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Research Article

Investigation of Positive Error Climate in Mathematics Teaching with Mixed Method*

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Abstract – The purpose of the study is to investigate the effects of the classroom climate created according to the 'positive error climate framework programme' on the error orientations of teachers and students in mathematics lessons. Intervention design based on mixed methods was used. The data were collected from four classes (two study and comparison classes) selected by purposive sampling, involving 145 students and 4 mathematics teachers. 'Classroom Error Climate Scale' (CECS), lesson observation form and notebook, semi-structured teacher and student interview form were used. At the end of the fifteen-week study, interviews were conducted with the teachers and students in the study groups. T-test results showed positive and significant change in the perceived classroom error climate in the study groups. Qualitative data analyses showed that the error orientations of the study group teachers and students were more positive than the comparison group. Teachers and students stated that positive error climate helps them to comprehend the correct information better, increases participation and self-confidence in the lesson and helps permanent learning.

Keywords: Error Orientation, mathematics teaching, mixed method, permanent learning, positive error climate.

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Introduction

For a long time in the field of education, errors have been seen as signals of lack of ability or misunderstandings in the learning process (Matteucci et al., 2015). However, studies in the literature show that making mistakes positively affects learning and improves the learning process (Borasi, 1989; Huelser & Metcalfe, 2012; Rach et al., 2013; Soncini et al., 2021). Evidence from studies in the field of educational psychology suggests that making mistakes can promote learning and create opportunities for teaching (Borasi, 1989; Metcalfe, 2017; Tulis, 2013). According to these studies, errors are natural elements of the teaching process and can be utilised as teaching tools (Borasi, 1989; Matteucci et al., 2015).

A positive error climate is observed in classroom environments where errors are used and evaluated as an integral part of the teaching process (Steuer et al., 2013; Tulis, 2013). The error climate of the classroom is determined by the error orientations of teachers and students. Error orientation consists of perception, attitude and subsequent behaviours towards errors (O' Dell, 2015; Özkaya et al., 2022). In a positive error climate, teachers see student errors as learning opportunities, act tolerant towards errors, and make errors a topic of discussion in the classroom. Instead of responding to student errors directly, they guide the student toward the correct answer using appropriate (McMillan & Moore, 2020; O'Dell, 2015; Oser & Spychiger, 2005; Tulis, 2013). In a positive error climate, teachers constantly interact with students who make mistakes. During these interactions, the teacher avoids verbal or non-verbal negative indicators (anger, frustration) (Steuer & Dresel, 2015). In such an environment, the student's attitude towards errors and error orientation is positive (Käfer et al., 2019; Tulis, 2013; Özkaya et al., 2022). In positive error climate students do not hesitate to make mistakes, take the risk of making mistakes and participate actively in the lesson (Özkaya et al., 2022; Soncini et al., 2021).

Tulis (2013) categorised the error climate of the classroom as positive or negative by looking at the adaptive or maladaptive responses of teachers to errors. She showed adaptive responses as including the whole class in the discussion environment, giving the student enough time to respond, preventing negative reactions of classmates, and emphasising that errors are opportunities for learning. Maladaptive reactions are ignoring errors, criticising the student, directing the question to another student, laughing, mocking or showing disappointment. In a negative error climate, maladaptive error correction feedback is used more frequently and as a result, students develop negative feelings towards making errors and avoid the risk of making errors. However, it has been observed that in positive error climates,

students can learn more easily from errors and actively participate in the lesson (He, 2020; Soncini et al., 2021).

Steuer et al. (2013), in their study investigating the perceived classroom error climate, stated that the error climate has eight interconnected sub-dimensions. These are; error tolerance by the teacher, independence of errors from evaluation, teacher support following errors, absence of negative reactions of the teacher against errors, absence of negative reactions of classmates against the error maker, taking the risk of making errors, analysis of errors, and functionality of errors for learning. Özkaya et al. (2022) states that the first four of these sub-dimensions are related to the teacher's error orientation. While taking the risk of making mistakes and the absence of negative reactions to mistakes in the classroom are related to the student's error orientation, the last two sub-dimensions are related to the evaluation of errors (Özkaya et al., 2022). Käfer et al. (2019) stated that the error climate is a multidimensional structure that includes not only student-specific but also classroom-wide and teacher's attitude towards errors.

Research in neuroscience has found that the human brain is programmed to learn from errors (Boaler, 2022; Moser et al., 2011). Similarly, evidence from studies in cognitive and educational psychology suggests that making errors can promote learning (Borasi, 1988; He, 2020; Metcalfe, 2017; Tulis, 2013). These studies indicate that making mistakes can create valuable opportunities for learning when corrective feedback is given after an error occurs (He, 2020; Metcalfe, 2017). In a positive error climate, positive motivational responses such as positive learning orientation, joy, and decreased fear of making mistakes have been found to occur in students (Käfer et al., 2018; Rach et al., 2013). In such an environment, students feel safe about making mistakes and take the risk of making mistakes (He, 2020; Steuer et al., 2013).

When error-based teaching studies are examined, it is seen that video recording studies are predominant (Didiş et al., 2016; Ingram, 2013; Matteucci et al., 2015; Santagata, 2005; Son, 2013; Tulis, 2013; Türkdoğan & Baki, 2012). These studies describe the current situation and offer solutions to the problems identified. When the studies on error climate are examined, there are very few qualitative-quantitative supported or mixed design studies (Alvidrez, 2019; O'Dell, 2015; Soncini et al., 2021; Tulis, 2013; Wasilewski, 2023). It is seen that these studies generally investigate the affective effects of positive error climate on teachers and students.

When the teacher dimension of error-based learning studies was examined, it was observed that although teachers generally accepted the instructional potential of errors, they had concerns about their use in the classroom environment. Teachers stated that the use of errors in the classroom is not appropriate and may create some affective (embarrassment, loss of self-confidence, etc.) and cognitive barriers (learning the wrong, learning incorrectly, etc.) in students (Palkki & Hastö, 2018; Wasilewski, 2023).

When the feedback given by teachers to errors are analysed, it is seen that feedback such as ignoring, telling the right directly, and redirecting the question to another student are used more frequently. These feedback are ineffective error correction feedback (Didiş et al., 2016; Oser & Spychiger, 2005; Santagata, 2005; Son, 2013; Tulis, 2013; Tükdoğan & Baki, 2012). These findings suggest that teachers are not sufficiently aware of the instructional potential of student errors.

In the studies, it is seen that teachers who create a positive error climate in classrooms sometimes do this consciously and sometimes unconsciously (Abay & Clores, 2022; Alvidrez, 2019; Matteucci et al., 2015). In these studies, it is seen that a framework plan that will help to create a positive error climate in the classrooms has not been put forward. For this reason, Özkaya et al. (2022) proposed the "positive error climate framework programme" to create a positive error climate in the classroom (Appendix 1). The programme includes the steps to be followed to create a positive error climate in the classroom. In the "positive error climate framework programme", what needs to be done for teachers to create a positive error climate in the classroom with adaptive error correction behaviours and attitudes and to reinforce this with assessment exams are explained item by item. "Positive error climate framework programme" is given in the appendix.

