



Is dealing with errors in the classroom specific for school subjects? A study of the error climate in mathematics, German, and English

Gabriele Steuer^{1,2}  · Maria Tulis³ · Markus Dresel⁴

Received: 10 July 2020 / Revised: 8 December 2020 / Accepted: 28 December 2020 /

Published online: 13 March 2021

© The Author(s) 2021

Abstract

A frequent observation in the school context is that opportunities to learn from errors are often missed. However, a positive error climate may support learning from errors. For the school subject of mathematics, some findings about characteristics of the error climate already exist. But, a comparison of the error climate between different school subjects is still pending. In the present study, it is analyzed whether the error climate differs in different school subjects and whether the same interrelations between the ways in which individuals deal with errors can be found in these different school subjects. In a study with 937 students from 48 classrooms from grades 5 to 7, in different secondary schools in Germany and Austria, we assessed the error climate and individual reactions following errors in mathematics, German, and English. Small mean differences between mathematics and the two language subjects were yielded. In addition, we found medium-sized correlations between the error climate measures in the three school subjects. However, the same pattern of interrelations between error climate and the way individuals deal with errors for all three school subjects could be shown. The results suggest that the perception of the error climate is rather similar in different school subjects. This has implications, for instance, for interventions that aim at fostering the error climate.

Keywords Error climate · Reactions to errors · Domain specificity · Classroom teaching · Learning

✉ Gabriele Steuer
gabriele.steuer@uni-bielefeld.de

¹ Department of Psychology, AE 12, University of Bielefeld, P.O. Box 10 01 31, D-33501 Bielefeld, Germany

² University of Augsburg, Augsburg, Germany

³ Department of Psychology, University of Salzburg, Salzburg, Austria

⁴ Department of Psychology, University Augsburg, Augsburg, Germany

Theoretical background

Many errors that occur in the classroom offer the opportunity to learn from them: They provide information for students as well as for teachers about false concepts, non-functional strategies, and which learning activities are (not) sensible (see Clifford 1991; Hascher and Hagenauer 2010; Weinert 1999). Thus, they help with the construction of negative knowledge, which is knowledge about what is not the case and how it does not work (see Oser and Spychiger 2005). Next to these rather cognitive aspects, errors may lead to positive emotional and motivational outcomes. Hence, overcoming errors—for instance, during independent error correction—may lead to experiencing positive emotions like joy or pride and to an increase in competence (see Seidel and Prenzel 2003). Actually, the potential that is inherent to errors is frequently not used (e.g., Weinert 1999), and errors are regarded as disruptions of the learning process. In fact, findings from classroom observations and students' self-reports of perceived error climate show that teachers often place little emphasis on the learning potential of errors (Tulis 2013). On the part of the students, dysfunctional reactions like negative emotions, feelings of helplessness, and actions to protect self-worth (e.g., covering up errors) take place in the classroom. As a consequence, cognitive resources, that deal with the content of the error at hand and its causes, vanish. The environment—and the behavior of the teacher, which is a crucial factor here—has an impact on the handling of errors by the students (Oser and Spychiger 2005; Turner and Patrick 2008; Urdan and Schoenfelder 2006). In an environment where errors are seen as potential learning opportunities, students can deal with errors with more self-confidence and with less fear compared to an environment in which errors are avoided and result in negative consequences (e.g., Althof 1999).

The error climate has already been assessed in different school subjects but most of the time in mathematics (e.g., Heinze et al. 2012). But, a systematic comparison between school subjects on an empirical basis is still pending. Also, frequent conceptualizations were used that assume a general single factor for the error climate (e.g., DESI-Konsortium 2008). With the present paper, we analyze whether the error climate (based on a multidimensional model) differs between school subjects and if similar interrelations to the individual dealing with errors persist.

Definition, relevance, and structure of the error climate

A functional error climate may be described as perception, evaluation, and usage of errors as crucial elements of the learning process within the classroom (cf. Oser and Spychiger 2005; Steuer 2014). This includes that errors have positive connotations and are evaluated as potentially helpful by the teacher as well as by students. Furthermore, errors are used as learning opportunities. Therefore, an error climate is a complex construct that affects teachers and students as well as their interactions. Besides concrete behavior on the teacher and student level, the error climate also pertains to attitudes and potential behavioral intentions towards errors. For the school subject of mathematics, an eight-factor model was already developed (Steuer et al. 2013). The eight subdimensions of the error climate model comprise the error tolerance by the teacher (attitude of the teacher towards errors: positive and open minded towards errors or error avoidant), irrelevance of errors for assessment (extent to which errors lead directly to negative evaluations and bad grades; separation of learning; and achievement situations), teacher support following errors (supportive behavior of the teacher after errors), absence of negative teacher reactions (verbal and non-verbal reactions of the teacher that

express displeasure, e.g., expression of anger or embarrassing students), and analysis of errors (extent to which one gets to the bottom of the errors or communication about errors). On the student level, absence of negative classmate reactions (classmates' behavior, e.g., laughing (at), taunting), taking the error risk (extent to which students in the classroom dare verbal contributions during the lesson even if they are not sure whether they are correct), and functionality of errors for learning (extent to which errors are seen and utilized as a starting point for learning in the classroom in general) are included in the conceptualization of the error climate. All of them are interrelated but nevertheless can be differentiated from each other. It is assumed that all eight dimensions contribute to an adaptive error climate. Therefore, an additional superordinate factor that describes the error climate in total is postulated.

Despite the relatively young research tradition in the pedagogical and psychological context, clear hints for the relevance of an error climate exist: It could be shown that error climate is interrelated with many central characteristics of the quality of teaching. Positive relationships between classroom management and cognitive activation could be demonstrated (cf. Steuer 2014). Also, for the classroom goal structure (which describes the influence of the context of the classroom on how students pursue learning or achievement goals), differential interrelations could be shown: The error climate is interrelated more closely with learning goal structures compared to achievement goal structures (cf. Steuer 2014). In addition, the error climate is interrelated with many characteristics on the student level. It has been replicated several times that the dimensions of error climate predict how students handle their own errors. A positive error climate is closely related to adaptive individual reactions following errors. This is true for rather cognitive-behavioral reactions (concrete learning behavior that is focused on overcoming the error and underlying misconceptions) as well as for affective-motivational reactions after errors (maintaining motivation and positive emotions towards the learning content) (Kreutzmann et al. 2014; Steuer et al. 2013). Kreutzmann et al. (2014) analyzed a series of characteristics with respect to their interrelations with the error climate by using a sample of 421 primary school students. Associated with the interrelation between the error climate and emotions, it could be revealed that the error climate is positively related to the experience of positive emotions (like joy for learning) and negatively with unfavorable emotions (like fear and experiencing helplessness). Also, a positive association of the error climate with motivational characteristics and learning characteristics like higher self-efficacy expectations, stronger interest, and more willingness to put in effort was demonstrated in this study. Moreover, interrelations with grades could be proven (Kreutzmann et al. 2014). In other studies, interrelations between error climate and achievement—assessed via achievement tests (for German and English: DESI-Konsortium 2008; for English: Käfer et al. 2018; for mathematics: Steuer 2014)—could be empirically shown.

