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Development of a Pedagogical Content Knowledge test of chemistry language and models

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ABSTRACT
In 1986 Shulman developed a typology of teachers' professional knowledge. Since this, research on teachers' professional knowledge, especially on the measurement of professional knowledge, has increased. Measuring teachers' professional knowledge requires tests which focus on specific knowledge types and subjects. However, there are only few professional knowledge tests analysing teachers' pedagogical content knowledge of using models and chemistry language in chemistry classes. The following article describes the development of a pedagogical content knowledge test for chemistry teachers, which focuses on teachers' pedagogical content knowledge regarding the handling of models and chemistry language. As a result the test measures the intended construct reliably.

KEYWORDS: pedagogical content knowledge, models, chemistry language

Resumen (Desarrollo de una prueba de Conocimiento Pedagógico del Contenido sobre modelos y el lenguaje de la química)
En 1986 Shulman desarrolló una tipología del conocimiento profesional de profesores. Desde ese momento, la investigación sobre el mismo se ha incrementado. La medición del conocimiento profesional de profesores requiere de pruebas que se enfoquen sobre tipos y contenidos específicos. Sin embargo, existen solamente unas cuantas pruebas de conocimiento profesional que analicen el conocimiento pedagógico del contenido sobre el uso de modelos y el lenguaje de la química en las clases. El siguiente artículo describe el desarrollo de una prueba sobre conocimiento pedagógico del contenido para profesores de química sobre este tópico en particular. Como resultado, la prueba parece medir el constructo pretendido fidedignamente.

Palabras clave: conocimiento pedagógico del contenido, modelos, lenguaje de la química

Introduction

Teachers' professional competence is supposed to have an influence on students' achievement (Kunter, Kleickmann, Klusmann, and Richter, 2011), and includes for example teachers' motivation, beliefs and professional knowledge (Baumert and Kunter, 2006). Teachers' professional knowledge is a substantive precondition for their competent acting in classroom situations. In the last centuries, different national and international studies have already measured and analysed teachers' professional knowledge (e.g. COACTIV, MT21). In Germany, research on pedagogical content knowledge in chemistry, especially on using models and chemistry language in class, is limited. Analysing teachers' pedagogical content knowledge focusing on using models and chemistry language, especially in large-scale assessments, requires a valid, reliable, and objective test-instrument.

Teachers' Professional Knowledge

Shulman (1986, 1987) describes seven types of teachers' professional knowledge ("curriculum knowledge", "knowledge of educational ends, purposes, and values, and their philosophical and historic grounds", "general pedagogical knowledge", "content knowledge", "pedagogical content knowledge", "knowledge of learners and their characteristics", and "knowledge of educational contexts" (Shulman, 1987, p. 8)). Contemporary research mainly focuses on content knowledge (CK), pedagogical knowledge (PK), and pedagogical content knowledge (PCK) (Baumert and Kunter, 2006).

Pedagogical content knowledge is described by Shulman (1987) as a "special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding" (Shulman, 1987, p. 8). At a PCK summit in 2012 a definition of pedagogical content knowledge was devised by a workgroup led by Gess-Newsome, Carlson, and Gardner. They defined pedagogical content knowledge as "the knowledge of, reasoning behind,

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planning for, and enactment of teaching a particular topic in a particular way for a particular reason to particular students for enhanced student outcomes" (Gess-Newsome, 2013; Garritz, 2013). In this article pedagogical content knowledge is defined as the knowledge that enables teachers to structure, link, represent, and explain the content to students (Schmelzing, Wüsten, Sandmann, and Neuhaus, 2010; Krauss, Neubrand et al., 2008). This includes the knowledge of how to present the content of a subject comprehensibly to learners by using e.g. analogies and demonstrations (Shulman, 1986). In addition, pedagogical content knowledge involves knowledge about students' conceptions and misconceptions, and how to deal with them (Shulman, 1986; Garritz, 2013).

