Correct Classification Rate	%70,6
Incorrect Classification Rate	%29,4

In Table 10, it is seen that the correct classification rate and correlation value of the MLP model are higher than the RBF model. When it is examined in terms of both correct classification rate, correlation value and error values, it is seen that the MLP model performs better than the RBF model. Therefore, the findings of the MLP method will be taken into account in this study.

Table 10 Comparison of the performance of MLP and RBF methods

	Correct Classification Rate%	Correlation	MSE	RMSE	MAE	RAE	RRSE
MLP	73,1	0,42	0,30	0,54	0,30	0,59	1,09
RBF	70,6	0,38	0,31	0,56	0,31	0,62	1,12

In Table 11, variables that have an effect on the TD in the e-learning environment according to MLP and RBF methods are seen. Quickness of the instructor to give feedback on messages, type of course content, style of the instructor, instructor's encouragement and guidance to applications (Whatsap, Messenger, e-mail vb.) outside the learning management system in order to enable students to interact and share, mother's education level, age, Instructor's application of measurement and evaluation methods such as self-assessment and peer assessment, portfolio etc. apart from the exam (classical exam) variables have an effect on the TD in the e-learning environment in both MLP and RBF methods. On the other hand, some variables such as the monthly income of family, number of siblings, the tool used more while providing access to the e-learning environment, the e-learning style used by the instructor, the distance education experience of the students outside the pandemic process were not found to be effective on TD in the e-learning environment in both methods.

4 Conclusion and discussion

The aim of this study is to determine the factors that can affect the TD in e-learning environments with Multilayer Perceptron Neural Networks and Radial Based Function Artificial Neural Networks models.

As can be seen in Table 4, the general perceptions of TD of the participants were at an average level, general perceptions of student–teacher interaction were at a high level, general perceptions of student–student interaction were at an average level, general perceptions of student–environment interaction were at an average level. From those results, it can be said that the students have transactional distance in e-learning environment. Also, it can be seen from Table 11 that there are some factors affect transactional distance in terms of two artificial neural networks algorithms. According to the results of this study, it is seen that transactional distance can be found in the e-learning environment, just like in the normal classroom environment. According to the results of this study, it is seen that TD can be found in the e-learning environment, just like in the normal classroom environment. Since the research is not focused on a certain geographical region to select students, it makes the results more general. As a result, it is seen that the TD of undergraduate and graduate students in Turkey may emerge according to certain variables which are also mentioned in this study in the e-learning environment, or that many students may develop operational distance according to certain factors in the e-learning environment.

Table 11 Independent variables having an effect on transactional distance dependent variable according to MLP and RBF methods

	MLP	RBF
1	Quickness of the instructor to give feedback on messages	Instructor's encouragement and guidance to applications (Whatsap, Messenger, e-mail vb.) outside the learning management system in order to enable students to interact and share
2	Father's education level	Quickness of the instructor to give feedback on messages
3	Type of course content	Instructor's application of measurement and evaluation methods such as self-assessment and peer assessment, portfolio etc. apart from the exam (classical exam)
4	Style of the instructor	Style of the instructor
5	Grade level	Mother's education level
6	Instructor's encouragement and guidance to applications (Whatsap, Messenger, e-mail vb.) outside the learning management system in order to enable students to interact and share	Age
7	Possibility of access to the internet	Type of course content
8	Mother's education level	Science area
9	Age	Social anxiety perception
10	Instructor's application of measurement and evaluation methods such as self-assessment and peer assessment, portfolio etc. apart from the exam (classical exam)	Gender

When the literature is examined, it is seen that there are many studies dealing with the TD. In these studies, the relationship of TD with independent variables such as lifelong learning, social presence, motivation, learning determination, learning curiosity, student success, satisfaction and self-efficacy perception was examined (Hamutoğlu et al. 2010; Horzum, 2007; Ekwunife-Orakwue & Teng, 2014; Burgess, 2006; Force, 2004; Jung, 2006; Kinyanjui, 2016). The aim of these studies is to determine to what extent TD is related to these variables and to consider these variables in the process of developing hypotheses to reduce TD in the next stages.