In scientific studies, it can be said that a framework plan that helps to create a fully positive error climate in classrooms has not been put forward. For this, there is a need for planned intervention research to reveal the effects of classroom error climate. Looking at the studies claiming to conduct such research (Soncini et al., 2021), it was observed that they proceeded through a lesson scenario and limited observations were made. However, positive error climate is a multidimensional field that needs to be observed in long-term and real teaching environments (Käfer et al., 2019; O'Dell, 2015; Spychiger et al., 1998; Steuer et al., 2013; Soncini, 2021; Özkaya et al., 2022; Tulis, 2013; Wasilewski, 2023).This is also the reason for the current study. The aim of the study is to examine in detail the effects of the classroom climate created according to the "positive error climate framework programme" on

teachers' and students' error orientations in mathematics lessons. The sub-problems sought to be answered in this context are given below;

1. Is there a significant difference between the classroom error climates perceived by the study and comparison groups before the implementation?

2. Is there a significant difference between the classroom error climates perceived by the study and comparison groups after the implementation?

3. What are the similarities and differences between the error orientations of the teachers in the study and comparison groups?

4. What are the error orientations of the students in the study and comparison groups?

5. What are the opinions of the study group teachers and students about the positive error climate process?

Method

The intervention design, which is one of the mixed method designs, was selected in order to investigate in detail the effect of the positive error climate created in the classrooms on students and teachers. The purpose of this design is to study the research problem in detail by adding qualitative data to an intervention programme process (Creswell, 2021). In the current study, the intervention programme was examined with a quasi-experimental design and the process was observed with qualitative data. In this method, when presenting findings, qualitative and quantitative findings are given separately and their interpretation is usually made in the discussion section. (Creswell, 2013).

In the quantitative dimension of the study, a quasi-experimental design with pretest-posttest comparison groups was used. In this model, which is the most frequently used type of quasi-experimental design, study and comparison groups are selected. Pre-test and post-test are applied to both groups, but the intervention process is applied only to the study group (Creswell, 2013; McMillan & Schumacher, 2010). In the qualitative dimension of the study, the positive error climate intervention programme was observed through the lesson observation forms. At the end of the implementation, interviews were conducted with the teachers and students in the study groups. At the end of the intervention, a focus group interview was conducted with 16 students from the study group. These students were selected according to the opinions of the teachers and the purpose of the research according to the

purposeful sampling maximum diversity method. In maximum diversity, the experiences of different participants are obtained (Yağar & Dökme, 2018).

Sample

The research data were collected in a secondary school in a province in eastern Turkey during the 2022-2023 academic year. The research sample consisted of four classes (two study and two comparison classes), 145 students studying in these classes, and four mathematics teachers teaching in these classes, selected by purposive sampling. Purposive sampling occurs when the researcher makes a judgement about which participants should be selected to provide the best information to address the purpose of the research based on the population information about the subject of the study (McMillan & Schumacher, 2010).

While determining the school to be researched, one of the schools with strong representativeness was selected. Although this school is one of the central schools in the province, its achievement level is at the provincial average according to the LGS (a High school entrance exam) exam. It was understood from the opinions of the school administrators and teachers that the socio-economic level of the students was moderate. Class size varies between 25-35. The school has eight mathematics teachers and five different classes at each grade level. This school was selected as the research school by purposive sampling with the belief that it would serve the purpose, external validity and generalisability of the research.

It was confirmed by the school administrators that the selected classes were equivalent to each other in terms of academic success compared to the previous semester and that their socio-economic levels were close. These classes were randomly assigned as study and comparison groups. The classes in the study groups were coded as 6D and 7D, while the classes in the comparison groups were coded as 6K and 7K. The numbers of students in these classes are given in Table 1.

Table 1 Number of Students in the Study and Comparison Groups

Group	Class	Female	Male	Total
Study	6D	17	19	36
	7D	18	20	38
Comparison	6K	15	21	36
	7K	16	19	35

In order to reveal the effects of the error climate implementation at different grade levels, two different grade levels were selected. The mathematics teachers of these four grades are different persons and the implementation was carried out with these teachers on a

voluntary basis. Teachers in both groups stated that they had not heard of error climate before. In addition, all of the teachers stated that although they believed that errors were inevitable in the classroom and that errors played an important role in teaching, they rarely made use of errors in their lessons. This situation suggested that teachers' error orientations were similar.

Data Collection Tools

Classroom Error Climate Scale (CECS). The scale was developed by Steuer et al. (2013) to measure the perceived error climate in the classroom. The adaptation, validity and reliability studies of the scale for use in the Turkish sample were conducted by Kalaç et al. (2022). As a result of the adaptation studies, it was determined that the scale consists of seven factors and 27 items. The internal consistency Cronbach Alpha coefficient of the scale was .86, and the internal consistency coefficients of the factors were determined between .73 and .89. When calculating students' perceived error climate scores, negative items were first reverse coded. Afterwards, the subscale averages were summed and the total scores were obtained. CECS was chosen because it measures the perceived error climate of the classroom in a multidimensional way and serves the purpose of the research. The scale was used to measure the perceived error climate of the classroom. Craonbach's alpha coefficient for this study was found to be .85.A summary of the scale is given in Appendix 2.

Lesson Observation Forms. Lesson observation forms, which include the teacher's attitudes, behaviors and feedback regarding errors in the classroom, are semi-structured forms designed according to the "positive error climate framework program". Two field experts were consulted for the form. This form was used to analyse the teacher's error orientation. It was completed for both study and comparison groups at the end of each lesson. During the lesson, observers noted the dialogues and observations about the lesson. At the end of the lesson, the observers compared their notes and corrected the missing and incorrect parts. Thus, a single lesson observation note was created for that lesson. The observation notes were checked and the teacher's attitude and behaviour in the face of errors in that lesson and the feedback given were written on semi-structured forms. Then qualitative analysis was applied to the data. The lesson observation form is given in detail in Appendix 3.

Lesson Observation Notebooks. The observation notebooks in which the in-lesson activities and dialogues were written were filled in separately by the two observers who attended the lesson by giving the date and time information. At the end of the lesson, both observation notebooks were combined by the observers to form a single lesson observation.

These notes were used to investigate the error orientations of the students and the teacher. Then qualitative analysis was applied to the data.

Focus Group Interview Form. Focus group interviews were conducted with eight 6th grade and eight 7th grade students in the study classes at the end of the experimental research. The students were selected by purposive sampling and maximum diversity method. Observer and teacher opinions were taken into consideration while selecting the students. Focus group interviews were conducted through a semi-structured interview form prepared with expert opinions. The interviews of both groups were conducted separately and lasted 35 minutes each. Questions that were not understood or thought to be misunderstood by the students were immediately corrected and asked again. The groups were interviewed separately. During the interviews, students were asked about the positive error climate process and what kind of changes occurred in their mathematics lessons and what effects these changes had on them. This form was used to analyse students' error orientations. Then qualitative analysis was applied to the data.

