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Further evidence on the structural relationship between academic self-concept and self-efficacy: On the effects of domain specificity

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ABSTRACT

Given the importance of students' competence beliefs in science learning, many researchers have focused on the interplay between self-concept and performance in various domains. However, little research has been undertaken on the structure of competence beliefs and the domain specificity in scientific subjects such as chemistry. This study, consequently, aims to analyze the structure of competence beliefs by taking into account components of self-concept and self-efficacy as well as domain and construct effects. By using the data of 459 German high-school students of grade levels 10 to 13, it was found that structural models, which distinguish between general self-concept, chemistry self-concept and chemistry self-efficacy, represented the data reasonably well. The results provide evidence for (1) the empirical distinction between self-concept and self-efficacy within the domain of chemistry; (2) significant differences between general academic and domain-specific self-concept; and (3) substantial relationships among students' competence beliefs and school achievement. Furthermore, teachers' orientations towards hands-on inquiry activities and students' enjoyment in science were strongly related to self-concept and self-efficacy. Based on present competence-oriented curricula, it was possible to clarify the relationship among self-concept and self-efficacy in chemistry.

1. Introduction

Students' competence beliefs can be regarded as essential predictors of performance, motivation, and learning. Especially in scientific domains, these constructs play an important role when it comes to achieving learning goals, developing adequate epistemic beliefs, and solving problems (Mason, Boscolo, Tornatora, & Ronconi, 2013; Tsai, Ho, Liang, & Lin, 2011). Competence beliefs are broadly defined as "children's cognitive representations of how good they are at a given activity" (Freiberger, Steinmayr, & Spinath, 2012, p. 518). In this context, they refer to self-concepts and self-efficacy which have been extensively studied for general academic, mathematical, and verbal domains (e.g., Van Dinther, Dochy, & Segers, 2011). For instance, Marsh, Walker, and Debus (1991) were able to show that academic self-concept comprises different components within a hierarchical structure and that self-concept and self-efficacy are related constructs. However, research suggests that there is evidence on the empirical distinction between self-concept and self-efficacy (e.g., Bong & Skaalvik, 2003; Ferla, Valcke, & Cai, 2009; Marsh et al., 1991). Wagner, Göllner, Helmke, Trautwein, and Lüdtke (2013) and Marsh and Scalas (2010) pointed out that students' perceptions of competences or classroom-based aspects such as instructional quality can be regarded as multidimensional and domain-specific. However, little research has been proposed on whether or not this distinction holds for scientific domains such as chemistry. In this context, the conceptual approach of analyzing domain specificity, which was proposed by Brunner (2008), could provide a reasonable tool to address this shortcoming. Additionally and due to a lack of appropriate assessments, little is known about how students evaluate their competences according to the demands of specific curricular standards. In light of recent developments on establishing national standards in scientific subjects in Germany, it is of interest to assess students' specific competence beliefs in order to use these as sources of individual feedback and predictors of achievement (Köller & Parchmann, 2012; Marsh & Martin, 2011).

The present study, consequently, aims to analyze the relationship between chemistry-specific self-concept and self-efficacy and intends to check whether or not these two constructs are related and could be distinguished from general academic self-concept. In this context, a methodological approach is presented which allows researchers to obtain evidence on domain and construct specificity (Marsh et al., 2013). Besides analyzing the structure of students' competence beliefs (internal validation), their relationships with further constructs are investigated in order to externally validate the assessment (Messick, 1995). In this study, methods of structural equation modeling are applied to a sample of 459 German high-school students.

1.1. Literature review

1.1.1. Construct definitions

In general, academic *self-concept* has been defined as students' perception of themselves within the academic environment (Marsh,

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1990; Marsh & Scalas, 2010). Self-concept is continually formed by experience and interaction with the environment (Bandura, 1997; Spinath & Steinmayr, 2012). In educational sciences, this construct has been extensively studied and, up to now, much is known about the general structure of self-concepts. For instance, research has shown that there is evidence for a multidimensional and hierarchically organized structure of the construct (e.g., Arens, Craven, Yeung, & Hasselhorn, 2011; Marsh, 1990; Marsh et al., 1991). On the first level, one can distinguish between academic and non-academic self-concepts (Marsh & Martin, 2011; Marsh & Scalas, 2010). The second level comprises subjects as further factors which are indicated by perceptions of one's competence in these subjects (Marsh et al., 1991). This model has become known as the Marsh/Shavelson model (Brunner, Keller, Hornung, Reichert, & Martin, 2009; Marsh, 1990).

In educational research, academic *self-efficacy* refers to students' perceptions on their ability to master given tasks or develop specific competences (Bong, 2001; Gallagher, 2012; Van Dinther et al., 2011). Consequently, these self-beliefs are task- and future-oriented (Bong & Skaalvik, 2003). Hoffman and Schraw (2009) pointed out that students' self-efficacy in science plays an important role in solving problems, which demand a higher level of working memory capacity in science. Also, Chen and Usher (2013) argued that self-efficacy strongly affects students' general abilities and competences in science. This argumentation was supported by further studies which systematically analyzed the effects of different aspects of self-efficacy on students' achievement (e.g., Freiberger et al., 2012; Hoffman & Schraw, 2009). Chen and Usher (2013) further investigated the sources of science self-efficacy and proposed a framework with four determining factors: observation of activities, verbal and social persuasions from others, interpretation of past performance and master experience, and affective states such as anxiety.

