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Written feedback in mathematics: Mediated by students' perception, moderated by goal orientation

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ABSTRACT

Although feedback is a popular topic in educational research, the question of how and on what conditions feedback in mathematics affects learning seldom has been addressed. In this study, we investigated: (1) whether process-oriented feedback in mathematics leads to greater interest and higher achievement development compared to social-comparative feedback; (2) whether students' perception of feedback with regard to usefulness and competence support mediates these effects; and (3) whether the impact of feedback is moderated by students' mastery approach goal orientation. To answer these research questions, 146 ninth-grade intermediate school students in Germany were randomly assigned to both feedback conditions. Results of path analyses revealed (1) no significant total feedback effects on interest and achievement development, but (2) indirect effects on the development of interest via perceived competence support and usefulness, and on achievement development via perceived usefulness, as well as (3) a moderation effect of mastery approach goal orientation on the impact of feedback on perceived usefulness.

1. Introduction

Feedback has been identified as one of the most powerful influences on the learning process (Hattie, 2009). Although extensive research has been conducted on the properties that make feedback effective (for comprehensive overviews see Bangert-Drowns, Kulik, Kulik, & Morgan, 1991; Hattie & Timperley, 2007; Kluger & DeNisi, 1996; Shute, 2008), investigations in this field have had two main limitations. First, effects of feedback have been studied mostly in laboratory contexts (Deci, Koestner, & Ryan, 1999; Shute, 2008) rather than in ecologically valid settings. Second, according to Shute (2008), "the specific mechanisms relating feedback to learning are still mostly murky, with very few (if any) general conclusions"(p. 157). To address these challenges, we developed a type of feedback called process-oriented feedback, which combines the properties found in previous (mainly laboratory) studies to be beneficial. We provided students with written process-oriented feedback on their performance on a curriculum-embedded mathematics test and then compared the effects of such feedback to the impact of feedback usually given in instruction, namely grades (social-comparative feedback) on students' achievement and interest development in mathematics. To gain deeper understanding of how process-oriented feedback works and whether learners' individual prerequisites influence feedback effects, we analyzed two intervening variables (i.e., perception of usefulness and competence support), and one potential moderator (i.e., mastery approach goal orientation) as an individual prerequisite. Thus, fine-grained analyses were conducted of psychological mechanisms within an ecologically valid setting.

We investigated the effects of process-oriented feedback on students' performance in mathematics as over 80% of mathematics instruction in school is spent working on tasks and problems (Hiebert et al., 2003). As process-oriented feedback may help students learn more about their performance and how to proceed when facing difficulties in solving mathematical tasks and problems it should play an especially important role in this subject.

1.1. Feedback and its impact on learning

One of the most influential feedback theories was developed by Hattie and Timperley (2007). In agreement with other reviews and meta-analyses (Bangert-Drowns et al., 1991; Kluger & DeNisi, 1996; Narciss, 2008), Hattie and Timperley emphasize that the main

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purpose of feedback is to highlight the discrepancy between current understanding and performance on one hand and the learning goal on the other, and to encourage and enable students to reduce the discrepancy. To this end, according to Hattie and Timperley (2007), feedback must provide information regarding three major questions: (a) "Where am I going?", (b) "How am I going?", and (c) "Where to next?". They distinguish four levels on which feedback relating to these questions can operate: (a) task performance, (b) process of understanding, (c) regulatory or metacognitive process, and (d) self-regulation. Operating on the task and process of understanding levels means that the cognitive processes (in our case mathematical operations) which are involved in solving a task are addressed. Feedback on the regulatory or metacognitive process level addresses the ways in which students monitor, direct, and regulate their own actions toward reaching a learning goal. Feedback operating on the levels of task performance, process of understanding and self-regulation is more powerful than feedback solely on the self level, as it focuses on the learner as a person (Gibbs & Simpson, 2004; Hattie & Timperley, 2007).

Butler and Winne (1995) suggest that productive elaborated feedback consists of at least two components: a product-oriented component that offers information about a domain (e.g., a specific topic within mathematics); and a process-oriented component to regulate the learning process (e.g., when and how a particular strategy is appropriate). By combining the demand for answers to the three feedback questions and the focus on cognitive and self-regulation processes according to Hattie and Timperley with the two components presented by Butler and Winne, we can assume that feedback should provide the following if it is to be effective. First, it should offer information on which of the mathematical operations needed to solve a task have been appropriately applied by the student (strengths) and which have not (weaknesses). This information represents the domain-specific product and answers the first two feedback questions by showing the relationship between mathematical operations applied ("How am I going?") and needed ("Where am I going?"). Second, it should offer information on how task solutions can be improved (strategies). This represents the process regulation and answers the third feedback question ("Where to next?"). Such process-oriented feedback comprises two of Narciss's (2008) elaborated feedback components: 'knowledge about mistakes' by informing students about their weaknesses, and 'knowledge about how to continue' by giving students strategies to solve the task. In this way, process-oriented feedback serves a corrective function and at the same time fulfills the following basic motivational functions listed by Narciss (2008): it provides an incentive (by rendering the result visible), it facilitates task completion (by offering suggestions to overcome difficulties), it enhances self-efficacy (by making it possible to master tasks), and it contributes to mastery experience that can be attributed to personal causation.