Teacher Interview Form. Semi-structured interviews were conducted with two teachers in the study groups after the implementation. The teachers were asked about their error climate experiences, their thoughts, whether they found this method effective or not, their strengths and weaknesses, and whether they would like to use it again or not. Expert opinion was used while preparing the form. The interviews with the teachers were conducted separately and lasted 25 minutes each. This form was used to analyse teachers' error orientations. Then qualitative analysis was applied to the data.

Procedures

Necessary ethical permissions were obtained from relevant institutions before starting the research. There are three teacher candidates who served as observers in the research. Observers, like teachers, stated that they had never heard of the concept of error climate before. Twelve hours of scientific research techniques training and eight hours of positive error climate training were provided to prospective teachers. Teachers in the study groups were given eight-hour positive error climate training simultaneously with the observers. The implementation phase of the research lasted 15 weeks. The groups were observed for two hours a week.

A study group and a comparison group were selected at the sixth and seventh grade level. Classroom observations were made in all four groups and observation forms were kept.

Likewise, CECS was administered to all groups as pre-test and post-test. At the end of the research, interviews were conducted with the teachers and students in the study groups. An intervention programme with the "Positive Error Climate Framework Programme" was applied to the study groups. No intervention was applied to the comparison groups.

"Positive Error Climate Framework Program" was taken into consideration when planning lessons in the study groups. Errors were included in the teaching process in a planned manner, and the causes of errors and correct answers were discussed in the classroom so that students could learn from these errors. Students were asked to express the correct answers in their own words. Erroneous questions were added to the course, not at the first stage, but after sufficient question solving was completed at the end of the subject. Otherwise, since the student's readiness is lacking at the first stage, she/he may perceive the incorrect information as correct and develop misconceptions (Konyalıoğlu, 2021). To prevent this, the use of incorrect questions or statements in the process must be planned. Lesson plans were prepared with the teachers in the study groups the week before the topic would be taught, and any mistakes students might make were added to the plan. Lesson plans were made separately for both grade levels. The plans were prepared in accordance with national education outcomes by taking the opinions of two field experts and teachers. An example of a lesson plan applied in the study groups is given in Appendix 4.

Data analysis

When analysing the data, quantitative and qualitative data were analysed separately and the two grade levels were evaluated within themselves. CECS pre-test post-test scores were used to determine the perception of classroom error climate. Before analysing the quantitative data, the conformity of the scores obtained from the CECS to the normal distribution was examined. To decide normality, Shapiro-Wilk normality test, skewness (SC), and kurtosis (KC) coefficients were examined. The CECS pre-test and post-test data of all classes were found to fit the normal distribution according to Shapiro Wilk normality coefficient ($p>.05$) and skewness kurtosis values (-1.5, +1.5) (Büyüköztürk, 2020; Tabachnick&Fidell, 2013). While the differences between groups were analysed by independent samples t-test, the differences within groups were analysed by paired-samples t-test (Büyüköztürk, 2020). Cohen's effect size formula was used to find the effect size value of the significant values (Cohen, 1988). The d (effect size) value found is interpreted as follows; if $0.5>d> 0.2$, it is considered as small effect, if $0.8>d>0.5$, it is considered as medium effect, if $d>0.8$, it is considered as large effect (Büyüköztürk, 2020).

In the research, descriptive analysis and content analysis were applied to the qualitative data obtained through observations and interviews. In accordance with research ethics, the names of participating teachers and students were coded and stated in the forms. Firstly, the obtained data was converted into written form and made suitable for the analysis process. The data was coded by the researcher and the MAXQDA analysis program was used to analyze it. Relevant codes were brought together, placed under appropriate themes after the appropriate category, and the findings were interpreted. Presentation and visualization of the findings were also provided with the same program.

As a result of content analysis and descriptive analysis in the research, the themes of the teacher's error orientation, the student's error orientation and the positive error climate process were created in accordance with the literature. Under these themes, the data are presented by associating them with appropriate codes and categories. While coding, another researcher other than the author, who is an expert in the field, was asked to code the data. The consensus between coders was found to be 90%, which is within acceptable limits according to Miles and Huberman (1984).

Validity and Reliability of the Research

To ensure the validity and reliability of the research, Büyüköztürk et al. (2020) and Creswell (2013) suggestions were taken into consideration. Accordingly, the precautions taken for the validity and reliability of the research are as follows; the groups to be investigated were randomly assigned as study and comparison groups. The research was conducted at the same grade levels in the same school. According to the opinions of the school administration and teachers, classes with similar socio-economic levels were selected. The selected school is one of the central and most representative schools in the province where the research was conducted. In addition, four classes were selected in terms of representation adequacy. A wide range of data collection tools were used in the research process. Long-term observations were made. Participant confirmation was frequently used in the interviews. The research findings were examined by different researchers.

The study was limited to four class sections of secondary school mathematics courses in a school located in a province in eastern Turkey during the second semester of the 2022–2023 academic year.

Results

In order to examine the changes in the error climates perceived by the groups before and after the implementation, which are the first and second sub-problems of the study, the CECS data were analysed. In order to measure the perception of classroom error climate, CECS was applied to all groups at the beginning and end of the study. Independent sample t test was applied to determine whether there was a difference between the groups' perceptions of classroom error climate. Significant differences within groups were analysed with paired-samples t-test. Independent samples t test analysis and effect values between groups are given in Table 2 below.

Table 2 CECS Independent-Samples T-test Analyzes

Test	Class	n	M	t	p	d
CECS pre-test	6D	28	28.520	1.489	.14	-
	6K	30	27.306			
	7D	30	27.238	.471	.61	-
	7K	26	26.730			
CECS post-test	6D	24	31.138	4.918	.001	1.42
	6K	24	28.138			
	7D	29	29.669	2.098	.041	.61
	7K	19	27.802			

When Table 2 is examined, it can be seen that there was an increase mean scores in the post-test in all classes. When the pre-test was examined, no significant difference was found between the study and comparison groups at both grade levels ($p>.05$). In this context, it can be said that the error climate perceptions of the study and comparison groups were the same before the application.

When looking at the CECS post-test, significant differences were found in favor of the study groups at both grade levels. ($p<.05$). While the Cohen effect size value of the significant difference in the sixth grades shows a high effect ($d>.80$), the Cohen effect size value of the difference in the seventh grades shows a medium effect ($.5<d<.80$). In this case, there was a positive increase in the perceptions of classroom error climate in the study groups compared to the comparison groups at the end of the intervention programme. This increase was found to be significant and effective.

It was decided to conduct a paired t-test to determine whether the increase in the CECS scores of the groups in the post-test created a significant difference within the group. Paired-samples t-test analyses are given in Table 3 below.

Table 3 CECS Paired-samples T-test Analyzes

Class	n	t	p	d
6D	19	3.456	**.003**	**.80**
6K	21	1.564	.133	-
7D	24	3.819	**.001**	**.77**
7K	16	.464	.649	-

When Table 3 is examined, it is seen that there is a significant difference in favor of the post-test in both study groups ($p < .05$). While the effect size value of the significant difference occurring in the 6D class indicates a large effect ($d > .80$), the significant difference occurring in the 7D class has a medium-sized effect ($.50 < d < .80$). When looking at the comparison groups, no significant difference was found in terms of CECS pre-test and post-test. As a result of the pre-test and post-test findings of CECS, it can be said that the intervention program made a significant and effective change in the study groups' perceptions of classroom error climate.

