RESEARCHING SCIENCE TEACHER PEDAGOGICAL CONTENT KNOWLEDGE

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Abstract

Pedagogical content knowledge (PCK) has been embraced as a way of describing the knowledge possessed by teachers and developing models of science teacher education. We try to analyse the possibility of improving quality of science teacher training on the basis of PCK development. The Taxonomy of PCK Attributes addresses the distinctions within and between the knowledge bases of various disciplines, science subjects and science topics. The concept of PCK conceived by Shulman (1986) embraces the idea that successful teachers have a special understanding of content knowledge and pedagogy which they draw on in teaching that content.

Over the past two years we researched the pedagogical content knowledge (PCK) of pre-service and experienced Czech science teachers. The aim has been to capture, document and share teachers' PCK about specific science topics in ways that may be accessible to teachers and researchers involved in science education.

One of the tasks of the science teacher is to help students to understand some of the content knowledge of science. In doing so, Shulman (1986; 1987) posited that teachers make use of pedagogical content knowledge (PCK), a special kind of knowledge that teachers have about how to teach particular content to particular students in ways that promote understanding.We are more interested in finding ways of helping pre- and in-service teachers to improve their practice.

Key words: *pedagogical context knowledge (PCK), science teachers, general PCK, subject-specific PCK, domain-specific PCK, topic-specific PCK, taxonomy of PCK attributes*.

Introduction

There is not doubt that science teaching has a crucial role to play in shaping the future development of society. Science education has become an important prerequisite for a successful economy especially with the emerging global economy. Many industrial nations are seeking to improve the quality of science education because of the vital role science and technology play in a nation's economy and standard of life.

A new way of teaching and learning about science reflects how science itself is done, emphasizing inquiry as a way of achieving knowledge and understanding about the world. Teachers must have theoretical and practical knowledge and abilities about science, learning, and science teaching. The quality of science teacher training and its relationship with improving the quality of the education systems generally have become key issues of public concern across the world in recent years.

An important task of science education is making science more relevant to students, more easily learned and remembered, and more reflective of the actual practice of science. The science teacher training is very important part for the future quality of science education. Nearly everyone now accepts the premise that teachers have an influence on the quality of science education. The public also recognizes the importance of well-prepared teachers. There is a strong belief by the public that prospective science teachers need high quality training and skills.

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Theoretical Framework

Pedagogical Content Knowledge

Prospective science teachers learned pedagogy apart from subject matter. In science education some efforts have recently begun to bridge the gap between the pedagogical and content aspects of science teacher preparation by advocating the development of a cohesive knowledge base (Doster, Jackson, & Smith, 1994). Pedagogical content knowledge (PCK) has been suggested as one knowledge base for science teacher preparation (Anderson & Mitchener, 1994). Anderson and Mitchener (1994) have suggested that PCK could be an alternative perspective from which science educators could view secondary science teacher preparation. The concept of PCK offers the potential for linking the traditionally separated knowledge bases of content and pedagogy.

Knowledge bases of science teacher education have focused on the content knowledge of the teacher (Shulman, 1986). Shulman (1986) developed a new framework for teacher education by introducing the concept of pedagogical content knowledge. Rather than viewing teacher education from the perspective of content or pedagogy, Shulman believed that teacher education programs should combine these two knowledge bases to more effectively prepare teachers. The current initiatives in science provide a guide for some teacher educators to develop models of science teacher development (Bell & Gilbert, 1996; Cochran, 1993; Cochran, King, & DeRuiter, 1991; Sakofs, 1995). Some of these models have been specific to PCK development of pre-service science teachers (Cochran, 1993; Cochran, King, & DeRuiter, 1991). Recently, in some countries (EU countries, USA) developed science teacher preparation standards that highlight the need for teachers to develop PCK. Accordingly, teacher educators continue to recognize the need for an adequate model for teacher preparation.

Currently, there are few models for secondary school teacher development (Bell & Gilbert, 1996; Sakofs, 1995; Saunders, 1994). As part of the standards demands that professional education programs adopt a model that explicates the purposes, processes, outcomes, and evaluation of the program. There exists a "traditional" polarization of content and pedagogy in science preparation programs. Current models fail to accurately address and outline the role of PCK in secondary science teacher preparation.

Pedagogical content knowledge was first proposed by Shulman (1986) and developed with colleagues in the *Knowledge Growth in Teaching* project as a broader perspective model for understanding teaching and learning (e.g., Shulman & Grossman, 1988). This project studied how novice teachers acquired new understandings of their content, and how these new understandings influenced their teaching. These researchers described pedagogical content knowledge as the knowledge formed by the synthesis of three knowledge bases: subject matter knowledge, pedagogical knowledge, and knowledge of context. Pedagogical content knowledge (PCK) was unique to teachers and separated, for example, a science teacher from a scientist (Cochran, King & DeRuiter, 1991).

