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# The effect of positive error climate on affective domains in mathematics teaching

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**Keywords:**
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**Abstract:** The aim of this study is to investigate the effect of positive error climate in classrooms on middle school students' error orientations and attitudes towards mathematics. The data of the research were collected in the 2021-2022 academic year. The participants of the study consisted of 44 students in two 6th grade classes in a middle school in the city of Van, Türkiye. Quasi-experimental design was used in the research and the pre and post scores of the experimental and comparison groups were compared before and after the study. The data obtained using the "Mathematics Attitude Scale" and the "Error Climate Scale" were analyzed to examine the differences within and between groups. As a result of the findings, it was seen that the positive error climate in the experimental group made a positive significant difference both on the attitude towards mathematics and on error orientations of the students. No significant change was observed at the end of the study in the comparison group in which a neutral error climate was applied. The interviews with the course teacher who carried out the application and the observations made in the classroom reinforced the positive effect of the application. Positive error climate can be seen as a part of formative assessment as it has a corrective effect on teaching in the process.

## 1. INTRODUCTION

The classroom is the main environment where learning and teaching activities take place while each class has its own classroom climate that changes depending on the in-class variables. Classroom climate can be defined as consisting of mutual relations and communication between teachers and students (Akınoğlu, 2004; Kalaç & Özkaya, 2021). Similarly, in the classroom, the class has its own attitudes, behaviors, and perceptions towards errors. This situation, called the error climate, is likely to turn into a positive error climate in the classrooms where errors are considered as an integral part of the learning process (O'Dell, 2015; Stuer et al., 2013). In the related literature, it has been found that error-based learning studies applied in classrooms

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generally give positive results in affective terms on students and teachers (Akkuşçi, 2019; Gedik, 2014; Heinze & Reiss, 2007; O'Dell, 2015; Özkaya, 2015; Soncini et al., 2021).

In order to increase the quality of learning that will take place in the classroom, teachers are expected to catch all kinds of clues that occur in students and give the most appropriate feedback (National Council of Teachers of Mathematics [NCTM], 2000). This is possible by correctly evaluating the changes in student behavior while in-class assessments being an important part of the teaching process. Such evaluations not only show the teachers what the students have learned in the lesson, but also provide feedback that shows whether the program applied functions effectively or not. Instead of ignoring errors and failures, accepting them and including them in the education process are integral parts of the evaluation process (McMillan, 2015).

Students' perceptions of the classroom assessment atmosphere are a significant predictor of their attitudes towards school (İlhan, 2017). While a positive classroom climate affects students' attitudes towards school, according to Kohen (2006), positive classroom climates are more effective on student success and performance than a negative classroom climate. A positive climate in the classroom also positively affects the quality of learning. The way to create a positive classroom climate is to use errors in the classroom. The purpose of the error in the classroom varies as Heinze (2005) states that errors can be used as teaching tools. Likewise, errors can act as a springboard in education, revealing some hidden points in teaching and contributing to teaching (Borasi, 1986; 1994). Borasi (1988) stated that in the practices she made with her students by using professional mistakes, the students gained benefits in the field of mathematics by understanding and perceiving the nature of mathematics.

Many studies dealing with errors have been related to mathematics courses (Borasi, 1988; Bray & Santagata, 2013; Heinze & Reiss, 2007; Özkaya, 2015; Palkki & Hastö, 2018; Rach et al, 2013). While the mathematics lesson is seen as a difficult lesson for which students develop negative attitudes since primary education, it is also seen by teachers as a lesson difficult to teach as students have a low interest in such a lesson (Avcı et al., 2011; Öcalan, 2004). Furthermore, not only students but also teachers have different attitudes towards mathematics. According to Trisha (1999), teachers' attitudes towards mathematics can also affect students. Attitude is a learned tendency to react positively or negatively to a particular object, situation, institution, concept, or other person (Tezbaşaran, 1997). The results of the teacher's attitude towards mathematics and the results of the attitude towards errors show similarities. As a matter of fact, the attitudes of the students towards errors in the classroom are determined by the attitude of the teacher towards errors. It has been observed that the same attitude develops in students in studies where the teacher is moderate towards errors and sees them as learning opportunities (Borasi, 1988; Bray, 2011; Heinze & Reiss, 2007; Tulis, 2013). On the contrary, a strict teacher's attitude towards errors reduces the possibility of learning from errors (Oser & Spychiger, 2005). Showing students how to improve their learning by using errors in the learning process is one of the components that increase student motivation (McMillan & Workman, 1998).

It is also important to note that there used to be a negative view of errors in teaching. This understanding of error, which was accepted before the constructivist approach, was also used in mathematics teaching. According to this understanding, error is a situation that should be avoided. However, errors are an important tool used to identify students' learning difficulties and provide important information about students' thinking processes (Baştürk, 2014; Borasi, 1996). In addition to this diagnostic feature of errors, errors can be turned into an opportunity in the classroom (Guzmán-Muñoz et al., 2009).

Error in mathematics teaching is the misuse and conclusion of mathematical expressions and ideas (Erbaş et al., 2010). From another perspective Borasi (1988) describes the use of errors in teaching as a springboard. According to Borasi (1988), errors save students from regarding mathematics as unnecessary and allow teachers to use errors as a teaching tool in the curriculum. Borasi (1988) also stated that errors in teaching are not adequately examined, and with her work, she showed that the conscious use of errors in teaching enriches teaching since students not only have the opportunity to learn mathematical concepts more deeply, but also increase their interest and curiosity towards mathematics (Borasi, 1986; 1989). In this way, in classroom atmospheres where a positive error climate is created, both students and teachers have a positive perception of errors. Students not afraid of making errors can turn this situation into a positive one (Guzmán-Muñoz et al., 2009; Heinze, 2005; Heinze & Reiss, 2007).

The effect of using errors in teaching on secondary and high school students was investigated by Heinze and Reiss (2007) and their study showed that although there was no cognitive difference between the two groups, it was determined that the students in the experimental group were positively affected. Akkuşçi (2019) obtained similar results in his study and found that there was an increase in students' critical thinking skills although he did not find a difference between the academic achievements of the students in the quasi-experimental stage of his study. Error-based practices had positive effects not only on students but also on teachers. In Gedik's (2014) and Özkaya's (2015) studies, it was also found that the affective effects of the error practices in the classroom were more than the cognitive effects on the teachers, and that these practices provided the teachers with the ability to conduct research and critical thinking affectively. In the study of Oser and Spychiger (2005), it was seen that students were affected by their teachers in their attitudes towards errors as the teacher's view and attitude towards errors cause the student to have the same point of view.