Content analysis was applied to the observation form data in order to analyse the similarities and differences between the error orientations of the teachers in the study and comparison groups, which is the third sub-problem of the research. The analyses obtained from both grade levels are given separately below. As a result of the analysis, the categories of attitude towards errors, feedback on errors and handling of errors were formed under the theme of teacher's error orientation. Different codes emerged under these categories. The frequency of the resulting codes according to the code matrix browser of the classes is given in Figure 1 below.

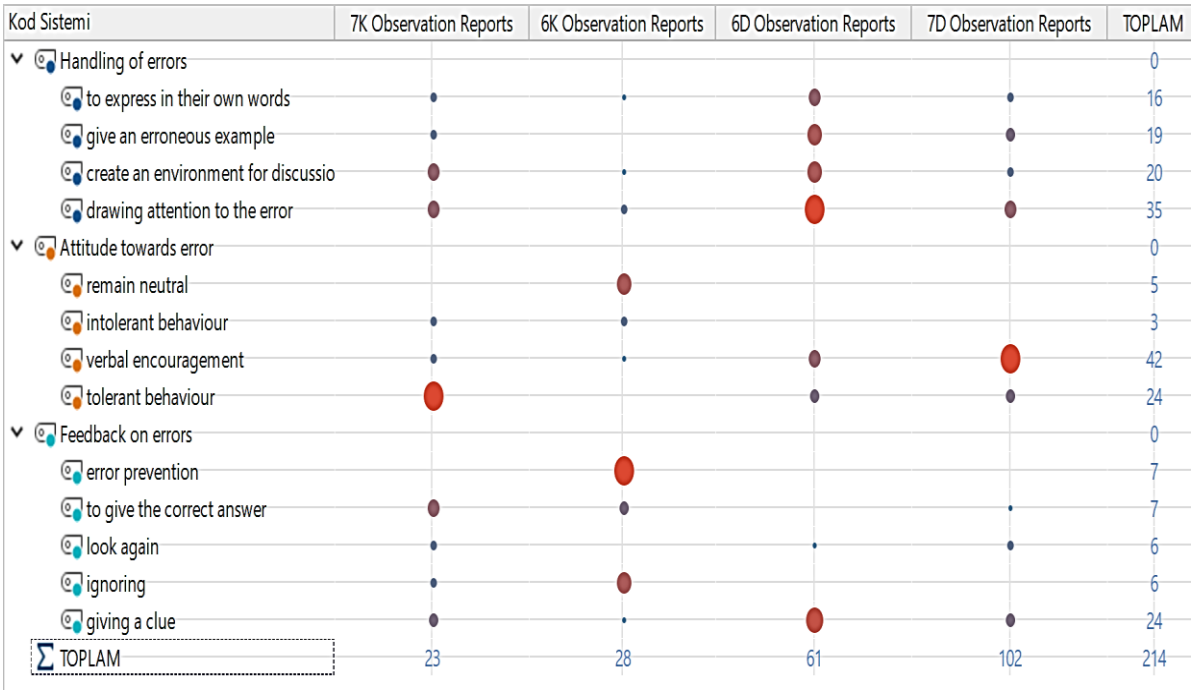


Figure 1 Frequency of Codes by Code Matrix Browser

When Figure 1 is examined the size of the dots in the figure shows the frequency of the code in the observed class. The total row and column show how many times the code is repeated in total. According to the observation reports, the most recurring code in class 7K was tolerant behavior, the most recurring code in class 6K was error prevention. In class 7D, the most recurrent code was verbal encouragement, and in class 6D, the most recurrent code was drawing attention to the error. In the study groups, the codes of remain neutral, intolerant behaviour, error prevention and ignoring, which are among the negative teacher feedbacks, were not encountered during the 15-week observation.

The comparison of the 6D study group and the 6K comparison group at this grade level under the theme of *teacher's error orientation*, and the codes resulting from this comparison and their frequency are given in Figure 2 below.

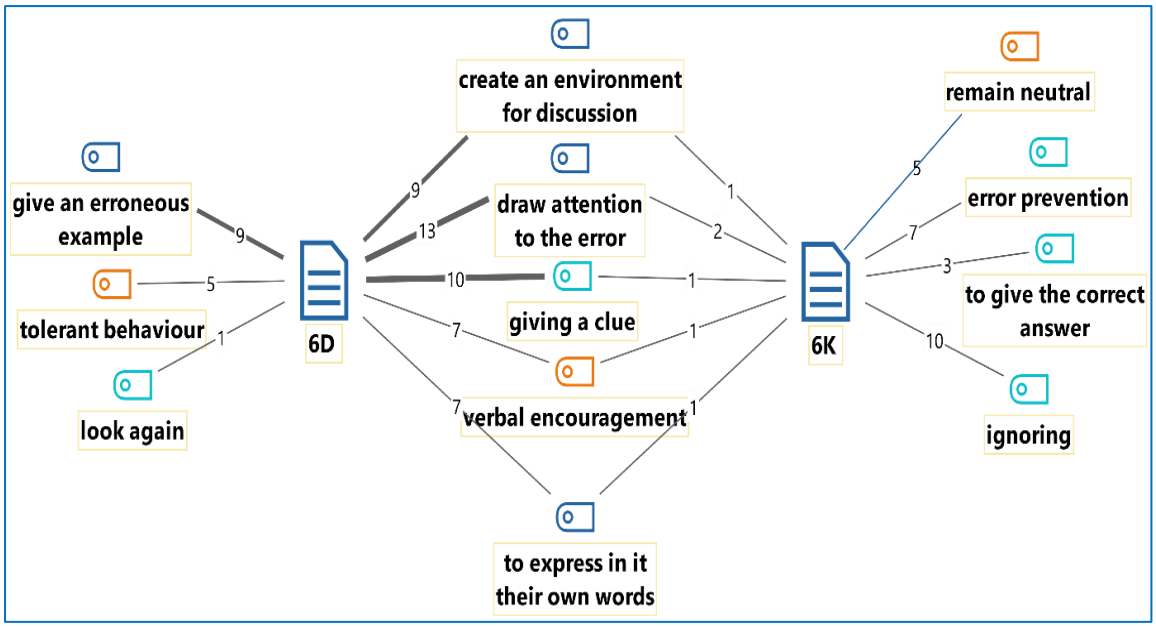


Figure 2 Comparison of 6th Graders under the Theme of Teacher's Error Orientation

When Figure 2 is examined, although there are common codes observed in both classes, the classes also have their own codes. Accordingly, while the codes of create an environment for discussion, draw attention to the error and to express in it their own words under the category of handling of errors were observed in both classes, the code of give an erroneous example belonging to this category was observed only in the study group. Likewise, while the giving a clue code, belonging to the category of feedback on errors, was observed to be common in both classes, the code look again, belonging to this category, was observed only in the study group. Again, the codes of error prevention, ignoring and to give the correct answer belonging to this category were observed only in the comparison group. According to Figure 2, it can be said that a positive error climate was observed in the 6D class and a relatively negative error climate was observed in the 6K class throughout the process. At the same time, when the error orientations of the teachers are examined, it can be concluded that the error orientation of the study group teacher is more positive than the error orientation of the comparison group teacher.