Error climate in other school subjects than mathematics

Error climate was analyzed in previous studies predominantly in the school subject of mathematics (e.g., Heinze et al. 2012). Compared to other domains, errors are often more clearly defined in mathematics and as such are more obvious to perceive (and possibly more comprehensible) for the students. Whether the handling of errors in different school subjects is equally relevant and whether the error climate with its postulated subdimensions is appropriate to describe and explain the subsequent individual reactions that follow errors are open questions at this point. The school subjects we focused on in the study presented here are German (as the first language) and English (as a foreign language). These school subjects were

chosen because of two reasons: In the German school system, major school subjects and minor school subjects are divided. Both selected school subjects are major school subjects and therefore more important for succeeding at school. The second reason, which also is related to the first, is that both school subjects are taught with similar amounts of hours per week (i.e., 4 to 5 h). Minor subjects (e.g., geography, religion) have much lower amounts of time and are less comparable in this respect. Thus, we decided to choose major school subjects that are usually taught for a high amount of hours per week.

Errors, error correction, and error climate in German (as the first language instruction)

Errors in first language instruction differ from errors in mathematics or second language instruction. In this school subject, errors are usually less clear as the focus shifts from isolated spelling or grammatical errors to errors occurring in the argumentation or composition of texts, reading and presenting, understanding texts, and other media, with not just right-or-wrong answers (Kunze 2004). Therefore, errors are rarely detected by the students themselves but mostly by the teacher. This requires teachers to guide students to work with errors independently, for example, by structuring and classifying errors so that they can be identified more easily in the future (Kunze 2004). For students to be able to learn this and, furthermore, to develop other competencies like reading comprehension, attention in the classroom lies on discussion and reflection of errors in order to develop strong meta-cognitive strategies (Goer 2014). From this, it follows that teachers in German may be more challenged in inducing a positive error climate than in other school subjects, where errors are more apparent.

Errors, error correction, and error climate in English (as foreign language instruction)

For English as a foreign language, one may find a change in the way errors are dealt with over the years. Dating back, ideas of behaviorism are used to inspire the handling of errors (see Lightbown and Spada 2006). The rationale was to avoid errors and if they occurred, they should be corrected as soon as possible in order to not consolidate false knowledge (e.g., Heuer 1968). Only in the last few decades, a process of rethinking has begun and the immediate correction of errors faded into the background in favor of language production. Students should now be encouraged to produce language rather than be interrupted after every error, which also led to a decrease of motivation. Similar approaches may be observed in other countries (e.g., Japan; Sato 2003).

When it comes to written mistakes, a correction occurs in the way that it helps guiding a student's learning process and, ultimately, enables self-correction. Generally, all mistakes are considered learning opportunities (Klieme 2006) now and should be grappled with individually and transparently while considering affective-emotional components. The ultimate aim for students changed from achieving perfect native-speaker level to simply using the language, with what comes to a certain mistake tolerance (Bohnensteffen 2010).

However, in the actual classroom, it is more common to act on mistakes than not to. When corrections are made, teachers use different methods for different types of mistakes. Unfortunately, students are barely cognitively involved in making corrections and mistakes are still used as indicators of performance rather than a chance to advance (DESI-Konsortium 2008; Klieme 2006).

Comparisons of error climate between the three school subjects

Until now, only a few studies have analyzed error climate (often whilst using the term “error culture”) in different school subjects at the same time in order to find out about differences between school subjects. To the best of our knowledge, only a single study has drawn a comparison between two school subjects: mathematics and German. This work stems from Spychiger et al. (1998) and was conducted within the context of the validation of their questionnaire (“Student questionnaire for dealing with errors at school,” S-UFS(-K)). In this study, 641 students from 33 classrooms in grades 4 to 9 answered their questionnaire ($N = 295$ mathematics; $N = 346$ German). Spychiger et al. (1998) chose to include two different school subjects in the study in order to find out if there were any differences between them regarding the error culture. For the short version utilized in this work, three components of the error culture are differentiated: *teacher behavior*, *self-factor cognitive*, and *self-factor emotional*. The component *teacher behavior* comprises aspects like error tolerance of the teacher and non-existence of negative teacher reactions or corrections and opportunities for repetition. This corresponds in large parts to the understanding of the error climate as it is presented here. The components *self-factor cognitive* and *self-factor emotional* describe how individual students deal with errors on an individual level and would therefore not fall into our definition of error climate. It was analyzed whether the means of the three error culture components in mathematics differ from the ones in German. Results yielded that mean differences were significant for two of the three components—among them also *teacher behavior* ($M_m = 3.42$, $M_d = 3.35$, $p < .05$) (Spychiger et al. 1998), which is the component that is the closest to the conceptualization of error climate used in this paper. The presented results might implicate that mathematics teachers’ reactions after errors in the classroom are perceived slightly more positive compared to German teachers. However, the differences are marginal and scarcely reached significance. The authors themselves ascribe no special relevance to the differences and emphasize that more analyses are needed.

Also, in the DESI-study, an analysis of the error climate in different school subjects, German and English, was performed. The instrument utilized to assess the error climate was based on the questionnaire from Spychiger et al. (1998). It was adapted for the study (i.e., items that are specific for language courses were added), conceptualized unidimensionally, and shortened considerably.¹ The instrument was employed for both school subjects—German and English—addressed within the study. However, no direct comparison between the school subjects was carried out. Thus, it can only be stated that the means in both subjects were similar ($N_D = 4719$, $M_D = 2.76$, $SD_D = 0.55$; $N_E = 4667$, $M_E = 2.80$, $SD_E = 0.55$ by using a Likert-type scale ranging from 1 to 4) (DESI-Konsortium 2008; Wagner et al. 2009). At the same time, there are no hints for the comparability of the structure of the error climate, due to the fact that the measurement instrument was unidimensional.

Research questions

Overall, it can be stated that the status quo of research concerning the error climate in different disciplines still leaves considerable gaps. An approximation may be made by drawing comparisons to results from other constructs that are closely related to the error climate. For instance, it is known that constructs that influence the perception of the error climate are organized rather than domain specifically, e.g., goal orientations (Sparfeldt et al. 2007), value for a school subject (Green et al. 2007), or ability self-concept (Rost and Sparfeldt 2002). Furthermore, risk-taking behavior with

¹ The instrument comprised 15 items in total.

regard to task selection is different between school subjects. Clifford (1988) could show in different studies in various grades that students consistently chose tasks in mathematics that resulted in fewer errors than in language tasks. An explanation could be that tasks in mathematics are easier to verify compared to language tasks. This may directly influence the students' choice. But, errors may also be more easily recognized by students themselves in mathematics due to better potential verifiability (cf. Clifford 1988).

For the individual reactions following errors in mathematics, German, and English, there are hints for (minor) domain specificities regarding adaptive learning behavior following errors (action adaptivity). These kinds of reactions following errors include, for instance, that errors are regarded as cues in order to practice target oriented. Regarding the maintenance of motivation and joy for learning after errors (affective-motivational adaptivity of error reactions), domain specificity could not be proven (Tulis et al. 2017) despite the fact that Spychiger et al. (1998) found minor mean differences for the *self-factor emotional*, which is similar to affective-motivational adaptivity. No mean differences occurred in the subjects of German and mathematics for the cognitive and action-related component (cf. action adaptivity and attitude towards errors).

The overriding aim of the present paper is to investigate error climate (and its interrelations with an individual dealing with errors) in different school subjects. Therefore, we choose three major subjects that are taught a considerable amount of hours per week in secondary school. As a groundwork, the validity of the error climate model for the school subjects of mathematics, German, and English shall be examined before differences between the three school subjects will be analyzed. Examining the validity of the error climate model for these school subjects is important, as similarities or differences in the error climate in the three school subjects can only be compared properly if the underlying error climate model is the same for all the subjects. Therefore, it has to be examined whether the error climate model is valid for all of the three school subjects. Overall, we presume that the model of the error climate with its eight subdimensions—plus one superordinate factor—is suitable to describe how errors are dealt with in other school subjects. Between the subjects, errors may have a distinct significance and thus their characteristics (i.e., means) may vary. However, we assume that the factor structure of the error climate in mathematics, German, and English is similar.

