TSPK and beliefs about teaching and learning electricity in lower secondary: A comparison between teacher students and first year teachers

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Abstract. The relationship between teachers’ beliefs, topic specific professional knowledge (TSPK) and their teaching practice has driven research in the field of teachers’ professional knowledge for the last decades. Currently in Austria teacher education programmes and induction phases are reformed. In the course of the development of new curricula and courses knowledge about their quality and effectiveness is essential. Therefore, appropriate test-instruments are needed. This contribution presents results of a pilot study focusing on teacher students and first-year teachers TSPK and beliefs. In order to investigate whether and to what extent TSPK varies between teacher students and fully educated teachers, the presented study focuses on the comparison of TSPK-test results of pre-service teachers and first year teachers in Austria. Additionally, the relationship between TSPK, beliefs and knowledge of the Nature of Science was investigated.

1 Introduction

In science education research, two major aspects of teacher’s resources are said to especially influence students’ learning outcomes: professional knowledge and beliefs about teaching and learning science. Therefore, an important aim of teacher education programs should be the development of those two aspects. In the past years, various studies have been conducted that focus either on the development of the professional knowledge while becoming a teacher [1] or how teacher students’ beliefs about teaching and learning science develop over time [2]. What still remains to be resolved is how the professional knowledge acquired in the course of their studies relates to teacher students’ later classroom practice, and how the relationship between parts of their professional knowledge and their beliefs about teaching and learning is shaped.

In this article, we focus on the relationship between specific parts of teacher’s professional knowledge, namely parts of topic specific professional knowledge (TSPK) [3], knowledge about the Nature of Science, physics-teaching self-efficacy and beliefs about teaching and learning of physics. Furthermore, we want to investigate the influence of the first year of teaching on topic specific professional knowledge and beliefs. Previous research often reports a so called “practice shock”, where first year teachers change their beliefs about teaching and learning physics due to their exposure to authentic school life and autonomous teaching responsibility for physics classes and students [4].

To investigate these aspects, 118 teacher students and first year teachers filled in a test consisting of an instrument measuring topic specific professional knowledge (TSPK) concerning the teaching of introductory electricity, beliefs about teaching and learning physics, knowledge about the Nature of Science and physics-teaching self-efficacy.
The following section outlines the theoretical background based on the model of teacher professional knowledge and skill, resulting from the PCK-Summit held in 2013 [3]. Thereby, one focus is to distinguish between conceptualizations of PCK and TSPK. In the results section, differences between teacher students and first year teachers will be reported. An emphasis will be put on the relationship between TSPK, knowledge about the Nature of Science and beliefs. In addition the appropriateness of the test instrument used will be discussed.

2 Theoretical Background

In the science education research community there is no doubt that teachers’ professional knowledge is an important prerequisite for good classroom practice. Although professional knowledge is conceptualised differently by various research groups, there is consensus that teachers’ professional knowledge can be divided into three parts: content knowledge (CK), pedagogical knowledge (PK) and pedagogical content knowledge (PCK), which was first declared by Shulman (1986). Since the introduction of PCK, numerous interpretations and views of how this profession-specific knowledge can be defined and operationalized have been discussed. A few “big ideas” which characterize PCK have emerged [3, 5–7] and can be summarized as:

- PCK is a teacher-specific knowledge base
- PCK is topic-specific
- Beliefs about learning and teaching are distinct from PCK, but act as amplifiers and filters for teaching physics
- PCK is related to content knowledge as well as pedagogical knowledge
- The integration and reflection-in-action of PCK plays a crucial role while teaching

One approach to specifying PCK was developed during the first PCK-Summit held in 2013. This summit resulted in the formulation of “the model of teacher professional knowledge and skill” (TPK&S). The model is shown in Figure 1.

![Model of teacher professional knowledge and skill including PCK](image)

**Figure 1.** Model of teacher professional knowledge and skill including PCK [8].
The TPK&S model merges the ideas of former research about PCK and extends them. The model describes the interaction between the five general teacher knowledge bases, topic-specific professional knowledge and amplifiers and filters (like teachers’ beliefs, orientations, prior knowledge and context or classroom practice). All these aspects influence classroom practice and thus students’ learning outcomes. There are also amplifiers and filters on the level of students which influence learning outcomes (beliefs, prior knowledge and behaviour).

One main part of the model are the teacher professional knowledge bases (TPKB) which are defined as generic and include ‘knowledge about assessment, pedagogy, content, students and curriculum’ [3]. However, when it comes to teaching a specific content topic-specific professional knowledge (TSPK) is necessary. TSPK comprises for example knowledge of instructional strategies, selecting multiple representations or understanding of student’s prior knowledge or misconceptions. However, we also understand TSPK as canonical; in a way it serves as a normative basis for what we want teachers to know for teaching a specific topic at a specific grade.