Comparison of the 7D study group and the 7K comparison group at this grade level under the theme of *the teacher's error orientation*, the resulting code map and the frequency of the codes are given in Figure 3 below.

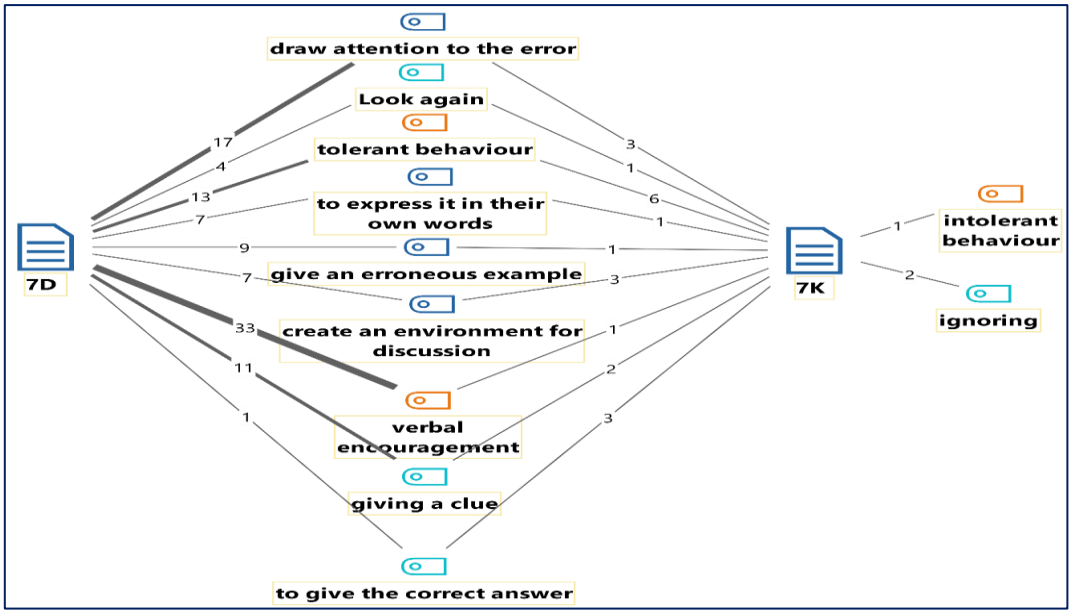


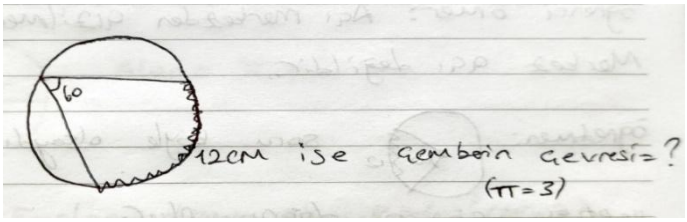
Figure 3 Comparison of 7th Graders under the Theme of Teacher's Error Orientation

When Figure 3 is examined, although there are common codes observed in both classes, the classes also have their own codes. Accordingly, under the category of handling of errors, the codes of create an environment for discussion, draw attention to the error, give an erroneous example and to express it in their own words were observed in both classes. While the intolerant behaviour code belonging to the attitude towards errors category was observed only once in the comparison group, the ignoring code belonging to the feedback on errors category was observed twice during the in-class observations in the comparison group.

In order to examine the error orientations of the students in the study and comparison groups, which is the fourth sub-problem of the research, content and descriptive analyses were applied on the lesson observation books. The themes of teacher's error orientation, student's error orientation and positive error climate process for the study groups were analysed. As an example, one lesson observation of the study and comparison classes is shared below, and the 15-week observation process was evaluated at the end according to the lesson observation notebooks of the classes. In the Table 4 below, a lesson observation of class 7D in the study group is presented.

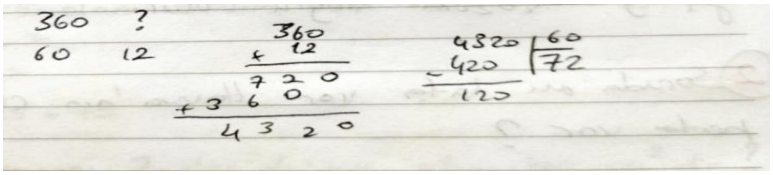
Table 4 Class 7D Lesson Observation

7D 12.05.2023



The teacher wrote a question on the board and asked the students to solve it. (The question asks for the perimeter of the circle).

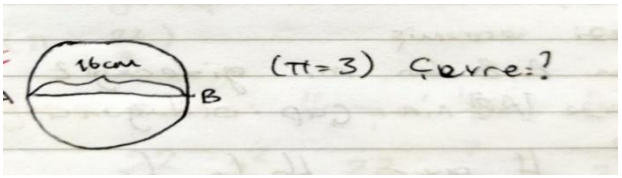
Teacher said "Don't be afraid to get on the board, don't be afraid of making mistakes. I want someone who has never came up before." Student N stood up and did the solution as follows.



When the teacher did not get any reaction from the class, he asked "What is the problem in this question?".

Student O: "Since the angle is not drawn from the centre, angle isn't a Central angle"

Teacher said "Well done" and drew the correct form of the question and said "Very good, if the question was like this, Student N's solution would be correct. Thank you Student N you have made us see a very good point."



The following example was written. The teacher waited for a while for the students to read and understand the question. (The question asks for the perimeter of the circle)

Student H: "we are given the diameter 16. To find the radius, we divide it by two. R=16, r=8, 2.πr=2.3.8=48"

After the solution, the teacher asked the class "Is there a mistake in the question or in the solution?".

Student N said, "We were not given a centre."

Student O said, "Teacher, do we go from A, B?"

Teacher: "Yes, well done. Did he say that [AB] is the diameter? The mistake is here. If we write [AB]diameter, the question would be corrected."

In class 7D, the teacher frequently encouraged students to participate in the lesson. Over time, the number of students who hesitated to participate in the lesson decreased. The teacher frequently used the feedback of drawing attention to the error and giving hints. It can be said that the error orientations of teachers and students in this class are positive and errors are actively used in the classroom. Similar situations were also observed in class 6D. In the study group classes, it was observed that participation in the lesson was very diverse throughout the semester and almost all students came up to the board for questions. It was observed that

while the students were timid at the beginning of the implementation, they participated more at the end of the term. In this case, it can be said that the error climate process in the study groups progressed as planned. Lesson observations of the comparison groups are given in the Table 5.

