CHEMISTRY TEACHERS' CONTENT KNOWLEDGE AND ITS CORRELATION TO PEDAGOGICAL CONTENT KNOWLEDGE

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Abstract: Although the construct of professional knowledge has been gained in center stage of educational research, content knowledge as one of the main aspects is only marginally handled. While in many studies teachers' content knowledge and its relation to other teacher characteristics are not based on a direct measurement, a large-scale test instrument for quantifying chemistry teachers' content knowledge has been developed. The development of test items in a multiple choice single select format was based on a theoretical model which considers different types of knowledge, different topics, and curricular classifications. Besides evaluation of content knowledge, a scale for describing teachers' pedagogical content knowledge was used and background information was collected. This study's sample includes 166 teachers of different school types (basic general education, extensive general education, intensified general education, and comprehensive school) which show significant differences both in content knowledge and in pedagogical content knowledge. This procedure allows for revealing aspects influencing teachers' content knowledge and information about the correlation between content knowledge and pedagogical content knowledge. Furthermore presented results serve as a basis for discussion on teacher's content knowledge needed in school, which is one main topic of the overarching symposium.

Keywords: content knowledge, large-scale test instrument, chemistry, professional knowledge, pedagogical content knowledge

BACKGROUND, FRAMEWORK, AND PURPOSE

Teachers' professional knowledge is widely believed to be one of the most important factors contributing to high quality instruction (Abell, 2007; Peterson, Carpenter, & Fennema, 1989). Recent literature conceptualizes professional knowledge in three dimensions, mainly based on Shulman's ideas for teacher education (Baumert et al., 2010; Shulman, 1987; Shulman, 1986): Pedagogical knowledge (PK), content knowledge (CK), and pedagogical content knowledge (PCK). These are seen as common facets that should be taken into account when considering competencies a good teacher should possess (Baumert et al., 2010; Grossman, 1990). This study focuses on subject-specific knowledge of chemistry teachers.

On a subject-related level, CK is conceptualized as knowledge of subject-specific facts and concepts (Cochran & Jones, 1998). Referring to Baumert et al. (2010), content knowledge is formed as a result of curriculum-related work; that is, the designing and structuring of subject-specific contents for teaching. It embodies much more than just factual, everyday knowledge based on academic fundamentals (Shulman, 1987). CK could be seen as one of four components of subject matter knowledge (content, substantive, syntactic knowledge, and beliefs), which includes some aspects of PCK, already (Cochran & Jones, 1998). PCK can be described as a fusion of pedagogical and content knowledge. This type of knowledge is used to transform a specific topic into teachable content (Shulman, 1987). When exploring teachers' CK, it can be useful to take aspects of PCK into account, additionally, because an explicit connection between PCK and CK in a teacher's knowledge base is assumed.

RATIONALE

The study is based on recent data gathered from mathematics teachers showing that teachers teaching 11-18 year olds hold more secure subject-specific CK and demonstrate better quality PCK than those teaching 11-16 year olds alone (Krauss et al., 2008). We were prompted to investigate if such findings hold true for chemistry teachers. In Germany, the locus for our study, a "non-intense", non-academic general education ends at 16. There are two school types, in which only this lower secondary age group is taught: basic general education (Hauptschule), and extensive general education (Realschule). In other secondary schools, a more intense, academic, general education is offered that ends at age 18 (intensified general education, Gymnasium) and at age 19 (comprehensive school, Gesamtschule) with the award of an entrance qualification for university. In general, CK can be assumed to be a precondition for PCK (Baumert et al., 2010).

Our study therefore investigates:

1. What differences in chemistry CK are observed in teachers teaching at intensified and non-intensified level?

2. To what extent does the quality of chemistry PCK correlate with teachers' chemistry CK?"

METHODS

166 chemistry teachers working at non-intensified level (basic general education, extensive general education), and intensified level (intensified general education, and comprehensive school) were asked to complete questionnaires probing their chemistry CK and PCK. Both were constructed in a paper/pencil form and required approximately 45 minutes to complete.

The questionnaires were based on content themes centered on 'structure of atoms and the periodic table', 'chemical bonding', and 'chemical reactions using acids and bases'. Because these topics are part of the curriculum of all middle schools, every chemistry teacher could reasonably be expected to hold CK and PCK about them.