According to this model, the resources teachers draw upon the most in classroom practice are personal PCK and personal PCK/Skill during reflection-in-action and reflection-on-action. Personal PCK and PCK/Skill are shaped by several factors including the transformation of TSPK in classroom practice. Additionally, beliefs, orientations, prior knowledge and context can function as amplifiers and filters for classroom practice and therefore for personal PCK. For example, when a teacher thinks that knowledge about the Nature of Science is an important aspect of teaching science, this mind-set will guide his decisions when designing learning environments to support students in understanding concepts of Nature of Science. Or, when a teacher believes that constructivism is just a theory and students learn best when a teacher directly transmits the content by explaining, this belief will act as a filter and the teacher will design instruction following this idea.

The relationship between teachers’ beliefs and personal PCK is still one main area of research. However, some empirical evidence about how TSPK can be developed and transformed into personal PCK is available. Stender et al. [9] for example examined how TSPK can be transformed into personal PCK while developing teaching scripts. Research also has shown that TSPK is developed during teacher education programs, however, mechanisms behind this development have not been identified. In addition, there is also uncertainty to which extent beliefs can be developed and enhanced during teacher education.

3 Research Design and Research Methods

In order to investigate the relationship between TSPK and beliefs of teacher students and first year teachers, this study focuses on the comparison of pre-service teachers from two universities at the end of their studies and first-year teachers in Austria. The research questions guiding the analysis of the collected data are as follows:

- Is the modified test an adequate instrument to measure TSPK and beliefs of our sample?
- How well-developed is the TSPK of pre-service and beginning teachers in the field of electricity? Which differences can be detected between the two groups?
- What is the relationship between the participant’s TSPK, knowledge about the Nature of Science, beliefs about the teaching and learning of physics and physics-teaching self-efficacy?
- Which differences concerning beliefs can be discovered between pre-service teachers and beginning teachers?
3.1 Selection and Description of the Sample

In total, 118 participants took part in our study. Amongst those were 86 students and 32 first year teachers, as shown in Figure 2.

![Distribution of students and first year teachers by gender](image)

**Figure 2:** Distribution of students and first year teachers by gender

The sub-sample of students consists of participants from two different universities in Austria who are near the completion of their studies. Teacher education in Austria lasts at minimum 9 semesters. The average age and semesters of the participants can be found in Table 1.

|                     | Age       | Semesters studied |
|---------------------|-----------|-------------------|
| students from       | 24,7 ± 2,9| 9,9 ± 4,1         |
| university A        |           |                   |
| students from       | 25,3 ± 5,6| 7,4 ± 2,6         |
| university B        |           |                   |

3.2 Description of the Instrument

In general, our instrument is divided into four parts: The first part consists of multiple choice and open formulated TSPK-items concerning the teaching of introductory electricity. To be more precise, it covers knowledge about students’ preconceptions and knowledge about instructional strategies concerning the teaching of introductory electricity. In total, this TSPK-part contains of 21 items. Most of these items were taken from already existing tests [10, 11]. In addition, a few new items were developed to fit the goal of our study. The second part of the instrument is made up of scales measuring beliefs about teaching and learning physics [12], items of the third part measure self-efficacy about teaching physics [13] and the last part consists of two scales concerning knowledge about the Nature of Science.

3.3 Administration

The instrument was administered between December 2017 and January 2018. The students as well as the first year teachers participated voluntarily. The test was administered during regular courses of the teacher students and a regular reflection session of the first-year teachers. The tests were administered by the authors and lasted 90 minutes.
3.4 Data Analysis

The tests were coded according to the coding manuals [10, 11] and coding rules for the newly developed items have been formulated. Overall, 15% of the tests have been double-coded, reaching an accordance of $\kappa = .83$. For all four parts of the test instrument, partial credit models were estimated using maximum-likelihood-estimation with the R-package eRm.

4 Selected Results

The TSPK-test showed sufficient reliability (EAP-Reliability = 0.75) and infit-parameters (0.8 < MNSQ < 1.2, -1.7 < T < 1.8). This holds also true for the belief-scales used in this study (0.68 < EAP-Reliability < 0.84). Furthermore, Andersen-LR tests (median and teacher student/teacher split) were performed for each scale to detect possible differential item functioning [14]. One item of the TSPK-test revealed differential item functioning, hence it was excluded from the analysis. Furthermore, Martin-Loef Tests (e.g. cited in [15]) were conducted to ensure unidimensionality for the TSPK-test as well as the belief scales (the assumption was not statistically violated).

