Patrick Enkrott
David Buschhüter
Andreas Borowski

Universität Potsdam

Modeling and Development of Professional Content Knowledge of Pre-Service Physics Teachers

Should pre-service physics teachers attend theoretical physics classes if they only teach school knowledge? Research assumes teachers' content knowledge (CK) to be of vital importance for teaching physics. Nevertheless, we still don't fully understand the role of highly formalized university physics courses in the development of knowledge important to a physics teacher.

The study examines the development of CK of pre-service physics teachers in a longitudinal study during their teacher education at university. We divide CK into school-, and more advanced types of knowledge. CK is examined using a standardized test at twelve different German universities at different measuring times (N = 182). Mapping learning gains in dependence of courses taken part in, it is possible to investigate which courses lead to learning gains regarding the different types of knowledge. First results indicate that we will be able to show that formalized university physics courses also lead to a better understanding of school physics. Based on our results we will give guidance related to the question which types of courses should be strengthened in teacher education. This study also sets the base for investigations regarding the relation between the different types of CK and indicators of effective teaching practice.

Rational and Goal: Development of relevant Content Knowledge for successful teaching

Do highly formalized university physics courses improve future physics teachers' performance in classroom practice and understanding of school knowledge?

Research regards content knowledge as a key resource for teaching but it is uncertain which parts of the content knowledge are more or less important for successful classroom practice. It is further uncertain whether the learning of university physics knowledge improves the understanding of school physics. In order to address these two research gaps, it is first necessary to develop a model which distinguishes between different curricular dimensions of CK. This study`s first goal is to validate such a model of CK in mechanics using a standardized test. The second goal is to use this test in a longitudinal study in order to find out how pre-service physics teachers' CK develops with regard to the different types of courses they attend. As this study is part of a larger project we present the framework of the project first.

Context of this study and project framework

Research assumes teachers' professional knowledge, as an aspect of teachers' professional competence (Baumert & Kunter, 2013), to be necessary for successful teaching (Riese, 2010; Woitkowski et al., 2011). With some exceptions (Sadler et al., 2013), recent studies had issues showing the relation between professional knowledge and student outcomes (e.g. Liepertz, 2017). These issues can be explained by the model of Gess-Newsome (2015). It assumes filters and amplifiers (e.g. beliefs, context, prior knowledge) moderating the relation between professional knowledge, classroom practice and learning outcomes. These filters and amplifiers could be covering the statistical relations between professional knowledge and learning outcomes.

The study is embedded in a larger project whose goal it is to evaluate the relations between professional knowledge and classroom behavior (explaining physics, planning and reflecting a physics lesson). The project uses more standardized testing environments to answer the question, what happens with the relation between the professional knowledge base and classroom practice if we reduce the influence of filters and amplifiers? Within this project, this study's goal is to provide a valid model of CK and the related standardized test, which can differentiate between different types of knowledge in order to find out which types of knowledge are most vital for classroom practice.

Theoretical Framework of Content Knowledge

CK, as a component of teachers' professional knowledge, is described by different models. Shulmann (1986) differentiates between content knowledge (CK), pedagogical content knowledge (PCK) and pedagogical knowledge (PK). Quite similar, Julie Gess-Newsome (2015) describes professional knowledge as the bases for teaching as consisting of assessment-, pedagogical-, content-, curricular knowledge and knowledge of students.

As CK is of a high research interest, the concept itself has been further specified by several studies (e.g. Ball, Thames, & Phelps, 2008; Heinze et al., 2016; Riese, 2009). In line with (Kirschner 2013; Riese 2011) we distinguish between three dimensions of knowledge: school-, university- and deeper school knowledge (SK, UK, DSK). School knowledge is described by the official school curricula and university knowledge can be operationalized by the university curriculum. Deeper school knowledge, based on (Riese et. al., 2015) is defined as (1) identifying relations between physics ideas, (2) handling model limitations, and (3) identifying suitable problem solving approaches. As described by (Riese, 2010) this knowledge is assumed to be of special importance for teachers.

Even if research acknowledges the importance of CK (Baumert et al., 2010; Krauss et al., 2008) we know little about the development of CK during teacher education in physics (Woitkowski & Reinhold, 2017; Sorge et al., 2017).

In order to provide a valid model to investigate the relations between the different types of CK and simulated classroom performance we derive research question 1:

> RQ1: Is the postulated 3D-model a valid empirical model for CK of pre-service physics teachers?

