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Editorial: Technology teachers and their professional competence – peculiarities and starting points for subject-specific didactical research

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Technology teachers and their professional competence – peculiarities and starting points for subject-specific didactical research

1 Introduction

It goes without saying that teacher competence is an influential factor in pupil education and learning. The importance of professional competence in teachers has increased and become more generally recognised in recent years (cf. for example Baumert et al. 2010; Kunter et al. 2013). Professional knowledge, i.e. subject-specific, didactic, pedagogic and psychological knowledge, is a core area of every teacher's professional competence. Several studies have shown that the professional knowledge of teachers plays a critical role in the quality of their instruction and the learning success of their pupils (Lipowsky et al. 2009; Voss, Kunter & Baumert 2011; Voss et al. 2014; Wagner et al. 2016). Despite existing research deficits, the current standing of international research leaves no doubt as to the importance of the teacher's professional competence for the learner's development (e.g. Zlatkin-Troitschanskaia et al. 2009; Terhart, Bennewitz & Rothland 2014; KMK 2014). This competence is therefore also significant in economic terms.

While a substantial body of knowledge exists as to the professional competence of teachers of various school subjects such as mathematics and physics (cf. for example Tatto et al. 2012; Riese et al. 2015), research findings on teachers of technology and interdisciplinary subjects such as natural sciences and technology (NST) are still comparatively few and far between. After outlining the theoretical background, this editorial article will discuss selected peculiarities and possible approaches to research into the professional competence of technology and NST teachers at comprehensive schools, focusing primarily on upper secondary level.

2 Theoretical background

Despite the discrepancies between proposals for modelling the professional competence of teachers (cf. for example Shulman 1987; Baumert & Kunter 2006), a general consensus exists with regard to the fundamental topology of the subdimensions of professional competence. Conventional models of professional competence integrate professional knowledge with the teachers' convictions, values, motivational orientation and self-regulatory skills (cf. for example Shulman 1987; Bromme 1997; Baumert & Kunter 2006). Teacher training researchers have been developing and conducting empirical tests of professional competence models as part of the COACTIV research programme and other follow-up studies (e.g. Blömeke, Kaiser & Lehmann 2008; Baumert & Kunter 2011). The professional knowledge possessed by teachers is customarily divided into the categories Pedagogical Knowledge (PK) or Pedagogical/Psychological Knowledge (PPK) (Voss, Kunter & Baumert 2011), Pedagogical Content Knowledge (PCK), and Content Knowledge (CK) (Shulman 1987; Baumert & Kunter 2011).

PPK encompasses part of the teacher's knowledge of educational science, although it primarily incorporates general pedagogical knowledge and skill (cf. for example Voss & Kunter 2011). Its central facets comprise basic conceptual knowledge of educational science, knowledge of general didactic conceptualisation and planning, knowledge relating to instruction and the orchestration of learning opportunities, knowledge of the interdisciplinary principles of diagnosis, testing and evaluation, and knowledge of the methodological foundations of empirical social research (cf. for example Baumert & Kunter 2011, p. 39). Various tests have been developed for evaluating PPK (e.g. Lenske et al. 2015; Voss, Kunter & Baumert 2011). The test instrument for measuring pedagogical/psychological knowledge developed by Voss, Kunter and Baumert (2011) as part of the COACTIV research program, for example, encompasses four sub-scales: class management, teaching methods, performance evaluation, and pupil heterogeneity. Another measuring instrument for evaluating the pedagogical/psychological knowledge of trainee teachers was developed as part of the KiL project (cf. Hohenstein et al. 2017); it comprises ten differentiated facets, takes the results of previous studies into account, and incorporates teacher training standards in the area of educational science (KMK 2014). When modelling pedagogical/psychological knowledge, it has been established that teacher training in educational sciences sometimes varies widely from college to college (Hohenstein et al. 2017), and that learning opportunities for students can also vary significantly despite the KMK standard (2014). Knowledge of the potential of academic material for learning processes, knowledge of subject-related pupil cognition, and knowledge of subject-specific instruction strategies are all viewed as standard facets of PCK in the natural sciences (cf. for example Schmelzing et al. 2008, p. 645). In contrast, the COACTIV study used a two-dimensional model for measuring PCK which comprised knowledge of the curricular and lesson planning requirements made of the teacher, and knowledge of learning process related requirements referring directly to the teacher's own classroom activities (Baumert & Kunter 2011, p. 37). Other starting points in the reference field of mathematical and science subjects are provided for example by the COACTIV study (cf. for example Kunter et al. 2011), the ProwiN study (cf. for example Fischer, Borowski & Tepner 2012), the ProfiLe-P study (cf. for example Riese et al. 2015), the KiL study (cf. for example Hohenstein et al. 2017), and TEDS-M (cf. for example Tatto et al. 2012). Nevertheless, there is no doubt that focused research efforts are needed in the light of the relational disciplines and peculiarities of teaching technology or interdisciplinary subjects including technology (e.g. natural sciences and technology).

