THEMATIC ISSUE

STUDIES ON TEACHING AND LEARNING IN DIFFERENT SCHOOL SUBJECTS

Guest Editors

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EDITORIAL

The monothematic issue 2/2009 of Orbis Scholae focuses on teachers' and students' knowledge and its relation to teaching and learning processes. Published articles are bound by three central themes: (1) the nature of teachers' knowledge for teaching (i.e. pedagogical content knowledge – PCK) in different cultures and school subjects; (2) students' knowledge and understanding of the outside-world phenomena; (3) the nature of teaching and learning in different school subjects.

Pertti Kansanen attempts to find the core of pedagogical content knowledge by analysing the central concepts of the teaching-studying-learning process. Esther M. van Dijk in her comment on Kansanen tries to clarify the nature of pedagogical content knowledge using two different perspectives: PCK as a general body of knowledge and PCK as an element of teacher knowledge. Birgit Pepin explores mathematics teachers' knowledge for teaching, in the Anglo/American, French and German 'scene', and how this may relate to teachers' beliefs and practices as a 'teacher of mathematics'. Tomáš Janík, Petr Najvar, Jan Slavík and Josef Trna illustrate the dynamic nature of physics teachers' pedagogical content knowledge. Renate Seebauer attempts to identify possible modifications of subjective theories with teacher trainees in the course of study for future lower secondary teachers over a period of four semesters of study. The topic of students' knowledge and understanding is presented in several articles. Daniela Schmeinck examined the map-drawing abilities of an international sample of ten-year-old children. Milan Kubiatko and Pavol Prokop attempts to find misconceptions about mammals among elementary children of various ages. Petr Najvar, Veronika Najvarová and Tomáš Janík aimed to investigate the nature of every-day teaching in different school subjects.

A range of content domains (school subjects) is featured throughout these articles – Mathematics, Physic, Geography, Biology, English and Physical Education. The authors employed both quantitative and qualitative approaches – including comparative research design. The comparative perspective on teachers' knowledge in different countries (England, France, Germany) is presented in the article by Birgit Pepin. Daniela Schmeinck uses comparative perspective to report results of a study focused on map-drawing abilities of an international sample of ten-year-old children. The idea of comparative understanding of school subjects is elaborated in the article by Petr Najvar et al., which aims at illuminating the nature of teaching in Physics, Geography, English and Physical Education.

These articles span empirical research carried out in different European countries. They consider how knowing, teaching and learning in different cultures and in different school subject may be examined, while remaining sensitive to comparative perspective in broader sense in educational research.

Tomáš Janík & Pertti Kansanen

THE CURIOUS AFFAIR OF PEDAGOGICAL CONTENT KNOWLEDGE

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Abstract: *This paper attempts to find the core of pedagogical content knowledge by analysing the central concepts of the teaching-studying-learning process. The various relations between these concepts – teacher, student, content – lead to possible explanations about the nature of pedagogical content knowledge. The role of practice, empirical and normative sides, and personal practical theories are the essential features in understanding pedagogical content knowledge. And its dependence on the curriculum raises the question of latency as its theoretical existence. Moreover, this paper discusses the connection of pedagogical content knowledge to the German fachdidaktik as well as its relation to the French didactiques. The increasing use of pedagogical content knowledge may likely show the way to a more heterogeneous usage of this concept in the future.*

Key words: *pedagogical content knowledge, teaching-studying-learning process, German fachdidaktik, French didactiques*

To begin with …

Once upon a time I, among others, was celebrating the retirement of a kindergarten teacher at the University of Gothenburg, Sweden. She was a lively person, and many lovely stories and anecdotes were told during the evening. In one of them, a well-known professor of mathematics was once visiting a kindergarten and observing an incident of mathematics teaching. Not entirely satisfied with the event, he asked the teacher how many credit points she had in mathematics studies. The teacher replied with lightning speed, saying "At least as many as my dear professor has in teaching small children".

The cornerstones of the teaching-studying-learning process

Content is one of the fundamental concepts in the teaching-studying-learning process. It is quite common to present the cornerstones of this process, in addition to content, as comprising of a teacher and a student. To avoid misunderstandings, one should note that, although such models present the student as a singular concept, the question focuses on a group of students studying at the same time. Between these concepts takes place a complex interaction (Klingberg, 1995; Kansanen, 2003). With the help of the didactic triangle, we can also describe the role of these basic concepts and characterise their mutual relations. Emphasising their reciprocal positions can highlight their importance and meaning (Paschen, 1979; Diederich, 1988; Künzli, 1998; Hopmann, 2007).

Every relation between the cornerstones has its special meaning. The relation between the teacher and the student is a pedagogical relation (Klafki, 1970, pp. 55-65) and necessary from a young person's point of view; it aims to draw out the person's best. It is also interactive in nature, and a student cannot be forced into it. Nor is it a permanent relation, but one which the young person gradually grows out of, developing into independence. This relation gradually takes shape as the development of the young person brings with it different perspectives. This relation between the teacher and the student cannot be primary because the reason for its existence comes from the reasons for participating in the teaching-studying-learning process. As a secondary relation, however, it is of paramount importance. If it is unbalanced, it can ruin the entire communication in the interaction. We can say that it is a necessary condition for a fruitful instructional process.