1.1.2. On the empirical relationship between self-concept and self-efficacy

Pajares and Miller (1994) showed that self-efficacy was an important predictor of achievement in math whereas students' gender mediated this relationship in favor of males. Similar results were obtained by Pietsch, Walker, and Chapman (2003) who, additionally, studied the relationship among self-concept and self-efficacy. In their study, they argued that students' self-efficacy and their general perceptions of competences were empirically distinct. Further research suggests that both constructs are positively and substantially correlated (Bong & Skaalvik, 2003). On a conceptual level, both refer to students' perceptions of their competences and their evaluations of mastering tasks and problems in the academic environment. Consequently, they are mainly based on mastery experience, performance, and behavior of avoidance (Mason et al., 2013) and focus on perceived competences which are often referred to as "competence beliefs". Based on these competence beliefs, performance goals could be developed (Komarraju & Nadler, 2013; Mason et al., 2013; Spinath & Steinmayr, 2012). Moreover, there is evidence that both constructs are domain-specific and multidimensional in nature (Bong, 2001; Bong & Skaalvik, 2003; Marsh & Scalas, 2010).

On the other hand, self-concept and self-efficacy are also different, as they differ in the context of students' evaluations. Self-efficacy largely refers to context-specific judgments whereas self-concept mainly relies on aggregated and global perceptions (Bandura, 1997; Bong & Skaalvik, 2003). Additionally, there has been empirical support for the structural distinction of both constructs which was mainly based on language and math learning (Bruning, Dempsey, Kauffman, & McKim, 2013; Marsh et al., 1991). For instance, Ferla et al. (2009) found a moderate correlation for math ($\rho = .37$), meaning that students who perceive their specific competences in math as high are more likely to regard themselves as generally competent in this subject. This result appears reasonable if self-efficacy is defined as a more specific competence belief (e.g., Gallagher, 2012; Van Dinther et al., 2011). Consequently, the constructs of self-concept and self-efficacy are both components of students' competence beliefs. However, only a few studies systematically analyzed this relationship for scientific domains (Bruning et al., 2013; Ferla et al., 2009; Lewis, Shaw, Heitz, & Webster, 2009; Lin & Tsai, 2013).

Regarding the covariates of self-efficacy and self-concepts, there is a great variety of common factors. For instance, in many studies, researchers found significant and substantial effects of interest (Freiberger et al., 2012), gender (Velayutham, Aldrige, & Fraser, 2012), anxiety (Ferla et al., 2009), achievement as indicated by grades (Brunner et al., 2009; Velayutham et al., 2012), epistemological beliefs (Tsai et al., 2011), and cultural differences (Lee, 2009; Marsh et al., 2013). These findings enable researchers and teachers to predict and influence students' competence beliefs in many different settings (Huang, 2011; Van Dinther et al., 2011). Lin and Tsai (2013) pointed out that these relationships could also be used to obtain evidence on construct validity in terms of an external validation (see also Messick, 1995).

1.1.3. Assessing and modeling self-concept and self-efficacy

By extending the Marsh/Shavelson model, Brunner et al. (2009) proposed a new measurement perspective which did not only take into account the different factors of self-concept but also the issue of domain specificity. In their model, they suggested a nested structure of students' academic self-concepts (Fig. 1) and assumed that, first, self-concepts are domain specific and, second, there is a general academic factor which shares variance with specific self-concepts (see also Brunner et al., 2010). From a statistical point of view, the Correlated-Trait-(Method-Minus-One) model represents this structure within a confirmatory factor analysis framework (CTC[M-1] model; Eid, 2000). However, this model has not yet been applied to self-concept and self-efficacy in chemistry in order to address domain and construct specificity.

As Tsai et al. (2011) suggested, valid assessments of specific competence beliefs (self-efficacy) can be designed by using specific descriptions of competences required to achieve a learning goal or to solve a scientific problem. Such operationalizations are necessary in order to capture students' individual convictions on mastering academic tasks as well as their test-taking efforts and perseverance in specific problems (Bandura, 1997; Liu, 2010; Pajares & Miller, 1994). By using statements of self-perception regarding different competences requires an appropriate rating scale which is used to measure the outcome on different levels. Liu (2010), thus, proposed developing items with Likert-type scales to capture these perceptions.

Based on a multidimensional framework, Lin and Tsai (2013) were able to develop a rating test on science self-efficacy with considerably substantial evidence on reliability and validity. The resulting factorial structure referred to different competences in science classrooms: (1) conceptual understanding, (2) higher-order cognitive skills, (3) practical work, (4) everyday application, and (5) science communication. This approach contrasted unidimensional assessments of self-efficacy in science (Glynn, Brickman, Armstrong, & Taasoobshirazi, 2011; Glynn, Taasoobshirazi, & Brickman, 2009; Hoffman & Schraw, 2009) and stressed the importance of defining an appropriate conceptual framework of the competences, used as indicators of self-efficacy (Bong & Skaalvik, 2003; Lin & Tsai, 2013; Marsh et al., 1991). As the curricular specifications of scientific literacy play a crucial role in implementing science education (Köller & Parchmann, 2012), these could form the basis for developing assessments of students' competence beliefs in a more specific context, providing feedback towards particular standards. In Germany, for instance, there are four competences which take into account different skills and abilities in science classrooms. These are mainly based on the concept of scientific literacy (see Table 1; Neumann, Fischer, & Kauertz, 2010). This framework does not only refer to the acquisition of domain knowledge but also includes inquiry, communication, and decision-making skills. Due to this broad operationalization, which is specified for chemistry as a scientific domain, the framework was used to establish standards in chemistry education for 10th graders in Germany. Although there is some overlap with the multidimensional conceptualization of science self-efficacy proposed by Lin and Tsai (2013), which was developed for science as