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Dealing with errors in mathematics classrooms: Structure and relevance of perceived error climate ☆

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ABSTRACT

Errors are often perceived by students as self-threatening and not as learning opportunities. The present work focuses on contextual influences on reactions to errors and learning processes. Based on prior research, a conceptualization of perceived error climate in the classroom with eight subdimensions and one superordinate uniform factor is proposed and a newly developed student questionnaire for its assessment is presented. Results of a study with $N = 1116$ students from 56 mathematics classrooms in German secondary schools indicated the validity of the error climate conceptualization and the suitability of the questionnaire. Moreover, the results showed that perceived error climate in the classroom predicted the adaptivity of students' individual reactions to errors above and beyond perceived classroom goal structures and personal achievement motivation (academic self-concept, mastery goal orientation). In addition, the study provided evidence that perceived error climate affects – partially mediated through students' individual reactions to errors – the quantity and self-regulation of students' effort.

1. Introduction

Although making errors while learning is common, it is also frequently perceived as something negative, shameful and self-threatening. These perceptions and reactions often prevent persons from seeing errors as learning opportunities (see Oser & Spychiger, 2005; Pekrun, 2009). However, making mistakes has important functions in learning processes since it helps to establish accurate mental models and, therefore, fosters learning progress (Jones & Endsley, 2000). Oser and Spychiger (2005) introduced the concept of negative knowledge (knowledge about that what does not work), which is acquired through errors and is postulated to have positive effects on performance. As an impressive body of research in the past decades has shown, the way a student will deal with errors and failure depends heavily on personal achievement motivation, especially goal-orientation and academic self-concept (for an overview see Wentzel & Wigfield, 2009).

Nevertheless, in addition to influences of personal achievement motivation, influences generated by contextual characteristics in the classroom have to be assumed (Turner & Patrick, 2008; Urdan & Schoenfelder, 2006). To describe the extent and the quality in which the environment supports or inhibits learning from errors, researchers working in educational and organizational settings introduced the concept of "error climate" or "error culture" (e.g., Oser & Spychiger, 2005; Van Dyck, Frese, Baer, & Sonnentag, 2005). Accordingly, a social learning environment which is characterized by a positive error climate fosters adaptive affective, motivational, cognitive and behavioral reactions to errors, which, in turn, ensure learning from errors. Nevertheless, no theoretical consensus has yet been reached regarding the conceptualization of the error climate in learning environments (as perceived by the learners). Open issues concern the relevant subdimensions of the perceived error climate and their relation to similar and well-established contextual characteristics, primarily the perceived classroom goal structure (for an overview see Meece, Anderman, & Anderman, 2006). Moreover, there is a lack of empirical evidence of the consequences perceived classroom error climate has on how individuals deal with errors and the quantity and quality of learning processes.

Consequently, the aim of the present work is to conceptualize perceived classroom error climate and to develop a measuring instrument to adequately assess this perceived context characteristic. Moreover, an aim of the present work is to analyze the unique effects different perceived classroom error climates have on how adaptive students react to errors and how well they learn. This goal is addressed using a sample of German secondary school students in the subject of mathematics.

1.1. Individuals' reactions to errors

In recent decades affective and motivational reactions following errors and failure have been extensively studied under different

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theoretical perspectives (for an overview see Elliot & Dweck, 2005). Primarily, an adaptive reaction pattern is distinguished from a maladaptive pattern: An adaptive reaction pattern following errors and failure maintains learning motivation and functional affects such as joy; a maladaptive pattern decreases learning motivation and increases feelings of shame and hopelessness. These two patterns subsequently lead to different learning behaviors in terms of high vs. low effort and persistence, and in terms of adaptive vs. maladaptive self-regulation of learning activities. To explain why some students show adaptive affective and motivational reactions to failure and some do not, different theoretical approaches have been proposed.

Theoretical advancement primarily resulted from achievement goal theory (e.g., Ames, 1992; Dweck, 1986; Elliot, 1999; Nicholls, 1984; for an overview see Maehr & Zusho, 2009), which accounted for inter-individual differences with respect to mastery goals (goal to enhance own competency) and performance goals (goal to demonstrate high competency or to avoid demonstrating low competency). For individuals with a strong orientation on mastery goals, failure and errors are a source of information regarding one's own learning. This is frequently accompanied by an adaptive pattern characterized by functional attributions (such as effort attributions; Weiner, 1986, 2005), as well as adequate effort, appropriate task selection, and less negative affective reactions to errors. On the other hand, for individuals with a strong performance goal orientation, failure and errors are information about lacking abilities and are therefore a threat to self-esteem. This leads to consequences such as dysfunctional attributions (such as ability attributions), reduced effort, avoidance of challenges and negative affect.