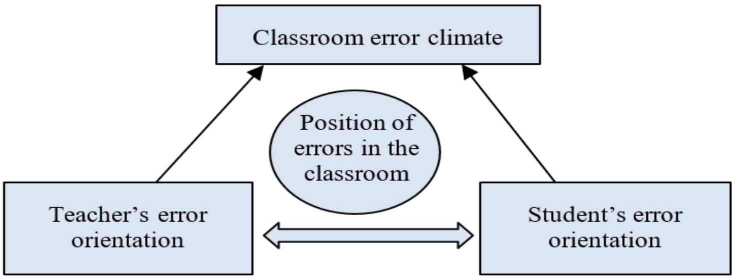
In their quasi-experimental study with middle and high school students Rach et al. (2013) found similar results like those in Heinze and Reiss's (2007) study. Rach et al. (2013) investigated students' attitudes towards errors and also whether students saw errors as an opportunity for learning. In their research, it was observed that the students in the experimental group were more courageous in making errors than the control group were although there was no significant difference between the two groups in terms of student attitude towards errors. It has been observed that while students are dealing with errors, learning processes are positively supported in a learning atmosphere that is moderate against errors. According to Rach et al. (2013) understanding of errors is necessary to distinguish between right processes or phenomena and wrong environment.

For errors to be effective in teaching, corrective feedback must be followed. Huelser and Metcalfe (2012) stated that generating an error serves more reminder than presenting the answer at the point of reaching correct answers, as long as it follows corrective feedback. With feedback, individuals not only get the right answer, but also increase their analysis and explanation abilities, thus in this way, the amount of learning from errors increases (Metcalfe, 2017). Accordingly, a positive classroom error climate is observed in environments where corrective and remedial feedback is given to errors.

Classroom error climate means how errors are used and evaluated in the classroom (O'Dell, 2015; Steuer et al., 2013). A positive error climate is observed in classroom atmospheres where errors are used as a part of the learning process in the classroom and errors are viewed positively. In such an atmosphere students can realize their misconceptions and start their learning process. These arrangements within the classroom express a positive culture of error (O'Dell, 2015; Oser & Spychiger, 2005). The classroom error climate is determined by the attitudes, behaviors, and perceptions of teachers and students towards errors.

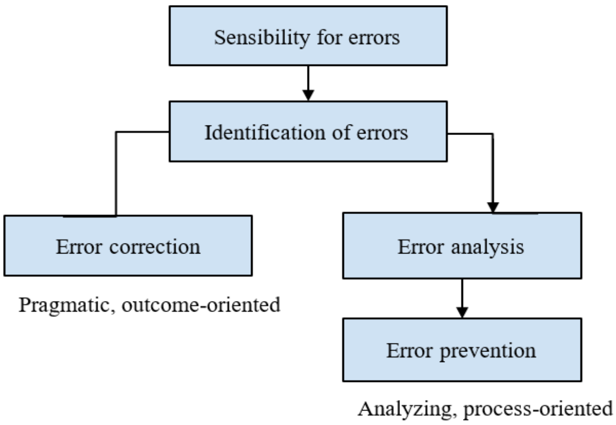
Error orientation refers to the way teachers understand, react, and use student errors in learning (O'Dell, 2015). Considering error orientation as part of the classroom error climate it can also be defined as the attitude of teachers and students towards errors, whether to use errors actively in the learning environment or not, the attitude towards making errors, and the accompanying behaviors (Kalaç & Özkaya, 2021). According to O'Dell (2015), a positive error orientation, which sees errors as learning opportunities rather than punishments, reduces negative academic motivation and can help improve students' perceptions, self-efficacy, and future goals. The classroom error climate is modeled in Figure 1.

**Figure 1.** *Components of the classroom error climate (Kalac & Ozkaya, 2021).*




There are two ways to evaluate errors in the classroom, one of which is result-based aimed at correcting errors directly and the other is process-based including analyzing errors and preventing error precaution. According to Heinze (2005), teachers look at errors negatively because they disrupt the process in the classroom and mostly refer to direct intervention to errors made in the classroom. In the related studies, it is seen that there is mostly teacher intervention to the errors and the answer is given directly to the student (Son, 2013; Son & Sinclair, 2010). Rach et al. (2013) modeled the role of errors in the learning process as in Figure 2.

**Figure 2.** *Model of the role of errors in the learning process.*




There are eight dimensions of the classroom error climate in the "Perceived Error Climate Scale" created by Steuer et al. (2013). One of the dimensions of the perceived error climate in the classroom is error tolerance by teacher. Cultural beliefs and teaching practices shape teachers' reactions to errors (Santagata, 2004). Another dimension is irrelevance errors to assessment, which is about whether student errors adversely affect their performance and grade evaluation. Teacher support following errors made in the classroom is also an important dimension. This sub-dimension expresses the teacher's patience, explanations, and assistance in the face of student mistakes. When the studies involving interventional approaches to errors are examined, it has been observed that most of the errors made are not ignored (Didiş et al., 2016; Didiş-Kabar & Amaç, 2018; Son, 2013; Türkdoğan & Baki, 2012). Analyzing the data they obtained from 44 pre-service teachers through teaching scenarios, Didiş-Kabar and Amaç (2018) revealed that pre-service teachers had interventions such as recognizing the error, explaining the question, and lecturing. Analysis of errors and functionality of errors for learning sub-dimensions express how errors are handled in the classroom and their status in learning processes. The sub-dimensions of Absence of negative classmate reactions to errors and Absence of negative teacher reactions to errors refer to verbal and nonverbal reactions to student mistakes. Taking the error risk, the other sub-dimension of the classroom error climate, expresses the student's courage to make errors without being sure of her answer. According to Steuer et al. (2013), although the sub-dimensions of the perceived error climate are distinguishable, they are closely related sub-dimensions.

Discussing the errors made in the classroom and using them in teaching constitute an important part of the classroom error climate (Steuer et al., 2013). This way of teaching positively affects student achievement (Barbieri & Booth, 2020; Heinze & Reiss, 2007; Rittle-Johnson & Star, 2009; Yıldırım, 2019) as if the error climate in the classroom is transformed into a positive one, students' perceptions of coping with their errors in a reliable and supportive learning environment will increase (Soncini et al., 2021).