For our main research question, we presume that small-sized differences in the extent of the error climate between the three school subjects may prevail. Relational patterns of error climate and how individuals deal with errors—with regard to action adaptive and affective-motivational reactions following errors—should be quite similar in the three school subjects.

Method

Sample

The sample comprised $N = 937$ students from 48 classrooms of 5th to 7th grades from different gymnasiums and secondary schools in southern Germany and Austria.² The sample was distributed quite similarly across the three grades (5th grade: 32.8%; 6th grade: 30.8%; 7th grade: 36.4%). 57.8% of the sample attended the gymnasium, whereas the rest attended

² We abstained from a classical power analysis due to given requirements concerning the sample size for multilevel analyses. A common desirable number for level two units is 50 (cf. Hox 1998; Maas and Hox 2004).

“Realschule” (i.e., intermediate secondary school). The schools were located in rather urban areas. The percentage of female students was 52.9%. The slightly higher proportion of females results from the fact that a school for girls only was included in the study.³ The average age in the sample was 11.9 years (SD = 1.00). By including schools from at least two different countries, different school types, and different grades in the sample, we tried to be able to generalize the results a bit broader compared to collecting data in only one country, one type of school, and a very narrow range of age. An additional reason for using students from two countries was that it could be assumed that the error climate is a universal phenomenon and thus should also work in different contexts—at least in such with the same language and similar culture. We controlled for school type and country in our analyses.

The paper-pencil surveys took place during one school lesson (45 min each). We decided for performing data collection directly within the lessons in order to improve data quality and completeness of data due to more concentrated work, compared to filling out the questionnaires at home. Trained university students conducted the surveys. The data collection took place in three waves. Participation in the study was voluntary and a parental agreement was given.

Measuring instruments

In the present study the three school subjects mathematics, German, and English were incorporated. This was implemented on item level by varying the school subject: “mathematics” was replaced by “German” or “English” and instead of “mathematics lesson” we used “German lesson” or “English lesson.” Aside from these changes, all items remained identical.

The perceived error climate of the students was assessed by utilizing the Error Climate Questionnaire (ECQ) from Steuer and colleagues (Steuer et al. 2013). The instrument comprises 31 items, which are assigned to eight dimensions and may be combined to a superordinate factor. All dimensions were assessed using four items.⁴ A sample item for *error tolerance by the teacher* reads: “In our Math class/German class/English class it is okay with our teacher if the assignments are not done correctly.” *Irrelevance of errors for assessment* was assessed by items like “If someone in our Math class/German class/English class says something wrong, it has an immediate effect on his grade” (negative item). A sample item for *teacher support following errors* would be “If someone in our Math class/German class/English class does something wrong, he will get support from the teacher,” whereas *absence of negative teacher reactions* was for instance inquired by “If someone in our Math class makes mistakes, the teacher often looks annoyed.” Parallel to that, *absence of negative classmate reactions* was conceptualized (e.g., “If someone in our Math class/German class/English class makes mistakes, his classmates will sometimes make fun of him”). A sample item for *Taking the error risk* reads as follows: “In our Math class/German class/English class a lot of students don’t dare to say anything because they are afraid it is wrong.” A sample item for *Analysis of errors* is: “In our Math class/German class/English class we discuss it in detail when something is done incorrectly.” The last dimension —*Functionality of errors for learning* was assessed for example by items like: “In our Math class/German class/English class wrong answers on assignments are used to learn something.” Reliabilities for the different dimensions

³ Single-sex schools for girls are quite common in southern Germany and Austria. Thus, considering these kinds of schools should increase rather than undermine the generalizability of the results. Furthermore, a study conducted in southern Germany revealed that teacher-student relationship—a variable that may be linked to error climate—did not differ between co-educational schools and girls’ schools (Schurt & Warburg, 2007).

⁴ An exception is *taking the error risk*, which is assessed by using three items.

in the three school subjects lay between $\alpha = .78$ and $\alpha = .92$ (cf. Table 1). Internal consistencies for the superordinate factor in the different school subjects were $\alpha = .78$ for mathematics, $\alpha = .80$ for German, and $\alpha = .79$ for English. Items of the error climate were answered on Likert-type scales ranging from 1 (*strongly disagree*) to 6 (*strongly agree*).

In order to operationalize *both kinds of adaptivities of reactions following errors*, 13 items were used in total, which proved to be reliable and valid in previous studies (cf. Dresel and Ziegler 2002; Dresel et al. 2013; Tulis et al. 2015). The scale *affective-motivational adaptivity following errors* comprised six items and captured functional affective and motivational reactions after errors during school lessons, e.g., maintenance of joy for learning. A sample item reads “When I can’t do something in Math/German/English, the lessons in the future will still be just as fun for me as always.” Reliabilities for different school subjects ranged from $\alpha = .81$ to $\alpha = .83$. The second scale to assess reactions following errors refers to cognitive aspects and concrete learning behavior, for instance, initializing goal-related learning activities. A sample item for *action adaptivity* reads “When I can’t solve a Math/German/English problem, then I practice these types of exercises on my own.” Reliabilities for the different school subjects were quite similar and lay between $\alpha = .89$ and $\alpha = .90$. For both scales, Likert-type scales ranging from 1 (*strongly disagree*) to 6 (*strongly agree*) were utilized.

Multimatrix design and handling of missing data

Due to economic reasons, a multimatrix design was used in this study (cf. Smits and Vorst 2007). Students answered the items for two of the three school subjects completely. For the

Table 1 Descriptive statistics of error climate and individual reactions following errors

	Number of items	Mathematics			German				English				
		<i>M</i>	<i>SD</i>	α	<i>ICC</i>	<i>M</i>	<i>SD</i>	α	<i>ICC</i>	<i>M</i>	<i>SD</i>	α	<i>ICC</i>
Error climate													
Error tolerance by the teacher	4	4.45	1.06	.78	.05	4.28	1.08	.78	.15	4.30	1.07	.78	.15
Irrelevance of errors for assessment	4	5.02	0.96	.90	.07	4.92	0.98	.89	.13	4.92	0.99	.89	.22
Teacher support following errors	4	4.86	0.99	.81	.12	4.63	1.08	.83	.17	4.68	1.02	.81	.16
Absence of negative teacher reactions	4	5.12	0.95	.82	.17	4.96	1.11	.87	.27	5.01	1.05	.85	.24
Analysis of errors	4	4.39	1.10	.90	.08	4.05	1.12	.90	.05	4.07	1.12	.89	.09
Absence of negative classmate reactions	4	4.56	1.29	.92	.13	4.59	1.27	.92	.14	4.53	1.27	.90	.17
Taking the error risk	3	3.58	1.40	.90	.09	3.64	1.38	.91	.10	3.49	1.37	.88	.10
Functionality of errors for learning	4	4.40	1.12	.85	.08	4.17	1.17	.87	.08	4.29	1.07	.82	.08
Superordinate factor of the error climate	8	4.55	0.70	.78	.16	4.41	0.74	.80	.20	4.41	0.72	.79	.26
Individual reactions following errors													
Affective-motivational adaptivity	6	4.56	0.98	.83	.08	4.55	0.94	.81	.09	4.61	0.94	.82	.12
Action adaptivity	7	4.54	0.93	.90	.08	4.49	0.92	.90	.10	4.59	0.88	.89	.08

Notes: $N = 937$ students. Theoretical range each 1–6

third school subject, they answered two anchor items per scale. Distribution of the different versions of the questionnaires was random. Any missing values were replaced by using tenfold multiple imputation using the full information maximum likelihood estimation (cf. Lüdtke et al. 2007; Peugh and Enders 2004). Multiple imputation is a recommended approach that leads to accurate and reliable databases (see Lüdtke et al. 2007).