Table 5 Class 6K Lesson Observation

6K 27.03.2023
Teacher: Children, we continue where we left off. Let's solve some questions.
Question: If the arithmetic mean of the data group 5,8,12,20,a is 16, what is a?
Student K: Teacher 35
Student M said, "Teacher, it was 35".
Teacher: Student B, how did you do it?
Student B said "Because it is the arithmetic mean..." (the teacher intervened before the student finished his sentence).
Teacher: "What do we do first? We write the arithmetic mean formula." and did the solution himself/herself. “Mean=Sum of data/ Number of data, 16=SD/5=>80, 5+8+12+20+a=80=>. 80-45=35=a” (S/He waited 1-2 minutes to write the solution)
Question: Esra got 60-70-80 in maths. How many marks should she get in the 4th exam for her average grade to be 75?
Teacher: We can do it by using a formula, but we can also do it by balancing. The grades are balanced at what point. Several students answered at the same time and said 70.
Teacher: No, they said 75.
Student K said, "But my teacher's average is 70."
Teacher: Yes, but it becomes 75 with the 4th exam. Let's do it with the formula first to balance 75. He said and did the solution himself. M=SD./ND. => 75=SD/4 => SD.=300, 60+70+80=210, 300-210=90.

In class 6K, the teacher preferred to solve the questions himself/herself throughout the term. This attitude also prevented the emergence of an erroneous situation in the classroom. This situation, which was done with the possibility of students making mistakes, reduced the participation of the students in the lesson and even the students who wanted to participate in the lesson experienced distraction towards the end of the lesson. In this class, three hardworking students generally participated in the lesson and the others preferred to remain passive in the lesson. With this observation, it can be said that the error orientations of the students are sometimes neutral and sometimes negative.

As a result of the lesson observations, it can be said that the situation was similar in class 7K, another comparison group. In class 7K, although the teacher occasionally used behaviour to encourage the students, the participation in the lesson was limited to a few

hardworking students. In this class, the teacher sometimes used intentionally misleading questions to attract students' attention. However, since it was not a planned process, it was insufficient to create the desired effect on the students. The teacher was generally tolerant towards student errors. As a result of the findings, it can be said that the teacher's error orientation in this class was sometimes positive and sometimes neutral. However, it can be said that the error orientation of the students was neutral throughout the class. Although the students were not hesitant to stay for the lesson, indifference and passivity towards the lesson were observed throughout the semester. It can be said that this situation is caused by the teacher's sometimes positive and sometimes neutral attitude towards errors.

The fifth sub-problem of the research, which is to examine the views of the study group teachers and students on the positive error climate process, focus group interviews were conducted with students and semi-structured interviews were conducted with teachers. Content and descriptive analyses were applied to the interview data. Interview analyses were handled separately.

Focus group interviews were held with 16 students in the study groups at the end of the application. Students of the two groups were interviewed separately. The students' answers during the interview were coded with related words and the students' positive error climate process category was created under the theme of positive error climate process. The code created under this theme, frequency and some expressions selected from participant responses are presented in Table 6.

Table 6 Students' Positive Error Climate Process

Code	f	Participant statements
Didn't feel the change	3	I didn't feel any change. My teacher is normally like this (S1, 7D)
Self-confidence increase	4	Even if we make mistakes now, our teacher does not get angry with us. He makes an effort for us to learn. (S6, 6D)
Engagement in the lesson	5	I used to not want to take maths lessons, sometimes I would fake it for that reason. But after the beginning of this semester, I focused more on maths and now most of the questions are easier for me, so my maths is better now than before. (S2, 6D)
Pleasant-fun	4	I think it's more fun if the lesson is like this.(S8, 6D)
Permanent learning	4	This teaching method did not cause wrong learning. I think it was the opposite, the mistake remained in our minds and we made the right one. (S10, 7D)
A useful process	8	In this way, teaching is more useful (S2, 6D)
Learning from mistakes	8	The teacher used to see the mistake at first but left it and picked up another one. Now he says his mistake and expects us to correct him. (S8, 6D). Now we learn right from wrong. (S1,7D)

When Table 6 is analysed, it can be said that the positive error climate process changed students' error orientation positively. The students who stated that they experienced an increase in self-confidence during the process stated that they were more connected to the lesson and did not hesitate to make mistakes. Similarly, students stated that they experienced permanent learning and learnt from mistakes. Students defined the process as a pleasant, fun and useful process.

Teachers' error climate experiences and thoughts, whether they found this method effective or not, its strengths and weaknesses, and whether they wanted to use it again were asked using a semi-structured interview form. Teacher interviews were evaluated under the theme of positive error climate process. Below is the positive error climate process category of teachers created from the common and separate opinions of both classroom teachers.

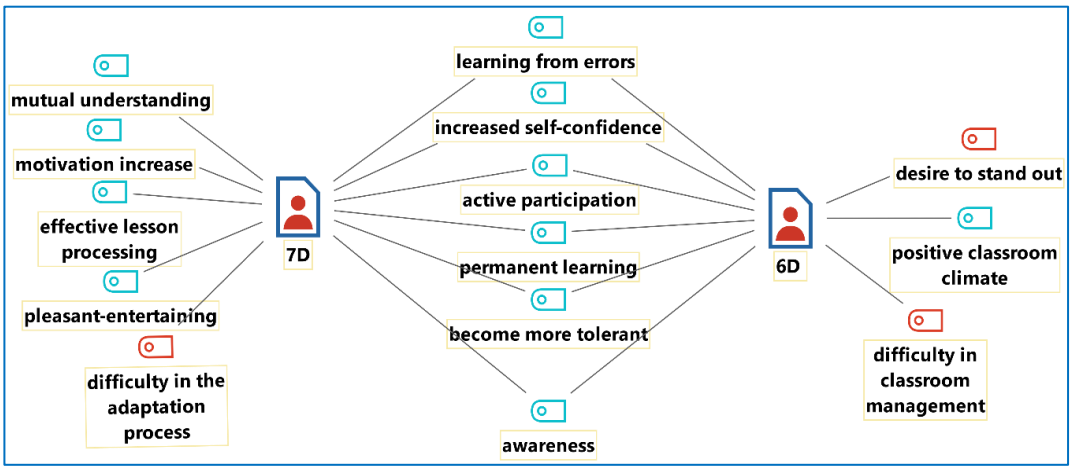


Figure 4 Teachers' Positive Error Climate Process

When Figure 4 is examined, the positive aspects of the process that teachers see in common are; increased self-confidence, learning from errors, active participation, awareness, become more tolerant, and permanent learning. While the 7D class teacher added the words "mutual understanding, motivation increase, effective lesson processing and pleasant" to these positive aspects, the 6D teacher added the expression "positive classroom climate" to these positive aspects. There was no common negative expression used by both teachers for the negative aspects of the process. While the 7D classroom teacher stated that he had difficulties in the implementation at the beginning, the 6D classroom teacher stated that the students' desire to stand out sometimes caused difficulties in classroom management. Both teachers stated that they would use the positive error climate in their classes in the future. From the data obtained as a result of the interviews with the teachers and the statements of the teachers,

it can be said that the error orientations of the teachers have changed positively and that they have seen this change in the students as well.