The student's relation to the subjects, or more generally to the content, is the key to understanding the instructional process. The content is generally defined in the curriculum as subjects and other content. Learning and other desirable changes, or more generally, the defined development of a student's personality, is the primary purpose of the teaching-studying-learning process. Thus we can say that the consequences – learning included – form the most essential aspect of the relation between the student and the content. A student's task is to study the content defined in the curriculum. Although we at the moment emphasise a personal approach to the studying and finding of one's own means to achieving instructional aims and goals, the student is not left alone in the teaching-studying-learning process. It is the responsibility of the teacher to facilitate this activity in such a way that learning takes place optimally. This leads us to examine the position and meaning of the teacher in the instructional process.

Being a teacher means being an expert in teaching in some content area. Mastering the content or content knowledge is the basis of the relation between the teacher and the student in addition to the pedagogical relation. The teacher's tasks include developing the skill to mediate and facilitate a student's studying of the content. If the content knowledge is emphasised, the role of the teacher becomes that of a specialist of that particular content. For this reason, curricular knowledge and pedagogical knowledge are needed, according to the definitions of Shulman

(1986; 1987). Thus, helping the student in his/her studying to learn implies that the teacher has enough content knowledge, enjoys a positive relationship with the student, and uses pedagogical knowledge to present the content in such a way that the student will learn optimally. Speaking of German pedagogical language, it is the didactical relation that is needed for optimal learning (Klingberg, 1995; Kansanen, 2003). One important part in this interaction is pedagogical content knowledge.

It is common to define pedagogical content knowledge as an intersection between content knowledge and pedagogical knowledge (Shulman, 1986; 1987). This intersection, although important, is only a part of the teaching-studying-learning process. This is also the line of reasoning in Shulman's knowledge model. All parts of the instructional process build a totality, and all parts are constantly needed. Taking a certain element from this totality to be examined is possible only in research; in practice, all the parts interact all the time. For the teacher and the students, the entire process is continuous reality. In this article, however, pedagogical content knowledge is reflected upon as a special theme and analysed as a central point of view.

Theoretical viewpoints

Pedagogical content knowledge: latent or overt?

An interesting question is how independent a concept pedagogical content knowledge can be? It is self-evident that all pedagogical concepts form a network where all are connected to each other and where their unique variance is difficult to define. Content is one aspect of the instructional process. There can be no teaching-studying-learning process without content. Content can also take different kinds of expressions; in teaching, even method turns out to be a certain kind of content. Content is usually defined in the curriculum; consequently, it develops into pedagogical content when brought into the real instructional process.

A highly important issue is the general existence of pedagogical content knowledge. If the content is expressed in the curriculum as divided into different subject matters (as is often the case in universities, adult education, and in school), pedagogical content knowledge becomes evident while teaching. It is thus overt by nature. But, can we be certain of its existence before it is brought into the instructional process and defined in the curriculum? Some content e.g., mathematics, religion, languages, seems so evident that we no longer problematise its reality. On the other hand, it is relatively easy to present content not yet mentioned in the curriculum. That kind of content has, perhaps, been defined elsewhere, but not in the curriculum. Pedagogical content knowledge connected to such content could be characterised as latent by nature. Or could the content also be totally new, discovered in connection with a particular new invention, for example? In that case, pedagogical content knowledge becomes real when the

new content is incorporated into the curriculum. In the same way certain content could disappear when removed from the curriculum.

As a consequence, one could say, on condition, that pedagogical content knowledge is content-specific, that its existence depends on its position in the curriculum.

The problem of pedagogy

The definition of pedagogical content knowledge as an intersection of content knowledge and pedagogical knowledge is clear in principle. Nevertheless, it has aroused much discussion (e.g., Gudmundsdottir & Shulman, 1987; Grossman, 1990; McCaughtry, 2005; Ball, Thames & Phelps, 2008). If the definition is taken earnestly, we quite soon realise that both parts of the intersection are very large. The pedagogical mission in the instructional process is to get the students to learn as effectively and qualitatively well as possible. This challenge requires the entire pedagogy, not only pedagogical content knowledge. I suspect that there is a certain inconsistency in using the concepts pedagogy, general pedagogical knowledge, and pedagogical content knowledge. Even in his own writing, Shulman (1986; 1987) uses these alternatively or without distinguishing between them. Pedagogy is, usually for the teaching-studying-learning process, where all the elements of the instructional process are always taken into consideration. If we keep this point in our mind, pedagogical content knowledge is also the one and only element in this process. In Shulman's knowledge system, both general pedagogical knowledge and pedagogical content knowledge comprise two of the seven types of knowledge. When speaking of pedagogical content knowledge, however, pedagogy is constantly used instead of general pedagogical knowledge. Are they synonyms that can be used interchangeably?

In his first article (1986) on teacher knowledge, Shulman distinguishes "… among three categories of content knowledge: (a) subject matter content knowledge, (b) pedagogical content knowledge, and (c) curricular knowledge" (p. 9). Describing and defining pedagogical content knowledge is very scarce; it is a "subject matter for teaching" (p. 9) and "…the particular form of content knowledge that embodies the aspects of content most germane to its teachability" (p. 9). Further, he presents a general conception: "…the ways of representing and formulating the subject matter that make it comprehensible." (p. 9). Later, he mentions "students of different ages" (p. 9) and, further, student misconceptions (p. 10). In this context, general pedagogical knowledge or the concept of pedagogy is not mentioned at all. In a footnote (p. 14), however, Shulman mentions in passing "pedagogical knowledge for teaching" that is "terribly important", but its connection to pedagogy or general pedagogical knowledge in this context is unclear.