The underpinning theoretical structure is provided by three axes (Tepner et al., submitted). Two, themes (listed above) and knowledge, are common to both tests. The knowledge axis comprises declarative, procedural, and conditional knowledge (Paris, Lipson, & Wixson, 1983). While declarative knowledge mainly refers to facts, procedural knowledge takes operations and processes into account. Conditional knowledge is knowledge about reasons and conditions under which some aspects are relevant for instruction. The third axis differs between the two questionnaires. In the CK questionnaire, the third axis was curricular classifications, which permitted grading of questions by level of difficulty suitable for students aged 12-15 (grades 7-9), aged 16-18 (grades 10-12) and first years of undergraduate study (aged 18-21). In the PCK questionnaire, the third axis was called "facets" (Park & Oliver, 2008), and comprised models, experiments, and students' preconceptions, all of which are assumed to be relevant for effective instruction (van Driel, Verloop, & de Vos, 1998).

Both questionnaires were developed in cooperation with teachers working in school for several years and lecturers in chemistry education at university. The CK questionnaire comprises 25 multiple choice/single select items (four answer alternatives per item), and the

PCK questionnaire includes 19 items. The reliability of both tests is good (CK: $\alpha = .83$, PCK: $\alpha = .83$).

RESULTS

The first research question deals with differences between teachers of intensified education and teachers of non-intensified education regarding their chemistry content knowledge. Revealed CK differences are significant ($t(164) = -10.79$; $p < .001$; $d = 2.02$ [Figure 1]).

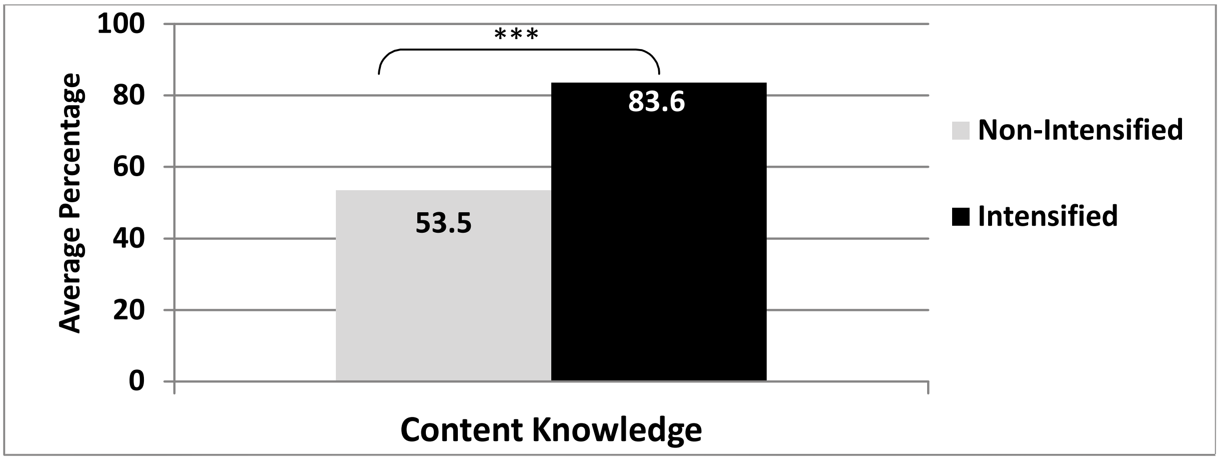

Figure 1. Differences between teachers of different school levels regarding their CK

Furthermore, CK has a substantial influence on developing PCK. While differences between teachers of intensified education and non-intensified education in terms of PCK are significant ($t(32.94) = -3.68$; $p = .001$; $d = 1.01$ [Figure 2]), PCK differences decrease when CK is incorporated as a covariate.

