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Empirical study

Epistemological beliefs in science—a person-centered approach to investigate high school students' profiles

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ABSTRACT

Epistemological beliefs (EB) are a prominent topic in educational research and considered important for the learning process. Science EB in particular are not only important for learning in science but also a unique learning goal itself. They are connected to science abilities and achievement as well as to students' personal features and background. Since EB are domain-specific we investigated the four relevant dimensions for the domain of science: justification, development, source, and certainty. We explored the number and characteristics of science EB profiles among 4995 tenth graders and, by means of latent profile analysis (LPA), related them to students' characteristics. We identified four groups that show level and shape differences. These groups also differed considerably regarding constructs related to students' learning, namely, self-concept, motivation, and science achievement as well as gender, social background, and school type. Implications for further research, in particular for cross-cultural studies, are discussed.

1. Introduction

In educational research, epistemological beliefs (EB) have been and still are a prominent subject of various studies (e.g., Bråten, Britt, Strømsø, & Rouet, 2011; Buehl & Alexander, 2001; Conley, Pintrich, Vekiri, & Harrison, 2004; Elder, 2002; Hofer, 2000; Hofer & Pintrich, 1997; Kitchener, 2002; Perry, 1999; Schommer, 1990, 1994). Defined as "individual representations about knowledge and knowing" (Mason & Bromme, 2010, p. 1), EB are viewed as an important factor with respect to the interpretation of information and knowledge and, therefore, with respect to the process of learning in general. For example, EB have been found to be associated with students' learning motivation (e.g., Mason, Boscolo, Tornatora, & Ronconi, 2013), learning strategies (e.g., Schommer, 1994; Urhahne & Hopf, 2004), learning outcomes, and achievement (e.g., Hofer, 2001; Trautwein & Lüdtke, 2007) as well as students' conceptual understanding (e.g., Songer & Linn, 1991).

The importance for the process of learning also holds true for EB about science and scientific knowledge (science EB); in particular, as views about science are also regarded an important learning goal of science itself (for an overview on the relation between views of science [nature of science] and science EB, see e.g., Neumann & Kremer, 2013). As a consequence, there have been vital research activities on science EB (Conley et al., 2004; Mason et al., 2013; Urhahne & Hopf, 2004). The vast majority of research on science EB employed a variable-centered approach, which may overshadow subgroups that may vary between different cultural settings or between different samples. Person-centered approaches assume subgroups within a population rather than a homogeneous population and could be a way to detect differences and similarities between different countries. In our study, we combine the investigation of the relation between science EB and constructs of students' learning with a person-centered approach. Evidence about different profiles of science EB and the characterization of these profiles are a first step towards improving effective differentiation in science learning. So far, science EB have rarely been investigated from a person-centered perspective. To our knowledge only one study took this perspective when investigating U.S. high school students' science EB profiles (Chen, 2012). In our German study, we therefore aim to provide further insights into students' science EB profiles applying the person-centered approach in order to characterize EB profiles in more detail and compare these findings to results from other countries.

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1.1. Epistemological beliefs in science

Research on EB dates back to the 1970s and stems from various traditions.[1] More recently, researchers investigated the multidimensional structure and the domain-specificity of EB (Bromme, 2005; Buehl & Alexander, 2005; Chen, 2012; Conley et al., 2004; Hofer, 2001; Hofer & Pintrich, 1997; Schommer, 1990). As for general EB (Hofer, 2000; Schommer, 1990), in the domain of science, researchers conceptualized science EB as made up of core dimensions (Conley et al., 2004). In our study we refer to a four-factor structure of science EB, which is in line with previous research on science EB and which has already been successfully applied to samples of various age cohorts (e.g., sixth, ninth and tenth graders, Chen, 2012; fifth graders, Conley et al., 2004). The four factors split into two factors in the area of nature of knowledge ([1] *certainty* and [2] *development of scientific knowledge*) and two factors in the area of nature of knowing ([3] *source* and [4] *justification of scientific knowing*).

Beliefs on the *certainty of knowledge* span from viewing scientific knowledge as either being right or wrong (naïve) to viewing scientific knowledge as a reflection from more than one perspective (sophisticated). Beliefs on the *development of knowledge* span from viewing scientific knowledge as a static and unchanging subject (naïve) to accepting that scientific ideas and theories change over time in light of new evidence (sophisticated). Beliefs on the *source of knowing* refer to viewing knowledge as residing in external authorities such as scientists or teachers (naïve) versus viewing knowledge as created within the student (sophisticated). Beliefs on the *justification of knowing* refer to discovering phenomena through scientific investigations, e.g., experiment or observation (naïve) versus understanding that knowledge comes from reasoning, thinking, and multiple experimentations as well as observations (sophisticated; Conley et al., 2004).

