Teaching and Teacher Education 37 (2014) 130–139

Contents lists available at ScienceDirect

Teaching and Teacher Education

journal homepage: www.elsevier.com/locate/tate

Resolving the chicken-or-egg causality dilemma: The longitudinal interplay of teacher knowledge and teacher beliefs

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HIGHLIGHTS

- Student teachers' early level of PCK determines their later knowledge levels.
- Early beliefs of student teachers determine their later beliefs.
- Student teachers' PCK causally influences their later beliefs.
- The higher student teachers' PCK is, the more constructivist are their beliefs.
- Differential beliefs do not lead to differential PCK.

ARTICLE INFO

Article history:
Received 6 April 2013
Received in revised form
10 October 2013
Accepted 14 October 2013

Keywords:
Causality
Chicken-or-egg dilemma
Longitudinal study
Autoregressive path model
Cross-lagged effect
Teacher learning
Teacher knowledge
Teacher beliefs

ABSTRACT

To examine the longitudinal relation between knowledge and beliefs and to determine cause and effect, 183 mathematics teachers were assessed three times during their first years of teacher education on their mathematics pedagogical content knowledge (MPCK) and their beliefs about teaching and learning. The data revealed that prior MPCK predicted later achievement. Prior beliefs also determined later ones. In addition, MPCK affected later beliefs: Higher MPCK at the first measurement resulted in more constructivist beliefs at later time points. By contrast, beliefs did not predict later MPCK. If constructivist teacher beliefs are to be fostered, teacher education should strengthen MPCK.

Identifying causes and effects and examining longitudinal relations are two of the most difficult tasks in teacher research around the world. Teacher characteristics are so intertwined that it is difficult to disentangle causes and effects in cross-sectional studies. Thus, we are not fully able to resolve this fundamental research problem of teacher learning in this paper, either, but we designed a prospective study—using lower secondary mathematics teachers in Germany as an example—to address this research gap with respect to the question "Which comes first during teacher education: teacher knowledge or teacher beliefs"?[1]

Answers to this question will help the international audience to understand the development that occurs during teacher education. As is true in many countries, mathematics teacher education in Germany is characterized by high drop-out rates (between 30 and 40% in the first years at a university; Dieter, Brugger, Schnelle, & Törner, 2008). Given the high national and international demand for mathematics teachers (KMK, 2011), such high drop-out rates are critical. Therefore, there is a need for scientific investigation into

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[1] We are very grateful for the reviewers' comments. They helped to improve the paper substantially.

0742-051X/$ – see front matter
http://dx.doi.org/10.1016/j.tate.2013.10.007

how teacher education can be improved. This includes, among other approaches, an analysis of the development of teacher knowledge and teacher beliefs in a longitudinal design.

1. Theoretical framework

1.1. Teacher knowledge and teacher beliefs

Teacher knowledge can be subdivided into different facets that have been frequently discussed in the literature (Baumert & Kunter, 2006; Shulman, 1985). According to current research, two subject-related and one generic facet of teacher knowledge can be distinguished: content knowledge (CK), pedagogical content knowledge (PCK; including curricular knowledge), and general pedagogical knowledge (GPK). With respect to lower secondary mathematics teachers in Germany, Baumert et al. (2010) provided evidence that it is mainly teachers' PCK that is related to student achievement in mathematics. Therefore, we focused on this facet of teacher knowledge in our study.

Shulman (1986) defines PCK as subject-specific knowledge that is relevant for teachers with regard to "the ways of representing and formulating the subject that makes it comprehensible to others" (p. 9). On the one hand, PCK includes a pedagogical perspective on teaching and learning: "Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of the most frequently taught topics and lessons. If those preconceptions are misconceptions, which they so often are, teachers need knowledge of the strategies most likely to be fruitful in recognizing the understanding of learners […]" (Shulman, 1986, p. 9). It is this notion of "what counts as professional knowledge from the perspective of improving outcomes for diverse learners" (Timperley & Alton-Lee, 2008) that drove much of our conceptualization.

Besides such pedagogical knowledge for dealing with diversity, PCK includes *curricular knowledge*, which covers the selection and arrangement of the material that is to be taught and learned (Shulman, 1987). Bromme (1995, 1997) points to the connection between Shulman's (1987) pedagogical perspective and curricular knowledge: "In order to find appropriate forms of presentation of the content, to determine the arrangement of topics and to weight which topics are treated more intensively, subject-specific pedagogical knowledge is necessary" (Bromme, 1997, p. 197).