Students operate a verbal or nonverbal reasoning process in the lessons. One of the courses in which reasoning processes are most intense is mathematics. Students can make errors and these errors often put the student in a negative situation. It is thought that turning this situation into a positive one can contribute both cognitively and affectively to the students in many courses, especially in mathematics. In order to reveal whether this mentioned purpose can be realized or not, decimal notation has been chosen. Although the learning outcomes of decimal notation are seen in the fifth and sixth grades in the curriculum, this subject is related to most concepts in mathematics (for example percentages, rational numbers, length, and liquid measures). Apart from its importance, students have difficulty in understanding decimal notation and they make a lot of errors (Haser & Ubuz, 2000; Kaya, 2015; Yenil, 2020). Using errors in the mathematics teaching process within the framework of a planned learning process can create a positive error climate in the classroom. It is thought that a positive error climate may also affect attitude, which is another affective condition such as motivation. In this context, the aim of this specific research is to reveal the effect of the positive error climate in mathematics lessons on students' error orientations and attitudes towards mathematics.

To this end, the problem statement of the research is "Does the positive error climate created in mathematics lessons make a significant difference in students' error orientations and attitudes towards mathematics?" The research questions generated for this problem statement are as follows:

- Does the positive error climate created in the classroom make a significant difference on students' error orientations?
- Does the positive error climate created in the classroom make a significant difference on students' attitudes towards mathematics?
- What are the changes observed in students in the classroom where the positive error climate is created?
- What are the views of the teacher who performed the application in the process?

## 2. METHOD

In the research, a quasi-experimental design with nonequivalent pretest-posttest comparison group from quantitative approaches was decided as a research method in order to compare a positive error climate against a neutral error climate and examine the effects of a positive error climate. The quasi-experimental design is one of the research designs used to explore cause-effect relationships between variables. In this design, the groups available are randomly assigned as comparison and experimental groups. Designs with nonequivalent pretest-posttest comparison groups assign the groups randomly because it is not possible to randomly assign the participants and such designs are widely used in the field of education (Fraenkel et al., 2012; McMillan & Schumacher, 2010).

## 2.1. Participants

The participants of the research consisted of two 6th grade classes and 44 students studying in those classes in a middle school in Van, Türkiye in the 2021-2022 academic year and they were selected by purposive sampling. Purposive sampling occurs when the researcher makes a judgment about which participants should be selected in order to provide the best information that will serve his/her purpose (McMillan & Schumacher, 2010). The 6A class was assigned as the experiment and the 6B class as the comparison group by random assignment. The distribution of the samples by group and gender is given in Table 1.

**Table 1.** *Distribution of students in the sample by group and gender.*

| Groups | Gender | | Total |
|---|---|---|---|
| | Female | Male | |
| Experimental Group | 9 | 11 | 20 |
| Comparison Group | 9 | 15 | 24 |
| Total | 18 | 26 | 44 |

It is known that these groups had similar success averages according to the mathematics score averages found the previous year. Neither of the groups learned in a positive error climate before the application. On the other hand, when the situation of the students in the sample of the research is evaluated in terms of socio-economic status, it is known that the students came from families with a medium socio-economic status. Students were coded S1, S2…, S44. The mathematics teacher who performed the application throughout the process had ten years of experience at the time of data collection and taught at every grade level.

## 2.2. Data Collection Tools

In the research, "Error Climate Scale", "Mathematics Attitude Scale", in-class observations, and interview forms were used.

### 2.2.1. *Error climate scale (ECS)*

This scale was developed to measure the perceived error climate in the classroom by Steuer et al. (2013). The scale is a 5-point Likert type scale, where 1 indicates that participants strongly disagree with the statement, while 5 indicates strongly agree. It was adapted into Turkish by Kalaç et al. (2022). As a result of the adaptation study of the classroom ECS, the scale consisted of 27 items and 7 factors for the Turkish sample; namely, A1; Irrelevance of errors for assessment, A2; Teacher support after errors, A3; Absence of negative teacher reactions to errors, A4; Absence of negative classmate reactions to errors, A5; Taking error risks, A6; Analysis of errors, A7; Functionality of errors for learning. While the Cronbach Alpha internal consistency value was .86 for the general scale, it was found between .73 and .89 for the sub-factors. The answers given by the students to the items are scored between 1 and 5 and the error orientation score of the student is determined. With the data obtained from the students before the application, the Cronbach Alpha reliability coefficient for the ECS was found to be .81.

### 2.2.2. *Mathematics attitude scale (MAS)*

The scale was prepared by Önal (2013) to measure the mathematics attitudes of middle school students. Validity and reliability studies of the scale consisting of 22 items and 4 sub-dimensions (B1: interest, B2: anxiety, B3: necessity, B4: study) were conducted. The internal consistency coefficient for the whole scale was found to be .90. The internal consistency coefficient of the factors that form the scale varied between .69 and .89. The answers given by the students to the items were scored between 1 and 5 so that the student's mathematics attitude scores could be determined. With the data obtained from the students before the application, the Cronbach Alpha reliability coefficient for the MAS was found to be .83.

### 2.2.3. *Observation and interview*

Teaching was carried out in the classroom under the guidance of the Positive Error Climate Framework program. Observations and interviews as data collections methods were used to illustrate the situation in the classroom. Thus, the findings obtained from the MAS and ECS were also supported. In the experimental group, an observation form was prepared to follow the process of the activities prepared with the teacher within the scope of the Positive Error Climate Framework program. With this form, which was prepared as unstructured, the important points about the errors in the classroom were recorded. During the process, an interview was held to reveal the teacher's thoughts on the positive error climate. The interview questions prepared were examined by two researchers as experts in their fields. With the common opinions of these experts, the interview questions took their final form.

In the pre-interview and post-interview, the teacher was asked such questions as "What is your view on students' errors?", "What do you think about using error examples in the lesson?", "What is the situation of students' fear of making mistakes in the lesson?", "If you evaluate the two classes together, is there a difference between the error orientations? If so, what is the relationship?", "How is the error tolerance of the students towards each other?" Thus, the teacher's views on the change in the process were also taken.