The distribution of person parameters for the whole sample is shown in Figure 3. A Shapiro-Wilk test confirms normal-distribution of the personparameters concerning the TSPK-test ($W = .984, p = .173$).

![Figure 3: Distribution of person parameters for the TSPK-test for the whole sample](image)

However, when comparing the results of the different subgroups (students of university A, students of university B and first-year teachers), one could assume differences between the two groups, as shown in Figure 4. To gain further insights into the differences the boxplots suggest, a one-way ANOVA was calculated. Levenes-test showed that the assumption of homogeneity of variance was not violated ($p > .05$) to ensure applicability of an ANOVA. The ANOVA, however, revealed no significant differences between the groups ($F(2,115) = 1.269, p = .129$).

Furthermore, a MANOVA was conducted to test whether the three groups differed in various aspects of interest, namely: TSPK, knowledge about the Nature of Science, epistemological beliefs, beliefs about the role of experiments in physics teaching and self-efficacy. However, no significant differences could be detected (Pilliais’ Trace = .05, $F(10,115) = 0.59, p = .821$).
In a next step, the relationship between TSPK and four other aspects of professional resources – knowledge about the Nature of Science, self-efficacy, epistemological beliefs and beliefs about the role of experiments in physics teaching was analysed. The relationship between the belief-scales and TSPK was not significant. However, significant correlations were found between TSPK and knowledge about the Nature of Science (r = .23, p < .01) and between TSPK and physics-teaching self-efficacy (r = .23, p < .01).

Figure 5 shows a scatterplot of the relationship between the knowledge about the Nature of Science and TSPK. The x-axis describes how well developed the participant’s knowledge about the Nature of Science is, the higher the score the better the knowledge. The same accounts for the y-axis (TSPK), the higher the score the better is the participant’s topic specific knowledge concerning the teaching of introductory electricity. The blue line indicates the relationship between knowledge about the nature of science and TSPK, the transparent grey area indicates the 95-% confidence interval.
Figure 5: Scatterplot of the relationship between knowledge about the Nature of Science and TSPK

5 Interpretation and Conclusion

The statistical analysis shows that the modified and extended test instrument is psychometrical suitable to measure different facets of teachers’ professional resources like aspects of TSPK concerning the teaching of introductory electricity, knowledge about the Nature of Science, physics-teaching self-efficacy, epistemological beliefs and beliefs about the role of experiments in physics teaching. So, a first goal of our study, to modify existing TSPK-tests and combine them with reliable scales measuring other aspects of professionalization, was achieved.

As far as our second goal is concerned, to identify the level of professionalization of teacher students and first year teachers of physics and to investigate the influence of authentic school practice on it, a number of interesting results could be generated. The analysis of the data shows that no significant differences can be found between the three subgroups of our sample – teacher students of university A, teacher students of university B and first-year teachers of physics. First, it needs to be mentioned that university A and B educate future physics teachers in comparable training programmes as far as content of the teacher education and time on task is concerned. However, there are some differences in course formats. In general data show that both teacher education programmes lead to quite similar results in our test, which was a quite surprising result. Another interesting finding is that half a year of immersion into teaching practice in an authentic school setting does obviously not change the aspects of teacher professionalization we measured: TSPK, knowledge about the Nature of Science, epistemological beliefs, beliefs about the role of experiments in physics teaching and self-efficacy.

Based on these findings several conclusions are possible. First, the timespan of half a year may be too short to trigger changes on the level of beliefs and TSPK, especially when we consider the mechanism suggested in the model of teacher professional knowledge and skill, where classroom practice and student outcome have feedback effects on TSPK and amplifiers and filters. Another line of interpretation is that the often mentioned “practice shock”, which mainly influences beliefs, does not happen because teacher education did not contribute to a noteworthy change in most participants’ original beliefs. This suggestion is for example supported by a very transmissive view of our sample as far as learning processes or epistemological issues are concerned. Of course, this hypothesis needs further
investigation, which includes the monitoring of the development of beliefs during different phases of teacher students’ education at university.

Finally, we could detect significant correlations between TSPK and knowledge about the Nature of Science and between TSPK and self-efficacy for all groups of our sample. Both results are in good accordance with previous findings of other research groups, which show that content knowledge – of which the knowledge of the Nature of Science is one aspect – is a prerequisite for a high level of TSPK. All in all, the output of this study provides us with a psychometrically solid test instrument we can use for different aspects of our research in the field of professionalization. In addition, the above discussed results brought insights which are very valuable for modifications in the new teacher education programme we are currently developing and which is characterised by a big emphasis on long practice phases.

6 References

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