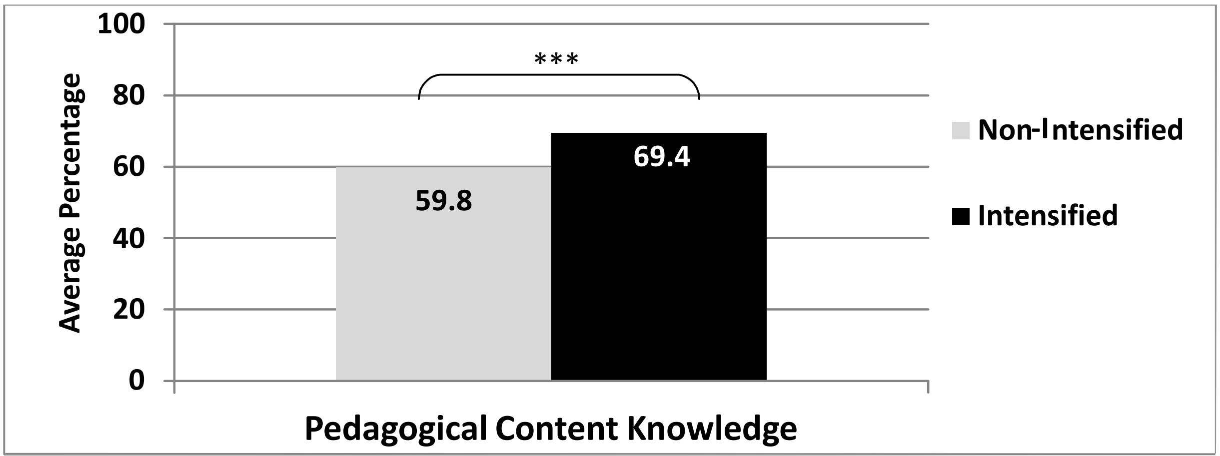

Figure 2. Differences between teachers of different school levels regarding their PCK

If CK is taken into account the ANOVA reveals a non-significant difference between intensified and non-intensified teachers' PCK ($F(1,163) = 1.413$; $p = .236$ [Figure 3].

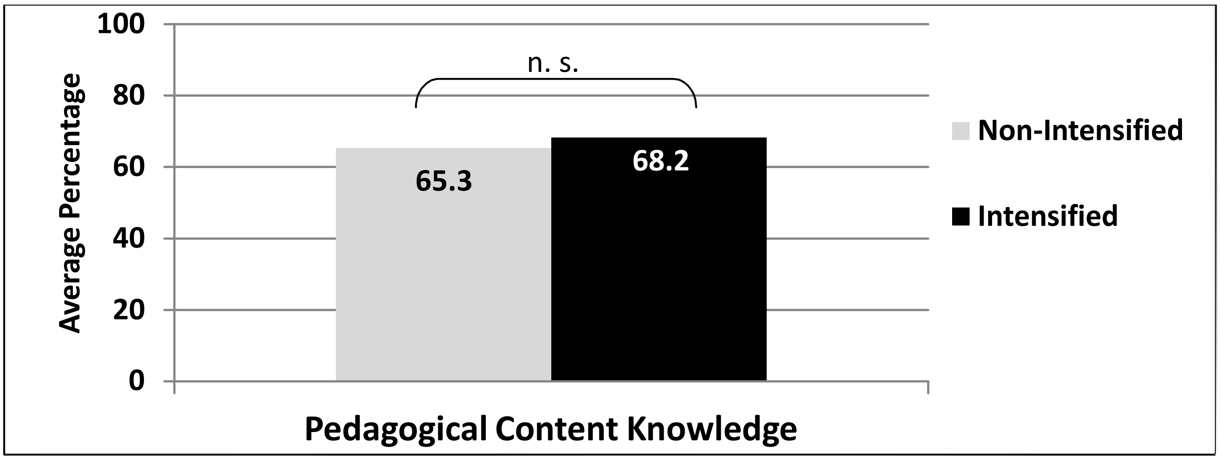

Figure 3. Differences between teachers of different school levels regarding their PCK (Covariate: CK)

The second research question analyses correlations between CK and PCK. Analysing the sample, a significant correlation of $r = .36$ ($p < .001$) between CK and PCK questionnaire can be found [Figure 4]: for example, teachers scoring highly on the CK questionnaire regarding a specific topic know much more about students' misconceptions in the same topic than those with poor quality CK, who scored badly in this aspect of the questionnaire. Nevertheless, the intensified education teachers' correlation between CK and PCK ($r = .17$; $p = .047$) is weaker than that of the non-intensified teachers ($r = .44$; $p = .018$).