3 Peculiarities and starting points for subject-specific didactical research

Heterogeneous study structure

One characteristic of technical instruction at comprehensive schools is that it constitutes a part of varying subject clusters and denominations that in some cases have markedly different focal points. In North Rhine-Westphalian comprehensive schools, for example, technical material is taught as a single discipline (Technology) (MSW 2014), while in Baden-Württemberg it is taught as part of the interdisciplinary subject Natural Science and Technology (NST) (MKJS 2016) (cf. for example Zinn 2014) The diverse subjects and school settings in which technological material is taught have given rise to differentiated teaching training programs with varying course descriptions and customised course content. There are a number of courses, mostly based on the description of the subject provided by the respective state; the content of these sometimes varies significantly. Technological content knowledge (CK-T, PCK-T) can for example be acquired as part of a monodisciplinary course on technology (e.g. North Rhine-Westphalia) or an interdisciplinary course such as natural sciences and technology (e.g. in Baden-Württemberg). When developing test instruments for measuring professional knowledge in interdisciplinary subjects incorporating technology, it can therefore be assumed that in the case of complex test items such as CK, problems may arise in terms of clearly assigning knowledge to the technological and scientific disciplines. The interfaces between PCK and PPK and between PCK and CK are also not without significance. In the case of PCK and PPK, for example, it is not always clear what separates facets of specialised didactic competence from facets of pedagogical competence. In many cases, pedagogical knowledge only unfolds in subject-specific contexts. Difficulties also arise from the fact that PCK tasks often require a certain degree of content knowledge (CK) and are therefore directed at more than one facet of competence. This can cause problems in terms of test theory. In the case of test questions relating to the handling of preconceptions in technology lessons (focusing on PCK), for example, the question can only be answered with thorough content knowledge (CK) of the technical issue at hand.

Lack of standardisation

The Standing Conference of the Ministers of Education and Cultural Affairs (*Kultusministerkonferenz* – KMK) has implemented a set of national teacher training standards with the aim of facilitating the standardisation of academic teacher training in the pedagogical sciences (KMK 2014). The KMK teacher training standards cover the competence areas of instruction, education, evaluation and innovation, and apply to both the theoretical and practical phases of the teacher's training (ibid). With regard to teacher training in technology and NST, it would also be desirable to define content-related requirements pertaining to subject knowledge and specialised didactics that are common to all states; these already exist for certain other subjects. The overarching goal requiring the definition of nationally standardised content-related requirements relating to subject knowledge and specialised didactics in teacher training is to assure mobility and transparency in the German university system in general and, acting in the interest of the students, to guarantee mutual inter-state recognition of study achievements and qualifications preparing students for the teaching profession (KMK 2008). No common, content-related requirements relating to subject knowledge and specialised didactics have yet been defined for technology as a subject, even though pupils studying technology or NST at comprehensive schools presumably also have an interest in mobility and transparency, and the standardisation of university-based teacher training would appear to be beneficial in helping to assure academic quality. The establishment of common content-related requirements relating to subject knowledge and specialised didactics would also provide conceptual support promoting goal clarity and laying the foundation for systematic examination of the professional competence of trainee technology and NST teachers.

