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STUDY

ERROR CLIMATE AND GENDER AS FACTORS INFLUENCING ERROR REACTIONS IN PRIMARY SCHOOL CHILDREN

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ABSTRACT

Errors can support learning processes when students react to errors on an affective-motivational adaptive and action-adaptive level. Empirical findings indicate that these adaptive reactions to errors are influenced, among others, by the error climate in the classroom as an overarching factor of different dimensions. There is further evidence that there are gender differences in student reactions to errors and that these are differently associated with the dimensions of the error climate. Less is known about the interaction between these variables and whether there are gender-specific differences in adaptive reactions to errors, specifically in primary schools. The aim of the study was to replicate findings on the relevance of error climate as an overarching factor and its dimensions for adaptive reactions to errors in primary school children. The study also investigated gender differences in student perceptions of the error climate, which may explain gender differences in students' adaptive reactions to errors. The sample encompassed third and fourth graders (N=675). Analyses at both the individual and class levels replicated findings from the secondary level for the primary level and revealed further gender-specific differences in student learning from errors that were associated with gender differences in primary school children's perception of the error climate.

KEYWORDS

error climate, error climate dimensions, adaptive reactions to errors, primary level, gender differences

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1 Introduction

The learning processes of children and adolescents in schools manifest diversely, including in reactions to teacher questions in class discussions, working on practice exercises to reinforce lesson content, or being questioned by parents to assess their own knowledge. Throughout these learning processes, students inevitably make errors, defined as actions or outcomes that unintentionally deviate from a norm or goal and are judged as incorrect (Zhao & Olivera, 2006). Errors become salient through a comparison of the desired and actual states, with the desired state determined by existing norms (e.g., spelling rules) or goals (e.g., correctly solving a task) (Grassinger et al., 2015). Errors can be more or less unpleasant for individuals depending on the situation and may be associated with emotions such as self-directed and other-directed anger, frustration, and helplessness, and in threats to self-esteem (Weinert, 1999). At the same time, errors are discussed as valuable learning opportunities, revealing misunderstandings, knowledge gaps, and areas where actions are not yet competently performed (Hascher & Hagenauer, 2010; Kreutzmann et al., 2014; Zhao & Olivera, 2006). Errors are considered particularly relevant for the development of negative knowledge, defined as knowledge about how something is not correct (Minsky, 1994; Oser & Spychiger, 2005; Zhao, 2011). The inherent learning potential in errors is realized primarily when students learn from them. Specifically, affective-motivational and action-related reactions of students in error situations are differentiated; these reactions can be more or less adaptive in terms of learning from errors. Tulis et al. (2016) presented a process model of individual learning from errors that, inspired by a self-regulatory perspective on learning (Boekaerts & Niemivirta, 2000; Zimmerman, 2008), postulates the regulation of both affective-motivational and cognitive-behavioral processes for successful learning from errors. It is further assumed that the error climate in school classes influences students' adaptive reactions to errors. This error climate encompasses the attitudes and behaviors of teachers and students as a multidimensional construct (Steuer, 2014). Central statements of the model were empirically supported through several samples of secondary school students (e.g., Dresel et al., 2013; Grassinger & Dresel, 2017; Steuer et al., 2013). These samples cannot be directly transferred to primary school children due to developments in motivational beliefs, tendencies, and self-regulated competencies. Thus, there is limited empirical evidence for assumptions made in the process model of individual learning from errors (Tulis et al., 2016) for primary school children in general. Moreover, while previous studies considered the error climate as an overarching factor, there is initial evidence that different dimensions of the error climate are differentially associated with affective-motivational adaptive and action-adaptive reactions to errors

(Steuer et al., 2021), an aspect that is not yet extensively explored, especially in the context of primary school-aged children. Additionally, there have been initial inconsistent findings on gender differences in learning from errors. For instance, boys reported more affective-motivational adaptive reactions to errors than girls (Dresel et al., 2013; Grassinger et al., 2015). For action-adaptive reactions to errors, gender-specific differences are inconsistent in these works. To comprehend why boys and girls react differently to errors, we investigated whether there were gender differences in student perceptions of the error climate associated with gender differences in student learning from errors. In summary, this work aims to replicate central assumptions of the process model of individual learning from errors for primary school children. Additionally, we investigated gender differences in student perception of the error climate and analyzed their association with gender differences in students' adaptive reactions to errors among primary school children. Furthermore, we replicate previous findings from samples of secondary school students concerning gender differences in affective-motivational adaptive and action-adaptive reactions to errors, and both the importance of the error climate as an overarching factor and as a multidimensional construct in which the different dimensions of error climate are differentially associated with adaptive reactions to errors made by students of primary school age.