Methods for analyses

As we used similar questionnaires in different school subjects, we had to deal with measuring invariance. Therefore, we checked for measurement invariance by utilizing the alignment method (Asparouhov and Muthén 2014). First, we ran the free alignment model and afterwards the fixed alignment model by using MPlus 8.3 (Muthén and Muthén 2019). The results suggest invariance of means for all items, also almost all of the items showed similar loadings between the three groups. Only one item from the subdimension absence of negative teacher reaction (mathematics) and one from taking the error risk (English) differed significantly in the loading. The average invariance index was .61. This index, with a possible range between zero and one, is an average R^2 across all parameters and may be interpreted as a hint whether the means may be interpreted meaningfully across groups.

To analyze the factor structure of the error climate, confirmatory factor analyses were calculated for each school subject separately. For each school subject, two separate models were estimated: one with eight subdimensions and another that assumes an additional superordinate factor. We utilize both models in order to be able to use the superordinate factor to have a combined measure for the global error climate and the eight-factor model to be able to have a closer look at the single aspects of the error climate. In all models, the analyzing option “type = complex” was utilized, in order to take into account the nested data structure. Hereby a correction of standard errors was conducted, which is indicated due to the fact that students are clustered in classrooms.

Multilevel regression models were again computed separately for each school subject. As a dependent variable, one type of adaptive reaction following errors was entered and the error climate—respectively the single subdimensions—of the same school subject served as predictors. The perceived error climate was included on the individual as well as the classroom level, in order to be able to quantify effects on the second level. For these analyses, HLM 6.06 (Raudenbush et al. 2008) was utilized.

Model version 1:

$$\begin{aligned} \text{Level 1 : } Y_{ij} &= \beta_{0j} + \beta_{1j} \cdot \text{M_FKL}_{ij} + r_{ij} \\ \text{Level 2 : } \beta_{0j} &= \gamma_{00} + \gamma_{01} \cdot \text{M_FKL}_j + u_{0j} \\ \beta_{1j} &= \gamma_{10} \end{aligned}$$

Model version 2:

$$\begin{aligned} \text{Level 1 : } Y_{ij} &= \beta_{0j} + \beta_{1j} \cdot \text{M_TOL}_{ij} + \beta_{2j} \cdot \text{M_BIR}_{ij} + \beta_{3j} \cdot \text{M_LUN}_{ij} + \beta_{4j} \cdot \text{M_ALR}_{ij} \\ &+ \beta_{5j} \cdot \text{M_ANA}_{ij} + \beta_{6j} \cdot \text{M_AMR}_{ij} + \beta_{7j} \cdot \text{M_RIS}_{ij} + \beta_{8j} \cdot \text{M_LFU}_{ij} + r_{ij} \\ \text{Level 2 : } \beta_{0j} &= \gamma_{00} + \gamma_{01} \cdot \text{M_FKL}_j + u_{0j} \\ \beta_{1j} &= \gamma_{10}, \beta_{2j} = \gamma_{20}, \beta_{3j} = \gamma_{30}, \beta_{4j} = \gamma_{40}, \beta_{5j} = \gamma_{50}, \beta_{6j} = \gamma_{60}, \beta_{7j} = \gamma_{70}, \beta_{8j} = \gamma_{80} \end{aligned}$$

Student i in classroom j .

Dependent variable on level 1: Y = affective-motivational adaptivity in mathematics or action adaptivity in mathematics.

Predictors on level 1 (individual level, group-mean centered): M_FKL = error climate in mathematics. M_TOL = error tolerance by the teacher. M_BIR = irrelevance of errors for assessment. M_ALR = absence of negative teacher reactions. M_LUN = teacher support following errors. M_ANA = analysis of errors. M_AMR = absence of negative classmate reactions. M_RIS = taking the error risk. M_LFU = functionality of errors for learning.

Predictors on level 2 (classroom level, grand-mean centered): M_FKL = error climate in mathematics.

All remaining analyses were carried out with SPSS 23 (IBM Corp. 2015). For all analyses, two versions were computed: one with the data on the individual level and the other time on the classroom level (data was aggregated on the basis of membership of the same classroom).

Results

Descriptive statistics

Descriptive statistics as well as all internal consistencies and intraclass-correlations (ICC) are displayed in Table 1. ICCs for the superordinate factor of the error climate ranged between .16 and .26, which indicates that a substantial part of the variance is located on the classroom level.

Structure of the error climate in the three school subjects

First, confirmatory factor analyses were performed by using the 31 items of the scale to assess the error climate in order to scrutinize the assumed eight-factor model and the model with eight factors and one superordinate factor. The models yielded acceptable and similar model fits in all three school subjects (see Table 2). Loadings of the eight-factor model were—with one exception—satisfactory (mathematics $\lambda = .51-.91$; German $\lambda = .47-.89$; English $\lambda = .47-.95$). Correlations between the eight latent factors ranged from $\rho = .08$ to $\rho = .62$ for mathematics, $\rho = .12$ and $\rho = .71$ for German, and $\rho = .10$ and $\rho = .65$ for English.

By adding the superordinate factor, the models became slightly worse (see Table 2). Factor loadings for the models with a superordinate factor lay between $\lambda = .31$ and $\lambda = .81$ for mathematics, $\lambda = .31$ and $\lambda = .80$ for German, and $\lambda = .30$ and $\lambda = .79$ for English.

Table 2 Results of confirmatory factor analyses of the error climate in the school subjects mathematics, German, and English

Model	<i>df</i>	χ^2	RMSEA	CFI	TLI
Model fit					
Model 1: eight-factor model					
Model 1a: Mathematics	406	1221.1*	.05	.94	.93
Model 1b: German	406	1167.3*	.05	.95	.94
Model 1c: English	406	1295.5*	.05	.94	.93
Model 2: 8+1-model					
Model 2a: Mathematics	426	1497.9*	.05	.92	.91
Model 2b: German	426	1530.6*	.05	.93	.92
Model 2c: English	426	1639.5*	.06	.91	.91

Notes: $N = 937$ students in 48 classrooms

* $p < .05$

As the model fits for the model that incorporates a superordinate factor can also be evaluated as acceptable, the following analyses considered both the eight subdimensions as well as the model with the superordinate factor. This offers the chance to show a holistic more global view of the effects (by using the superordinate factor) and also be able to look at the details (by using the subdimensions).

Differences between school subjects in the error climate

In the next step, means were used to address differences in the characteristics of error climates between mathematics, German, and English (see Table 1). In order to compare the means of the error climate, we first performed an ANOVA with repeated measures for the superordinate factor, which was computed with individual data as well as with aggregated data. On both levels, on the individual level ($F(2,1872) = 24.09, p < 0.001, \eta_p^2 = .03$) and on the classroom level ($F(2,94) = 4.26, p < 0.05, \eta_p^2 = .08$), a significant effect—though not very large—was yielded. In mathematics, the superordinate factor was significantly higher than in German and English. The superordinate factor in German did not differ significantly from the one in English.