In his second article (1987), Shulman enumerates seven different types of knowledge. Significantly, he defines pedagogical content knowledge as "… the blending of content and pedagogy …" (p. 8). We suppose that, with pedagogy, he means general pedagogical knowledge. As a matter of fact, this indirectly indicates

a close connection to the German fachdidaktik, but it turns out that the broad concept of pedagogy is clearly unintended. There is, however, a certain seed for a broader understanding of pedagogical content knowledge because students are also mentioned and all the other categories of knowledge are dealt with in the same context. Caillot (2007, p. 127) presents an opposite example. He consciously rejects "pedagogy or some 'general didactics'" as too speculative a field of study.

If we look at the knowledge base presented by Shulman (1987), we find almost all the basic concepts used in pedagogy. If we begin with general concepts, we find curricular knowledge that connects the teacher's work with the curriculum. This is an important point that makes the process pedagogical (cf. Hinchliffe, 2001). The instructional process is thus placed inside the framework of the curriculum; the curriculum is the criterion for all that takes place in the instructional process. In close connection to this is Shulman's knowledge of contexts and of pedagogical aims, goals and purposes. Students are taken into account through the knowledge of learners. The remaining types of knowledge deal with central pedagogical concepts: general pedagogical knowledge, content knowledge, which refers to the teacher's understanding of the subject-matter, and finally, pedagogical content knowledge. These seven concepts of knowledge make it possible to construct a model, and Grossman (1990) has developed this idea further, presenting a hierarchical system of these knowledge concepts. However, if we look at the types of knowledge separately, as is done with pedagogical content knowledge, the text quite often contains many times broader aspects, although the writers do not say so. Values, for example, are an essential and inseparable factor of the instructional process (Gudmundsdottir, 1991; Kansanen, 2003).

My assumption is that there is a big difference when pedagogical content knowledge is considered from the viewpoint of the student or teacher. If the student is the focus, as in pedagogy in general, pedagogical knowledge is combined with all types of knowledge, not only with content knowledge. The content is developed with the goal that learning is optimal. Pedagogical knowledge is easily seen as pedagogy with all the types of knowledge. McCaughtry (2005) wants to broaden the concept of pedagogical content knowledge to include knowledge of the students. Strictly taken, McCaughtry's point of view is logical; according to Shulman's categories, there is a separate type of knowledge of learners. If we think of the meaning of pedagogy, however, this type of knowledge is already included in pedagogical content knowledge because pedagogy also contains the knowledge of the students. This reasoning leaves open the question of what is really meant by pedagogical knowledge or what is left to pedagogical knowledge if all other types of knowledge are removed from the system. Apparently the concept of pedagogical knowledge was not particularly clear in Shulman's knowledge system. The most problematic point hampering the analysis is the indistinctness between general pedagogical knowledge and pedagogy in general. McCaughtry (2005), in contrast, makes use of Dewey's claim to combine the child and the curriculum. That is to define, in a different way, what pedagogy is.

Further, if the teacher is at the focus when looking at pedagogical content

knowledge, the analysis is of a different kind. It then seems common that content is mainly analysed, and only for the teacher's use. The purpose seems to be to organise the content in such a way as to make it easy for the teacher to teach it to the students, and for the students to learn the content as easily as possible. This is happening, however, chiefly from the viewpoint of the teacher. The other types of knowledge in the system are not taken into consideration; the analysis concentrates, rather, on the structure, the method, or presentation order of the content. This seems to be the problem that Ball, Thames and Phelps (2008) deal with in their article. Their discussion continues to reflect on whether there are similarities and differences between different content or school subjects. A fruitful viewpoint, apparently, is that the problems of the content are dealt with by taking the expertise of the teacher into consideration and trying to identify the difficult parts of the subject matter and those paragraphs where mistakes are generally made. At least two problems from the content side follow: first, how is experience or wisdom of practice taken into account, and is there theoretical pedagogical content knowledge that could be tested empirically? In close connection to that is what the students are really learning. If the teacher resorts to pedagogical content knowledge in teaching, are the students learning the original content knowledge or the special pedagogical content knowledge that the teacher is applying?

Teacher knowledge

Ball, Thames and Phelps (2008) remark that pedagogical content knowledge lacks definition. It is also interesting to note that they view pedagogical content knowledge as a "bridge between knowledge and practice" (p. 389). In the amalgam of content and pedagogy, as Shulman would say (1987), the latter is represented by practice, not by general pedagogical knowledge or pedagogy. This is quite logical because pedagogical content knowledge is understood as teacher knowledge. It follows that it is the teachers who, through their own practice, wisdom of practice, develop a way of pedagogical content knowledge that they think is of use in the instructional process. It also follows that pedagogy in this case is understood as a practical viewpoint. Practice, on the other hand, means actions, thinking, reasoning, and making decisions.

Making decisions turns the nature of pedagogical content knowledge normative by nature. Taking a stand and deciding between alternatives requires personal beliefs; using pedagogical content knowledge is thus one type of teachers' pedagogical thinking (Kansanen, Tirri, Meri, Krokfors, Husu & Jyrhämä, 2000). Teaching is taking place according to the justifications behind the decisions when pedagogical content knowledge is developing in a teacher's mind. In other words it is personal practical knowledge (Levin & He, 2008), and the content of pedagogical content knowledge thus, perhaps, cannot be defined externally. Behind the justifications may be many kinds of reasons: rational, intuitive, and mixed, etc. The teacher's understanding of pedagogical content knowledge is, consequently, also tacit knowledge (Toom, 2006), and thus difficult to define as an object theory.