With respect to mathematics pedagogical content knowledge (MPCK) specifically, this theoretical framework means that MPCK includes knowledge about how to present fundamental mathematical concepts to K-12 students, some of whom may have learning difficulties. Before instruction in the classroom can begin, the mathematics content and concepts must be selected appropriately, prepared with respect to the learners' preconditions, and connected to a range of different teaching strategies (Krauthausen & Scherer, 2007; Vollrath, 2001). Knowledge about the ways in which students learn is part of such an MPCK conceptualization as well. Mathematics teachers should be able to use the language of mathematics appropriately in order to communicate mathematical ideas, ask questions of varying complexity, identify common misconceptions, provide feedback, and react with appropriate intervention strategies. MPCK also includes information about how to deal with the consequences in future lessons if a key topic in the curriculum was removed or taught in a different context.

Beliefs can generally be defined as "understandings, premises or propositions about the world that are felt to be true" (Richardson, 1996, p. 103). Beliefs are, thus, not a well-defined construct (Pajares, 1992). Clear distinctions from terms such as attitudes, perceptions, or conceptions are rare. Rodd (1997) points out that beliefs rely on evaluative and affective components. At the same time, the distinction between beliefs and knowledge—for PCK in particular—is more an analytical tool than that it can strictly be kept up (Furinghetti & Pehkonen, 2002). Several efforts have been made to categorize the beliefs of mathematics teachers (Op 't Eynde, De Corte, & Verschaffel, 2002). If the beliefs facets that are selected include both the content being taught and the professional task that needs to be mastered, evidence suggests that there would be a link between these facets and K-12 student achievement (Bromme, 2005).

The link between beliefs and student achievement exists via teacher knowledge. Beliefs are a crucial aspect of teachers' perceptions of teaching situations and thus influence their choice of teaching methods (Leder, Pekhonen, & Törner, 2002). Beliefs also influence which parts of their knowledge teachers choose to draw from in class (Leinhardt & Greeno, 1986). Staub and Stern (2002) provided evidence that, in particular, constructivist beliefs about the teaching and learning of mathematics are significantly related to K-12 student achievement in mathematics: Teachers who tend to hold more constructivist beliefs tend to have students who are better able to solve complex problems. Therefore, we focused on this facet of teacher beliefs in our study.

1.2. The development of knowledge and beliefs during teacher education

There are very few longitudinal studies that have examined the development of teacher knowledge during teacher education with standardized tests. Whereas much research exists on the professional development of practicing teachers (see e.g., Clarke & Hollingsworth, 2002), most studies on teacher growth during their training have been case studies (Kagan, 1992); have used self-reported data (e.g., Grossman & Richert, 1988), which carry the risk of being biased by differences in the future teachers' educational aspirations (Blömeke, 2014); or have used nonstandardized distal indicators such as coursework or grades, which carry the risk of being biased by differences in institutional curriculum standards (e.g., Turner, 2008).

The international comparative study "Mathematics Teachers in the 21st Century (MT21)" was one of the few studies that tested future mathematics teachers' MPCK in a standardized way. As indicated by mean differences between student cohorts in different years of teacher education as well as their standard deviations, the results of this study suggested that teachers' knowledge grows significantly during teacher education and that, at the same time, its variance increases (Schmidt, Blömeke, & Tatto, 2011). However, the MT21 study had methodological limitations because it was based on only cross-sectional data from different student-teacher cohorts—beginning students, mid-program students, and students in their final year of teacher education—so that the relations between the cohorts in terms of the future teachers' rank ordering could not be analyzed.

Longitudinal data on the development of knowledge that allows for such a relational approach has been collected on K-12 students. From these studies, we know that prior knowledge significantly determines later achievement (Simmons, 1995). An explanation for this phenomenon is that higher prior knowledge facilitates the acquisition of new knowledge, for example, by supporting the integration of new information into existing schemata, the modification of knowledge structures, or the compilation and chunking of knowledge (Anderson & Lebière, 1998). Thus, one objective of our study was to be the first to use longitudinal data to examine whether the MPCK of future mathematics teachers grows during