In a subsequent step, we conducted a 3×8 MANOVA, in order to consider the single subdimensions and detect possible differences between them. On the level of individual data, a significant main effect of the school subject ($F(2,1872) = 24.09, p < 0.001, \eta_p^2 = .03$), a huge significant main effect of the error climate ($F(7,6552) = 394.16, p < 0.001, \eta_p^2 = .30$), and a significant interaction effect ($F(14, 13104) = 74.91, p < 0.001, \eta_p^2 = .07$) emerged. A similar pattern was revealed on the classroom level (main effect subject: $F(2,94) = 4.26, p < 0.05, \eta_p^2 = .08$; main effect error climate: $F(7,329) = 154.16, p < 0.001, \eta_p^2 = .77$; interaction effect: $F(14, 658) = 32.74, p < 0.001, \eta_p^2 = .41$). Differences were larger for subdimensions that are related to teacher behavior and smaller for dimensions related to student behavior (*absence of negative classmate reactions* and *taking the error risk*). All means on the individual level are displayed in Table 1.

Interrelations of the error climate between the three subjects

For a further inspection of the interrelations of the error climate in the three subjects, bivariate correlations were computed. Here we first used the superordinate factor of the three school subjects. On the individual level, a correlation of $r = .57$ was found between mathematics and German. Between mathematics and English, the correlation was $r = .53$ and between both lingual school subjects $r = .51$. On the basis of aggregated data, the picture was quite similar: The interrelation between mathematics and German was $r = .69$, between mathematics and English $r = .47$, and between German and English $r = .45$.

On the level of the single subdimensions, correlations between mathematics and German ranged from $r = .43$ to $r = .65$, for mathematics and English from $r = .36$ to $r = .61$, and for German and English from $r = .36$ to $r = .63$.

Patterns of interrelations of error climate and individual dealing with errors

A multilevel regression model was utilized to analyze whether the interrelations of the error climate vary between different school subjects. Both kinds of individual reactions following errors served as dependent variables. The superordinate factor was inserted as a predictor on

both levels. In the results, it could be shown that for all three school subjects, the relation between error climate and affective-motivational adaptivity was stronger ($\beta = .48$; $\beta = .52$; $\beta = .55$) (cf. Table 4) compared to action adaptivity ($\beta = .43$; $\beta = .42$; $\beta = .45$) (cf. Table 3). This is also true for the results on the classroom level. The explained variance ranged from $r^2 = .30$ to $r^2 = .70$ for the different models and different levels. The range was identical for both types of individual reactions following errors.

In additional models, we incorporated all eight subdimensions of the error climate in order to make their respective contributions more explicit. Here we found that more subdimensions contribute to the explanation of affective-motivational adaptivity (cf. Table 4) compared to action adaptivity (cf. Table 3). Furthermore, differences between the subscales were yielded. For instance, analysis of errors was significant for all three school subjects for action adaptivity. For affective-motivational adaptivity, the absence of negative teacher reactions was significant in all school subjects.

Table 3 Multilevel analyses for the prediction of action adaptivity in the school subjects Mathematics, German, and English

Predictors	Mathematics		German		English	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Intercept	− 0.02 (0.04)	− 0.02 (0.04)	− 0.02 (0.05)	− 0.02 (0.05)	− 0.01 (0.04)	− 0.02 (0.04)
Error climate on an individual level						
Superordinate factor of the error climate	0.43*** (0.04)		0.42*** (0.03)		0.45*** (0.05)	
Error climate on a classroom level						
Superordinate factor of the error climate	0.45*** (0.09)	0.45* (0.09)	0.45*** (0.10)	0.45*** (0.10)	0.35*** (0.08)	0.45*** (0.08)
Error climate on an individual level						
Error tolerance by the teacher		− 0.06* (0.03)		− 0.07 (0.04)		− 0.01 (0.04)
Irrelevance of errors for assessment		0.02 (0.04)		0.00 (0.05)		− 0.06 (0.04)
Teacher support following errors		0.13** (0.05)		0.17*** (0.05)		0.10* (0.05)
Absence of negative teacher reactions		0.08 (0.05)		0.00 (0.05)		0.05 (0.04)
Analysis of errors		0.17*** (0.04)		0.19*** (0.05)		0.33*** (0.05)
Absence of negative classmate reactions		0.02 (0.03)		0.02 (0.04)		0.03 (0.04)
Taking the error risk		0.07* (0.03)		− 0.05 (0.03)		− 0.02 (0.03)
Functionality of errors for learning		0.26*** (0.04)		0.33*** (0.04)		0.25*** (0.05)
$R^2_{\text{Individual level}}$	.39	.70	.39	.39	.70	.70
$R^2_{\text{Classroom level}}$	.30	.34	.30	.30	.34	.34

Notes: $N = 937$ students (individual level) from 48 classrooms (classroom level). Displayed are regression coefficients β and corresponding standard errors (in brackets). All variables were z -standardized beforehand so that coefficients may be interpreted like conventional standardized regression coefficients

* $p < .05$

Table 4 Multilevel analyses for the prediction of affective-motivational adaptivity in the school subjects mathematics, German, and English

Predictors	Mathematics		German		English	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Intercept	− 0.02 (0.04)	− 0.01 (0.03)	− 0.01 (0.03)	− 0.01 (0.03)	− 0.01 (0.04)	− 0.01 (0.04)
Error climate on an individual level						
Superordinate factor of the error climate	0.48*** (0.04)		0.52*** (0.04)		0.55*** (0.04)	
Error climate on a classroom level						
Superordinate factor of the error climate	0.53*** (0.08)	0.53*** (0.08)	0.53*** (0.08)	0.53*** (0.10)	0.56*** (0.11)	0.56*** (0.11)
Error climate on an individual level						
Error tolerance by the teacher		0.06* (0.03)		− 0.01 (0.04)		0.14*** (0.04)
Irelevance of errors for assessment		0.13** (0.04)		0.14*** (0.04)		0.09* (0.04)
Teacher support following errors		0.08** (0.03)		0.25*** (0.05)		0.11** (0.04)
Absence of negative teacher reactions		0.15*** (0.05)		0.06 (0.05)		0.09* (0.04)
Analysis of errors		0.09** (0.03)		0.00 (0.04)		0.06 (0.04)
Absence of negative classmate reactions		0.00 (0.04)		0.04 (0.04)		0.07 (0.05)
Taking the error risk		0.15*** (0.03)		0.13*** (0.04)		0.18*** (0.03)
Functionality of errors for learning		0.07* (0.04)		0.17*** (0.04)		0.13*** (0.04)
$R^2_{\text{Individual level}}$	.32	.70	.39	.39	.70	.70
$R^2_{\text{Classroom level}}$	.61	.34	.30	.30	.34	.34

Notes: $N = 937$ students (individual level) from 48 classrooms (classroom level). Displayed are regression coefficients β and corresponding standard errors (in brackets). All variables were z -standardized beforehand so that coefficients may be interpreted like conventional standardized regression coefficients

* $p < .05$

Discussion

The overarching aim of the present paper was to scrutinize the error climate in three different school subjects. Therefore, we initially analyzed whether the theoretical model of the error climate with eight subdimensions and the model with eight subdimensions and an additional superordinate factor can be applied. After safeguarding the appropriateness of the two models—the one with eight subdimensions and the one with eight and an additional superordinate factor—for all three addressed school subjects, the main objective was to investigate differences and interrelations of the error climate between the school subjects. Finally, the pattern of interrelations of the error climate with individual reactions following errors was analyzed in order to be able to compare relations of error climate and individual dealing with errors in the different school subjects.

Concerning the groundwork of this paper, confirmatory factor analyses could empirically confirm the theoretically assumed structure with eight subdimensions (plus one superordinate factor) for mathematics, German, and English. This had only been proven for mathematics so far (cf. Steuer 2014; Steuer et al. 2013). The findings suggest that the subdimensions are quite

similarly relevant to other subjects and that all subdimensions are essential to describe the error climate.