Shulman (1987) describes pedagogical content knowledge as an amalgam of content knowledge and pedagogical knowledge. Based upon this assumption, a correlation between the two knowledge categories should be expected. The correlation between pedagogical content knowledge and content knowledge of mathematic teachers has been examined by Krauss, Brunner et al. (2008). They concluded that teachers who taught mathematics at *Gymnasium*[1] (GY) scored higher in content knowledge and pedagogical content knowledge than mathematic teachers of other secondary schools. However, they could not "distinguish the two knowledge categories empirically in the high-expertise group of GY teachers, but that this distinction was clearly visible in the group of NGY[2] teachers" (p. 724). Differences between types of school could be found in chemistry as well (Tepner and Dollny, 2014). Chemistry teachers teaching at the GY score higher at the content knowledge (CK) test and pedagogical content knowledge (PCK) test than teachers of other secondary schools. However, reported differences in PCK regarding different types of school are smaller if effect of CK variance on PCK variance is controlled by including CK as a covariate (Tepner and Dollny, 2014). Overall, content knowledge seems to be a precondition for developing pedagogical content knowledge (Baumert et al., 2010; Tepner and Dollny, 2014).

The Facets Models and Chemistry Language

Using Models in Class

Models play an important role in the acquirement of knowledge in science and science education (Justi and Gilbert, 2002a). "(...), they function as a bridge between scientific theory and the world-as-experienced ('reality')" (Gilbert, 2004, p. 1169). Based on Hodson's (as cited in Justi and Gilbert, 2002a) purposes for science education ("learning of science", "learning about science", "learning to do science"), Justi and Gilbert (2002a, 2003) describe the role of models in science education: Students should know the most important models in science, how they were developed and the limitations of models. They should develop and test their own models and know about the importance of models when scientific findings were disseminated and accepted (Justi and Gilbert, 2002a; 2002b; 2003). In this context Gilbert (2004) speaks of "Learning to Use Models", "Learning to Revise Models", and "Learning the Reconstruction of a Model". These intentions can be found in national and international standards which ask for using models, developing, and testing models and reflecting on models in class (NRC, 1996; KMK, 2005).

Teachers can help students learning about and with models by differentiating between the model and the experience (Mikelskis-Seifert, 2009; Saari and Viiri, 2003). In addition, it is important to discuss the limitations of models (Justi and van Driel, 2005; Saari and Viiri, 2003) and to carve out the change or replacement of models (Maia and Justi, 2009; Mikelskis-Seifert, 2009). It is also necessary for learning to use different models which represent a concept under different aspects or for different purposes (Grosslight, Unger, and Jay, 1991; Harrison and Treagust, 2000; Saari and Viiri, 2003). The colour of a model can lead to students' misconceptions, because of this it is important to discuss the function of the colour in class (Justi and van Driel, 2005). Teachers should involve students in modelling processes, by creating, developing, building, testing, communicating, and reflecting their own models (Gilbert, 2004; Grosslight et al., 1991; Henze, Van Driel, and Verloop, 2007a; Justi and Gilbert, 2003; Maia and Justi, 2009).

In order to do so, it is important for teachers to know how to create learning opportunities which include e.g. adequate teaching models, modelling activities and reflection on models (Gilbert, 2004; Henze, Van Driel, and Verloop, 2007a; Justi and van Driel, 2005). Recent studies indicate a small teachers' knowledge about models and modelling in science (Henze, Van Driel, and Verloop, 2007b; Justi and Gilbert, 2002a, Justi and van Driel, 2005). Research on teachers' pedagogical content knowledge on using models and modelling is rare in Germany.

Operationalization of Chemistry Language

Before discussing the importance of language and chemistry language in class, the meaning of language and communication is reflected.

[1] In Germany, after primary school students and parents can choose between four types of secondary school in Germany. The difference between these four is the intensity of general education. In the lower secondary schools (Realschule and Hauptschule), general education is not as intense as in secondary schools (comprehensive school and Gymnasium) (Tepner and Dollny, 2014). Students finish lower secondary school at about the age of 16 years. They are qualified to do an apprenticeship e.g. as a cook, mechanic or administration officer. Students who get a "high school graduation" (German Abitur), finish comprehensive school (Gesamtschule) at the age of 19 years or Gymnasium at the age of 18 years. These students have the opportunity to study at university.

[2] Annotation of the authors: NGY means non-Gymnasium and is synonymous with lower secondary schools.