Starting points for a core curriculum

The only way to facilitate empirical comparisons of the professional competence of teachers is to systematically establish the tertium comparationis in the form of a widely adopted core curriculum and, building on this, to develop valid, reliable test instruments. In order to define the core areas of technological knowledge (CK-T), Palm (2016) evaluated the study regulations of the Universities of Stuttgart, Tübingen, Ulm and the Karlsruhe Institute of Technology (KIT) for the secondary school teacher training course in Natural Sciences and Technology (NST) by analysing their content. The central core areas (with their content) of the technology courses were accordingly found to comprise: (1.) Material and energy flows (machine construction, statics, strength of materials, drive technology etc.), (2.) Information and energy flows (electrical engineering, informatics, renewable energies etc.), (3.) Building technology and design (building construction, structural physics, CAD etc.). Comparable areas and content are listed for the secondary school teacher training courses in technology at the University of Duisburg-Essen and at RWTH Aachen. The University of Duisburg-Essen's core curriculum for training technology teachers for upper secondary and comprehensive schools encompasses the following: The "purposeful use of materials, energy and information with the aid of technical systems and their realisation under certain circumstances (technology) for the benefit of the individual and of society at large. The phases in the life cycle of technical systems, i.e. planning, development, construction, operation, maintenance, repair, disposal/recycling, and the scientific investigation of these. The use of scientific methods to monitor technical thinking and actions and orient them on goals, e.g. optimising existing systems or developing new ones, limiting technical risks in such a way that they do not constitute a hazard for living beings or for the environment. In doing so, technology should be understood [by the student] as a human endeavour to reconcile what is possible in accordance with natural law with what is economically expedient and what is desired and accepted by society" (University of Duisburg-Essen Study Regulations for the Course in Technology for Students Training as Teachers at Upper Secondary and Comprehensive Schools, 17/02/2011, p. 7, joint authorship). Starting points for a core curriculum for technology PCK (PCK-T) were analysed by Wittke (2016), who likewise investigated the study regulations of the Universities of Stuttgart, Tübingen, Ulm and the Karlsruhe Institute of Technology (KIT) for the secondary school teacher training course in natural sciences and technology (NST) with regard to core areas of PCK-T. Following the theoretical model proposed by Schmelzing et al. (2008), the following core areas and content stand out for empirical comparison: (1.) Knowledge of the academic material's potential for learning processes (educational standards, learning goals, subject tasks, e.g. construction and assembly tasks) (2.) Knowledge of subject-related pupil cognition (pupil ideas, typical pupil errors, performance evaluation, empirical teaching and learning research) (3.) Knowledge of subject-specific instruction strategies (analogies, subject-specific diagnostics, subject-specific teaching strategies, technology-related didactic theories and approaches, the use of media, e.g. 3D printers and microcontrollers, and the use of subject-specific methods, e.g. technical experiments or project work).

Although the core curricula for CK-T and PCK-T are found to be universally consistent, each of the institutions analysed (see above) have curricular and structural peculiarities (Wittke 2016; Palm 2016). These are the result of the individual focal points set by each institution, and systematic, site-specific effects must therefore be expected when performing comparative studies of professional knowledge. Test instruments that can be used for comparative studies of different systems generally tend to underestimate site-specific strengths (cf. Lüders 2012). Additional small-scale assessments could be integrated into comparative studies in order to evaluate corresponding effects and analyse the specific strengths of the teacher training provided at each location. Until now, small-scale assessments have primarily been used to ascertain the active pedagogical competence of teachers (cf. for example Lüders & Seifert 2016) in order to establish the differential effects of various teacher training systems.