Discussion and Conclusion

It was observed that there was a positive and significant increase in the classroom error climate perceptions of the study groups due to the positive error climate, and that teachers and students emphasised the positive aspects of the process. At the same time, it was observed that the error orientations of the students in the study groups turned positive over time. Students stated that they participated more in mathematics lessons compared to the previous semesters and this was also determined through lesson observations. Students described the positive error climate process as useful, teaching from mistakes, helping permanent learning and developing self-confidence. Teachers stated that the process was beneficial for active participation, helped permanent learning and created awareness. It can be said that in classrooms where positive error climate is established, positive development and change are experienced in terms of both affective and cognitive aspects (Özkaya, 2015; Steuer et al., 2013; Soncini et al., 2021). The results in the study are similar to the literature at this point. In the studies, most of the teachers and students stated that they believe that making mistakes is an important part of the learning process (Özkaya, 2015; Palkki & Hastö, 2018). As a matter of fact, in Wasilewski's (2023) study, the belief in the instructiveness of errors was found to be 100% in teachers and 79% in students. However, teachers and students stated that errors may create affective barriers in the use of errors in the lesson. These barriers were also mentioned by the teachers before the current study and it was determined that they were concerned about the use of errors in the lesson. As a result of the findings, it can be said that prejudices and concerns are ungrounded.

When the qualitative and quantitative findings were evaluated together, the positive error orientations of the study group teachers changed their students' error orientations into positive ones. When the literature is examined, it is seen that the students of teachers with positive error orientation are more tolerant towards errors and do not hesitate to make mistakes (Heinze & Reiss, 2007; Tulis, 2013). This situation was also observed in the current study. While class participation was low in the study groups at the beginning, it was observed that there was more participation in the lesson at the end of the process and students gained self-confidence. One of the reasons for this situation can be said to be the corrective feedback given by the teachers. When the feedback types of the teachers in the study group are examined, it can be said that mostly adaptive feedback are used (Soncini et al., 2021; Tulis et

al., 2018). Huelser and Metcalfe (2012) emphasised the importance of corrective feedback and stated that it serves to remember more than giving ready answers at the point of reaching the correct answers. The emergence of permanent learning code in the interviews with teachers and students also supports this situation. Qualitative findings revealed that teachers in the study groups used corrective feedback more than teachers in the comparison groups. With feedback and correct guidance, individuals not only reach the correct answer, but also their ability to analyse and explain increases. In this way, they start to question and the amount of learning from errors increases (Metcalfe, 2017). Corrective feedback, which is one of the sub-items of the "positive error climate framework programme", was frequently used by the study group teachers and was found to have positive effects on students.

During the process, it was observed that the teachers in the comparison groups prevented the emergence of errors. Teachers showed direct intervention behaviour to prevent erroneous learning and to ensure the continuation of the lesson. This finding coincides with the finding in the literature that direct intervention is one of the ways to prevent errors from occurring (Özkaya, 2015; Santagata, 2005). Although the comparison group teachers stated that they gained awareness and experience by accepting the role of errors in teaching, it can be said that the feedback they used was aimed at preventing errors rather than using errors. According to Tulis (2013), the feedback used by teachers are maladaptive error correction feedbacks. Although teachers exhibit positive error correction behaviours from time to time in the process, it is seen from the findings that this is not sufficient to create a positive error climate. At the same time, the fact that there is no significant change in CECS pre-test and post-test findings of the comparison groups supports this conclusion.

Research shows that some teachers believe that if more attention is paid to students' mistakes, students will be embarrassed and confused by the spread of their mistakes in the classroom (Bray, 2011; Wasilewski; 2023). However, research has also shown that students in more reliable and supportive error environments can learn from mistakes more easily (Soncini et al., 2021). At the same time, it has been observed that learning from errors increases students' success (Heinze & Reiss, 2007; Steuer et al., 2015) and their interest in the course by providing motivation to students (Borasi, 1988; Özkaya et al., 2022). As a result, it can be said that the positive error climate does not interrupt the lecture and waste time, on the contrary, it provides permanent learning.

In this study, it is seen in the qualitative findings that the comparison group teachers sometimes wanted to use errors as a teaching tool in the lesson. Teachers sometimes

supported this situation with their tolerant attitudes. However, as a result of both qualitative and quantitative findings, it can be said that this situation did not have the desired and expected effect on students. Likewise, when the study group teachers first started the intervention programme, it was observed that the students did not have the expected change in error orientation and that their error orientations turned positive over time. In this case, it can be said that the error climate should be implemented in a planned manner. As a result of qualitative and quantitative data, it can be said that the positive error climate led to a positive change in the error orientations of the study group students. However, it can be seen from the observation findings that the emergence of this situation is a matter of process. The change in the teacher's error orientation caused the student's error orientation to change. However, it is important that the process is implemented effectively.

Suggestions

In the study, it was seen that the use of the "Positive Error Climate Framework Program" in mathematics lessons at two different grade levels yielded positive results. Accordingly, the use of "Positive Error Climate Framework Programme" in other grade levels and courses can be the subject of future research.

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Compliance with Ethical Standards

Disclosure of potential conflicts of interest

Authors declare that they have no competing interest.

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CRediT author statement

The researchers took full responsibility for the research.

Research involving Human Participants and/or Animals

The research was approved by Atatürk University Social and Human Sciences Ethics Committee dated 10.12.2021, meeting number 13, decision number 12.

Matematik Öğretiminde Olumlu Hata İkliminin Karma Yöntem ile Araştırılması

Özet:

Çalışmanın amacı, matematik derslerinde "olumlu hata iklimi çerçeve programına" göre oluşturulan sınıf ikliminin öğretmen ve öğrencilerin hata yönelimlerine etkilerini incelemektir. Karma yöntem desenlerinden müdahale deseni kullanılan araştırmanın verileri, amaçlı örneklem ile seçilmiş dört sınıf (iki çalışma ve iki karşılaştırma sınıfı), bu sınıflarda öğrenim gören 145 öğrenci ve dört matematik öğretmeninden toplanmıştır. Araştırmada "Sınıf Hata İklimi Ölçeği" (SHİÖ), ders gözlem formu ve defteri, yarı yapılandırılmış öğretmen ve öğrenci görüşme formu kullanılmıştır. On beş hafta süren araştırma sonunda çalışma gruplarında yer alan öğretmen ve öğrenciler ile görüşmeler yapılmıştır. T-testi sonucuna göre çalışma gruplarında karşılaştırma gruplarına göre algılanan sınıf hata ikliminde olumlu ve anlamlı bir değişim gözlemlenmiştir. Nitel veri analizlerinde çalışma grubu öğretmenlerinin ve öğrencilerinin hata yönelimlerinin karşılaştırma grubuna göre daha olumlu olduğu görülmüştür. Öğretmen ve öğrenciler, olumlu hata ikliminin doğru bilgiyi daha iyi kavrattığını, derse katılım ve özgüveni artırdığını ve kalıcı öğrenmeye yardımcı olduğunu belirtmiştir.

Anahtar kelimeler: Hata yönelimi, kalıcı öğrenme, karma yöntem, matematik öğretimi, olumlu hata iklimi.