1.1 Learning from errors

Learning processes of students in primary schools are often stimulated by the encouragement to explore. The initiation of a such a "trial and error" approach is particularly beneficial for knowledge construction when children learn from their errors (Hascher & Hagenauer, 2010; Spychiger et al., 2006). According to the process model of learning from errors by Tulis et al. (2016), this is especially the case when student reactions to errors are affective-motivationally adaptive and action-adaptive (Dresel et al., 2013; Steuer et al., 2013). If students can perceive errors as learning opportunities rather than threats to ones' self, attribute errors favorably in terms of motivation, regulate emerging negative emotional reactions such as disappointment, anger, shame, or frustration, and counteract a reduction in positive emotions like joy of learning, then they react affective-motivationally adaptive to errors (Tulis et al., 2016). In other words, affective-motivational reactions to errors are considered adaptive when they energize and steer an engagement with an error, thereby maintaining or enhancing learning motivation and joy. On the other hand, action-related reactions to errors manifest through actions such as ignoring or analyzing an error in terms of its origin, searching for appropriate solution strategies, and planning and initiating learning actions to avoid similar errors in the future. Action-related reactions to errors are considered adaptive when they contribute to the (meta-)cognitive (re-)construction of knowledge

structures (Dresel et al., 2013; Grassinger et al., 2015). For example, if students contrast their erroneous homework with the correct solution to the task, explore the misunderstanding or knowledge gap that led to the error, and correct this misunderstanding or fill the knowledge gap, they demonstrate action-adaptive reactions to the error made in their homework.

Previous empirical findings in samples from fifth to eighth graders (Grassinger et al., 2018), sixth to seventh graders (Dresel et al., 2013), and ninth graders (Dresel et al., 2013; Tulis et al., 2011) support the idea that affective-motivational adaptive and action-adaptive reactions to errors are distinct and have differential effects. In particular, affective-motivational adaptive reactions to errors seem to be significant for action-adaptive reactions to errors. The latter, in turn, have been shown in previous studies to be associated with student performance.

1.2 The error climate as a contextual determinant for learning from errors

Steuer (2014) introduced the term "positive error climate," which is defined and manifested through a multidimensional structure in which the attitudes and behaviors of both teachers and students within a classroom interact. Steuer (2014) described the error climate using eight dimensions that emerge in learning and performance situations: (1) The error tolerance of the teacher, which encompasses allowing errors or perceiving them as learning opportunities. This is reinforced by (2) adequate support for learners with difficulties and (3) the absence of negative teacher reactions to errors (e.g., embarrassing individual students, making fun of student errors), corresponding with (4) a positive handling of errors in learning and performance situations, characterized by the natural inclusion of errors in the learning process and utilizing them as learning opportunities. Another dimension of the error climate involves the design of tasks and challenges in which students are likely to make errors. This is referred to as (5) taking the risk of error. Additionally, an error climate is characterized by the attitude and behavior of the students in a class. Specifically, this includes (6) the absence of negative classmate reactions and (7) the analysis of errors within the class and among students. Finally, (8) the learning functionality of errors indicates the extent to which students use errors as learning opportunities.

Steuer et al. (2013) examined the structure and relevance of the error climate for individual handling of errors in mathematics education in a sample of sixth to seventh graders. The eight postulated error climate dimensions were found to be independent factors that concurrently formed an overarching factor. This indicates that a positive error climate is expressed as a characteristic of a class characterized by these eight dimensions. It was also observed that the subjective perception of the error climate in the classroom corresponded to the adaptivity of affective-motivational and action-related reactions to