Understanding pedagogical content knowledge as personal and practical also makes it unique. It is thus every teacher's professional expertise. On the side of content knowledge it requires study of the subject matter; combining it with pedagogical expertise distinguishes the teacher as a pedagogue from a content expert. An interesting question is how much expertise is needed and with how little expertise it is possible to obtain good results? "Nothing is enough" is the answer when I ask a content expert. Is it, however, possible to find empirical evidence as an answer to this question? Unfortunately the issue remains empirically unresolved despite various attempts (e.g., Wilson, Floden & Ferrini-Mundy, 2001; Krauss, Brunner, Kunter, Baumert, Blum, Neubrand & Jordan, 2008). On the other hand, it is not difficult to find textbooks and guides full of teaching tips for various content knowledge. These are normative, of course, but as a rule they are based on empirical teaching experience; in that way, they have validity.

It seems safe to say that content knowledge is objective knowledge in a particular external form; it can be analysed and presented formally (text, pictures, tables, figures, etc.). The teacher creates a special version of this content knowledge in order to get the students to learn it as easily and effectively as possible. Every teacher gradually develops a personal understanding to realise this task, and the result of this development is pedagogical content knowledge. What the students are learning in this process is a personal conception of this content knowledge mediated via pedagogical content knowledge.

Pedagogical content knowledge is thus personal, based on practice, but it is possible, at least in principle, to present it in some external form and to become empirically tested in that way. It can further be investigated in different circumstances with different kinds of students. In this way, personal knowledge may become generalised knowledge shared with other teachers. In the same way, the theory of pedagogical content knowledge can be developed and further tested empirically.

Fragmentation of content knowledge for teaching

Ball, Thames and Phelps (2008) attempt to develop the definition of pedagogical content knowledge further and to find subcategories within it. In principle, this happens by dividing pedagogy in smaller parts, but also doing the same with content knowledge. The difficult point here is how to restrict ourselves to pedagogical content knowledge, and specifically, taking it to the letter, only to pedagogical content knowledge. If we bear in mind that pedagogical content knowledge is an amalgam of content knowledge and pedagogy, then other knowledge types must be kept out of this enterprise. It is possible, however, to emphasise content knowledge in such a way as to combine it also with other types of knowledge than pedagogical knowledge. Thus follows the expression of content knowledge for teaching.

First Ball, Thames and Phelps (2008) present two types of content knowledge: common content knowledge and specialised content knowledge. Their subject

matter is mathematics, and with 'common' they refer to such mathematical substance that is "not unique to teaching" (p. 399). This, I suppose, is mathematics as a discipline as it is taught at the universities, and as I understand it as content knowledge. Specialised content knowledge, on the other hand, "… is the mathematical knowledge and skill unique to teaching" (p. 400). What is difficult to understand is why call this with a new term when, I suppose, this is actually original pedagogical content knowledge. It is content knowledge combined with pedagogy where teaching is used in the place of pedagogy.

The next type is knowledge of content and students. Here, knowledge is combined with students and, using Shulman's own expression, with knowledge of learners. In this way, we encounter difficulties if our purpose is to restrict ourselves to content only. Content can be combined with any components of pedagogy or teaching: the problem here, however, is that the knowledge system contains a horizontal type of knowledge besides pedagogy, knowledge of learners. If we combine content with students, it is, according to the knowledge system, no longer a category of pedagogical content knowledge. As such, this new category is, without a doubt, fruitful. It indicates, however, that in the instructional process, all the elements of pedagogy are needed all the time. Pedagogical content knowledge is a theoretical concept that becomes active in practice; it can be investigated as such, but applying it in practice requires all the other elements of pedagogy (e.g., knowledge of students). Taking only knowledge of content and students is "the intersection of content and students" – in other words, mathematics and students. That is, however, just what a teacher needs in pedagogy, and when using this knowledge in teaching, it becomes more than pedagogical content knowledge. It becomes pedagogical content knowledge with knowledge of students. We note once again that Shulman also uses the category of knowledge of learners in connection with pedagogical content knowledge (1986, p. 9) and implies a more extensive area for it. It is difficult to know whether this use was intentional.

The last new category is knowledge of content and teaching. It seems that pedagogy has been compensated for with teaching. This is an interesting viewpoint and leads us to ask what we mean by teaching and how teaching and pedagogy are related. At once, one could say that teaching is action based on thinking and decisions, and presents activity to fulfil pedagogy in school according to the conditions of a curriculum. Further, it is closely connected with teachers and their decisions and actions. The focus is on teachers, as it is with pedagogical content knowledge also.

If we attempt to understand teaching more holistically, taking the students' decisions and actions into the same process and, most importantly, deal with them jointly, it is possible to enlarge the content knowledge to contain the entire instructional process where the basic conception is interaction (Kansanen, 1999). Then it is also possible to combine content knowledge with any aspect of the instructional process, that is, with teaching. Further, it is possible, particularly for research purposes, to define more precise concepts of content knowledge. In practice, these are parts of the pedagogy used to realise the aims and goals of the curriculum.

The analysis by Ball, Thames and Phelps (2008) clearly demonstrates how much benefit can result from developing the content side of the instructional process. The category of pedagogical content knowledge is so extensive that it easily becomes the same as pedagogy in general. In European and especially in German pedagogy, this is very often the result. An important question, however, is whether we look at the content from a research point of view or how the instructional process functions in reality. According to that viewpoint, the role of content has a different status and characteristics.