Competence – a complex term

Professional competence in teachers is generally understood as the individual requirements that teachers need to meet if they are to fulfil their mandate successfully (Kunter et al. 2011). In this context, the model developed by Baumert and Kunter (2006) is based on Weinert's definition of competence (2001). According to Weinert, competences are defined as propensities that help persons cope with situational demands in a specific domain or areas of activity while using various individual resources (knowledge, skills, proficiency, motivational, emotional and volitional potential etc.) (Weinert 2001, p. 27f.). When modelling teacher competence on the basis of Weinert's definition, which forms the foundation of numerous studies, it is found that there are two central spheres of activity. The first sphere of activity relates to decisions as to how cognitive skills can be operationalised, particularly with regard to their proximity to practice. A sole or predominant focus on teacher knowledge when modelling and/or measuring professional competence does not really do justice to Weinert's definition of competence (2001), which explicitly encompasses skills and proficiency. However, empirical test procedures based on a combination of knowledge measurement and instruction analysis (cf. for example Vogelsang & Reinhold 2013; Goreth, Rehm & Geissel 2016) can facilitate closer proximity to practice. The profile-supported test procedure developed by Goreth, Geissel and Rehm (2015) for measuring the didactic competence of technology tuition in comprehensive schools appears to be one solution that could be built upon. The second sphere of activity relates to the question of how far affective/motivational propensities can be seen as a significant component of competence alongside cognitive skills. This is the case in a number of studies (e.g. COACTIV, TEDS-M), and the corresponding propensities (e.g. motivation, beliefs, attitudes) are measured empirically. Various aspects of professional competence such as professional knowledge, job-related beliefs, motivational focuses or self-regulatory skills are accordingly personal traits that go beyond individual circumstances and enable teachers to act appropriately in various work-related situations (Blömeke, Gustafsson & Shavelson 2015; Kunter et al. 2011). The model developed by Blömeke, Gustaffson und Shavelson (2015) therefore sees professional competence as a continuum that begins with the individual's existing propensities and moves through their situation-specific skills to their observable teaching activities, i.e. performance. This model implicitly distinguishes between competence in the sense of personal propensities that can be learnt and changed, and activities in the sense of performance.

Lack of empirical research

It is increasingly becoming understood both in Germany and abroad that teachers are seen as members of a profession with high, research-based skills (Niemi 2008; Bauer, Gräsel & Prenzel 2012). According to Bauer, Gräsel and Prenzel (2012, p. 98), this understanding "is associated with the realisation that the challenges of a so-called knowledge-based society demand not only an evidence-based educational policy, but also evidence-based professional activity on the teachers' part" (Davies 1999; Petty 2009). With regard to technology, empirical educational research, including teacher training research, is still largely in its infancy (cf. Theuerkauf 2009; Euler 2008; Zinn 2014 for an overview). While substantial progress has been made into researching teaching competence in the mathematical and scientific subjects, the relevant research and developments in technical tuition at comprehensive schools have barely been elaborated upon. At present, there are only a few isolated German-language studies that facilitate statements on selected facets of the professional knowledge of (trainee) technology teachers (cf. for example Goreth, Rehm & Geissel 2016; Zinn, Latzel & Ariali 2017). Internationally, the number of studies on training technology teachers is significantly higher (cf. for example Rohaan, Taconis & Jochems 2012; Rauscher 2011; Hynes 2012; Yoon, Diefes-Dux & Strobel 2013; Williams & Lockley 2012). The few existing empirical studies in the field of reference provide starting points for training technology teachers, but if – as desired – evidence-based professional activity is to be fostered in the teachers, as for example in the KMK teacher training standards (KMK 2014), more diverse empirical research efforts are required with regard to technical education in general and teacher training in particular. Research into the teaching profession has many facets and encompasses the history of the profession, its characteristics and general conditions, research perspectives, professional biographies and teacher careers, research into teacher training, cognition, emotions and competences, teacher activities, workloads and stress in the teaching profession (cf. for example Terhart, Bennewitz & Rothland 2014; Terhart 2015).