To address the lack of knowledge on the development of CK in the physics teachers' university education we pose research question 2:

> RQ2: Which types of courses lead to which learning gains in the dimensions of CK?

Design

To answer these questions, we administer a standardized test longitudinally to N = 143 (more expected) pre-service physics teachers at different universities. The test is conducted at three different measuring times in a bachelor cohort at twelve different German universities and also at two times in a master cohort with a pre-post design at four different universities.

In order to answer RQ1 the standardized test assigned to the dimensions (SK, UK, DSK) was constructed. In order to investigate the structure of the test data, we compared Rasch Models with different dimensions.

The longitudinal design of this study is a necessary condition to answer RQ2. To connect the students' learning gains in the dimensions of CK (SK, UK, DSK) to the courses they took, pre-service physics teachers have to report which courses they have already passed and the grades they achieved in these courses.

Analysis & Findings

Until now we collected data of the first measurement point in the bachelor (N = 143) and master (N = 39) cohort. In the following we will present results of a quasi-longitudinal comparison between these bachelor and master students using Rasch-Measurement. This provides us with first evidence to answer RQ2. In order to provide a first answer to RQ1 we added test responses of 230 students studying the research-oriented physics bachelor program to the sample to get more accurate model estimates.

With regard to RQ1 the reassignment of items to the dimensions of CK was successful (Agreement 96%, κ = 0.948***). All information and fit criteria in table 1 show that the three dimensional model is to be preferred. As expected, WLE-Reliabilities of UK and DSK are low because the sample mainly consists of students who do not possess UK and DSK yet. We are confident that this will improve in the course of students' university education.

Table 1 First results from a WLE comparison of 3D and 1D model of CK for bachelor and master

	1D Model	3D Model		
AIC	22233	22052		
BIC	22422	22261		
		SK	**DSK**	**UW**
Rel. (WLE)	0.80	0.74	0.38	0.34
Rel. (EAP	0.80	0.82	0.72	0.82
χ^2-Test		χ^2= 191.87; p>.001		

Table 2 shows that the master students possess significantly higher knowledge measures in all three dimensions with medium to high effect sizes. This result yields optimism that, with regard to RQ2, we will be able to show that university courses lead to a significant improvement in all dimensions of CK.

Table 2 First results from a comparison of WLE-measures of bachelor vs. master students by dimension in a quasi-longitudinal comparison

	Bachelor		Master				
Dimension	M	SD	M	SD	Cohen's d	t(df)	p
SK	-0,099	1,111	0,886	1,136	0.88	-5,17(46)	< .001
DSK	-0,036	0,798	0,518	1,006	0.68	-3,33(43)	.002
UK	-0,057	0,809	0,556	0,795	0.76	-4,621(48)	< .001

Discussion

Even if the results above are preliminary they already provide first evidence that CK can be described as a three dimensional construct, in which DSK is believed to be of special importance for teachers (e.g. Ball et al., 2008; Heinze, et al. 2016). In this study, we successfully operationalized this form of CK and provided evidence that it can be regarded as a separate dimension of knowledge. This is in line with the results on a similar form of CK (Woitkowski & Riese, 2017).

The results also show significant differences between bachelor and master students with considerable effect sizes. Despite the expected low WLE-reliabilities (EAP-Reliabilities are good to sufficient), this provides evidence that we will be able to measure individual development in all postulated dimensions of CK. The study will provide valuable insights regarding the development of professional knowledge in teacher education and will lead to implications on the question which types of courses should be strengthened.

Acknowledgement

Profile-P+ project is supported by the BMBF-Rahmenprogramm KoKoHs (FKZ 01PK15005A-D).

References

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content Knowledge for Teaching: What Makes It Special? *Journal of Teacher Education*, *59*(5), 389–407. https://doi.org/10.1177/0022487108324554

Baumert, J., Kunter, M., Blum, W., Brunner, M., Voss, T., Jordan, A., ... Tsai, Y.-M. (2010). Teachers' Mathematical Knowledge, Cognitive Activation in the Classroom, and Student Progress. *American Educational Research Journal*, *47*(1), 133–180. https://doi.org/10.3102/0002831209345157

Gess-Newsome, J. (2015). A model of teacher professional knowledge and skill including PCK: Results of the thinking from the PCK Summit. In A. Berry (Ed.), *Re-examining Pedagogical Content Knowledge in Science Education* (pp. 28–42). New York: Routledge.