In addition to achievement goals, academic self-concept can be seen as an important predictor of affective and motivational reactions following errors and failure. It reflects individuals' beliefs about the extent of their abilities (i.e., perceived competencies) and is rather domain-specific, e.g. specific for separate school subjects (Harter, 2006; Marsh, Xu, & Martin, 2012). The quality of the self-concept highly influences an individual's causal attributions. Students with low academic self-concepts are more likely to attribute failure to internal and stable causes, such as lack of ability, which are characteristics of the maladaptive pattern following errors (e.g., Skaalvik, 1994). Therefore, a strong mastery goal orientation and a positive academic self-concept seem to protect against maladaptive reactions to errors.[1]

Beyond affective and motivational reactions to errors, cognitive and behavioral reactions, which are specifically adjusted to the error in question, have to be considered (e.g., Dresel, Schober, Ziegler, Grassinger, & Steuer, submitted for publication; Dresel & Ziegler, 2002; Tulis, Grassinger, & Dresel, 2011). These reactions could be a detailed analysis of the error in order to identify misconceptions, a self-evaluation of one's specific knowledge, or deliberately practicing the type of task in which the error occurred in order to bridge the knowledge gap that was responsible for the error. Works which addressed how students deal with errors such as, Dresel and Ziegler (2002) and Dresel et al. (2013), revealed that these cognitive-behavioral reactions to failure and errors are best conceptualized distinguished from (but nevertheless interrelated with) the affective-motivational reactions described above. Accordingly, they proposed a two component model of individuals' reactions to errors, which comprises of the adaptivity of affective-motivational error reactions (''affective-motivational adaptivity'') and the adaptivity of learning actions following errors (''action adaptivity''). Affective-motivational adaptivity of error reactions is defined as the degree to which the learner maintains positive affect (e.g., joy) and motivation to learn in the face of errors. On the other hand, action adaptivity of error reactions is defined as the degree to which the learner initiates cognitive processes and behaviors aimed to specifically overcome a possible misconception underlying the present error. It can be assumed, that regulating negative affect and detriments in learning motivation potentially associated with errors, i.e. an affective-motivational adaptivity of reactions to errors, is a prerequisite of cognitive activities and learning behaviors specifically adapted to the error, i.e. an action adaptivity of error reactions (cf. Boekaerts, 1999).

Referring to the definition of action-adaptive error reactions of learners, it becomes clear that these are best conceptualized as a special class of self-regulated learning processes (e.g., Zimmerman, 2000). They encompass several cognitive and meta-cognitive processes which are located in all phases of the self-regulation process (pre-actional, actional, and post-actional phases; see Schmitz & Wiese, 2006). The conceptual difference of the action adaptivity of error reactions, in contrast to general self-regulated learning, can be seen in two aspects: First, action adaptivity of error reactions refers to a specific trigger for regulation, namely the error at hand. Errors can be seen as a prominent class of occasions for self-regulating one's learning behavior, but are by no means the only one. Depending on the theoretical position, a variety of triggers, or even no trigger, for regulation is possible in general models of self-regulated learning (see Zimmerman & Schunk, 2011, for an overview). Second, the adaptation of learning processes to this trigger is constitutive for the concept of action adaptivity and a strong action adaptivity of error reactions only exists, when this adaptation is adequate (i.e. when learners initiate learning activities well-adjusted to the error). In models of self-regulated learning focusing primarily on the quantity instead of the quality of self-regulated learning this is not the case in a similar vein (cf. Wirth & Leutner, 2008).

Until now, relatively little empirical evidence has been provided about the association of action-adaptive error reactions with other, more general aspects of students' learning. Dresel and Ziegler (2002) as well as Dresel et al. (submitted for publication) provided evidence that action-adaptive reactions to errors (such as learning activities specifically adjusted to the error in question) are interrelated to general cognitive and meta-cognitive aspects of the learning process, such as the use of learning strategies, effort, self-regulation of learning and achievement. However, the affective-motivational adaptivity of error reactions was strongly related to affective and motivational aspects, such as helplessness. Results of Dresel et al. (submitted for publication) as well as Tulis et al. (2011) indicated that the affective-motivational adaptivity of students' reactions to errors is primarily predicted by their academic self-concepts (β =.29–.40), while the action adaptivity of error reactions mainly depends on students' mastery goal orientations (β = .30–.46).

1.2. Perceived error climate in the classroom

It can be assumed that reactions to and learning from errors depend not only on individual characteristics, but also on characteristics inherent to the (learning) environment. Contextual features regarding the interpersonal handling of errors, which foster or prohibit learning from errors, are included in the concept of ''error climate'' or ''error culture''. This concept is already the subject of a larger body of research in the organizational context, where its relevance has already been demonstrated (e.g., Cannon & Edmondson, 2001; Rybowiak, Garst, Frese, & Batinic, 1999; Van Dyck et al., 2005). However, for the educational context there is little research (mainly conducted by the research group of Oser and colleagues in

[1] Other concepts interrelated with achievement goals and academic self-concepts that have to be mentioned but are not the focus of the present work are the concepts of implicit theories regarding the malleability of one's abilities (Dweck & Leggett, 1988; Dweck & Molden, 2005) and interest (cf. Schiefele, 2009).