Pedagogical content knowledge (PCK) has also been viewed as a set of special attributes that helped someone transfer the knowledge of content to others (Geddis, 1993a). A knowledge base for science teaching is not fixed and final. As more is learned about teaching, we will come to recognize new categories of performance and understanding that are characteristic of quality science teaching, and we will have to reconsider and redefine other domains. As base, Shulman (1987) believed that scholars and expert teachers are able to devone, describe and reproduce quality teaching. He suggested that pedagogical reasoning and action involve a cycle through the activities of comprehension, transformation, instruction, evaluation and reflection. The starting point is an act of comprehension. To teach science is first to understand science. We expect teachers to understand what they teach and, when possible, to understand it in several ways. They should understand how a given idea relates to other ideas within sciences and to ideas in other subject as well. The key lies at the intersection of content and pedagogy, in the capacity of science teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and to be understood by the learnes. Process of transformation can be seen as the essence of the act of pedagogical reasoning, of teaching as thinking and of quality of teaching.

Some research that has stemmed from the introduction of PCK has attempted to address the question of how pre-service teachers learn to teach subjects that they already know or are in the process of acquiring (Grossman, 1990; Grossman, Wilson, & Shulman, 1989; Gudmundsdottir, 1987; Magnusson, Borko, & Krajcik, 1999; Marks, 1991).

Many of these researchers listed attributes or components of PCK (Cochran, King, & DeRuiter, 1991; Shulman & Grossman 1988; Smith & Neale, 1989; Tamir, 1987). Typically the attributes of these PCK models are represented so that the overlap or relatedness of all the attributes determines the amount or development of PCK. Smith and Neale (1989) described PCK as having three components: knowledge of typical student errors, knowledge of particular teaching strategies, and knowledge of content elaboration. They stated that “many of these kinds of teaching knowledge would be in simultaneous use during science teaching and that their integration would contribute to the complexity of teaching” (Smith & Neale, 1989, p. 4). Smith and Neale believed that the integration of the components was vital to effective science teaching.

Along similar lines, Cochran, King, and DeRuiter (1991) defined PCK as “the manner in which teachers relate their pedagogical knowledge to their subject matter knowledge in the school context, for the teaching of specific students” (p. 1). This definition incorporated four components: knowledge of subject matter, knowledge of students, knowledge of environmental contexts, and knowledge of pedagogy.

Pedagogical content knowledge (PCK) is the ability to translate subject matter to a diverse group of students using multiple strategies and methods of instruction and assessment while understanding the contextual, cultural, and social limitations within the learning environment. The term translate is used instead of transform (Shulman, 1987), because content is adjusted to fit a teacher´s understanding of the students. When the principles of translation are applied to science, the teacher must have the associated knowledge of a translator (knowledge of students, content, pedagogy, context, and environment) to properly convey his/her message (chemistry or physics) and/or provide appropriate opportunities for students to discover various science concepts and content within an activity or laboratory.

Pedagogical content knowledge (PCK) has been defined as “the transformation of subject-matter knowledge into forms accessible to the students being taught” (Geddis, 1993 b, p. 675). Grossman (1990) and later Magnusson et all., (1999) defined separate components of PCK, including orientation, knowledge of science learnes (requirements for learning science concepts, areas that students find difficult, approaches to learning science, teacher knowledge of alternative conceptions, teacher images of the ideal science student), curriculum (knowledge of science curriculum, knowledge of goals and objectives, planning), instructional strategies (subject-specific strategies, topic-specific teaching methods and strategies, labs, demonstrations) and assessment (methods for assessing). Some researches directly studied PCK, but only a small portion explicitly discussed a particular kind of PCK. Science education PCK literature lacks coherence and it is difficult to cathegorize. Grossman´s (1990) model of PCK included the category “conception of purposes for teaching subject-matter” (p. 5), for which Magnusson et al. (1999) subsistuted the label “orientation”. They used the label to represent teacher knowledge of the purposes and goals for teaching science at a particular grade level, after Grossman (1990), but also called an orientation “a general way of viewing or conceptualizing science teaching” (p.97). The inclusion of “orientation” in the PCK model is problematic. First of all, an orientation is theorized as a generalized view of science teaching, not topic-specific knowledge. Second, this general view of science teaching and learning are often studied as an interaction among knowledge, beliefs, and values, not strictly as knowledge structures. Furthemore, these general views have been called by number different names in literature. For example, researches have used labels such as "conceptions of science teaching" (Hewson&Hewson, 1987; Porlán & Martín del Pozo, 2004), "preconceptions of teaching" (Weinstein, 1989). Another line of research on orientations introduced the term "conceptions of teaching" as the set of ideas, understandings, and interpretations of experience" concerning teaching, learning and the nature of science that teachers use to make sciences (Hewson&Hewson, 1988). Some research adopts PCK as their theoretical perspective, some use theories other than Shulman´s to guide their work, and others appear to be atheoretical in their approach. Rather than introduce new terms, it would benefit the field to more deeply understand the existing constructs.