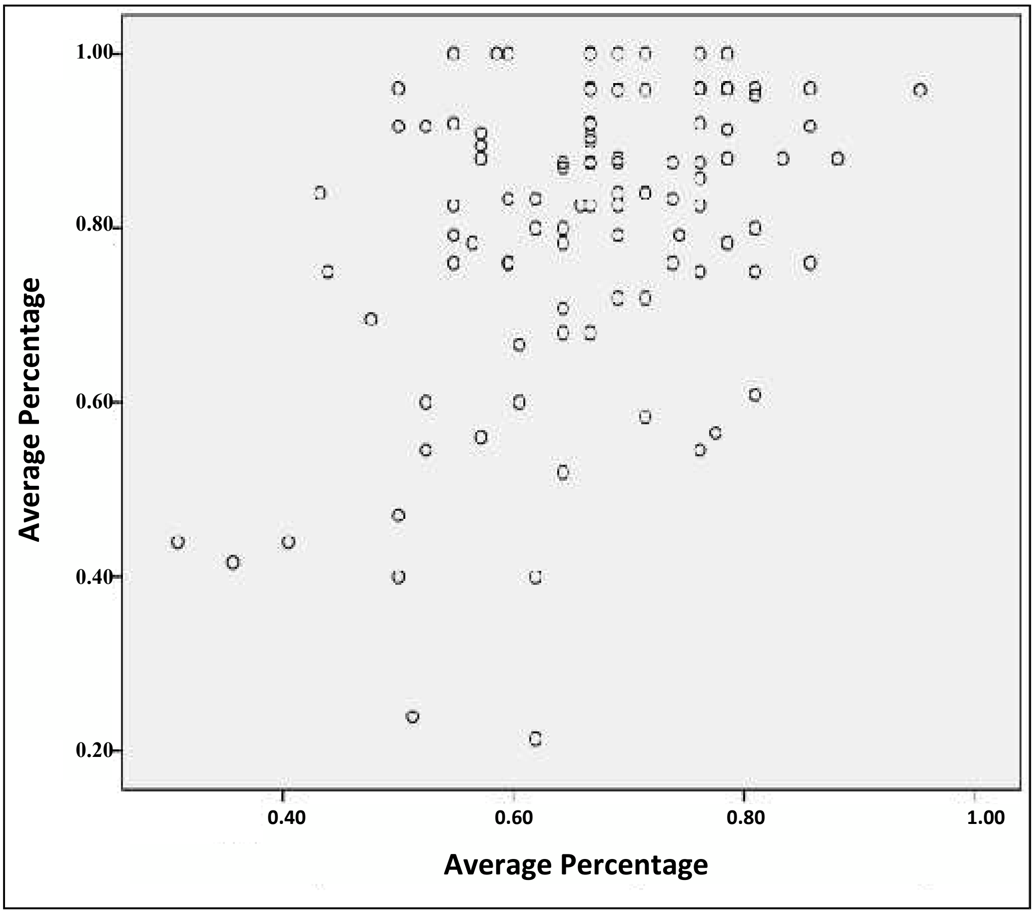

Figure 4. Correlation between CK and PCK

CONCLUSIONS AND IMPLICATIONS

Our evidence suggests that teachers' chemistry content knowledge varies according to the type of school in which they work. Teachers not using all tested levels of CK in school everyday show limited chemistry CK. The development of CK is more related to school type than development of PCK. This might be a matter of learning opportunities in studies, and a matter of requirements in daily work.

Correlation between CK and PCK is sufficiently high to be interpreted as substantial, but low enough to see CK and PCK as different dimensions (Baumert et al., 2010). The moderate but significant correlation corroborates the increasingly accepted belief that possession of good CK is a pre-condition for developing high quality PCK. Higher correlation between CK and PCK at non-intensified level might give a hint that a basic level of CK is a prerequisite for developing PCK, while a high CK does not affect a high PCK to the same extent. So CK might be a necessary but no sufficient condition for developing PCK. Additionally, intensified education teachers seem to be specialists either in PCK or in CK.

As a consequence, focusing on school type specific knowledge aspects should be reconsidered and CK immediately interlinked with PCK as it is needed in school. Discussion about this topic will contribute to recent international debate about the relative effectiveness of school- and university-based teacher education programs (Dreyer, Lesser, & Scheder, 2011; Ohle, 2010).

From a methodological point of view, this study reveals that developing and effectively using a large-scale test instrument for measuring chemistry teachers' CK and PCK is possible. The assessment tool could be used for further research on chemistry teachers' knowledge and serve as an adequate feedback tool for teachers.

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