errors in samples of sixth to eighth graders (Soncini et al., 2022), sixth to seventh graders (Steuer et al., 2013), fifth to seventh graders (Steuer et al., 2021), and fifth to eighth graders (Grassinger et al., 2018). Additionally, Steuer et al. (2024) reported associations between the error climate and student alienation from their teachers in samples of fifth to sixth graders. Furthermore, Steuer and Dresel (2015) found associations between the error climate and student achievement in a sample of seventh to ninth graders. Moreover, Käfer and colleagues (2019) found that teacher attitudes toward errors and teacher responses to student errors—both aspects of the error climate (Steuer, 2014)—were associated with student perception of errors as useful for learning, student motivation, and student achievement. This corresponds with Heinze et al. (2012), who argued that teacher attitudes and behavior regarding errors shape the error climate in the classroom. Additionally, Soncini et al. (2020) found in a sample of fifth graders that a constructive and encouraging teacher strategy for dealing with student errors was associated with student perceptions of a positive error climate and student beliefs about errors. As mentioned, the error climate is characterized by eight dimensions that describe the attitudes and behaviors of both the teacher and the students in a class. We argue that these dimensions are differently associated with either affective-motivational or cognitive-behavioral processes of learning from errors. For example, "taking the risk of error," "error tolerance of the teacher," "evaluation of error irrelevance," "absence of negative classmate reactions," and "absence of negative teacher reactions" predominantly address affective-motivational processes due to the associated lesser threat to self-esteem. In contrast, "analysis of errors," "learning functionality of errors," and "teacher support following errors" predominantly focus on supporting learning on a cognitive-behavioral level. This suggests potential differential associations with affective-motivational adaptive reactions on the one hand and action-adaptive individual reactions to errors on the other. Initial empirical evidence for this argumentation can be found in the study by Steuer et al. (2021). The authors found, in a sample of fifth to seventh graders, the assumed correlations between affective-motivational adaptive and action-adaptive reactions to errors and the different dimensions of the error climate.

Gender differences in learning from errors

Various empirical studies have indicated that boys and girls differ in their motivational beliefs and tendencies, particularly in primary school age. For instance, Hellmich and Jahnke-Klein (2008) and Stürzer (2003) reported that primary-school-age boys exhibit higher self-concepts for mathematics and more mathematics-specific interests than girls of the same age. Kreutzmann et al. (2014) found that primary-school-age girls reported experiencing more joy and having more mastery goals than boys. Additionally, empirical findings

by Dresel et al. (2001) indicated that girls had lower expectations of success in mathematics and experience more helplessness than boys. Hornstra et al. (2013) found that girls experience less self-efficacy than boys. Given the relevance of these motivational tendencies and beliefs for adaptive reactions to errors, it is reasonable to assume that gender-specific differences are observable in learning from errors, primarily in affective-motivational adaptive reactions to errors. Specifically, students with a higher self-concept of their ability reported more affective-motivational adaptive and more action-adaptive reactions to errors (Dresel et al., 2013; Grassinger & Dresel, 2017; Grassinger et al., 2015). The association of ability self-concept with affective-motivational adaptive reactions to errors was stronger than with action-adaptive reactions to errors. Additionally, students with a stronger focus on mastery goals reported more affective-motivational adaptive and more action-adaptive reactions to errors (Dresel et al., 2013; Grassinger & Dresel, 2017; Grassinger et al., 2015; Kreutzmann et al., 2014). Moreover, Kreutzmann et al. (2014) found that primary-school-age students who experienced more joy at school reported a more positive learning orientation towards errors.

Dresel et al. (2013) investigated this in samples of sixth to seventh graders and ninth graders and found that boys were more affective-motivationally adaptive to errors than girls. This finding was replicated by Grassinger et al. (2015) in a sample of fifth to eighth graders. Regarding action-adaptive reactions to errors, no gender differences were observed (Dresel et al., 2013; Study 1 with sixth to seventh graders) or there were differences in favor of girls (Dresel et al., 2013; Study 2 with ninth graders; Grassinger et al., 2015), which is explained by increased self-regulatory competencies in girls (Grassinger et al., 2015).

1.3 Gender differences in the perception of the error climate

The error climate varies both within and among classrooms (Steuer, 2014). Particularly, the variance within a classroom indicates an interindividual perception of the error climate. As a principle of information processing, student perception of a learning and achieving situation in general – and specifically of the error climate – follows cognitive consistency (Gawronski & Strack, 2012; van Kampen, 2019). This highlights, among other factors, the relevance of motivational beliefs or tendencies: students tend to perceive and attribute learning and achieving situations consistent with their own motivational beliefs or tendencies, such as ability self-concept, individual interest, and experience of helplessness.