General teaching skills or pedagogy should be developed by all teachers. These pedagogical strategies include, for example: planning, teaching methods, evaluation, group work, questioning, wait time, feedback, individual instruction, lecture, demonstration, and reinforcement. These strategies are not related to any specific content area, and can be used across content areas. Pedagogy becomes a component of PCK only when it is specified within the parameters of educational content areas.

Pedagogical context knowledge can be divided in 4 levels (Veal, Driel, & Hulshof, 2001). The first level is general PCK. It is implied that an experienced or expert teacher with general PCK would have a sound understanding of pedagogical concepts. General PCK is more specific than pedagogy, because the concepts and strategies employed are specific to the disciplines of science.

General PCK orientations might be applied to other disciplines, but the processes, purpose, and content or subject-matter would not be the same. In science, determining an unknown also involves the processes of discovery and guided-inquiry. Scientific inquiry encompasses the processes of predicting, testing, hypothesizing, logical thinking, and proposing alternative explanations, which are higher order process skills taught in secondary science. This unique combination of attributes present in science-specific guided inquiry exemplifies how pedagogy can be discipline-specific and is best viewed in the context of general PCK. Even though the process skills of predicting, testing, and hypothesizing can be learned and developed in other disciplines, these skills become unique and intended when applied to science concepts.

The second level can be called subject-specific PCK, where subject meant the content area of science. We can describe some subject-specific PCK strategies for teaching science: nature of science, pre-conception, process, conceptual change, activity-driven, problem solving, discovery, inquiry, project-based science, and guided inquiry. These strategies are subject-specific, because their goals and purposes focused on science.

The third level is domain-specific PCK. Domain-specific PCK is more distinct than general PCK, because it focuses one of the different domains or subject matters within a particular discipline. For example, if science was the subject matter, then an understanding of how to teach it to students would be characteristic of a teacher having developed domain-specific PCK. Domain-specific PCK is positioned between disciplines and domains of science to represent a different level and specificity of subject-matter and pedagogy.

The fourth level is topic-specific PCK. Theoretically, a teacher who has knowledge in this level of PCK could have a solid repertoire of skills and abilities in the previous three levels. Each domain or subject of science has its own list of concepts, terms, and topics, some of which overlap (Magnusson & Krajcik, 1993). Although the concepts unique to each domain may be taught differently, the common concepts are also taught differently on many occasions. For example, thermodynamics is a common concept found in physics and chemistry, yet this topic is typically introduced differently in the different domains. The corresponding laboratories and demonstrations are different, as well as the relevant examples used in each textbook. In chemistry, a laboratory to exemplify heat content that can be found in various chemistry textbooks and laboratory books is the burning of a peanut. The same laboratory is almost never found in physics textbooks or laboratory manuals. In another example, when discussing heat and temperature, a chemist might use the kinetic molecular theory to describe temperature. Whereas the physicist might say that temperature is just the measure of heat lost or gained in a system. Even though each concept being explored is found in both domains, the teaching styles, methods, and approaches to representing these topics usually differ. These differences legitimate the need for developing topic-specific PCK as an instructional paradigm for prospective science teachers.

Priority for Domain- and Topic-specific PCK

Kuhn´s (1962) ideas outline the inherent distinction present among the different domains of science. The chemist develops way of thinking, and uses it to perceive and describe new or different phenomena. For example, if a chemistry teacher were to see a laboratory that introduces the concept of conservation of energy, then he/she would view the laboratory as a possible introduction to exo- and endothermic reactions. This is different than the view of a physicist. He/she might perceive the conservation of energy as a law applicable to electricity or heat within a system. Using this type of argument, Kuhn illustrated the difference among the world views within different fields of science.

A similar argument can be used to support topic-specific PCK. Kuhn (1962) provided the example of an investigator who hoped to learn something about how scientists understood the atomic theory. The investigator asked a distinguished physicist and an eminent chemist whether a single atom of helium was or was not a molecule. Both answered without hesitation, but their answers were quite different. For the chemist, the atom of helium was a molecule because it behaved like one with respect to the kinetic theory of gases. On the other hand, the physicist stated that the helium atom was not a molecule because it displayed no molecular spectrum. Presumably both men were talking of the same particle, but they were viewing it through their own research training and practice. Paradigm differences of this sort can be influential in science, education, and science education. These differences embody the distinctions provided by topic-specific PCK. Physics and chemistry teachers develop the same divergent world views as physicists and chemists. Just as scientists prepare for a career in a particular field, such as chemistry and physics, so must a chemistry teacher and a physics teacher prepare for membership into their respected communities.