## 2.3. Data Analysis

As a result of the application, there may be differences in the pre-test and post-test scale scores within and between the groups. In order to decide the significance of this difference, the paired t-test among the parametric tests and the independent sample t-test between groups were used. While the paired-sample t-test is used to decide whether the mean score difference that may occur within the group is significant or not, the independent sample t-test is used to decide whether the difference between the means of two independent groups is significant or not. Both tests are expected to satisfy the assumption of normal distribution. Otherwise, non-parametric equivalents of these tests, Wilcoxon test and Mann-Whitney U test can be used (Büyüköztürk, 2020; Özdamar, 2018). Likewise, these tests were used in the sub-dimensions of the scales, depending on the condition of providing the assumption of normal distribution. In order to control the assumption of normality, Shapiro-Wilk normality analysis and skewness- kurtosis values of the data were examined according to the groups to be compared.

ECS and MAS were applied to both classes before and after the application. The scores obtained from the ECS were evaluated as error orientation scores, and the scores obtained from the MAS were evaluated as mathematics attitude scores. Negatively worded items were reverse coded before the analysis. While calculating the total scale scores, the scores given by the participants to each item were added. While calculating the scores in the sub-factors, the scores in the items related to each sub-factor were summed and the total factor scores were calculated, and the analyzes were made on these scores. Paired sample t-test and Wilcoxon signed-rank analysis, which is the nonparametric equivalent of this test, were used to understand whether the differences within the group were significant or not. In order to understand whether the differences between the groups were significant, the independent sample t-test and Mann Whitney U test, which is the nonparametric equivalent of this test, were used. To calculate the effect size (d) of the differences found to be significant in the paired t-test analyses, the t value obtained was calculated by dividing the square root of the total number of participants. To calculate the effect size (d) of the differences found to be significant in the paired t-test analyses, the t value obtained was calculated by dividing the square root of the total number of participants. Likewise, the *z*-value obtained was divided by the square root of the total number of the participants in order to calculate the effect size (*d*) of the differences found to be significant in the Wilcoxon Signed Rank Test analysis. The effect size found (*d*) .2, .5 and .8 are interpreted as small, medium and large effects, respectively (Büyüköztürk, 2020; Cohen, 1988; Özdamar, 2018).

The data obtained from the observations and interviews were analyzed descriptively. Descriptive analysis details the obtained data by quoting directly. By reducing the data, it allows the subject to be presented and defined in a regular way (Ekiz, 2009).

### 2.4. Description of the Learning Environment on Positive Error Climate in the Classroom

In our study, a Positive Error Climate Framework program was prepared by associating the framework program suggested by Bray (2011) with the classroom error climate components of Steuer et al. (2013). In the research, it has been determined that although teachers look at mistakes positively, they are hesitant at the point of use in the classroom, and it has been revealed that teachers do not know how to use mistakes as an opportunity to teach (Özkaya & Konyalıoğlu, 2019; Palkki & Hastö, 2018). Bray (2011) presents a framework program that details how lessons are designed and implemented in order to take advantage of the teaching potential of errors in mathematics education. The program steps are given as follows:

i. Choosing mathematical tasks for their potential to elicit students' misunderstandings.
ii. Planning lessons by evaluating how mistakes can be used to improve students' mathematical understanding.
iii. Developing a plan for including mistakes in class discussions.
iv. Involving all students in the class to analyze and review errors so that students are elucidated on fundamental mathematical concepts.

In order to use this framework program suggested by Bray (2011), first of all, teachers should know the error climate of the classroom and be willing to turn it into a positive one.

In the research conducted using a quasi-experimental design, one of the classes was assigned as the experimental group and the other as the comparison group with purposive sampling. During the study, which lasted for six weeks and twelve hours, the class selected as the comparison group was given the learning outcomes-based instruction in mathematics lessons during the research. In the class assigned as the experimental group, the lessons were taught by creating a positive error climate in the classroom in addition to learning outcomes-based instruction.

The teacher who would carry out the application was informed about how to create a positive error climate in the classroom. The Positive Error Climate Framework plan was made together with the teacher. In this plan, it was stated how the teacher should give feedback to the errors, how she would motivate the students, and also how she would carry out the process. “The Positive Error Climate Framework” plan is given in Appendix at the end of the article. An interview was held with the course teacher about the error orientations of the classes. ECS and MAS pre-tests were applied to both groups before the application. In-class observations were used to observe the progress of the process.

A positive error climate activity was held every week in the classroom where a positive error climate was created. The teacher encouraged the students who did not attend the lessons and obtained answers from them about the question/subject. The answers of the students were discussed in the class and the teacher gave feedback to the students who gave wrong answers such as" Why did you think that way, let's think about the answer together, well done, you caught a very good point, you have revealed a general error made on this subject, thank you..." in order to motivate the students. During the lesson, the teacher tried to show the students that she was tolerant of errors with her actions and words.

At the end of the subject, the teacher added incorrect questions/phrases to the evaluation exam. Students were asked to write why the statements they thought were errors. The teacher solved the evaluation questions in the classroom with the students. Those students who did not want to go to the blackboard in the classroom and who were behind the class academically in mathematics lessons were encouraged to attend the lesson. At the end of each answer, the teacher asked the students to explain their answers and ECS and MAS were applied to both groups again as a post-test. The course teacher was interviewed about the process, as well.

## 3. RESULTS

In this section, first the pre-test, post-test ECS, and MAS analyzes of the experimental and comparison groups are given, and then, one of the observations made in the classroom and the teacher's views are presented.

### 3.1. Analysis of the ECS and MAS

Both the whole scale and the sub-factors were examined separately to see whether the changes in the pre-test and post-test scores in the ECS and MAS made a significant difference. Table 2 shows the statistics of the difference in the total scores of the groups in the ECS and MAS and the results of the Shapiro-Wilk normality test.