This argument is supported by the study by Skaalvik (1994), who found that students with low ability self-concept tended to attribute their failure on fewer abilities, or the study by Durik and Harackiewicz (2007), who found that student personal interest moderated the effect of situational factors on

task interest. Moreover, empirical findings by Odabasi (2013) indicated that students who experienced helplessness tended to fail.

Considering the gender differences in primary school students' motivational beliefs and tendencies (Dresel et al., 2001; Hellmich & Jahnke-Klein, 2008; Kreutzmann et al., 2014; Stürzer, 2003), we argue that there are also gender differences in student perceptions of the error climate.

To illustrate our argument: If teachers provide more support for learners facing difficulties, as one dimension of the error climate, students with a lower ability self-concept may perceive this as a confirmation of their low ability or as a threat to their self-esteem. Alternatively, if teachers demonstrate a positive approach to handling errors as another dimension of the error climate, and they integrate errors in the learning process, students with low interest in the topic may perceive a lack of situational interest in addressing their own errors. As another example, if teachers embrace the risk of error as a further dimension of the error climate and design tasks and challenges that are likely to lead to errors, this may be perceived as a threat to self-esteem for students with lower ability self-concepts. As a result, we assume that girls perceive the error climate less positively due to their lower ability self-concept, diminished interest in the subject, decreased self-efficacy, unfavorable attributional processes, and increased experience of helplessness.

Consistent to this argumentation, Steuer (2014) reported from her study with seventh to ninth graders that girls rated the error climate as an overarching factor more positively than boys. When examining the relationships between gender and error climate dimensions in a differentiated manner, significant associations in favor of girls were particularly evident in the dimensions of "error tolerance of the teacher," "evaluation of error irrelevance," "teacher support following errors," "absence of negative teacher reactions," and "absence of negative classmate reactions."

2 Hypotheses

According to the theoretical concept in the process model of learning from errors (Tulis et al., 2016), learning from errors is characterized by affective-motivational adaptive and action-adaptive reactions to errors. There is broad evidence that these reactions are favored by a positive error climate as an overarching factor (Grassinger et al., 2018; Soncini et al., 2022; Steuer & Dresel, 2015; Steuer et al., 2013). Furthermore, the different error climate dimensions primarily address either affective-motivational or cognitive-behavioral processes, suggesting differential patterns of association with individual affective-motivational and action-related reactions to errors. Specifically, stronger associations between action-adaptive reactions to errors

and the error climate dimensions "analysis of errors," "learning functionality of errors," "teacher support following errors," and stronger associations between affective-motivational adaptive reactions to errors and the error climate dimensions "taking the risk of error," "error tolerance of the teacher," "evaluation of error irrelevance," "absence of negative classmate reactions," and "absence of negative teacher reactions" are assumed.

Initial evidence for this argumentation was offered by Steuer et al. (2021) with a sample of fifth to eighth graders. The first aim of our paper is to replicate prior findings for younger primary school children. Due to developmental changes in self-regulatory competencies (Fox & Riconscente, 2008; Holodynski et al., 2013), attributional processes, ability self-concepts (Cimpian, 2017; Spinath & Spinath, 2005a, 2005b; Spinath & Steinmayr, 2008), learning and performance goals (Schwinger & Wild, 2006; Schwinger et al., 2016), and cognitive abilities (Büttner, 2019), findings from samples of fifth graders and older cannot be simply transferred to third and fourth graders. Additionally, to the best of our knowledge, there is only initial evidence for the different associations of the error climate dimensions with affective-motivational adaptive and action-adaptive reactions to errors. Replication studies are considered essential and address the need to scientifically verify observable results and protect them from randomness (Crandall & Sherman, 2016; Rost & Bienefeld, 2019). Therefore, the following hypotheses are investigated:

- H1a) Students in third and fourth grade show more adaptive reactions to errors when they perceive a more positive error climate.
- H1b) The error climate dimensions "taking the risk of error," "error tolerance of the teacher," "evaluation of error irrelevance," "absence of negative classmate reactions," and "absence of negative teacher reactions" are more strongly associated with affective-motivational adaptive reactions to errors than with action-adaptive reactions to errors.
- H1c) The error climate dimensions "analysis of errors," "learning functionality of errors," and "teacher support following errors" are more strongly associated with action-adaptive reactions to errors than with affective-motivational adaptive reactions to errors.