In this study, the variables that the MLP method finds important will be discussed in discussion section because MLP method outperformed the RBF method in terms of performance criteria. Actually, it is not aimed in this study to compare MLP and RBF method, however, In order to get a more accurate result, the accuracy score of both methods is evaluated in this study, and accordingly, it is decided which method will be the main output of this study according to the best accuracy score. According to this, in this study, it is accepted that the most effective variable on TD is quickness of the instructor to give feedback on messages, the second one is father's education level, the third one is type of course content, the forth one is style of the instructor, the fifth one is grade level, the sixth one is instructor's encouragement and guidance to applications outside the learning management system in order to enable students to interact and share, the seventh one is possibility of access to the internet, the eight one is mother's education level, the ninth one is age, and the last one is instructor's application of measurement and evaluation methods.

According to the MLP method, it is seen that the most important independent variable affecting the TD dependent variable is quickness of the instructor to give feedback on messages. The quick response of the instructor has been defined as an important measure of psychological distance (Wheeler, 2007). According to Barbour and Reeves (2013), psychological distance is known as one of the phenomena that determine the criterion of TD. According to Argyle and Dean (1965), the instructor's rapid feedback (urgency) can be associated with perceived social presence in remote environments. Social presence is the degree of perception of each person in interpersonal relationships (Gunawardena & Zittle, 1997). Perception of lack of intimacy caused by a reduced sense of social presence is likely to increase the harmful effect of TD. One of the important factors that enable the instructor to respond quickly is intimacy. According to Gunawardena and Zittle (1997), there is a connection between intimacy and social presence, and they are the measure of the psychological distance which a communicator puts between herself and the object of her communication. Furthermore, Wheeler (2007) states that the instructor's rapid response to messages should be considered as an important determinant of student satisfaction, and therefore it can be considered as an important indicator of TD. In addition, distance learners often stated that the urgency of the responses from their teachers encouraged them to continue their studies and provided much-needed desire and motivation to continue studying (Wheeler, 2007). Also, Tallman (1994) states that timely responses and feedback from the instructor can be the most important predictor of distance student satisfaction. The increase in student satisfaction may cause an increase in interaction, thus it may affect the change in the level of TD in e-learning environments (Burgess, 2006). As the teacher-student interaction

is improved, the TD decreases (Saba & Shearer, 1994). Otherwise, Burgess (2006) state that timely responses provide comfort and increase interaction for confused and frustrated online students (Burgess, 2006). It can be expected that TD of the students, whose level of interaction with the instructor is high, will decrease with the decrease in the psychological distance of them. On the other hand, Moore and Kearsley (1996) state that many distance education systems like computer-based learning and contemporary mobile learning methods offer high TD when they cannot provide fast student-instructor interaction on time. When students ask a question to an instructor, they wait for the instructor to answer. When instructor doesn't answer students, this can cause students to be unsatisfied with the lessons and to increase feelings of isolation which often leads to lower satisfaction and retention (Northrup, 2005). In this case, a decrease in satisfaction may indirectly lead to a decrease in TD. Also, according to Pettazzoni (2008), timely feedback can be effective in eliminating students' misunderstandings. Similarly, according to Denton et al. (2008), timely feedback from the teacher can convey to the student what s/he does well and which areas s/he needs to develop. The student's misunderstandings about the course content or the student's failure to realize the aspects that need improvement can increase the TD as they prevent the correct transfer of data.

The second variable that the MLP method found to be important is the father's education level variable. Since TD is accepted as an obstacle to learning (Moore, 1980), an increase in TD may decrease student achievement. Anil (2009) and Karabay et al. (2015) state that there is a positive relationship between student achievement and father's education level. On the other hand, Tokan and Imakulata (2019) stated that motivation affects learning success and Aksu and Güzeller (2016) stated that there is a positive and significant relationship between student's academic success and motivation level. At the same time, Horzum (2007) reports that TD is affected by the motivation factor. In this case, the fact that there is a significant and positive relationship between father's education level and student success, and between student success and motivation strengthens the argument that TD can be affected by father's education level.

The third variable that the MLP method found to be important is the type of course content. The fact that the variable of the type of course content has an effect on the TD shows that the TD levels of university students who take operational, theoretical or applied courses can be affected by the content type of the course they take. When the literature was examined, no research was found on the relationship between TD and course content type variable. For this reason, examining the relationship between TD and this variable more frequently in studies to be conducted on TD will help to reveal clearer results.