Heinze, A., Dreher, A., Lindmeier, A., & Niemand, C. (2016). Akademisches versus schulbezogenes Fachwissen – ein differenzierteres Modell des fachspezifischen Professionswissens von angehenden Mathematiklehrkräften der Sekundarstufe [Academic versus school-related content knowledge - a differentiated model of the subject-specific professional knowledge of prospective secondary school mathematic teachers]. *Zeitschrift Für Erziehungswissenschaft*, *19*(2), 329–349. https://doi.org/10.1007/s11618-016-0674-6

Kirschner, S. (2013). Modellierung und Analyse des Professionswissens von Physiklehrkräften [Modeling and Analyzing Professional Knowledge of Pre-Service Physics Teachers]. Logos Verlag. Berlin

Krauss, S., Brunner, M., Kunter, M., Baumert, J., Blum, W., Neubrand, M., & Jordan, A. (2008). Pedagogical content knowledge and content knowledge of secondary mathematics teachers. *Journal of Educational Psychology*, *100*(3), 716–725. https://doi.org/10.1037/0022- 0663.100.3.716

Baumert, J., & Kunter, M. (2013). The COACTIV model of teachers' professional competence. In M. Kunter, J. Baumert, W. Blum, U. Klusmann, S. Krauss & M. Neubrand (Eds.), Cognitive activation in the mathematics classroom and professional competence of teachers. Results from the COACTIV project (pp. 25-48). Springer, New York.

Liepertz, S. (2017). Zusammenhang zwischen dem Professionswissen von Physiklehrkräften, dem sachstrukturellen Angebot des Unterrichts und der Schülerleistung [The Relation between Professional Knowledge of Physics Teachers, Lesson Structure and Student Performance]. Logos Verlag. Berlin.

Riese, J. (2009). *Professionelles Wissen und professionelle Handlungskompetenz von (angehenden) Physiklehrkräften* [Professional knowledge and competence of action of (prospective) physics teachers]. Logos Verlag, Berlin.

Riese, J. (2010). Empirische Erkenntnisse zur Wirksamkeit der universitären Lehrerbildung. Indizien für notwendige Veränderungen der fachlichen Ausbildung von Physiklehrkräften. [Empirical Evidence for Changes in Subject Matter Education of Pre-Service Physics Teachers] In. Physik und Didaktik in Schule und Hochschule 1(9), S. 25-33.

Shulman, L. (1986). Those Who Understand: Knowledge Growth in Teaching. Educational Researcher, 15(2), 4–14. https://doi.org/10.3102/0013189X015002004

Riese, J., Kulgemeyer, C., Zander, S., Borowski, A., Fischer, H., Gramzow, Y., Reinhold, P., Schecker, H. & Tomczyszyn, E. (2015). Modellierung und Messung des Professionswissens in der Lehramtsausbildung Physik. [Modelling and Measuring Professional Knowledge in Physics' Teacher Education]In S. Blömeke, & O. Zlatkin-Troitschanskaia (Hrsg.). *Kompetenzen von Studierenden: 61. Beiheft der Zeitschrift für Pädagogik* (S. 55-79). Weinheim: Beltz.

Sadler, P. M., Sonnert, G., Coyle, H. P., Cook-Smith, N., & Miller, J. L. (2013). The Influence of Teachers' Knowledge on Student Learning in Middle School Physical Science Classrooms. *American Educational Research Journal*, *50*(5), 1020–1049. http://doi.org/10.3102/0002831213477680

Sorge, S., Kröger, J., Petersen, S. & Neumann, K. (2017). Structure and development of pre-service physics teachers' professional knowledge. Interenational Journal of Science Education. http://dx.doi.org/10.1080/09500693.2017.1346326

Woitkowski, D., & Reinhold, P. (2017). Fachwissenserwerb in der Studieneingangsphase Physik [Content knowledge gains in the Intial Phase of the Physics Program]. In C. Maurer (Ed.), *Implementation fachdidaktischer Innovation im Spiegel von Forschung und Praxis. Gesellschaft für Didaktik der Chemie und Physik, Jahrestagung in Zürich 2016* (pp. 532–534). Regensburg: Universität Regensburg.

Woitkowski, D., Riese, J., & Reinhold, P. (2011) Modellierung fachwissenschaftlicher Kompetenz angehender Physiklehrkräfte [Modeling Physics Competence of Pre-Service Physics Teachers]. Zeitschrift für Didaktik der Naturwissenschaften, 17, 289–313.