The second aim of our paper is to investigate gender differences in student learning from errors. Prior work with older students provides evidence that boys show more affective-motivational adaptive reactions to errors. The findings have been inconsistent regarding action-adaptive reactions to errors (Dresel et al., 2013; Grassinger et al., 2015). With reference to cognitive consistency as a principle of information processing (Gawronski & Strack, 2012; van Kampen, 2019), we argue that girls perceive the error climate as less positive because of their lower ability self-concept. Based on the relevance

of the perceived error climate for students' adaptive reactions to errors, we further argue that gender differences in students' adaptive reactions to errors are mediated by student perception of the error climate.

- H2a) Boys show more positive affective-motivational adaptive reactions to errors than girls.
- H2b) There are gender differences in action-adaptive reactions to errors.
- H2c) Boys perceive the error climate as more positive than girls.
- H2d) Student perception of the error climate mediates gender differences in students' adaptive reactions to errors.

3 Method

The study involved a cross-sectional survey of primary school children. Specifically, the sample consisted of $N = 675$ students from 45 classes in 14 primary schools in Baden-Württemberg, Germany. The mean age of the overall sample was $M = 9.15$ years ($SD = 0.85$). In the third grade, 172 girls and 162 boys participated, with an average age of $M = 8.67$ years ($SD = 0.80$). The average age of the 161 girls and 180 boys in the fourth grade was $M = 9.62$ years ($SD = 0.58$).

To assess the error climate in the classroom and adaptive reactions to errors, a questionnaire for primary school children was designed. The perceived error climate was assessed using items from Steuer (2014). All eight postulated dimensions were considered, totaling 31 items. The internal consistencies of the scales for the error climate as a total measure ($\alpha = 0.89$) and its dimensions ($\alpha = 0.70–0.86$) were good to satisfactory. Affective-motivational adaptive and action-adaptive reactions to errors were operationalized using items from Dresel et al. (2013). The two scales consisted of a total of 13 items (Dresel et al., 2013). The internal consistencies of affective-motivational adaptive reactions to errors ($\alpha = 0.61$) and action-adaptive reactions to errors ($\alpha = 0.75$) were good to satisfactory. The questionnaire had a one-time cross-sectional administration in a paper-and-pencil format.

To test H1a), a two-level path model was estimated using the MLR estimator. Consistent with the process model of learning from errors, affective-motivational adaptive reactions to errors were regressed on the error climate both within-level and between-level. Action-adaptive reactions to errors were regressed on affective-motivational adaptive reactions to errors and the error climate. To test H1b) and H1c) regarding the differential patterns of association between error climate dimensions and individual reactions to errors, differences in the respective correlation coefficients were examined using z-tests (Hemmerich, 2017). To test H2a–c) on gender differences in student adaptive reactions to errors and in their perception of the error

climate, an analysis of variance (ANOVA) was conducted. Finally, to test H2d), regression analyses were conducted. In the first step, relationships between adaptive reactions to errors as dependent variables and gender as an independent variable were calculated. In the second step, the error climate or error climate dimensions were added as independent variables to examine their mediating effect.

3.1 Results

As preliminary analyses, we tested if affective-motivational adaptive reactions to errors can be separated from action-adaptive reactions to errors. Therefore, two measurement models were computed. For the assumed two-factor model, an acceptable fit was found ($\chi^2 = 399.60$; $df = 76$; RMSEA = 0.08; CFI = 0.90; TLI = 0.88; SRMR = 0.07; AIC = 25247.17; BIC = 25441.24). The loadings of the two-factor model were in a satisfactory range ($\alpha = 0.50–0.78$). The correlation between the two latent factors was $r = .45$. In contrast, for the model where all items loaded on one factor, no acceptable fit was obtained ($\chi^2 = 1161.50$; $df = 77$; RMSEA = 0.15; CFI = 0.65; TLI = 0.59; SRMR = 0.12; AIC = 26007.07; BIC = 26196.63). Also, the comparison of AIC and BIC suggests that the two-factor model better represents the reactions to errors of primary school children.