Taxonomy of PCK Attributes

Many researchers have described and defined pedagogical content knowledge incorporating different attributes or characteristics (e.g., Cochran, King, & DeRuiter, 1991; Magnusson, Krajcik, & Borko 1999). The various descriptive accounts and definitions in the literature have placed little significance on the “development” of pedagogical content knowledge. The only diagram that included an example of the development of pedagogical content knowledge was created by Cochran, King, and DeRuiter (1991). The Taxonomy of PCK Attributes in Figure 1a (Cochran, King, & DeRuiter 1991) possesses several unique characteristics compared to previous models. It details a hierarchical structure for pedagogical content knowledge and its attributes. The central location of pedagogical content knowledge signifies its importance. The surrounding attributes are all connected, representing an integrated nature of the epistemological components.

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The hierarchical structure suggests that a strong content background is essential to the development of pedagogical content knowledge. Content knowledge can be general, domain-specific or topic-specific. The second most important attribute a science teacher needs in developing PCK is a strong and thorough knowledge of their students. Only after a teacher understands or realizes the importance of the student component of teaching, can the other attributes of pedagogical content knowledge be learned or developed. The Taxonomy of PCK Attributes does not imply a linear progression of knowledge development. Rather, the taxonomy represents a multifaceted and synergistic developmental relationship between the various attributes. However, this does not preclude the significant impact of other social forces (e.g., teaching the way we were taught, teaching to the test, and efficiency of transmission).

One of the most significant aspects of the Taxonomy of PCK Attributes (Figure 1a) is the placement of pedagogical knowledge. Pedagogical knowledge is not as important in this taxonomy as it has been in other PCK models (Morine-Dershimer & Kent, 1999; Shulman, 1987; Tamir, 1987). In this treatise, the knowledge of the students component has more significance compared to pedagogical knowledge. A knowledge of the students includes understanding possible student errors and misconceptions. Figure 1b (Cochran, King, & DeRuiter (1991) portrays content knowledge and knowledge of students as embedded in one another because student errors and misconceptions are more easily recognized when a teacher knows the content topics and concepts. Finally, only after a teacher develops a solid understanding of his/her students can he/she apply any of the other eight attributes appropriate to the student, domain, or concept. This does not imply that a prospective teacher does not already possess some of the other eight attributes. Rather, prospective teachers develop and integrate the eight attributes into a coherent manner more readily when content knowledge and knowledge of students have been developed.