The results of the present study complement existing empirical evidence that already showed quite similar means between different school subjects (cf. Spychiger et al. 1998; DESI-Konsortium 2008). The mean differences that we found between mathematics and the two lingual school subjects can be regarded as indicators for differences in the perception of the error climate between school subjects. Overall, the effect of differences between school subjects can be classified as rather small. The highest means were found for mathematics and thus, its error climate was perceived as the most positive between the three school subjects considered in this study. This is in line with the findings from Spychiger et al. (1998) but is still remarkable in several respects: First, mathematics is related to negative emotions like fear or boredom (e.g., Ashcraft 2002; Götz 2004). Since a positive error climate is negatively interrelated with the experience of fear (cf. Kreutzmann et al. 2014), one could have presumed that the perception of the error climate in mathematics is less positive. Second, errors often are directly “visible” in mathematics so that one can react more quickly to them and feedback may be given more often. Otherwise, it may be this very aspect that fosters the more positive appraisal, insofar that in mathematics errors may be recognized and retraced by students themselves and related explanations and feedback may be given in a very precise and concrete manner.

Correlative analyses yielded medium-sized interrelations between the three subjects. These interrelations may be interpreted as indicating that students perceive similarities in the error climate between single school subjects. At the same time, they could indicate differences between teachers, which are relevant, too. Hence, a proportion of shared variance may be supplied by a shared school climate, the general principles of the school, or, in part, by the student-specific proportion within the error climate. Although in general it is assumed that the error climate is shaped predominantly by the teacher (e.g., Oser and Spychiger 2005; Steuer 2014), student behavior also plays an important role. And, this behavior is not only determined by the teacher but also by experiences in dealing with errors in other school subjects. Interestingly, the highest correlation was found between mathematics and German and not—like one may expect—along the linguistic dimension (for similar results see Tulis et al. 2017).

Still, one has to consider that the study design may also have influenced the results. As a result of the fact that we consecutively asked the same students about different school subjects within a joint survey (same source bias), it might be the case that the results rather underestimate than overestimate differences between the considered school subjects as assessments might have blended. Therefore, the correlations may have been lower if a different study design would have been chosen. This should also be kept in mind while interpreting the results of the regression models discussed below.

The findings showing that interrelations of the error climate and individual dealing with errors vary according to the outcome variables indicate that differentiating perceptions of the error climate promote different kinds of reactions following errors in the learning process. In concrete terms, interrelations between affective-motivational reactions following errors were stronger—a finding that is not new (cf. Steuer et al. 2013). It implies that a positive error climate is primarily more strongly connected to motivational and emotional aspects than to cognitive and behavioral aspects. A process-oriented model would be favorable here. It may be presumed that favorable motivational and emotional reactions following errors are needed as a basis to initiate learning activities on a behavioral level (cf. Tulis et al. 2017). It is barely conceivable that a student, who experiences strong fear after an error during the lesson and is

therefore busy with emotional regulation and protection of self-worth, may show adaptive and sensible learning activities since the cognitive resources are taken up elsewhere. The different patterns of interrelations of error climate with both types of individual reactions following errors were quite similar between the school subjects. On closer inspection of the models that consider the single subdimensions, it was consistently depicted for all three school subjects that the dimensions *teacher support following errors*, *analysis of errors*, and *functionality of errors for learning* were predictive for action adaptivity. Thus, functionally dealing with errors on the cognitive-behavioral level requires that the teachers foster a climate that regards errors as possible learning opportunities, which, in turn, triggers communication about errors and their causes. In addition, students need to receive support from the teacher in order to overcome their misconceptions. For affective-motivational adaptivity, a somewhat more heterogeneous pattern of results was apparent. Here too, three subdimensions were consistently predictive for all three school subjects, yet the height of the coefficients varied considerably more compared to action adaptivity. Secondly, there were some subdimensions that only reached a significant level for one or two school subjects.

For instance, *error tolerance by the teacher* was only predictive for affective-motivational adaptivity in mathematics and English but not in the school subject German. This may be due to the fact that errors in mathematics may be clearer and therefore easier to recognize for students and thus more salient. Thereby errors can be perceived as significant and potentially more threatening. A higher error tolerance by the teacher seems to make a functional contribution here. For the school subject of German, the findings indicate that errors should be uncovered and defined more clearly. This may be achieved by naming, analyzing, and discussing errors explicitly to help students understand the initial cause as well as an adequate reaction on a cognitive-behavioral level. This is especially true, as errors occurring in first language instruction tend to be less obvious as to more complex task requirements. Thus, German teachers need to help reflect on errors by structuring them and guide students into working independently with them. Overall, a set of several subdimensions for both kinds of individual reactions following errors were yielded in the three school subjects. This in turn can be regarded as a hint for mostly similar patterns of interrelations to similar constructs, which hence can be seen as another indicator for the validity of the error climate construct.

Like all research, the present study also has some limitations, which should be addressed in future research. In our study, we considered three school subjects; nevertheless, the majority of school subjects still remains neglected. For instance, school subjects like art, where errors are much more unclear compared to the school subjects we incorporated, have been ignored. Also, for sports, where errors may directly lead to accidents and injuries, the transferability of the construct of the error climate must be examined separately. Due to limited testing time, we had to fall back on a multimatrix design, which may have had an impact on the precision of the results. On a methodological level, it would have been desirable to utilize two-level factor analyses, which could not be realized due to the sample size. Another limitation is that the data comprises only self-reports from students. An option here would be to incorporate data from teachers or from objective observers. It has already been shown that the perception of the error climate differs strongly between students, teachers, and observers (cf. Steuer 2014). One may suggest that the structure does not differ here either, only the extent of the appraisal (cf. Steuer 2014). Due to the design of the study, one may not concretely quantify from where the discovered differences stem. As different teachers taught the different school subjects, differences may be teacher specific. In addition, the parallel item formulations may have led to a methodological bias.

Despite the aforementioned limitations, the results provide insights into students' perception of the error climate in three different school subjects. The findings suggest that the error climate is perceived quite similar in these three school subjects. Furthermore, the interrelations with an individual dealing with errors showed similar results. This implies that fostering a positive error climate may simulate an adaptive way of dealing with errors on the side of students—no matter which subject. In addition, the results indicate that the measurement instrument for the assessment of an error climate is also usable for the school subjects of German and English and therefore may also serve as a basis for future research beyond mathematics. The results may be particularly beneficial for the conception of interventions, e.g., trainings that aim to develop constructive error climates. Our results suggest that the identical factors are relevant to all of the three considered school subjects. This implies that future trainings could include mixed groups of teachers, who teach different school subjects, which in turn may be handy especially for in-house trainings in single schools—a positive error climate seems to be favorable for individual dealing with errors no matter which school subject. Furthermore, for students to adaptively handle errors, it needs a teacher's support, communication, and imparting that errors are learning opportunities. Thus, establishing a fruitful error climate in the classroom is worth the effort.