The path model testing hypothesis H1a revealed that at the between-level, the error climate of a class was positively associated with affective-motivational adaptive reactions to errors ($\beta = 0.77$. $p < 0.001$), but not with action-adaptive reactions to errors ($\beta = 0.28$, $p = 0.69$). There was no significant relationship between affective-motivational adaptive and action-adaptive reactions to errors at the between-level ($\beta = 0.35$, $p = 0.66$). At the within-level, a positive relationship was observed between the subjectively perceived error climate and affective-motivational adaptive reactions to errors ($\beta = 0.45$, $p < 0.001$) as well as action-adaptive reactions to errors ($\beta = 0.30$, $p < 0.001$). Table 1 presents the bivariate correlations between adaptive reactions to errors and the perceived error climate dimensions concerning H1b and H1c. As expected, the error climate dimensions were differentially associated with adaptive reactions to errors. Stronger correlations were found between affective-motivational adaptive reactions to errors and the dimensions "taking the risk of error," "error tolerance of the teacher," "evaluation of error irrelevance," "absence of negative classmate reactions," and "absence of negative teacher reactions." Simultaneously, stronger correlations were observed between action-adaptive reactions to errors and "analysis of errors," "learning functionality of errors," and "teacher support following errors." These differences in correlation coefficients were consistently significant. Table 1 presents the bivariate correlations and Steiger's (1980) variant of Dunn and Clark's z (1969).

Table 1
Bivariate correlations between error climate dimensions and reactions to errors and their differences

		1	2	z-value	p-value
1	Affective-motivational adaptive reactions to errors				
2	Action-adaptive reactions to errors	0.37			
3	Taking the risk of error	0.29	0.09	4.55	<0.001
4	Error tolerance of the teacher	0.31	0.19	2.75	<0.01
5	Evaluation of error irrelevance	0.33	0.10	5.29	<0.001
6	Absence of negative classmate reactions	0.36	0.06	7.00	<0.001
7	Absence of negative teacher reactions	0.37	0.24	3.07	<0.01
8	Analysis of errors	0.06	0.26	–4.59	<0.001
9	Learning functionality of errors	0.17	0.37	–4.85	<0.001
10	Teacher support following errors	0.29	0.43	–3.65	<0.001

Note: All bivariate correlations $r > 0.08$ are significant on the level $p < 0.05$.

Regarding H2a) and H2b), the assumed gender differences in affective-motivational adaptive reactions to errors (AMA) ($F(1,672) = 4.54$, $p = 0.03$, $\eta^2 = 0.007$) and action-adaptive reactions to errors (HA) ($F(1,672) = 4.08$, $p = 0.04$, $\eta^2 = 0.006$) were confirmed, favoring boys. With respect to H2c), gender-specific perceptions of the error climate were found ($F(1,673) = 17.35$, $p < 0.001$, $\eta^2 = 0.03$), favoring boys as assumed. Finally, with regard to H2d), this gender difference was mediated both through the perception of the error climate (AMA: $\beta = 0.49$, $p < 0.001$; HA: $\beta = 0.41$, $p < 0.001$) and through the perception of the error climate dimensions relevant for reactions to errors (see Table 2). It appears that the gender in student adaptive reactions to errors are associated with gender differences in student perception of the error climate. In more detail, indirect significant paths were found from gender via the perception of the error climate both to affective-motivational adaptive reactions to errors ($\beta = 0.08$, $p < 0.001$) and to action-adaptive reactions to errors ($\beta = 0.06$, $p = < 0.001$).

Table 2
Findings from regression analyses examining the mediating effect of perceived error climate on the relationship between gender and individual reactions to errors

	Affective-motivational adaptive reactions to errors	Action-adaptive reactions to errors	*p*
Step 1:			
Gender	0.08	0.08	<0.001
Step 2a:			
Gender	0.01	0.01	<0.05
Error climate (one factor)	0.07	0.41	<0.001
Step 2b:			
Gender	0.03	0.003	>0.38
Taking the risk of error	0.20		<0.001
Error tolerance of the teacher	0.16		<0.001
Evaluation of error irrelevance	0.12		<0.01
Absence of negative classmate reactions	0.16		<0.001
Absence of negative teacher reactions	0.16		<0.001
Analysis of errors		0.15	<0.001
Learning functionality of errors		0.21	<0.001
Teacher support following errors		0.34	<0.001