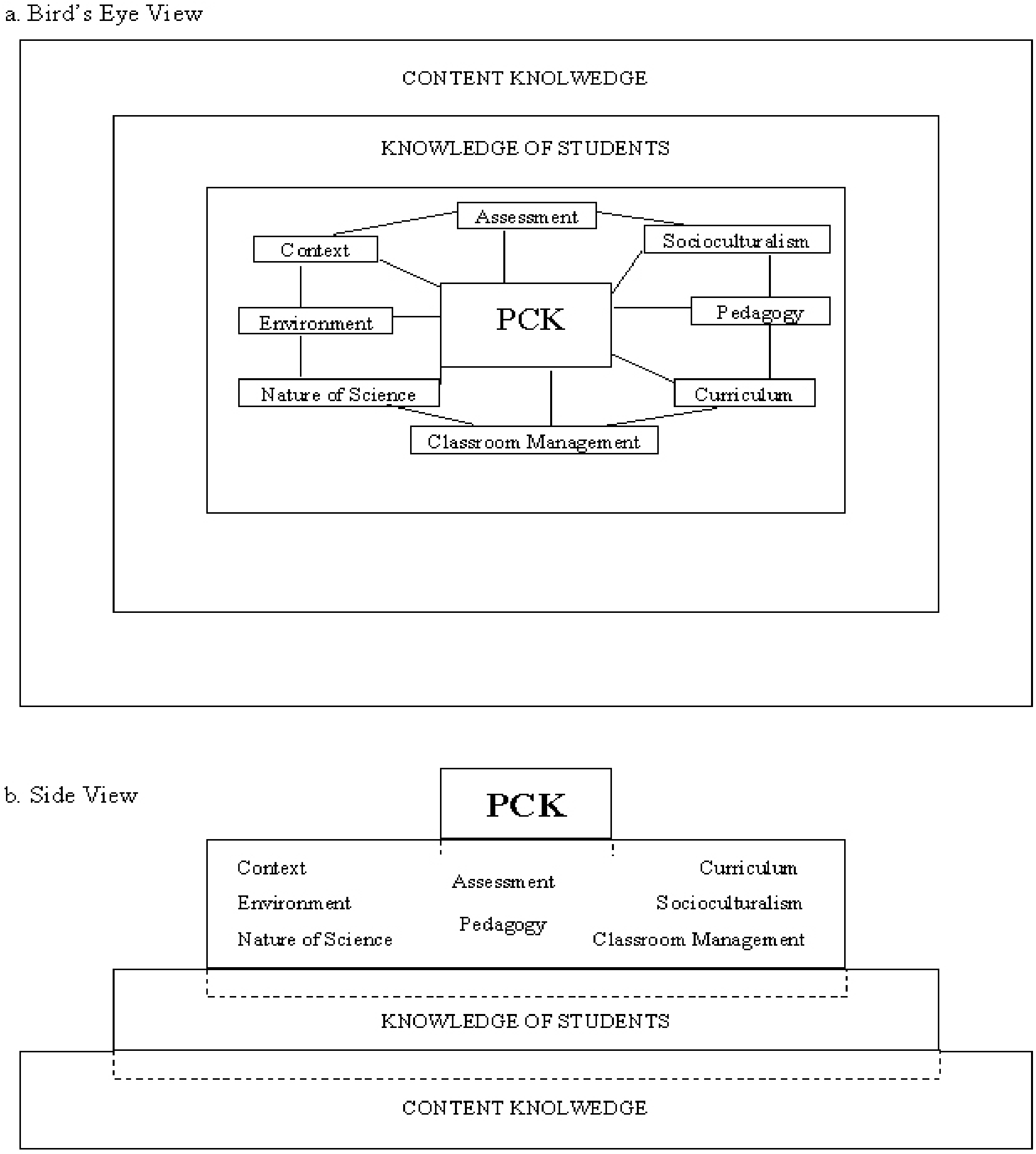

Figure 1: a, b Attributes of PCK.

The eight embedded attributes of PCK are not arranged in a hierarchical manner because they can be developed and understood by the teacher at any time during their teaching career. The attributes are inter-related; thus, the development of one can simultaneously trigger the development of others. For example, pedagogical knowledge and assessment are usually learned in methods classes. The knowledge of when, how, and why assessment is used combines two attributes. To extend this argument, when a prospective teacher experiments with performance assessment, he/she will probably integrate his/her knowledge of instructional methods to make sure the assessment device is fair (Payne, 1992). The attributes used in this taxonomy can also be found in expert and experienced science teacher literature (Tobin & Fraser, 1990; Tobin & Garrett, 1988).

The integration of all ten attributes can occur in stages, cooperatively, or separately. Either

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attribute could have been developed separately; however, the development of PCK requires one to integrate different types of knowledge. In addition, the variety of ways that a teacher can develop one or many of the PCK attributes also implies that there is no one prescriptive way to impart PCK to a teacher.

The interconnectedness of the Taxonomy of PCK Attributes promotes the idea of a teacher as a life long learner. Pedagogical content knowledge is a construct along a continuum. Individuals possess varying degrees of PCK, but they continually develop each of the attributes throughout their teaching career. It might be possible to develop all attributes in a science methods and curriculum class, but the usefulness, impact, and understanding will not be fully realized or integrated until a teacher has acquired several years of classroom experience (Clermont, Borko & Krajcik, 1990; Tuan, Jeng, Whang, & Kaou, 1995). The pyramid model does not imply that becoming an effective teacher is a linear process. Rather, it implies that a prospective secondary science teacher develops their content knowledge and learns about student differences while integrating other attributes. Usually, content knowledge is developed before knowledge of students for secondary science teachers. Over time, a teacher´s "pyramid of knowledge" grows in size due to a combination of teaching, professional development, and informal learning experiences.

Implications for Science Teacher Education

The Taxonomy of PCK Attributes provide a relatively comprehensive categorization scheme for future studies of PCK development in teacher education. The continued interest in PCK as an epistemological category and as a knowledge base for science teacher preparation has produced a need for a conceptual framework upon which future PCK studies can be based. The taxonomies provide such a framework. The Taxonomy of PCK Attributes will enable researchers studying knowledge development in teachers and teacher education programs to identify and characterize different attributes of science teaching. In addition, this taxonomy recognizes the relative importance that researchers and educators have given to the different components of PCK. These types of organizational frameworks will serve to organize and integrate research efforts centered around PCK.

The use of this taxonomy as a foundation for future research will also provide a model for science teacher preparation. For example, secondary science education programs could focus on developing topic-specific PCK in prospective teachers. Many prospective science teachers know their content well, but they have not learned how to transform or translate that knowledge into meaningful units for instruction. By focusing on topic-specific examples, laboratories, and demonstrations, prospective secondary teachers can focus and develop specific strategies. What is necessary is the effective use of exemplary models of science teaching within topics that can later be transferred to another topic or domain. They can then apply these strategies to other topics and domains based upon their content backgrounds.