The fourth variable that the MLP method found to be important is the style of the instructor. The fact that the instructor's style is sincere or formal was found to be a factor that may affect the level of TD. In support of this, Wengrowicz (2014) found that an instructor's pedagogical teaching style makes a significant and cumulative contribution to the estimation of TD. Likewise, Moore (1993) argues that there is a positive correlation between TD and teaching style, which is influenced by various factors, including the pedagogical characteristics of the instructor. The style, which is a communication element of the instructor, takes

shape according to basic elements such as tone of voice, enthusiasm and excitement of speaking. Çakmak and Aktan (2016) state that the style of expression, tempo, intonation, dynamics of the voice, noise, enthusiasm and excitement of the speech play an important role in the verbal communication of the instructor with the student. In this case, teacher-student interaction, which is one of the basic elements of TD, is likely to be affected by the style, which is one of the basic elements of communication. Also, the importance of instructor's physical technique, emotional sensory in both education and learning processes is revealed by videoconference in order to reduce the transactional distance between the teacher and the learner, and this leads to a better distance education experience (Kanellopoulos et al., 2021).

The fifth variable that the MLP method finds important is the grade level variable. The learning experiences, intellectual maturity levels or adaptation processes of students at different grade levels may differ. Küçüköğlu and Erdoğan (2008) stated in their study that there are differences between students' opinions according to the grade level variable. However, Özkaya (2013) determined that the TD did not differ according to the grade level unlike the results of our study. Also, Vasiloudis et al. (2015) found that the education year did not differ in terms of TD in their study named TD and autonomy in the distance education environment.

The sixth variable that the MLP method finds important is instructor's encouragement and guidance to applications (Whatsap, Messenger, e-mail vb.) outside the learning management system in order to enable students to interact and share. The study conducted by Horzum (2011) supports our results. Similarly, Bayır (2014) concluded that students' chatting and messaging via e-mail is important way to reduce their TD. Also, Ironsi (2021) confirms that the google meet was effective in achieving lesson objectives and making classroom activities more organized as proposed by transactional distance theories.

The seventh variable, in which the MLP method found its effect on the TD in the e-learning environment as significant, is possibility of access to the internet. Internet connection is required to enable interaction in online environments. Therefore, the possibility of accessing the internet is a necessity in order not to weaken the "dialogue" phenomenon, which is one of the most important phenomena of TD and includes student–student and student–teacher interactions, in the online environment. Sandoe (2005) argues that as the level of dialogue of the participants in the online environment increases, their TD may decrease. Supporting this, Karakuş and Yelken (2020) found that the TD levels of university students studying in e-learning environments differ according to their technological competencies. On the other hand, it was determined that internet access is not a significant variable in terms of TD in the study conducted by Akpınar (2019).

The eighth variable that the MLP method found to be important is the mother's education level variable. Since the TD is accepted as an obstacle to learning, increasing the TD may decrease student success. Dursun and Dede (2004), Gürsakal (2009), Savaş et al. (2010), Karabay (2013) reported that mother's education level has a positive effect on increasing student achievement. On the other hand, Aksu and Güzeller (2016), Ünal and Turabik (2016) stated that there is a positive and significant relationship between the academic success of the student and the level

of motivation. At the same time, Horzum (2007) reports that TD is affected by the motivation factor. In this case, the fact that there is a significant and positive relationship between the mother's education level and student achievement and between student success and motivation strengthens the argument that TD can be affected by mother's education level.

The ninth variable that the MLP method found to be important is the age variable. Moore (1989) suggested that younger students are more influenced by student–student interaction or pairwise group interaction. As a result of this hypothesis, the fact that younger students are more affected by student–student interaction, which is a sub-dimension of TD, supports the assumption that TD may vary according to age. On the other hand, Ashong and Commander (2012) stated that older students tend to struggle with course materials more than younger students. This situation supports that student–content interaction, which is a sub-dimension of TD, can be affected by the age factor. At the same time, when Huang (2002) examined the relationship between student perception and the age variable, he found that age was significantly related to interaction, which is one of the most important phenomena of TD. In addition, Jung (2006) and Horzum (2007) state that there is a significant relationship between the age variable and the perception of TD. On the contrary, Ekwunife-Orakwue and Teng (2014) found that the level of dialogue, which is a sub-dimension of TD, did not differ according to the age variable. In addition, Kinyanjui (2016), Akpınar (2019), Force (2004) and Vasiloudis et al. (2015) found that the age factor was not a significant predictor of TD perception. In this case, it can be said that the effect of age on TD differs according to the age level of the sample group in various studies.