The extraordinary instance of teacher education

In teacher education, studying the content or subject matter creates additional problems. Student teachers often study subject matter in the departments of content knowledge (e.g., department of mathematics, religion, languages, etc). Many times these studies are separate and bear no connection to teacher education. Sometimes, studying content and how to teach it are connected in teacher education. In principle, the teacher educator is not an expert of the disciplinary content; rather, the responsibility of a teacher educator is only how to teach the content. It is often difficult, however, to differentiate between content knowledge and pedagogical content knowledge. Thus student teachers sometimes complain that the courses of pedagogical content knowledge are simply more courses of content knowledge by nature. Essential, however, is that it is precisely pedagogical content knowledge that is intended to be taught and studied in those teacher education courses. Consequently, pedagogical content knowledge comprises not only personal practical knowledge, but is the knowledge that the teacher educator attempts to mediate to the student teacher. The same occurs with textbooks and teaching guides, which contain pedagogical content knowledge, in addition to content knowledge.

Thus we can say, at least to some extent, pedagogical content knowledge is also formal knowledge and a possible object of studying. In fact, a book dealing with special content differs from a textbook written about the same topic.

The connection of pedagogical content knowledge to the German fachdidaktik and the incident of French *didactiques*

Various journals have to some extent discussed the similarities between pedagogical content knowledge and the German fachdidaktik (e.g., Gudmundsdottir & Grankvist, 1992; Bromme, 1995, Westbury, Hopmann & Riquarts, 2000; Blömeke & Paine, 2008; van Dijk & Kattmann, 2007; Kansanen, 2009). According to the well-known problem of translating the German *Didaktik*, Hopmann and Riquarts (1995) have in a way ceased to use didactics as a translation of *Didaktik*. Rather, they suggest a variation with a different spelling, 'didaktik', instead of didactics. They apparently intend to refer to the German *Didaktik* without the negative connotations of

didactics while using a term that is still close enough to the original to suggest the real nature of the term *Didaktik*. I attempt to follow Hopmann and Ricquarts (1995) in using fachdidaktik in the same way.

Although pedagogical content knowledge emerged as a new idea in the 1980s, Bullough Jr. (2001) presents its background and links it to the discussion about teacher education reform that took place about a hundred years ago. It dealt with the controversy between content knowledge and pedagogy, and in many ways resembles the present discussion. During the following years, the development of pedagogical content knowledge and fachdidaktik, however, progressed separately with only some occasional connections.

In Germany, fachdidaktik has traditionally been a research area of its own and, together with the general didaktik, has constituted the background science of teacher education. Fachdidaktik is also organised systematically (http://gfd.physik.rub.de/), and the separate research associations for fachdidaktik have a common umbrella organisation: *Gesellschaft für Fachdidaktik – Association for Fachdidaktik*. It consists, for the time being, of 22 associations representing different content areas or subject matters, one of which is the fachdidaktik of educational sciences. An interesting detail is that the organisation does not translate the term *Fachdidaktik* into English in its original German form. In the text dealing with the tasks of the organization at least the terms *subject didactics* and *subject-oriented didactics*, are used but not the term pedagogical content knowledge.

The relation of pedagogical content knowledge and fachdidaktik is a good example of problems when comparing educational research internationally. Part of them may be explained with broader societal issues and particularly with the differences between school systems. It also indicates how national by nature educational research still is. This concerns research on teaching and teacher education especially, though not so much educational psychology. The case of French *didactiques* is yet another good example.

The origin of French *didactiques* is apparently independent of the development of the German didaktik, which is particularly valid with regard to the fachdidaktik. Using this same basis, however, the term didaktik indicates its origin at large. French *didactiques* is comparative didaktik in nature (Caillot, 2007); different fachdidaktiks are compared to each other (cf. Shulman & Sherin, 2004). The expression in plural, the French *didactiques*, is intentional, and the singular form, *didactique*, refers to only one single subject matter.

The birth of the French *didactiques* coincides with the reform of the school system in the beginning of the 1960s. Caillot (2007) states that during this period, researchers, teacher educators and teachers came closer to each other, cultivating the opportunity for co-operation. It was the beginning of the comparative didaktik. Caillot presents three content areas as an example of this development: linguistics, mathematics, and physics together with chemistry. Researchers played the main role in this process, whereas the departments of education elected not to participate in it. According to the representatives of comparative didaktik, the majority of educational researchers "… were inspired by a libertarian philosophy

and ideology" (Caillot, 2007, s. 126) that appealed, among others, to Ivan Illich, and failed to consider the content of the curriculum earnestly. The new didacticians, on the contrary, emphasised the content, but had no pedagogical background.

The French *didactiques* emphasise the specificity of the subject matter in teaching. Various articles seem to exaggerate this specificity. In some examples concerning mathematics teaching (Sensevy, Schubauer-Leoni, Mercier, Ligozat, & Perrot, 2005), one can pose the question of whether the content is often mathematics. Respective content also appears in other subjects. Nevertheless, no general area of *didactiques* is sought. If there are similarities between subjects, it falls under comparative didaktik. It seems that some conscious aversion to general didaktik prevents other interpretations. Abstractly taken, comparative didaktik sounds almost the same as general didaktik; when dealing with teacher education, however, co-operation with colleagues representing the French *didactiques* and general didaktik or pedagogy could prove difficult.