Directly or indirectly, teacher education programs will benefit from further PCK research. One obvious area of future research would be to focus on identifying and classifying the various types of PCK employed in the science classroom. This would allow both teachers and teacher educators to more easily identify PCK development in themselves and their students. The ability to track PCK development will enable science teacher preparation programs to modify their classes and curricula appropriately. It is our hope that this taxonomy will provide a foundation for future research and further discussion concerning the preparation of science teachers.

Finally, the identification and classification of the various types of PCK does not exclude the consideration of science areas that combine one or more of the traditional disciplines (i.e. biochemistry, physical ecology, geophysics, etc...). Once researchers are able to identify various components of PCK in the traditional scientific disciplines, then they can begin to examine how teachers contend with these "new" areas of science. Disciplines such as biotechnology or nanotechnology are rapidly becoming an integrated portion of the new science curriculum (AAAS, 1993; NRC, 1996). It is vital that we, as educators, develop an understanding about how to teach these new subjects in a manner that reflects the knowledge of today´s science in contrast the traditional discipline-bound courses (Hurd, 1997).

Implementation of PCK in Science Teacher Training

The implementation of every new perspective on teaching and learning in the classroom required new roles and tasks for science teachers. Teaching in many current science teacher courses often consists of a direct transfer of knowledge from the educator towards the (student) teachers. However, this 'top-down' instructional approach does not allow (student) teachers to construct their own knowledge base about science teaching because they do not get sufficient opportunities to learn in an active way. Although many science teachers educators are aware of this limitation, they try to implement alternative approaches. Many of them also encounter difficulties in using teaching strategies that takes much more into account (student) teachers' authentic ways of reasoning. Nevertheless, they are interested in tools that support teaching that fits modern views on teaching and learning. In our opinion, such a tool can be action research.

The content of teacher courses does not always link up well with the reality of classroom teaching. For instance, current pre-service courses usual recommend the use of student-centered teaching strategies (instead of teacher-centered strategies). As a consequence, many student teachers prefer to use these strategies, for instance, offering experiments to students instead of enacting teacher demonstrations. However, when the student teachers visit their practice schools and observe lessons, they conclude that the dominant teaching strategy in the classrooms is often teacher-centered. Moreover, when they teach their own classes, they experience that they are confronted with the pressure of the expectations of their classes to teach in the familiar way, that is, expository teaching.

The discrepancy between studied and observed/expected teaching strategies evokes a conflict among the student teachers. Many of them solve this conflict by changing their initial preference towards the use of more teacher-centered strategies. In sum, there is a weak match between the teaching strategies that are recommended in teacher courses and the strategies that are mainly used in practice schools. It is not easy to bridge the gap between teacher course 'theory' and classroom teaching 'practice'. Nevertheless, many science teacher courses try to improve the relationship with teaching practice.

The first step is focused on the initial personal evaluation of the pedagogical event. In case of pre-service science teacher education, many student teachers will observe about a problematic event, that happened in the real classroom that they visited and observed teaching – learning process. It could be for instance, a problematic situation in the classroom although that situation was not planned. The action research should be written by using a particular structure:

a. Context information (date, class, lesson topic);
b. Description of the situation or problem in the classroom (what happened?);
c. Identification of the problem (or success);
d. Analysis of the problem (or success);
e. Possible causes of the problem (or success);
f. Suggestion phase;
g. Writing a concluding note;
h. Possible solutions (in case of a problem).

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The second step of the action research consists of presenting and discussing. This is often done in the setting of a workshop with peers. The questions could focus on descriptions that are unclear for them, information that is lacking, and so on.

The third and final step is focused on the final personal evaluation of the pedagogical problem. This often includes a number of conclusions regarding new teaching intentions or instructional approaches. If necessary, the assistance from the teacher course can be asked. The student teacher and the peers discuss the content and value of the given descriptions. The aim of the whole procedure is to stimulate the participants of the workshop to express own knowledge and beliefs to each other and to place oneself in someone else's practices. The building of a collection of possible causes of problems, possible solutions, concerns, and questions can contribute to develop a better insight in the critical event. This is important because rather often the real problem is beyond the reported one. Identification of the real problem is a necessary condition for a fruitful discussion. Finally, the student teacher and the peers discuss the content and value of the given descriptions. The aim of the whole procedure is to stimulate the participants of the workshop to express own knowledge and beliefs to each other and to place oneself in someone else's practices. The building of a collection of possible causes of problems, possible solutions, concerns, and questions can contribute to develop a better insight in the pedagogical problem or event. The student teacher will finish action research with a short note about the main conclusions from the workshop. Special attention will be given to the formulation of new teaching intentions or instructional approaches for the near future. Requests for support from the teacher educator or mentor of the practice school can also be formulated.