**Table 2.** *Group statistics and Shapiro-Wilk normality test.*

| Groups | Scales | *N* | *D* | *SD* | SC | KC | *p* |
|---|---|---|---|---|---|---|---|
| Experimental | ECS | 20 | 11.10 | 12.22 | -.834 | -.278 | .038 |
| | MAS | 20 | 5.25 | 8.42 | -.850 | -.542 | .011 |
| Comparison | ECS | 24 | -.62 | 15.13 | -.695 | 1.14 | .283 |
| | MAS | 24 | 1.33 | 11.40 | 1.54 | 4.56 | .004 |

N: Number of students D: Difference score, SD: standard deviation, SC: Skewness coefficient, KC: Kurtosis coefficient, p: Significance value

In Table 2, it was seen that the difference between ECS and MAS of the experimental group and the MAS pre-test and post-test total score of the comparison group did not show a normal distribution ($p<.05$). In the comparison group, although the difference between the pre-test and post-test difference scores of ECS showed a normal distribution according to the $p$ value ($p>.05$), it was observed that the kurtosis value deviated from the normal distribution outside the range of (-1, 1) excessively. The main thing in the investigation of normality is that the data do not deviate excessively from the normal distribution (Büyüköztürk, 2020). In this case, it can be said that the difference between the total scores does not fit the normal distribution for both groups. Wilcoxon signed-rank test, which is the nonparametric equivalent of the paired t-test, was used to decide whether the difference between the pre-test and post-test scores of the groups at the end of the application was significant or not (see Büyüköztürk, 2020; Özdamar, 2018). Wilcoxon signed-rank test analysis results for two groups are given in Table 3.

As can be seen in Table 3, a significant difference was found between the pre and post test scores of the experimental group's mathematics attitude scores ($z$=-2.32; $p$=.020). Similarly, a significant difference was found between the error orientation scores of the group ($z$=-3.24; $p$=.001). When Table 3 is examined in both scales, it is seen that this difference is in favor of the post-test as positive rank totals are larger than the negative ones. The effect size of the difference in MAS was calculated as $d$=.51 and the effect size of the difference in ECS as $d$=.72. It can be said that the effect sizes found for both differences have medium effect. As a result of the post-tests of the experimental group, it was observed that there was a positive change in both their attitudes towards mathematics and their error orientation and this change was significant according to the Wilcoxon signed-rank test analysis results. When Table 3 is examined, it is seen that there is no significant difference between the pre-test and post-test mathematics attitude scores of the comparison group ($z$=-1.134; $p$=.257). Similarly, there is no significant difference between the error orientation scores of the group ($z$=-.237; $p$=.813). According to Wilcoxon test results, no difference was found between the pre-test and post-test scores in both error orientation and attitudes towards mathematics of the comparison group.

**Table 3.** *Wilcoxon test results of the groups' scores before and after the application.*

| Group | Scales | Pre-test/Post-test | $N$ | Mean Rank | Sum of Ranks | $z$ | $p$ |
|---|---|---|---|---|---|---|---|
| Experimental | MAS | Negative Ranks | 4 | 3.88 | 15.50 | -2.32 | .020* |
| | | Positive Ranks | 10 | 8.95 | 89.50 | | |
| | | Ties | 6 | 0 | 0 | | |
| | ECS | Negative Ranks | 3 | 2.67 | 8.00 | -3.244 | .001* |
| | | Positive Ranks | 14 | 10.36 | 145.00 | | |
| | | Ties | 3 | 0 | 0 | | |
| Comparison | MAS | Negative Ranks | 6 | 9.92 | 59.50 | -1.134 | .257 |
| | | Positive Ranks | 12 | 9.29 | 111.50 | | |
| | | Ties | 6 | 0 | 0 | | |
| | ECS | Negative Ranks | 9 | 7.94 | 71.50 | -.237 | .813 |
| | | Positive Ranks | 8 | 10.19 | 81.50 | | |
| | | Ties | 7 | 0 | 0 | | |

*$p$<.05

The normal distribution of the data was investigated to see if there was a significant difference between the post-test scores of the experimental and comparison groups. Descriptive statistics of scales and Shapiro-Wilk normality analyzes are given in Table 4.

**Table 4.** *Group statistics and Shapiro-Wilk test for ECS and MAS post tests.*

| | Group | $N$ | M | $SD$ | Shapiro-Wilk | |
|---|---|---|---|---|---|---|
| | | | | | $df$ | $p$ |
| ECS Post-test | Experimental | 20 | 105.40 | 15.83 | 42 | .009 |
| | Comparison | 24 | 95.83 | 26.41 | | |
| MAS Post-test | Experimental | 20 | 81.15 | 12.55 | 42 | .54 |
| | Comparison | 24 | 68.04 | 17.74 | | |

N: Number of students, M: Mean: SD: standard deviation, df: Degree of freedom, p: Significance value

When Table 4 is examined, it is seen that the ECS post-test does not comply with the normal distribution, while the MAS post-test complies with the normal distribution. Whether the differences between the groups caused a significant difference in the change in scale scores was analyzed with the independent sample t-test for normal distribution and Mann-Whitney U test for non-normal distribution.

According to the independent sample t-test results, there is a significant difference between the experimental and comparison groups' post-test scores in MAS [$t_{(42)}$=2.77, $p$<.05]. The effect size of the difference between the groups in the MAS post-test was calculated as $d$=.83. The difference between the experimental and comparison groups' MAS post-test scores is a large difference, which can be considered significant. Mann-Whitney U analysis was performed to examine the difference between groups for ECS post-test scores that did not fit the normal distribution. The results of the analysis ECS post-test show that the difference in scores between the groups was found to be insignificant ($U$=175; $p$ =.12; $z$ =-1.53). The effect size of the difference between the groups in the ECS post-tests was calculated as $d$=.23. This difference shows that experimental and comparison groups' ECS post-tests scores is a small difference which can be considered as non-significant.

ECS consisted of seven sub-dimensions and MAS consisted of four sub-dimensions, and as a result of the pre-test and post-test, changes occurred between the total scores of these sub-dimensions. In order to see whether these changes create a significant difference, first of all, group statistics and the normal distribution of total score differences were examined. The descriptive statistics of the total score differences of the factors and the significance values obtained as a result of the Shapiro-Wilk normality analysis are given in Table 5.