Feedback bearing a resemblance to process-oriented feedback has been shown to impact positively on students' performance (Krause, Stark, & Mandl, 2009; Narciss & Huth, 2006) as well as on their motivational beliefs and interest (Butler, 1987; Narciss & Huth, 2006). The parallels to process-oriented feedback are the combination of knowledge of result, knowledge of correct result, and corrective information in the study of Krause et al. (2009), and offering strategies for error correction (bug-related feedback) in the study of Narciss and Huth (2006). Butler (1987) examined written verbal comments on thinking tasks for fifth- and sixth-grade students containing a reinforcing and a goal-setting component.

Implementing process-oriented feedback is highly challenging for teachers (Hattie & Timperley, 2007). First, it is time-consuming, which means that teachers may need to automate classroom activities (while still providing rich learning opportunities for all students) in order to have the time and resources to provide process-oriented feedback to individual learners. Second, implementing process-oriented feedback requires knowledge and skill; therefore, teachers need appropriate and sufficient training on how to employ effectively this form of feedback. These may be reasons that performance in school is more frequently judged against a social frame of reference, namely by giving grades (Cizek, Rachor, & Fitzgerald, 1996). However, grades provide little information about the relation between performance and the learning goal, and they do not inform students about strategies. Research has provided empirical evidence that social-comparative feedback generally does not bring about positive effects and therefore is theoretically inferior (Deci & Ryan, 2000). In fact, social comparative feedback tends to undermine performance (Butler, 1987; for a review see Black & Wiliam, 1998) and interest (Butler, 1987; Kim, Lee, Chung, & Bong, 2010; Sansone, 1986, 1989) compared to written verbal comments (Butler, 1987), criterion-related feedback (Kim et al., 2010) and task-feedback (Sansone, 1986, 1989).

1.2. How feedback works: perceived usefulness and competence support as intervening variables

Given that students are "active makers and mediators of meaning within a particular learning context" (Higgins, Hartley, & Skelton, 2002, p. 53) and that according to Peterson and Irving (2008), a major challenge regarding feedback is that it needs to be understood in ways that contribute to the improvement of learning, it is remarkable that how learners perceive feedback content, and how the perception relates to learning outcomes has seldom been empirically assessed (Strijbos, Narciss, & Dünnebier, 2010). In this paper we investigate whether two variables which describe the perception of feedback – perceived usefulness and perceived competence support – help explain how feedback impacts on achievement and interest development.

1.2.1. Perceived usefulness

According to Bangert-Drowns et al. (1991), feedback needs to be received mindfully to promote learning, mindful processing being defined as "a reflective process in which the learner explores situational cues and underlying meanings relevant to the task involved" (Dempsey, Driscoll, & Swindell, 1993, p. 38). Similarly, Ilgen, Fisher, and Taylor (1979) identified the central role of perception in feedback processing. On a theoretical level they differentiated four stages in understanding how feedback results in behavior change: Feedback needs to (a) be perceived, (b) be accepted as accurate, (c) be perceived as useful, and (d) lead to actual behavior change. Brett and Atwater (2001) showed in the context of organizational psychology that feedback consisting of self-ratings and boss-ratings on leadership and managerial behavior of students in a master's of business administration program was indeed perceived as useful if accepted as accurate by the recipients. Strijbos et al. (2010) found that peer feedback which provided the performance and error type, as well as information on how to proceed (elaborated specific peer feedback) on academic writing revision tasks was perceived as more adequate than concise general peer feedback, which solely remarked on knowledge of result. The perception of usefulness, in turn, was related to a higher developmental focus rated by a facilitator on a development focused scale (e.g., "this person was open to feedback" and "this person was concerned with understanding what the feedback meant for his or her development") in Brett and Atwater's study. In the study of Strijbos et al., however, perception of usefulness was uncorrelated to performance, which the authors attributed to a particular feature of the study's design.

To fulfill its cognitive and motivational functions (as outlined by Narciss, 2008), feedback should initiate cognitive and behavioral