Technology for Pedagogical Content Knowledge

In his examination of the scholarship of teaching, Schulman´s work highlights the importance of teachers understanding structure of content knowledge so that they can help students connect their ideas and prior knowledge to the content being studied in the classroom (Shulman, 1986, 1987). Certainly, teachers must have an understanding of subject-matter knowledge itself, including the theories, principles, and concepts of a particular knowledge domain. Teachers must also develop a tool-kit of general instructional techniques for teaching students at a particular developmental level. Pedagogical content knowledge however, is at intersection between general teaching practices and particular content-area understandings. In this sence educators must simultaneously wrestle with issues as pedagogical content as well as general pedagogy (Goode, 2011).

To aid teachers´ development of pedagogical content knowledge, prospective science teachers must explore a repertoire of useful forms of representation and communication strategies to help students best learn specific concepts or skills (Goode, 2011). The affordances of technology clearly support the development of multiple representations for content-related knowledge in teaching and learning. Across subject-matter domains, computers enable multimedia depictions of knowledge for creating, organizing, linking, and communicating ideas. Particular technology applications (e.g. concept maps) can be used for instructional purposes to demonstrate the fluidity and structure of knowledge. These tools help highlight the social constructed nature of knowledge, rather than a portrayal of knowledge as an external element. Communication technologies, including websites, blogs, publication, and presentation software also provide pedagogical strategies that help students build knowledge and communicate their understandings of discipline in multiple formats. Particulary in mathematics and science instruction, micro-worlds and simultation software help students explore and engage in inquiry-based learning.

Beyond using new technologies as an inquiry-supporting tool in academic subjects, scholars also point to the importance of developing computational thinking practices for students across subject areas to improve learning. This type of thinking blurs disciplinary boundaries and makes use of problem solving capabilities of computers.

Teaching prospective science teachers to use these digital academic content tools and hone computational thinking skills requires more than an introduction to the technological software itself. Ruther, future science teachers must have opportunities to discuss the match between the culture of inquiry in the classroom and the software integration into lessons. Prospective science teachers need to consider other features of the classroom design for using such technologies, including issues of collaboration, assessment, curriculum, and assisting students with special needs. Having science teachers keep a running blog of their own inquiries as they begin entering classrooms as student teachers. Developing social networks for prospective teachers can help teachers learn to interact professionally in an intellectual, supportve atmosphere. And electronic portfolios are effective for keeping a running record of growth for teachers candidates as they progress through preparatory programs. Teacher science education programs should explicitly provide experience s for prospective science teachers to use these digital tools to gain the habits of minf for improvement of pedagogical content knowledge.

Case Study

On the basis of Shulman theory two science teacher (one student teacher and one experienced teacher) were interviewed to identify PCK of practicing science teacher and pre-servise teacher (science teacher student). The research questions that were formulated in the language of practicing teacher: How teacher knows what to teach in science and how to teach that? What is a role of his/her content knowledge of science? What is a role of his/her pedagogical content knowledge?

The first respondent was practicing science teacher who finished Faculty of Science and obtained Master degree in science teaching. She was licenced for physics and chemistry teaching. She was in teaching position for 24 years. She taught at upper secondary schools. She thought that initial teacher training at university gave her overview about science and possibility what to teach in the ideal conditions. When she started to teach she felt as her students. She did not know what to teach and how to teach. From the point what to teach the textbook was very important for her. The textbook was an actual piece of material she wished to have understood. She taught textbook. Textbook helped her to understand the content and structure of science to be taught. In the first period of teaching she taught everything in the textbook. Her own experience became also very important for her. Later she was able to make decision what is important in the content and what she could change and how to change the content. The initial science teacher training gave her content knowledge which allowed her to be sure in the content of her subjects and to add her understanding of science to her science teaching. She passed some courses and exams in pedagogy, psychology and didactics of subjects during her university studies. She thinks that it was for nothing but on the other side it was good for her because she was not influenced with the rules how to teach and she could find her ways on the basis of her experience. Her pedagogical knowledge were very weak. She was willing to apply what she observed in the instructions of other teachers in school, what she found in literature and in workshops of continuing development of teachers. Teaching experience improved her pedagogical knowledge. Integration of content knowledge and pedagogical knowledge was difficult for her and became in reality after many years of here science teaching.