**Table 5.** *Total score difference statistics of factors and Shapiro-Wilk normality test.*

| Group | Scales | Factors | *N* | D | *SD* | *p* |
|---|---|---|---|---|---|---|
| Experimental | ECS | A1 | 20 | .80 | 4.443 | .244 |
| | | A2 | 20 | .20 | 4.372 | <.001 |
| | | A3 | 20 | 3.15 | 5.214 | <.001 |
| | | A4 | 20 | 2.30 | 4.053 | .017 |
| | | A5 | 20 | 2.40 | 3.101 | .012 |
| | | A6 | 20 | 1.95 | 2.999 | .027 |
| | | A7 | 20 | .30 | 2.494 | .503 |
| | MAS | B1 | 20 | 3.75 | 6.455 | .310 |
| | | B2 | 20 | 1.10 | 3.291 | .042 |
| | | B3 | 20 | -.70 | 3.614 | .531 |
| | | B4 | 20 | 1.10 | 1.682 | .001 |
| Comparison | ECS | A1 | 24 | .125 | 5.407 | .157 |
| | | A2 | 24 | -.166 | 3.963 | .092 |
| | | A3 | 24 | -1.62 | 6.212 | .001 |
| | | A4 | 24 | -.291 | 2.475 | .053 |
| | | A5 | 24 | .958 | 2.710 | .026 |
| | | A6 | 24 | -.416 | 2.339 | <.001 |
| | | A7 | 24 | .791 | 4.117 | .001 |
| | MAS | B1 | 24 | 1.04 | 5.287 | .020 |
| | | B2 | 24 | .5417 | 5.815 | <.001 |
| | | B3 | 24 | -.6667 | 4.039 | .017 |
| | | B4 | 24 | .4167 | 2.244 | .001 |

N: Number of students D: Difference score, SD: standard deviation, p: Significance value

When Table 5 is examined, it is seen that the total score differences of the A1 (Irrelevance of errors for assessment) and A7 (Functionality of errors for learning) factors in the ECS test in the experimental group conform to the normal distribution ($p$>.05), while the total score differences of the other factors do not fit the normal distribution according to the results of Shapiro-Wilk normality analysis ($p$<.05). In the experimental group, it was also observed that the total score differences of the B1 (interest) and B3 (necessity) factors in the MAS test conformed to the normal distribution. In the comparison group, A1 (Irrelevance of errors for assessment), A2 (Teacher support after errors) and A4 (Absence of negative classmate reactions to errors) factor total score differences were in normal distribution, while total score differences of all sub-factors in the MAS scale did not comply with the normal distribution. In order to decide whether the difference between the factor total score difference obtained as a result of the pre-test and post-test is significant, the paired t-test for the factors satisfying the normality condition and the Wilcoxon signed-rank test were used to determine whether the difference between the total score differences of the factors that did not show normal distribution was significant or not.

Paired-sample t-test analyzes of A1, A7 and B1, B3 sub-factors satisfying the normality condition in the experimental group and A1, A2 and A4 factors in the comparison group providing the normal distribution condition were made and only the B1 factor in the experimental group was determined to have a significant difference in favor of the post-test [$t_{(19)}$=2.59, $p$<.05]. The effect size of this significance value was calculated as $d$=.57 and it was determined that the difference between them created a medium effect.

Wilcoxon signed-rank test was used for other factors that did not meet the normal distribution condition given in Table 6. The test results are given in Table 6.

**Table 6.** *Wilcoxon signed-row analysis results.*

| Groups | Factors | Pre-test/Post-test | *N* | Mean Rank | Sum of Ranks | *z* | *p* | *d* |
|---|---|---|---|---|---|---|---|---|
| Experimental | A2 | Negative Ranks | 4 | 4.13 | 16.50 | -.424 | .671 | - |
| | | Positive Ranks | 3 | 3.83 | 11.50 | | | |
| | | Ties | 13 | | | | | |
| | A3 | Negative Ranks | 12 | 8.25 | 99.00 | -2.937 | .003* | .66 |
| | | Positive Ranks | 2 | 3.00 | 6.00 | | | |
| | | Ties | 6 | | | | | |
| | A4 | Negative Ranks | 13 | 8.00 | 104.00 | -2.519 | .012* | .56 |
| | | Positive Ranks | 2 | 8.00 | 16.00 | | | |
| | | Ties | 5 | | | | | |
| | A5 | Negative Ranks | 13 | 8.69 | 113.00 | -3.035 | .002* | .68 |
| | | Positive Ranks | 2 | 3.50 | 7.00 | | | |
| | | Ties | 5 | | | | | |
| | A6 | Negative Ranks | 11 | 9.64 | 106.00 | -2.625 | .009* | .59 |
| | | Positive Ranks | 4 | 3.50 | 14.00 | | | |
| | | Ties | 5 | | | | | |
| | B2 | Negative Ranks | 10 | 6.75 | 67.50 | -1.544 | .123 | - |
| | | Positive Ranks | 3 | 7.83 | 23.50 | | | |
| | | Ties | 7 | | | | | |
| | B4 | Negative Ranks | 9 | 5.94 | 53.50 | -2.714 | .007* | .60 |
| | | Positive Ranks | 1 | 1.50 | 1.50 | | | |
| | | Ties | 10 | | | | | |

*$p$<.05

When Table 6 is examined, a significant difference was found in the A3, A4, A5, and A6 factors of the ECS test and the B4 factor of the MAS test in the experimental group compared to the Wilcoxon signed-row test ($p$<.05). When the effect size of these differences is examined, it is seen that they have a medium effect (.5<$d$<.8). No significant difference was observed between the pre-test and post-test for any of the factors in the comparison group according to the Wilcoxon signed-rank analysis.

### 3.2. In-class Observations and the Course Teacher's Views

As a result of the observations made in the classroom, it was observed that the students who did not want to attend the lesson or remained silent because they did not trust their answers at the beginning of the research increased their participation in the lesson at the end of the application and did not hesitate to answer even if their answers were wrong. At the end of the application, a decrease was observed in the behavior of the students who made fun of their friends who gave wrong answers to the questions in the lesson.

During the application, the teacher, who made the process evaluation at the end of the subject, gave midterm exams to the students. She added one incorrect statement/question to the exams she prepared. Emphasizing several times before and during the exam, she said, "Please write down why they are wrong in front of the statements that you think are wrong and do not leave them blank". At the end of the exam, she evaluated the questions in class with the students and solved the assessment questions in the classroom together with the students. An example of an evaluation of the third week of the positive error climate is given as follows:

*Question: Write a suitable number according to the expressions given in the blanks below:*

• *Greater than 8, less than 9……….*

• *Greater than 5, less than 5.1………..*

• ***Greater than 2.5, less than 2.45 ………***

• *Greater than 0.32, less than 0.33………..*

Yes children, most of you left question 3 blank. Let's examine together. Anyone wants to answer? (The teacher makes a promise to a student in the classroom who does not attend much.)