Naturally, the limits between the general and the specific are porous and depend on how we view them. Many times we use quite common concepts; they are apparently needed before proceeding to the more specific parts. Thus, Tiberghien and Buty (2007) use concepts such as "knowledge to be taught", and "taught knowledge", and "scholastic time, didactical time and learning time". These are undoubtedly general and could be used in any content. According to Caillot (2007, p. 128), however, one problem is that when pedagogy builds large overall theories that cannot be falsified, *didactiques* attempt to develop a theoretical framework that can be tested. If general didaktik is not a proper concept, comparative didaktik leaves the results of this comparison open; perhaps we can then move on to the level of some kind of metafachdidaktik? Although something may be common to all subject matters, it is not, however, general didaktik. The connecting factor is still content; general didaktik deals with other general aspects of pedagogy.

Recapitulation

Although Lee S. Shulman claimed that content had been missing from the research on teaching, his claim had to be understood in such a way that a new line of research would be desirable. In pedagogy, a tension has always existed between subject matter and general pedagogical knowledge. It remains to be seen in the different roles the teachers play in schools, however. The older the students, the more content knowledge is needed. Dispute arises: how much expertise of content and how much pedagogical knowledge is required? And how are they combined? It is, however, a totally different aspect to examine this matter from the point of view of research than from the point of view of teaching in the classroom. In research, it is possible to view the parts separately without correlation to other parts. In practice, this is unrealistic. The problem in articles such as this present one is how to deal with both aspects together, while at the same time considering the results of recent empirical research.

The problem with pedagogical content knowledge is apparently that its area is

quite narrow; it requires other knowledge types to become real. Strictly speaking, after adding other knowledge elements to pedagogical content knowledge it is no longer the same. This seems to be the approach initially with Ball (2000), and most recently with Ball, Thames and Phelps (2008). In fact, they aim to explore the content from a larger perspective than pedagogical content knowledge. The expression is content knowledge for teaching. It happens by combining one or more types of knowledge with the content as well as with various point of views related to teaching. In this way, the perspective approaches the area and content of the entire pedagogy by means of which the teaching-studying-learning process is realised (e.g., Ball, 2000, p. 244). As such, it also comes quite close to the German fachdidaktik.

It may be that part of the differences in using similar concepts originates in languages that, to a great extent, are connected with their cultural origins. Proceeding to empirical investigations, perhaps, could shed light on such indistinctness. In empirical research, concepts must be operationalised; comparisons, at least, become clearer.

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PEDAGOGICAL CONTENT KNOWLEDGE IN SIGHT?
A COMMENT ON KANSANEN

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Abstract: *In the debate on the nature of pedagogical content knowledge (PCK) two different perspectives on PCK need to be distinguished: PCK as a general body of knowledge and PCK as an element of teacher knowledge. It is foremost the discussion of the second perspective on PCK that contributes to our understanding of PCK. PCK is understood as topic-specific teacher knowledge that involves the transformation of content and pedagogical knowledge into instruction. Within the debate on the conceptualization of PCK there is agreement on two essential elements of PCK: knowledge of students' conceptions and of ways to react adequately to these conceptions. The definition of a 'special content knowledge' domain outside the PCK realm by Bass and colleagues provides a new impulse for the debate on the nature of PCK.*

Key words: *content knowledge, knowledge of students' conceptions, nature of pedagogical content knowledge, pedagogical content knowledge, pedagogical knowledge*

Shulman's PCK

In 1983, Lee Shulman stated at a national conference at the University of Texas that an element was missing in research on teaching, namely the study of subject-matter content and its interaction with pedagogy (Shulman, 1999). Shulman elaborated this idea – that became pedagogical content knowledge (PCK) – in two papers: 'Those who understand: Knowledge growth in teaching', published in 1986, and 'Knowledge and teaching: foundations of the new reform', published in 1987. In the first paper, Shulman (1986, p. 6) described the missing element in the study of teaching in terms of the interaction between content, teacher and student: "no one focused on the subject matter content itself. No one asked how subject matter was transformed from the knowledge of the teacher into the content of instruction. Nor did they ask how particular formulations of that content related to what students come to know or misconstrue."

In this paper Shulman not only presented a research program – 'Knowledge Growth in Teaching' – addressing questions concerning what a teacher knows,

the sources of teacher knowledge, how a new knowledge base is formed and the consequences of varying degrees of subject matter competence and incompetence; he also suggested a theoretical framework for inquiry into teacher knowledge. Within this theoretical framework Shulman distinguished three categories in the domain of 'content knowledge in teaching': curriculum knowledge, content knowledge and a new category named PCK. Shulman (1986, p. 9) described PCK as a special kind of content knowledge "which goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge *for teaching*." He writes further: "I still speak of content knowledge here, but of the particular form of content knowledge that embodies the aspects of content most germane to teachability." In this category of PCK Shulman includes:

> "For the most regularly taught topics in one's subject area, the most powerful analogies, illustrations, examples, explanations, and demonstrations – in a word, the ways of representing and formulating the subject that make it comprehensible to others. Since there are no single most powerful forms of representation, the teacher must have at hand a veritable armamentarium of alternative forms of representation some of which derive from research whereas others originate in the wisdom of practice.
> Pedagogical content knowledge also includes an understanding of what makes the learning of specific topics easy or difficult: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons. If those preconceptions are misconceptions, which they so often are, teachers need knowledge of the strategies most likely to be fruitful in reorganizing the understanding of learners, because those learners are unlikely to appear before them as blank slates." (Shulman, 1986, p. 9-10)[1]