Funding Open Access funding enabled and organized by Projekt DEAL.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

- Althof, W. (1999). *Fehlerwelten: Vom Fehlermachen und Lernen aus Fehlern: Beiträge und Nachträge zu einem Interdisziplinären Symposium aus Anlaß des 60. Geburtstags von Fritz Oser* [Error worlds. Error making and learning from errors. Contributions to an interdisciplinary symposium on the occasion of Fritz Oser's 60th birthday and further contributions]. Opladen: Leske + Budrich.
- Ashcraft, M. H. (2002). Math anxiety: Personal, educational, and cognitive consequences. *Current Directions and Psychological Science*, 11(5), 181–185.
- Asparouhov, T., & Muthén, B. (2014). Multiple-group factor analysis alignment. *Structural Equation Modeling: A Multidisciplinary Journal*, 21(4), 495–508.
- Dresel, M., & Ziegler, A. (2002). *Failure as an Element of Adaptive Learning*. Paper presented on the 8th Biennial Conference of the European Association for Research on Adolescence, Oxford, UK.
- Dresel, M., Schober, B., Ziegler, A., Grassinger, R. & Steuer, G. (2013). Affektiv-motivationale adaptive und handlungsadaptive Reaktionen auf Fehler im Lernprozess. *Zeitschrift für Pädagogische Psychologie*, 27(4), 255–271.
- Bohnensteffen, M. (2010). *Fehler-Korrektur. Lehrer- und lernerbezogene Untersuchungen zur Fehlerdidaktik im Englischunterricht der Sekundarstufe II* [Error correction. A teacher and learner related investigation of error correction in English classes in the final years of German secondary schools]. Frankfurt am Main: Peter Lang.
- Clifford, M. M. (1988). Failure tolerance and academic risk-taking in ten- to twelve-year-old students. *British Journal of Educational Psychology*, 58(1), 15–27.

- Clifford, M. M. (1991). Risk taking: Theoretical, empirical, and educational considerations. *Educational Psychologist*, 26(3), 263–297. https://doi.org/10.1207/s15326985Sep2603&4_4.
- DESI-Konsortium (2008). *Unterricht und Kompetenzerwerb in Deutsch und Englisch: Ergebnisse der DESI-Studie* [Education and competence acquisition in German and English: Results of the DESI-Study]. Weinheim: Beltz.
- Goer, C. (2014). *Fachdidaktik Deutsch* [Didactics German]. Paderborn: Fink.
- Götz. (2004). *Emotionales Erleben und selbstreguliertes Lernen bei Schülern im Fach Mathematik*. München: Utz.
- Green, J., Martin, A. J., & Marsh, H. W. (2007). Motivation and engagement in English, mathematics and science high school subjects: Towards an understanding of multidimensional domain specificity. *Learning and Individual Differences*, 17(3), 269–279. <https://doi.org/10.1016/j.lindif.2006.12.003>.
- Hascher, T., & Hagenauer, G. (2010). Lernen aus Fehlern [Learning from errors]. In C. Spiel, R. Reimann, B. Schober, & P. Wagner (Eds.), *Bildungspsychologie* [Psychology of education] (pp. 377–381). Göttingen: Hogrefe.
- Heinze, A., Ufer, S., Rach, S., & Reiss, K. (2012). The student perspective on dealing with errors in mathematics class. In E. Wuttke & J. Seifried (Eds.), *Learning from errors at school and at work* (pp. 65–80). Opladen: Verlag Barbara Budrich.
- Heuer, H. (1968). *Die Englischstunde. Unterrichtsgestaltung und Unterrichtsforschung* [The english lesson. Lesson planning and classroom teaching research]. Wuppertal: A. Henn Verlag.
- Hox, J. (1998). Multilevel modeling: When and why. In I. Balderjahn, R. Mathar & M. Schader (Eds.), *Classification, dataanalysis and data highways* (pp. 147–154). New York: Springer.
- IBM Corp. (2015). IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.
- Käfer, J., Kuger, S., Klieme, E., & Kunter, M. (2018). The significance of dealing with mistakes for student achievement and motivation: results of doubly latent multilevel analyses. *European Journal of Psychology of Education*, 34(4), 731–753. <https://doi.org/10.1007/s10212-018-0408-7>.
- Klieme, E. (2006). Empirische Unterrichtsforschung: Aktuelle Entwicklungen, theoretische Grundlagen und fachspezifische Befunde. Einführung in den Thementeil [Empirical research on instruction: recent developments, theoretical foundations, and subject-matter-specific findings. An introduction.]. *Zeitschrift für Pädagogik*, 52(6), 765–773.
- Kreutzmann, M., Zander, L., & Hannover, B. (2014). Versuch macht kluch/g?! Der Umgang mit Fehlern auf Klassen- und Individualebene. Zusammenhänge mit Selbstwirksamkeit, Anstrengungsbereitschaft und Lernfreude von Schülerinnen und Schülern [Managing mistakes on the class and individual level: Interrelations with students' self-efficacy, effort investment, and joy of learning]. *Zeitschrift für Entwicklungspsychologie und Pädagogische Psychologie*, 46(2), 101–113. <https://doi.org/10.1026/0049-8637/a000103>.
- Kunze, I. (Hrsg.). (2004). *Konzepte von Deutschunterricht: eine Studie zu individuellen didaktischen Theorien von Lehrerinnen und Lehrern* [Concepts of German instruction: A study on individual didactical theories of teachers]. Springer.
- Lightbown, P. M., & Spada, N. (2006). *How languages are learned*. China: Oxford University Press.
- Lüdtke, O., Robitzsch, A., Trautwein, U., & Köller, O. (2007). Umgang mit fehlenden Werten in der psychologischen Forschung. Probleme und Lösungen [Handling of missing data in psychological research: Problems and solutions]. *Psychologische Rundschau*, 58(2), 103–117. <https://doi.org/10.1026/0033-3042.58.2.103>.
- Maas, C. J. M., & Hox, J. J. (2004). Robustness issues in multi-level regression analysis. *Statistica Neerlandica*, 58(2), 127–137. <https://doi.org/10.1046/j.0039-0402.2003.00252.x>.
- Muthén, L. K., & Muthén, B. O. (2019). *Mplus 8.3 [Computer Software]*. Los Angeles: Muthén & Muthén.
- Oser, F., & Spychiger, M. (2005). *Lernen ist schmerzhaft: Zur Theorie des Negativen Wissens und zur Praxis der Fehlerkultur* [Learning is painful. On the theory of negative knowledge and the culture of mistakes in practice]. Weinheim: Beltz.
- Peugh, J. L., & Enders, C. (2004). Missing data in educational research: A review of reporting practices and suggestions for improvement. *Review of Educational Research*, 74(4), 525–556. <https://doi.org/10.3102/00346543074004525>.
- Raudenbush, S. W., Bryk, A. S., & Congdon, R. (2008). *HLM 6.06 for Windows [Computer software]*. Lincolnwood: Scientific Software International, Inc..
- Rost, D. H., & Sparfeldt, J. R. (2002). Facetten des schulischen Selbstkonzepts. Ein Verfahren zur Messung des differenziellen Selbstkonzepts schulischer Leistungen und Fähigkeiten (DISK-Gitter) [Facettes of scholastic self-concept: An instrument to assess the differential self-concept of academic achievement and abilities]. *Diagnostica*, 48(3), 130–140. <https://doi.org/10.1026/0012-1924.48.3.130>.