**S1**: It can be 2.44.

**Teacher**: Good answer. Why did you think like that?

**S1:** Because it is one step away from 2.45.

**S2:** But the number he said is less than 2.5. No way.

**Teacher**: So what could this number be? Or is it just one?

**S3:** No. The numbers are endless.

**Teacher**: Okay, then say one of those numbers, (the teacher picks up a student who doesn't raise a finger in the lesson) S4, which one of these numbers do you think is bigger?

**S4:** 2.45.,

**Teacher:** Why do you think so?

**S4:** Because the 45 is greater than 5.

**Class:** No, it's not. We can add as many zeros as we want to the end of the number after the comma. So it's not 5, it's 50 actually.

**S5:** We put a zero at the end of 2,5, it becomes 2.50. Then it becomes 2.50 > 2.45.

**Teacher**: Well done children, your friend S4 caught a very fine and important mistake. This is one of the most common mistakes made. Thanks for your friend pointing out this common mistake. S1-S4, did you understand the mistake? (Students say they understand and once again state why their answer is wrong in their own words.)

**Teacher:** Then what is the answer to this question, guys?

**S3:** There is no answer. There are no numbers in this range (Classmates confirm the answer).

As seen above, an evaluation exam was conducted at the end of the topic related to the order of decimal numbers, belonging to the third week of the positive error climate. The teacher solved the evaluation questions in the classroom together with the students. Those students who did not want to stand at the blackboard in the classroom and who were behind the class academically in mathematics lessons attended the lesson and misunderstandings in the students were revealed. At the end of each answer, the teacher asked the students to explain their answers. Misconceptions in students were both revealed and corrective feedback was given.

In the interview with the course teacher before the application, the teacher stated that she did not look positively towards making errors intentionally during the lesson. Although she did not have a negative attitude towards the students who made errors, the students kept silent in order not to give wrong answers. She also stated that the students often made fun of each other when they made errors in the class. At the end of the application, the course teacher said that she was very satisfied with the process since the process contributed positively to the students who did not attend the lesson much, and that if it was planned in this way, the students could benefit from their errors in the lessons.

## 4. DISCUSSION and CONCLUSION

As a result of the findings, it was observed that there was an increase in the error orientation and mathematics attitude scores of both the experimental and comparison groups. In the analyzes made to decide whether this increase had a significant effect or not, it was seen that only the increase in the experimental group was significant. When the error orientation and mathematics attitude scores of the experimental group before and after the application were compared according to the Wilcoxon signed-rank analysis, it was observed that there was a significant difference between the scores ($p<.05$). According to the research findings, it can be said that the positive error climate in the classroom has a positive effect on both students' attitudes towards mathematics and their error orientation. Independent sample t-test and Mann-Whitney U test analyzes were performed to see if there was a significant difference in error orientation and mathematics attitude post-test scores between the experimental and comparison groups. While there is a significant difference between the post-test scores of the experimental and comparison groups for MAS, there is no significant difference in ECS. Although there is no significant difference between the post-test scores of the two groups for ECS, the mean score of the experimental group ($M$=105.40) is higher than the mean score of the comparison group ($M$=95.83).

Paired sample t-test and Wilcoxon signed-rank test analyzes were applied to the sub-dimensions to decide whether the scores given by the experimental and comparison groups to the sub-dimensions of the ECS and MAS scales before and after the application made a significant difference or not. As a result of the analysis, it was seen that only the differences in the experimental group were in favor of the post-test. According to the paired t-test and Wilcoxon signed-rank test analyzes performed in the experimental group, a significant difference was found in favor of the post-test in the A3, A4, A5, and A6 sub-factors of the ECS ($p<.05$). Similarly, significant differences were found in favor of post-test in B1 and B4 sub-factors of MAS ($p<.05$). Thus, it can be said that the positive error climate application in the experimental group also gave positive results in the ECS and MAS sub-factors. During this application, it may be expected that there will be a change in A3 and A4 sub-factors since the teacher creates a positive error climate in the classroom since these two sub-factors include the positive behavior of the teacher against errors and support against errors. A5 and A6 sub-factors are related to the learners. With the positive error climate in the classroom, the students became able to take the risk of making errors and started not to react negatively to their friends who made errors in the classroom. The significant change in the B1 sub-factor indicates that positive classroom application increases the interest in the lesson; however, application has a medium effect on these significant changes. This effect is thought to increase with a longer application.

Error-based learning and teaching studies applied in the classrooms in the relevant literature generally leave a positive impression on students and teachers (Akkuşçi, 2019; Bray & Santagata, 2013; Gedik, 2014; Heinze & Reiss, 2007; O'Dell, 2015; Özkaya, 2015; Soncini et al., 2021). The results of this study show similarity to other studies in the literature at this point.

In studies conducted with teachers, it has been observed that they generally have positive beliefs about using errors in teaching, yet they are distant about making use of errors in the lesson (Ingram et al., 2015; Palkki & Hastö, 2018). The reason for this is the thought that the errors used will become widespread. A number of researchers show that one of the ways to prevent this is to intervene directly (Heinze, 2005; Özkaya, 2015; Santaga, 2005; Türkdoğan & Baki, 2012). When the views of the teachers before and after our specific research are examined, it can be seen that the course teacher had the same thought at the beginning of the research. When the study of Bray and Santagata (2013) was examined, it was determined that the teachers managed the learning process from errors better in the lessons in which lesson plans containing errors were applied. At the end of our research, the teacher who applied the positive error climate stated that she could also benefit from a planned error climate management process in the lessons.

According to research, teachers' attitudes towards errors in the classroom determine students' attitudes towards errors and mistakes. Teachers' tolerant attitude to errors and using them as teaching tools in the classroom cause students to adopt the same attitude (Bray, 2011; Heinze & Reiss, 2007; Tulis, 2013). Actually, it was seen that the students' error orientation and mathematics attitude scores increased positively as a result of the teacher's positive attitude towards errors in the experimental group in which a positive error climate was carried out.

If a teacher who includes errors in the learning process in the classroom knows how to benefit from errors and s/he draws a well line in teaching, he or she can benefit from errors as a teaching tool (Akpınar & Akdoğan, 2010; Heinze & Reiss, 2007). To such an end, the first step is to motivate the student. According to Tulis (2013), an error leads to an affective reaction and a good regulation process is required to turn this reaction into a positive one. When encouraging feedback is given to the student who is afraid of making errors, it has been observed that the student is more willing to participate in the lesson. In the same way, it was determined that there was a decrease in the behaviors of students who made fun of their friends' wrong answers during the process.