4 Discussion

Errors are an integral aspect of learning processes in schools and can provide valuable insights into the current understanding of curricular content (Hascher & Hagenauer, 2010). However, they can also contribute to the development of negative knowledge among learners (Oser & Spychiger, 2005). According to the process model of learning from errors proposed by Tulis et al. (2016), learning from errors involves both affective-motivational adaptive and action-adaptive reactions to errors. These adaptive reactions tend to be more successful for students when the learning environment is characterized by a positive error climate (Dresel et al., 2013; Grassinger & Dresel, 2017; Grassinger et al., 2015, 2018; Soncini et al., 2022; Steuer, 2014). These findings, derived from samples with fifth graders and older students, were replicated in the present study with younger students in third and fourth grades. The results affirmed that the model proposed by Tulis et al. (2016) concerning learning from errors is applicable to primary school children. This is significant because the framework by Tulis et al. (2016) primarily focused on a self-regulative perspective, encompassing affective-motivational and

cognitive-behavioral regulation of the learning process in error situations. Ten years of age is considered to be a sensitive phase for the development of these regulatory processes (Greve & Thomsen, 2019).

Furthermore, our findings support the argument that learning from errors in primary school is associated with characteristics of the learning environment—specifically, the error climate in the classroom and its individual dimensions. Third and fourth graders in classrooms with a more positive error climate reported more affective-motivational adaptive reactions to errors. Interestingly, the error climate of a class was not associated with the average action-adaptive reactions to errors within a class. One possible explanation for this could be that a positive error climate primarily facilitates affective-motivational regulation in error situations, which, in turn, promotes action-adaptive reactions to errors. Initial empirical evidence for this was provided by Grassinger et al. (2018) in a study involving fifth to eighth graders. In their study, the error climate between classes was more strongly associated with affective-motivational reactions to errors than with action-related reactions to errors. Additionally, the different dimensions of the error climate were associated with affective-motivational adaptive and action-adaptive reactions to errors. This particular finding replicates earlier evidence presented by Steuer et al. (2021). As a result, embracing the risk of making errors, fostering tolerance towards errors, assigning no relevance to errors in the assessment of student accomplishments, and refraining from negative reactions to errors seemed to be more appropriate for supporting student affective-motivational regulation in error situations. In contrast, analyzing errors, highlighting their functionality, and supporting students in error situations seemed to promote more action-adaptive reactions of students.

Consistent with previous findings, our results also revealed gender differences in reactions to errors among third and fourth graders – disfavoring girls. Since girls tend to have stronger self-regulatory competencies (Hannover & Kessels, 2011) but exhibit unfavorable motivational beliefs and tendencies, this finding strengthens the heightened significance of motivational beliefs and tendencies for (self-regulated) learning from errors. Moreover, our findings indicated that boys perceived the error climate more positively than girls, providing evidence for the relevance of motivational beliefs and tendencies in maintaining a cognitively consistent perception of the error climate (Gawronski & Strack, 2012; van Kampen, 2019). Furthermore, the perception of the error climate was found to mediate the gender difference in individual student reactions to errors. Girls seemed to learn less from their errors due to their less favorable perception of the error climate. Although this finding requires replication, it offers an intriguing insight into understanding gender differences in adaptive reactions to errors.

Limitations should be noted, as the study was conducted as a cross-sectional study, and consequently, causality in the relationships cannot be interpreted. Additionally, it should be noted that the error climate with all its dimensions was considered both as an overarching factor and as an eight-dimensional construct lacking empirical support for this age group. Further research is needed to test the structure of the error climate with primary school children. In addition, it is important to recognize that participation in the study was voluntary, and factors influencing voluntary participation could not be controlled. Additionally, the internal consistency of the scale for affective-motivational adaptive reactions to errors was only satisfactory. Nevertheless, the findings provide valuable insights into how learning from errors is understood by third and fourth graders and generally support the idea that previous findings with older students can be transferred to the age group examined in this study (Soncini et al., 2022). The process model of learning from errors by Tulis et al. (2016) appears to be applicable to various age groups within the student population.

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