The tenth variable that the MLP method finds important is Instructor's application of measurement and evaluation methods. The instructor's application of alternative measurement and evaluation methods (self-assessment, peer assessment, homework, e-portfolio, etc.) other than the traditional assessment and evaluation methods (written exam, multiple choice test, etc.) was found to be a factor affecting the TD. Moore (1973) stated that the most important and noticeable effect on teaching in the TD theory is distance, which imposes more responsibility (self-evaluation allowing to control time and pace of progress) on the learner. TD decreases when learning becomes stronger. The fact that learning can be achieved through indirect interaction and that indirect interaction can be accelerated by self-assessment strengthens the assumption that self-assessment can affect TD. The fact that learning can be achieved through indirect interaction and that indirect interaction can be accelerated by self-assessment strengthens the assumption that self-assessment can affect TD. Tezci and Dikici (2002) stated that the e-portfolio constantly supports the communication between the teacher and the learner. Supporting the communication between the teacher and the student may lead to a decrease in the TD as it increases the student–teacher interaction. On the other hand, Gömleksiz and Ayhan (2010) stated that the e-portfolio did not contribute to students' theoretical knowledge levels. The fact that the e-portfolio does not contribute to students' theoretical knowledge levels may affect student satisfaction. Burgess (2006) argues that student–teacher interaction and autonomy, which are the components of TD, may decrease with a decrease in student satisfaction. In addition, Kayri and Ceberut (2013) state that teachers find

the use of portfolios very time consuming in their study on the use of portfolios. It may not be appropriate to evaluate with a portfolio, because the use of very time-consuming applications in online environments where interaction with the student is difficult can adversely affect the TD. On the other hand, most teachers think that peer assessment is an effective way to increase student–student interaction as it encourages discussion among students (Van den Berg et al., 2006). Özkan and Yurdabakan (2008) determined that the use of self- and peer-assessment practices contributed positively to the success of students in basic communication skills. Moore (1993) stated that dialogue, which is a sub-dimension of TD, means a communicative operation related to instructor-student interaction. In this case, the development of basic communication skills may lead to a decrease in the TD, while enabling the development of student–student and student–teacher interactions, which are component of dialogue which is the sub-dimension of TD.

On the other hand, there are studies suggesting that there may be other factors affecting transactional distance. For example, Karaoglan Yilmaz and Yilmaz (2020) have seen that providing learning analytic based feedback is effective in reducing the perception of transactional distance in their studies on the effect of learning analytics on transactional distance. Also, Kara (2021) indicates that all types of interaction covered by transactional distance significantly affect student outcomes in online language teaching. As opposed to this, Walsh et al. (2021) indicate that the transactional distance does not affect the determination of learning outcomes according to the coding theme of the communication used to reduce the transactional distance.

5 Suggestions

- The continuity of communication, which decreases during the transition from the classroom environment to the online environment, can be supported by providing the feeling of being side by side with the instructor's quick response to student questions. In this case, the instructors should have an idea about the digital communication applications with which they can communicate with the students in the fastest way, and even the university administration should standardize the communication practices for the e-learning environment so that this process can be managed more seriously.
- When the instructor will counsel students with high TD levels, s/he should consider the education level of the student's parents and should prepare lesson plan accordingly.
- In this study, it was seen that the type of course content (operational, applied, theoretical) had an effect on the TD. While designing the course content, the instructors also choose the form of course. In the e-learning process, when choosing the type of course content, it may be beneficial for the instructor to design the course accordingly, knowing which course content type has the lowest TD perceptions of the students.

- In this study, it is seen that the style of the instructor while communicating with the student has an effect on the TD. In order to keep students' TD perceptions low, it may be beneficial for the instructors, whose communication elements should be stronger, especially during the period when they teach by distance education, to adjust their style of communication (enthusiasm, excitement, tempo, rhythm) in a controlled manner.
- It may be beneficial to consider the student's grade level and age information in the plan that the instructor or school administration will prepare to reduce the student's TD level.
- The instructor should recommend and encourage digital communication applications where social learning takes place, so that the students can exchange information with their peer and share the course outcomes with each other.
- The student and the instructor may become complacent and forget the sensitivity of the evaluation process with the feeling of not being side by side in the e-learning process. However, assessment is not only a structure that indicates the final state of the student, but also a structure that affects the development process. Therefore, the instructor should support the academic development of the student with assessment methods such as self-assessment and peer assessment, apart from standardized exams in the e-learning process.
- The independent variables of this research are limited to some demographic variables that may affect TD and the social anxiety structure perceived in the e-learning environment. However, there are many variables that are thought to affect TD. Increasing the diversity of different variables that are thought to affect TD in studies belonging to TD may be useful in developing hypotheses for further reduction of TD.

Data availability Data will be made available on reasonable request.

Declarations

Competing interest The authors declare that there is no conflict to interest related to this paper.

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