Mathematics curriculum in Türkiye expects teachers to evaluate students holistically and multidimensionally (MoNE, 2018). The quality of evaluations is determined by the methods and feedback used in the process (Bray, 2011). The purpose of evaluation is not only to grade the student but also to contribute to the improvement of the course. A positive error climate is one of the ways that can be used to improve the lesson while a positive error climate gives feedback to students' errors correctly and helps evaluate students for learning. Huelser and Metcalfe (2012) emphasized the importance of corrective feedback and stated that the correct feedback is more effective in remembering the answer than explaining the truth directly. With feedback and correct guidance, individuals not only get the right answer, but also increase their ability to analyze and explain; thus, they both begin to query and increase the amount of learning from errors (Karadağ, 2004; Metcalfe, 2017). In our specific study the teacher asked the student to explain his/her answer and made the class think about it, which contributed to the students' ability to explain the error and express why it was wrong, and which also contributed to their comprehension skills rather than memorizing the answer. Baki (2015) divides the evaluation approaches into three as diagnostic assessment, formative assessment, and complementary assessment. Formative assessment is the type of assessment that occurs in the process. In this respect, it can be said that the positive error climate is also a part of the formative assessment. Of course, seeing incorrect answers on the exam paper during the complementary assessment phase is annoying and causes a drop in the student's grade. However, until the complementary evaluation stage, managing errors in a positive way in the classroom and including them in the teaching process in a planned way will provide students with positive affective characteristics.

## 5. RECOMMENDATION

In this study, in which the effect of positive error climate on affective characteristics was examined, positive significant differences were found in the experimental group. ECS and MAS were used to measure the effectiveness of the positive error climate applied in the classroom. In future studies, positive error climate can be examined in more detail by increasing the number of practice lesson hours, teachers, and classes using various scales. The application was limited to the mathematics course. The effect of the positive error climate in other courses may be the subject of further research.

### Declaration of Conflicting Interests and Ethics

The authors declare no conflict of interest. This research study complies with research publishing ethics. The scientific and legal responsibility for manuscripts published in IJATE belongs to the authors. **Ethics Committee Number**: Atatürk University, 10.12.2021-2021/13/12

### Authorship Contribution Statement

**Merve Ozkaya**: Investigation, Methodology, Materials, Data collection, Analysis, Literature Review, Writing. **Senem Kalac**: Investigation, Data collection, Analysis, Writing. **Alper Cihan Konyalioglu**: Methodology, Supervision and Validation.

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## APPENDIX

| POSITIVE EROR CLIMATE FRAMEWORK PROGRAM |
|---|
| ***The teacher expresses her/his tolerance towards mistakes verbally and in behavior.***<br>***The feedback that can be given as follows:***<br>***Verbal feedback:***<br>• Answer even if you think you are wrong.<br>• Errors are ways that are not right, the m ore wrong ways we eliminate, the better.<br>• All mistakes are ways that will bring us closer to the truth.<br>• Making mistakes and giving wrong answers are inevitable in the classroom environment.<br>• You are a student, of course you will make mistakes to find the truth, do not hesitate.<br>• Do not think that I will be angry with you if you make a mistake.<br>• You are all classmates, let's try to learn a lesson instead of laughing or getting angry at wrong answers.<br>***Behavioral feedback:***<br>• S/he encourages students with low attendance and who are behind the class academically to get up and respond to the lesson.<br>• 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.<br>• S/he asks students to answer even if they are wrong.<br>• S/he asks the students who make mistakes why they think that way without getting angry.<br>• Be tolerant towards student mistakes.<br>***Associated sub-dimensions:***<br>✓ *Errors tolerance by the Teacher*<br>✓ *Absence of negative teacher reactions to error.* |
| ***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.***<br>***The feedback that can be given as follows*:**<br>• Why did you think like that?<br>• Your friend gave a very nice answer.<br>• Shall we think together?<br>• Your friend has mentioned a very good mistake, let's be careful about it.<br>• Thanks for your friend's reply.<br>• Well done, you have caught a very important point -to class- do you think your friend's answer is correct?<br>• If it's wrong, let's think about why it's wrong.<br>• You gave a very good answer. Thank you.<br>***Associated sub-dimensions:***<br>✓ *Functionality of errors for learning*<br>✓ *Analysis of errors*<br>✓ *Taking the error risk*<br>✓ *Absence of negative teacher reactions to errors*<br>✓ *Teacher support following errors*<br>✓ *Irrelevance of errors for assessment* |
| ***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.***<br>***The feedback on this issue is as follows:***<br>• 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.<br>• S/he asks questions that will help the student find the right answer.<br>• S/he draws the attention of the students in the class to the mistake made.<br>• S/he involves the whole class in the process.<br>• S/he explains the importance of the mistake made by the student.<br>• 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.

***Associated sub-dimensions:***

- ✓ *Functionality of errors for learning*
- ✓ *Analysis of errors*
- ✓ *Taking the error risk*
- ✓ *Absence of negative classmate reactions to errors*
- ✓ *Absence of negative teacher reactions to errors*
- ✓ *Teacher support following errors*
- ✓ *Irrelevance of errors for assessment*

***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.

***Associated sub-dimensions:***

- ✓ *Functionality of errors for learning*
- ✓ *Analysis of errors*
- ✓ *Taking the error risk*
- ✓ *Absence of negative classmate reactions to errors*
- ✓ *Absence of negative teacher reactions to errors*
- ✓ *Teacher support following errors*
- ✓ *Irrelevance of errors for assessment*

***After the teacher decides that 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?

***Associated sub-dimensions:***

- ✓ *Functionality of errors for learning*
- ✓ *Analysis of errors*
- ✓ *Taking the error risk*

***At the end of the subject, the teacher exams the students, the exam is not for scoring. Puts a wrong example in the exam. Waits for the student to realize the error. At the end of the exam, he/she solves the questions in detail in the class.***

***Associated sub-dimensions:***

- ✓ *Analysis of errors*
- ✓ *Taking the error risk*
- ✓ *Irrelevance of errors for assessment*