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Appendix 1

Positive Error Climate Framework Program

1. The teacher expresses her/his tolerance towards mistakes verbally and in behavior.
The feedback that can be given as follows:
Verbal feedback

- Answer even if you think you are wrong.
- Errors are ways that are not right, the m ore wrong ways we eliminate, the better.
- All mistakes are ways that will bring us closer to the truth.
- You are a student, of course you will make mistakes to find the truth, do not hesitate.
- Do not think that I will be angry with you if you make a mistake.
- You are all classmates, let's try to learn a lesson instead of laughing or getting angry at wrong answers.

Behavioral feedback

- S/he encourages students with low attendance and who are behind the class academically to get up and respond to the lesson.
- S/he encourages the student, who is hesitant and does not want to get up, to participate in the lesson and encourages them to respond.
- S/he asks students to answer even if they are wrong.
- S/he asks the students who make mistakes why they think that way without getting angry.
- Be tolerant towards student mistakes.

2. The teacher is tolerant of the student who makes an error or gives an incorrect answer, thanks him/her for the error s/he finds and turns students' attention to that error.
***The feedback that can be given as follows*:**

- Why did you think like that?
- Shall we think together?
- Your friend has mentioned a very good mistake, let's be careful about it.
- Thanks for your friend's reply.
- Well done, you have caught a very important point -to class- do you think your friend's answer is correct?
- If it's wrong, let's think about why it's wrong.
- You gave a very good answer. Thank you.

3. Instead of giving the answer directly, the teacher gives clues to the students. Discusses the given answers in class. Draws students' attention to the given answer.
The feedback on this issue is as follows.

- S/he does not directly say that the mistake made is wrong. Or s/he does not give the correct answer directly to the student.
- S/he asks questions that will help the student find the right answer.
- S/he draws the attention of the students in the class to the mistake made.
- S/he involves the whole class in the process.
- S/he explains the importance of the mistake made by the student.
- S/he gives corrective feedback to the student.
- S/he discusses the student's mistake in class.
- S/he allows students who gave wrong answers to express the correct answer in their own words.

4. The teacher encourages the student, who is shy and does not want to attend to lesson. S/he enables them to participate in the lesson and promotes them to respond.
The feedback that can be given as follows:

- It does not directly say that the answer given is wrong.
- Asks the students why they gave such an answer.

• Asks the class for the student's answer. • Makes the students think about their errors. • S/he thanks the student for the point s/he caught.
5. After the teacher decides that s/he has solved enough examples at the end of the subject, he gives an incorrect statement about the subject or makes an incorrect solution and waits for the students to catch the mistake. Ask students to express both the incorrect statement/solution and the correct statement/solution in their own sentences. ***The feedback that can be given as follows:*** • Let's examine the given statement/solution/question. • Do you think it is true? • If it's wrong, why is it wrong. • If true, why is it true?
6. At the end of the subject, the teacher exams the students, the exam is not for scoring. Puts an erroneous example in the exam. At the end of the exam, he/she solves the questions in detail in the class.

Appendix 2

CECS Sub-Dimensions and Representative Items

Sub-Dimensions	Representative Items
1. Irrelevance of errors for assessment	If someone in our Math class makes a mistake, he will get a bad grade.
2. Teacher support following errors	If someone in our Math class can't solve an exercise correctly,the teacher will help him.
3. Absence of negative teacher reactions to errors	If someone in our Math class says something wrong, sometimes the teacher will embarrass him in front of the entire class. If someone in our Math class solves an assignment incorrectly, once in a while the teacher will become angry.
4. Absence of negative classmate reactions to errors	If someone in our Math class makes mistakes, his classmates will sometimes make fun of him.
5. Taking the error risk	In our Math class a lot of students would rather say nothing at all than something that is wrong
6. Analysis of errors	In our Math class we discuss it in detail when something is done incorrectly.
7.Functionality of errors for learning	In our Math class we learn a lot from assignments that were not done correctly.

Appendix 3

Observation Form

(Write if the situation is observed, write if the opposite situation is observed)
Date: **Teacher:** **Lesson time:**

- The teacher verbally expresses tolerance towards mistakes.
- The teacher expresses his/her tolerance towards mistakes in behaviour.
- The teacher is tolerant to the students who make mistakes or give wrong answers.
- The teacher thanks the student for making a mistake or giving the wrong answer.
- The teacher draws the attention of the class to the error. The teacher discusses the answers given in the class.
- The teacher gives hints to the students instead of giving the answer directly.
- The teacher draws the attention of the students to the given answer.
- The teacher encourages the students who do not want to participate in the lesson.
- After the teacher decides that he/she has solved enough examples at the end of the subject, he/she gives an incorrect statement or makes an incorrect solution related to the subject and waits for the students to catch the error.
- The teacher asks the students to express both the incorrect statement/solution and the correct statement/solution in their own words.
- At the end of the subject, the teacher gives an evaluation exam to the students and puts an incorrect example in the exam.
- At the end of the exam, the questions are solved in detail in the classroom

Appendix 4

Example of a lesson plan

Course	Mathematics
Learning area	Ratio-proportion
Acquisitions	Solves problems related to direct and reciprocal proportion.
Academic and Social Skills	Reasoning, association, communication, Developing a positive attitude towards mathematics, creating a sense of curiosity, critical thinking,
Teaching Methods and Techniques	Investigation, active learning, question and answer, problem solving and discussion
Teaching practices	Positive Error Climate Framework Programme
Material	7th grade textbook, Smart board

Teaching and Learning Process

The teacher explains the relevant topic.

- ✓ The questions in the course materials are solved and the points that are not understood are explained again through the questions.

The teacher creates a positive error climate in the classroom.

- ✓ Encourages students with low attendance to attend the lesson.
- ✓ Gives clues to student errors s and makes them realise the errors.
- ✓ Discusses student errors in the classroom.
- ✓ Does not say any mistake is directly wrong.
- ✓ Gives appropriate time for the student to answer. It allows them to remember with clues.
- ✓ It makes the students rephrase the correct answer with their own sentences.
- ✓ Thank the student for his/her answer (it does not matter right or wrong).

Erroneous question use

The teacher utilises the teaching potential of errors. For this purpose, at the end of the subject, after solving enough examples, he/she uses questions containing erroneous expressions. The teacher asks the students to read the problem and think about the solution. He/she waits for the students to notice the incorrect expression. If the error is not noticed in the class, he/she ensures that the students notice it by using clues. The teacher evaluates these questions again in the class.

Examples of erroneous questions that can be used for the related subject

Question: The older of the two brothers who receive allowance in proportion to their ages is 15 years old and receives 100 TL. Since the younger brother receives 150 tl, what is his age?

Evaluation: The question is a direct proportion question and the first expectation here is that as the age increases, the allowance they will receive should increase. The student is expected to analyse the question through a logic filter before proceeding to the solution. Here, the teacher is expected to be patient and direct the students to the correct answer by giving hints instead of giving the answer directly.

Question: In a garden with 8 apricot trees and 17 apple trees, the ratio of the number of all fruit trees to the number of apple trees is 17/25.

Evaluation: Although the question seems correct as a solution, it is incorrect because we do not know the number of all trees in the garden. The number of all trees should be given in the question.