- Sato, K. (2003). Improving our students' speaking skills: Using selective error correction and group work to reduce anxiety and encourage real communication. Retrieved November 11, 2020, from <https://files.eric.ed.gov/fulltext/ED475518.pdf> (ERIC Document Reproduction Service No. ED475518).
- Seidel, T., & Prenzel, M. (2003). Mit Fehlern umgehen – Zum Lernen motivieren [Dealing with errors – Motivating to learn]. *Praxis der Naturwissenschaften - Physik in der Schule*, 52(1), 30–34.
- Smits, N., & Vorst, H. C. M. (2007). Reducing the length of questionnaires through structurally incomplete designs: An illustration. *Learning and Individual Differences*, 17(1), 25–34. <https://doi.org/10.1016/j.lindif.2006.12.005>.
- Sparfeldt, J. R., Buch, S. R., Wirthwein, L., & Rost, D. H. (2007). Zielorientierungen: Zur Relevanz der Schulfächer [Goal orientations. The relevance of school subjects]. *Zeitschrift für Entwicklungspsychologie und Pädagogische Psychologie*, 39(4), 165–176. <https://doi.org/10.1026/0049-8637.39.4.165>.
- Spychiger, M., Mahler, F., Hascher, T., & Oser, F. (1998). Fehlerkultur aus Sicht von Schülerinnen und Schülern. Der Fragebogen S-UFS: Entwicklung und erste Ergebnisse [Error culture from the point of view of students. The S-UFS questionnaire: Development and first results]. Schriftenreihe zum Projekt „Lernen Menschen aus Fehlern? Zur Entwicklung einer Fehlerkultur in der Schule“, Nr. 4. Freiburg, Schweiz: Pädagogisches Institut der Universität Freiburg. https://doi.org/10.1007/978-3-663-07878-4_2
- Steuer, G. (2014). *Fehlerklima in der Klasse. Zum Umgang mit Fehlern im Mathematikunterricht* [Error climate in the classroom: On handling errors in mathematics instruction]. Wiesbaden: Springer VS.
- Steuer, G., Rosentritt-Brunn, G., & Dresel, M. (2013). Dealing with errors in mathematics classrooms: Structure and relevance of perceived error climate. *Contemporary Educational Psychology*, 38, 196–210. <https://doi.org/10.1016/j.cedpsych.2013.03.002>.
- Tulis, M. (2013). Error management behavior in classrooms: Teachers' responses to students' mistakes. *Teaching and Teacher Education*, 33, 56–68
- Tulis, M., Steuer, G. & Dresel, M. (2015). Learning from errors: Process and contextual conditions. Towards a model of individual processes within contexts. In M. Gartmeier, H. Gruber, T. Hascher & H. Heid (Hrsg.), *Fehler. Ihre Funktionen im Kontext individueller und gesellschaftlicher Entwicklung* [Errors: Their functions in the context of individual and social development](S. 53–70). Göttingen: Waxmann.
- Tulis, M., Steuer, G., & Dresel, M. (2017). Positive beliefs about errors as an important element of adaptive individual dealing with errors during academic learning. *Educational Psychology*, 38, 139–158. <https://doi.org/10.1080/01443410.2017.1384536>.
- Turner, J. C., & Patrick, H. (2008). How does motivation develop and why does it change? Reframing motivation research. *Educational Psychologist*, 43(3), 119–131. <https://doi.org/10.1080/00461520802178441>.
- Urda, T., & Schoenfelder, E. (2006). Classroom effects on student motivation: Goal structures, social relationships, and competence beliefs. *Journal of School Psychology*, 44(5), 331–349. <https://doi.org/10.1016/j.jsp.2006.04.003>.
- Wagner, W., Helmke, A., & Rösner, E. (2009). *Deutsch Englisch Schülerleistungen International. Dokumentation der Erhebungsinstrumente für Schülerinnen und Schüler, Eltern und Lehrkräfte* (Materialien zur Bildungsforschung Nr. 25/1) [German English student achievement international. Documentation of measuring instruments for students, parents and teachers]. Frankfurt am Main: Gesellschaft zur Förderung Pädagogischer Forschung.
- Weinert, F. E. (1999). Aus Fehlern lernen und Fehler vermeiden lernen [Learning from errors and learning to avoid errors]. In W. Althof (Ed.), *Fehlerwelten. Vom Fehlermachen und Lernen aus Fehlern* [Error worlds. Error making and learning from errors] (pp. 101–110). Opladen: Leske + Budrich.

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Dr. Gabriele Steuer. University of Augsburg, Augsburg, Germany. Department of Psychology, AE 12, University of Bielefeld, P.O. Box 10 01 31, D-33501 Bielefeld, Germany. E-mail: gabriele.steuer@uni-bielefeld.de

Current themes of research:

Self-regulation with a special focus on motivational regulation.
Dealing with errors and error climate.

Most relevant publications in the field of Psychology of Education:

- Steuer, G., Engelschalk, T., Eckerlein, N., & Dresel, M. (2019). Assessment and relationships of conditional motivational regulation strategy knowledge as an aspect of undergraduates' self-regulated learning competencies. *Zeitschrift für Pädagogische Psychologie [Journal for Pedagogical Psychology]*, 33(2), 95–104. <https://doi.org/10.1024/1010-0652/a000237>.
- Engelschalk, T., Steuer, G., & Dresel, M. (2017). Quantity and quality of motivational regulation among University students. *Educational Psychology*, 37, 1154–1170. <https://doi.org/10.1080/01443410.2017.1322177>.
- Steuer, G., & Dresel, M. (2015). A constructive error climate as an element of effective learning environments. *Psychological Test and Assessment Modeling*, 57(2), 262–275.
- Steuer, G., Rosentritt-Brunn, G., & Dresel, M. (2013). Dealing with errors in Mathematics classrooms: Structure and relevance of perceived error climate. *Contemporary Educational Psychology*, 38(3), 196–210. <https://doi.org/10.1016/j.cedpsych.2013.03.002>.

Dr. Maria Tulis. Department of Psychology, University of Salzburg, Salzburg, Austria

Current themes of research:

- Individual and contextual preconditions for learning from errors.
Emotional and motivational self-regulation.
Development and change of psychological knowledge and (mis)conceptions.

Most relevant publications in the field of Psychology of Education:

- Tulis, M., Steuer, G. & Dresel, M. (2018). Positive beliefs about errors as an important element of adaptive individual dealing with errors during academic learning. *Educational Psychology*, 38, 139–158. <https://doi.org/10.1080/01443410.2017.1384536>.
- Tulis, M. (2013). Error management behavior in classrooms: Teachers' responses to students' mistakes. *Teaching and Teacher Education*, 33, 56–68. <https://doi.org/10.1016/j.tate.2013.02.003>.
- Tulis, M., Steuer, G., & Dresel, M. (2016). Learning from errors: A model of individual processes. Special issue "new theories of motivation and learning". *Frontline Learning Research*, 4(2), 12–26.
- Tulis, M. & Fulmer, S. (2013). Students' motivational and emotional experiences and their relationship to persistence during academic challenge in mathematics and reading. *Learning and Individual Differences*, 27, 35–47. <https://doi.org/10.1016/j.lindif.2013.06.003>.

Prof. Dr. Markus Dresel. Department of Psychology, University Augsburg, Augsburg, Germany

Current themes of research:

- Self-regulated learning (e.g., from errors).
Teachers' goal orientations.
Procrastination as a risk factor for abortion of study.

Most relevant publications in the field of Psychology of Education:

- Bälke, L., Eckerlein, N. & Dresel, M. (2018). Interrelations between motivational regulation, procrastination and college dropout intentions. *Unterrichtswissenschaft*, 46, 461–479.
- Daumiller, M., Dickhäuser, O., & Dresel, M. (2019). University instructors' achievement goals for teaching. *Journal of Educational Psychology*, 111, 131–148.
- Dresel, M., Schmitz, B., Schober, B., Spiel, S., Ziegler, A., Engelschalk, T., Jöstl, G., Klug, J. Roth, A., Wimmer, B., & Steuer, G. (2015). Competencies for successful self-regulated learning in higher education: Structural model and indications drawn from expert interviews. *Studies in Higher Education*, 40, 454–470.