Importance of ongoing teacher training

In view of the dynamic developments in technology, it must be assumed that ongoing teacher training is particularly important, particularly in terms of content knowledge (CK). The question of how far ongoing training for teachers positively influences their teaching has been discussed at length. The importance of further training for developing teacher competence is generally seen as high (cf. for example Lipowsky 2014), although findings on the effects of ongoing teacher training measures are heterogeneous. The meta-analysis conducted by Timperley et al. (2007, p. 58) collated a large number of individual studies and calculated an average effect size of d=0.66 for the influence of teacher professionalisation methods on pupil performance. The meta-analysis conducted by Yoon et al. (2007), which applied markedly stricter criteria when selecting the studies collated, likewise found that teacher professionalisation measures had on average a significant influence on pupil performance (d=0.54). The meta-analysis conducted by Hattie (2009) cites an average effect size of d=0.62 for the effects of ongoing teacher training measures. Significantly, many studies of the effects of ongoing teacher training have found that the teachers' routine activities are not improved by a short event such as the one-day training sessions customarily provided (cf. for example Terhart, Bennewitz & Rothland 2014). According to Dann, the knowledge acquired at such training events "is merely 'half-knowledge' compared to experienced-based knowledge; there is a risk that [they] could have no meaning for concrete teaching activities" (Dann 1994, p. 133). If new knowledge and methods are to be integrated, more time is needed for teachers to go through an intrinsic process of learning and reflection in peace; this is essential if the methods and knowledge are to be adopted successfully (Gräsel et al. 2004, p. 133). Possible starting points for concomitant academic research into implementing the new knowledge and methods acquired through ongoing training measures could be derived from empirical action research (cf. for example Altrichter et al. 1989). Action research could provide teacher support, mitigate any implementation problems in the classroom, and foster the much sought-after dialogue between theory and practice in teacher training by means of structural exchange between skilled staff and pedagogues.

4 Summary and outlook

This article discussed specific aspects of teacher training research in the context of an editorial. The aspects deemed significant were selected to highlight the structural challenges faced when conducting research into the professional knowledge of teachers in general and the peculiarities of technology and NST as classroom subjects in particular. The statements made contain implicit and explicit desiderata for subject-specific didactical research into the professional knowledge of technology teachers. As already mentioned, only a few empirical studies have as yet been conducted into the pedagogical competence of teachers of technology-related subjects. This is particularly true of technology tuition at comprehensive secondary schools. The study findings made to date provide starting points for evidence-based research of technology teaching, but the transferability of the results to the specific teaching context is limited. In particular, there are no specific studies of the structure and standing of (trainee) technology teachers at upper secondary level. In view of the wide range of reference disciplines, the fact that technology tuition is often integrated into interdisciplinary subjects (e.g. natural science and technology), and the (of necessity) highly interdisciplinary nature of the corresponding training courses, the central issue when training upper secondary school teachers focuses on the content competence that the teachers must actually acquire. In view of the limited time available on teacher training courses for the acquisition of adaptive technical knowledge, there may be a structural problem in the engineering fields (civil, electrical and mechanical engineering, informatics etc.) inasmuch as only elementary knowledge of the subject and basic subject-specific skills can be acquired during the first phase of teacher training. It therefore appears important to investigate the subject-specific and didactic competences that (trainee) teachers must have acquired by the end of the first and second phases of training if the scientific, propaedeutic demands of upper secondary education are to be met in a desirable manner. As described above, unlike other subjects, the courses intended for the acquisition of professional knowledge (CK-T, PCK-T) are by no means uniform. Technological content knowledge may be acquired as part of a monodisciplinary course on technology (e.g. North Rhine-Westphalia) or an interdisciplinary course such as natural sciences and technology (e.g. in Baden-Württemberg). Beside the fundamental lack of empirical evidence on the professional knowledge of teachers providing technical education, the central question of the effective structural design of upper secondary teacher training in technical subjects has yet to be answered.

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