The second respondent was one fourth-year pre-service physics teacher. Student enrolled in the PCK based Methods Course, Course of Observing Teaching in Schools and Course of Teaching Practice in School. She started these courses with the expectation of being a good teacher. She perceived all activities in the course as effective ways to accomplish her goals. This student-teacher designed a few action research which were focused on the educational

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problems in science lessons at schools. She observed physics classes and interviewed the teachers in schools. She learned many things, for example, having a good understanding of the topic taught, using a good probing questions, using interesting teaching materials, paying attention to all students. She started to be aware of the importance of representing content suitable to students´ backgrounds, i.e. the key idea of PCK. Her thinking about teaching and learning (e.g. setting teaching objectives, introducing the lesson, teaching, concluding lesson, assessing students´learning) became more complex. She increased the complexity of relationship among the components of PCK. She tended to progressively develop more complete PCK. In her development of PCK she recognized the importance of teachers´ content knowledge and knowledge of students´ learning. Her PCK were particulary formulated during pre-service studies.

Both representations of PCK are constructed from our research amongst a small group of teachers. They should not be interpreted as depicting the PCK of each teacher in the study. Rather, these representations are generalisations of teachers' pedagogical content knowledge about teaching particular science content to a particular group of students, and as such are potentially valuable contributions to the knowledge base of teaching.

Both forms of representation of teachers' PCK are limited in that they do not enable us to "see" the teaching in action, or tell us how teachers' beliefs about the nature of the knowledge represented influence their practice. Nevertheless allow insights into the ways that teachers think about science content in the context of teaching. Importantly, both provide reasons which support our assertion that the teachers' knowledge that is represented is pedagogical content knowledge. Teachers who have this knowledge do in fact teach in ways that lead to student understanding.

It is well accepted that much teacher knowledge is implicit, with teachers rarely having the opportunity to reflect on what they do in the classroom and why. Further, curriculum and other documents tend to represent the teaching of a topic in an undifferentiated form as certain content to be learned and understood, and activities that might engage students. Not surprisingly, teachers' framework for thinking about and discussing with colleagues the teaching of a topic is often limited to "what works". Teachers need help to think more complexly about their practice and the reasons behind their actions in the light of how particular pupils learn and in relationship to specific formal academic knowledge.

Experienced teacher is able to make a deeper interpretation of content events, interpreting significant contextual cues. This teacher had no effective pre-servise teacher training that was focused on the development of PCK. This teacher was able to develop PCK on the teaching experience for many years. For pre-service teacher, on the other hand, it is possible that representations of PCK, that was created on the basis of the course of pre-servise teacher traing, may not resonate with the context within which teacher will eventually teach. The goal of this case study is to explore the accessibility and usefulness of these representations of PCK for teachers and researchers, including the extent to which they are helpful in developing teachers' PCK.

Preservice teachers constructed PCK by linking their existing knowledge and experience with knowledge and experience derived from social interactions with the course instructor and peers through various learning activities (e.g. reflection, discussion, group work, worksheets, micro-teaching, action research) in the courses. Students develop their knowledge of curriculum, teaching strategies, and assessment, which are basic components of PCK. Experience in classroom is one factor for PCK development. Therefore the pre-service teachers were required to observe a physics classroom and interviewed teachers, followed by discussion and reflection about aspects learned. Methods course should be considered as an important opportunity and potential source for development of preservice teachers´ PCK. Preservice teachers´existing knowledge and experience related to components of PCK must be taken into account as guidelines for designing activities to enhance their understanding of each component of PCK and their integration of all components into PCK. Teaching experience is generally accepted as an important factor for PCK devekopment.

Conclusions

The innovation of science teacher education programs can focus attention on teachers´ pedagogical content knowledge. In usual courses, teacher educators have difficulties in examining the development of the PCK of their (student) teachers. However, innovative courses that use the action research and other newly developed strategies offer teacher educators the opportunity to get a clear insight in this PCK development, especially the growth of knowledge of students´ conceptions and related learning difficulties, and adequate instructional strategies. In this way, the use of action research and these strategies can contribute to increase the interest in (student) teachers' pedagogical content knowledge. The teacher educator can be helpful to offer additive information about teaching science topics. In this way can contribute to develop domain-specifics and subject-specifics PCK.

This innovation also can integrate teacher course "theory" and classroom "practice". In usual courses, (student) teachers often complain that their course does no fits well with their need to solve problems that they encounter in school teaching. However, innovative courses that use the action research and new strategies offer the opportunity to present classroom activities and pedagogical problems or events for further discussion. The participants, including the teacher educator, are confronted with difficulties (or successes) in teaching particular science topics. Suggestions from the course workshop regarding revised teaching strategies can be discussed with the mentor at the practice school and applied. These approaches could facilitate development of PCK of science student teachers.

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Received: *May 20, 2011*   Accepted: *July 16, 2011*

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