In the second aforementioned paper, Shulman (1987) described PCK as one of seven categories of a knowledge base for teaching instead of a subcategory in the content knowledge domain: (1) content knowledge, (2) general pedagogical knowledge, (3) curriculum knowledge, (4) PCK, (5) knowledge of learners and their characteristics, (6) knowledge of educational contexts, (7) knowledge of educational ends, purposes and values, and their philosophical and historical grounds. With respect to this knowledge base for teaching Shulman (1987, p. 8; emphasis added) stated that: "Among those categories, pedagogical content knowledge is of special

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1   Examples of science teachers' PCK can be found in studies of Mastrilli (1997), Van Driel, Verloop, & De Vos (1998) and myself (Van Dijk, 2009). Mastrilli (1997) focused on the use of analogies in the science classroom. The biology teachers in his study used analogies like, "nucleosomes in prokaryotic cells are like beads on a string." Van Driel et al. (1998) studied and discussed teachers' PCK about the dynamic nature of chemical equilibrium. For example, one chemistry teacher tried to clarify the dynamic nature of chemical equilibrium by comparing the equilibrium system with a classroom with two doors, through which students continuously move in and out. Van Dijk (2009) focused on the PCK of biology teachers concerning evolutionary theory. The interviewees in her study discussed a number of problems and possible solutions – for example, that the students often have a mono-causal conception of selection. In reaction to this problem skin colour was suggested as an example, because more than one selection factor plays a role here.

interest because it identifies the distinctive bodies of knowledge for teaching. It represents the *blending of content and pedagogy* into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction."

After Shulman introduced PCK in the research literature the concept was developed further, resulting in a plethora of conceptualizations of this category of teacher knowledge. Differences occur with respect to the elements that scholars include or integrate in PCK and with respect to the descriptions of these elements. In this process of further development, the concept of PCK lost its most important characteristic, namely its topic specificity (see also Hashweh, 2005). For example, Magnusson et al. (1999) suggested a broader view of PCK than the original conceptualization (Abell, 2007; Ball, Thames, & Philips, 2008). They distinguished five components within PCK namely (1) orientation to teaching science, (2) knowledge of assessment of science literacy, (3) knowledge of science curricula, (4) knowledge of instructional strategies and (5) knowledge of students' understanding of science. But including orientations as a component of PCK is problematic, as orientations are *general* views on science teaching and not *topic-specific* knowledge (Abell, 2007). Another example is McCaughtry (2005), who argued that teachers' understanding of students' emotional and social lives is an overlooked form of PCK. As more and more is included in PCK, we appear to be losing sight of PCK as a specific domain of teacher knowledge.

Kansanen's Point of View

The paper titled 'The curious affair of pedagogical content knowledge' by Pertti Kansanen (in this issue) represents an attempt to find the core of PCK. Considering the brief description of the development of the PCK concept above, this is an extremely relevant topic. Kansanen aims to find the core of the PCK concept by analysing its relation to three important elements of the teaching-studying-learning process: the student, the teacher, the subject matter, as well as the interrelationships between these. In Germany and the Nordic countries these elements of the teaching-learning process are often presented in the form of a didactic triangle, a tool to structure the field of educational research. Within this triangle Kansanen characterizes the relationship between the student and the content as studying. The relation that the teacher has to this relationship between the student and the content is the so-called didactical relation: "Thus, helping the student in his/her studying to learn implies that the teacher has enough content knowledge, enjoys a positive relationship with the student, and uses pedagogical knowledge to present the content in such a way that the student will learn optimally" (Kansanen, this issue). PCK is considered to be one important part of this interaction. Figure 1 shows a reproduction of a figure from Kansanen (2003) depicting the didactical relation in the didactic triangle, in order to clarify the position of PCK within the didactic triangle.
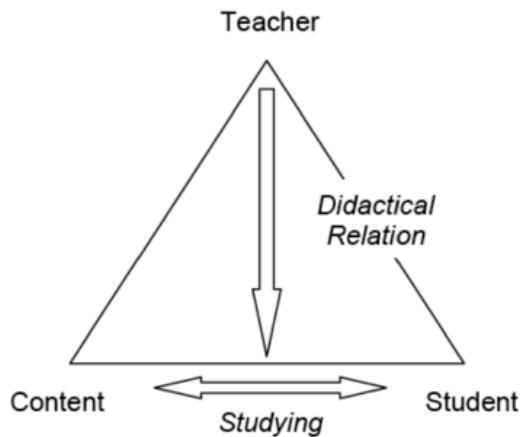
Figure 1. The didactic relation in the didactic triangle (reproduction from Kansanen, 2003, p. 230)

Additionally, Kansanen presents a number of different considerations concerning the nature of PCK. Two issues that remain underexposed in the text seem relevant for our understanding of the considerations that are presented. The first point is that these considerations are based on two different perspectives on PCK: PCK as a body of knowledge existing independent of the teacher, that can be represented as abstract ideas in teacher education and textbooks, and PCK as a subjective representation – an element of teachers' personal professional knowledge (cf. Bromme, 1995). Kansanen starts by considering PCK from the first perspective, a general knowledge domain. He assumes that there is a big difference when PCK is considered from the viewpoint of the student or the teacher. If the focus is on the teacher "it seems common that content is mainly analysed, and only for the teacher's use. The purpose seems to be to organise the content in such a way as to make it easy for the teacher to teach it to the students, and for the students to learn the content as easily as possible" (Kansanen, this issue). Kansanen observes further that: "A fruitful viewpoint, apparently, is that the problems of the content are dealt with by taking the expertise of the teacher into consideration." These considerations concerning PCK as a general body of knowledge then lead to a discussion of PCK as teacher knowledge.