This dimensional approach enables researchers to investigate whether views on science EB dimensions are separate and may develop independently. For example, a person could view the knowing of science as absolutely right or wrong (naïve view regarding source) and at the same time believe that scientific knowing is justified by empirical evidence gained from experiments (sophisticated view regarding justification). Dealing with a multidimensional EB model makes it possible to analyze different aspects of EB in more detail and to explore the relationship of the differentiated EB construct with other important personal features, such as motivation, self-concept or learning strategies (Conley et al., 2004; Trautwein & Lüdtke, 2007).

Although first evidence on differences in science EB dimensions for specific groups (e.g., ethnic background and gender) has already been obtained by various studies (for a review see Chen, 2012; Dai & Cromley, 2014), this research was largely based on variable-centered investigations. The first large-scale exploration of science EB employing a person-centered approach and leading to a systematic characterization of groups has recently been provided by Chen (2012). In his study, 1225 sixth, ninth and tenth graders from one U.S. state completed a science EB instrument (four subscales) by Conley et al. (2004) and an adapted scale on implicit theories of science ability by Dweck (1999). Implicit theories of ability refer to the students' opinion on whether effort or one's own ability is seen as a cause of performance outcome. The students also reported on their science grade, self-efficacy, science achievement, goal orientation, gender, and race/ethnicity. Chen, (2012) investigated profiles regarding science EB *and* implicit theories by means of latent profile analysis (LPA) and identified four differing profiles: *thriving, fixed/sophisticated, growth/passive*, and *uncommitted*. He found the majority (62.8%) of the surveyed middle and high school students to show a thriving or fixed/sophisticated profile. Both profiles did not differ with regard to science EB but did so with regard to implicit theories. Students in these two profiles held science EB that can be seen as more sophisticated beliefs on all four science EB dimensions. They rejected the idea that knowledge in science resides in science teachers or professional scientists only, believed that scientific knowledge is constantly evolving and that there is not just one answer to a scientific question. These students only differed regarding implicit theories. Students in the thriving profile showed a more incremental view which means that they put more emphasis on effort; students in the fixed/sophisticated profile showed a more fixed view which means that they put more emphasis on ability. Students in the growth/passive profile (31.2%) held the least sophisticated views with respect to the source and certainty aspect of science EB, and therefore, reflected a rather passive view of science knowledge. They did not believe that they themselves are able to construct knowledge and they believed that knowledge is rather fixed. Students in the uncommitted profile (6.0%) did not hold a particular position about science EB, and thus, the values of all four dimensions grouped around the scale mean. Both groups showed average scale means regarding fixed implicit theories and the students in the growth/passive group had higher values on incremental implicit theories than students in the uncommitted profile.

Overall, many studies on science EB have been performed, yet person-centered research on science EB profiles is far less established. Also, most of the variable-centered studies have been carried out in the U.S., where the majority of instruments on EB and science EB had been developed (Khine, 2008), and there is only little research in other cultural contexts or even on comparing different cultures. The present study therefore aims to address both issues, by applying a person-centered approach to identify science EB profiles of German students, which then may be compared to Chen's findings. By implementation of a person-centered approach, our study also provides the opportunity to identify similar and different groups when interpreting results across differing countries and samples.

1.2. Relation of EB to other student learning constructs

Literature provides a substantive amount of research on how EB relate to other aspects of students' learning (e.g., Hofer, 2001; Köller, Baumert, & Neubrand, 2000; Mason & Bromme, 2010; Nussbaum, Sinatra, & Poliquin, 2008; Songer & Linn, 1991; Tsai, Jessie Ho, Liang, & Lin, 2011; Urhahne & Hopf, 2004). Researchers have provided various models, for example on how EB relate to motivation, learning strategies, and learning outcomes (e.g., Hofer, 2001; Kizilgunes, Tekkaya, & Sungur, 2009; Köller et al., 2000). All of these studies either employed the instrument developed by Conley et al. (2004) or an adapted version (with the exception of the early work of Köller et al., 2000). Also, the existing models conceptualize science EB either as dependent variables (Chen, 2012; Conley et al., 2004), as independent variables (Kizilgunes et al., 2009; Köller et al., 2000; Mason et al., 2013; Tsai et al., 2011) or in path models as both at the same time (Trautwein & Lüdtke, 2007). These different conceptualizations indicated that the effect mechanisms are not clarified yet. For example, Kizilgunes et al. (2009) and Tsai et al. (2011) modeled self-efficacy as being a dependent variable with EB as the independent variable whereas Chen (2012) modeled these constructs within a LPA framework with these constructs as independent variables and students'

[1] We are aware that several labels as well as closely related constructs such as epistemic beliefs, personal epistemology or epistemic cognition do exist. We understand epistemological beliefs as individuals' theory of the epistemic (Kitchener, 2002).