The reasons for choosing this approach toward understanding PCK from the first perspective are not explicated by the author. Furthermore, it is not made sufficiently clear exactly what insights this approach provides for our understanding of PCK. In my opinion it is foremost the discussion of the second perspective on PCK that contributes to our understanding of PCK. The problems for empirical research of PCK are rooted in the fact that PCK is *personal* teacher knowledge. Moreover, PCK is personal teacher knowledge that involves the *transformation* of other types of knowledge. This makes it so difficult to conceptualize PCK and to understand how certain factors like other knowledge categories, orientations, and teaching experience influence the development of PCK.

An additional issue concerns the definition of PCK that underlies the considerations that are presented. Kansanen more than once describes PCK as an *intersection* of content knowledge and pedagogical knowledge. For example, he observes that: "If the definition is taken earnestly, we quite soon realise that both parts of the intersection are very large." However, this definition is not compatible with Shulman's descriptions of PCK (presented above). Shulman described PCK as the ways of representing and formulating the subject that makes it comprehensible to others, the most powerful analogies, illustrations, examples, explanations, and demonstrations. Within these examples the content knowledge and pedagogical knowledge are blended or merged. The development of PCK is not just the summation of these two knowledge domains; it involves the *transformation* of content and pedagogical knowledge into instruction. It is this transformed knowledge that can be observed in the classroom. Kansanen's theoretical considerations appear to be rooted in an understanding of PCK that is very different from Shulman's ideas. When combined with empirical studies that aim to elaborate on the construct of PCK as defined by Shulman, like the study of Ball et al. (2008), this different perspective forms a hurdle for the development of an understanding of the nature of PCK.

Personal Teacher Knowledge

Ball et al. (2008) present a practice-based theory of content knowledge for teaching built on Shulman's notion of PCK. Within the domain of 'mathematical knowledge for teaching' Ball et al. describe two subject matter knowledge categories, 'common content knowledge' (CCK) and 'specialized content knowledge' (SCK), and two pedagogical content knowledge categories, 'knowledge of content and students' (KCS) and 'knowledge of content and teaching' (KCT). They define these knowledge categories as: (1) CCK: the mathematical knowledge and skill used in settings other than teaching, (2) SCK: the mathematical knowledge and skill unique to teaching, (3) KCS: knowledge that combines knowing about students and knowing about mathematics, (4) KCT: knowledge that combines knowing about teaching and knowing about mathematics. In order to clarify the subtle differences between the first three categories they add that: "recognizing a wrong answer is common content knowledge (CCK), whereas sizing up the nature of an error, especially an unfamiliar error, typically requires nimbleness in thinking about numbers, attention to patterns, and flexible thinking about meaning in ways that are distinctive of specialized content knowledge (SCK). In contrast, familiarity with common errors and deciding which of several errors students are most likely to make are examples of knowledge of content and students (KCS)" (Ball et al., 2008, p. 401).

In relation to the work of Ball et al. Kansanen (this issue) observes that: "The difficult point here is how to restrict ourselves to pedagogical content knowledge, and specifically, taking it to the letter, only to pedagogical content knowledge." In light of the development of the concept of PCK in the last two decades this is indeed

a matter of concern. By taking PCK to the letter, Kansanen comes to the conclusion that the KCS concept is not a category of PCK. Because KCS is the intersection of two knowledge domains, namely knowledge of content and students (Shulman's knowledge of learners) and not a combination of content and pedagogy it becomes more than PCK. In my opinion Kansanen is mistaken in his definition of KCS. Ball et al. (2008, p. 402) state that the KCS and KCT domains "coincide with the two central dimensions of pedagogical content knowledge identified by Shulman": (1) the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons" and (2) the ways of representing and formulating the subject that make it comprehensible to others. KCS is, thus, not defined as the *intersection* of knowledge of content and students but as the *transformation* of the knowledge of content and students into an understanding of the topic specific conceptions that students bring into the classroom.

The considerations concerning the definition of KCS and SCK bring us to the heart of the issue concerning the nature of PCK. With respect to the SCK category Kansanen observes that it is difficult to understand why Ball et al. use a new term when this is actually original PCK. Indeed, it is an interesting question why SCK is not, in addition to KCS and KCT, contained in PCK (see also Van Dijk, & Kattmann, 2007). In an earlier paper Ball together with Bass (2000, p. 87) described PCK as a body of bundled knowledge.

> "Pedagogical content knowledge – representations of particular topics and how students tend to interpret them and use them, for example, or ideas or procedures with which students often have difficulty – describes a unique subject-specific body of pedagogical knowledge that highlights the close interweaving of subject matter and pedagogy in teaching. Bundles of such knowledge are built up by teachers over time as they teach the same topics to children of certain ages."

Ball and Bass (2000, p. 88) observed further that: "a body of such bundled knowledge may not always equip the teacher with the flexibility needed to manage the complexity of practice. Teachers also need to puzzle about the mathematics in a student's idea, analyze a textbook presentation, consider the relative value of two different representations in the face of a particular mathematical issue. To do this, we argue, requires a kind of mathematical understanding that is pedagogically useful and ready". In their more recent paper Ball and colleagues (2008, p. 398) develop this idea of pedagogically useful mathematical understanding further:

> "What caught us by surprise, however, was how much special mathematical knowledge was required, even in many everyday tasks of teaching – assigning student work, listening to student talk, grading or commenting on student work. Despite the fact that these tasks are done with and for students, close analysis revealed how intensively mathematical the tasks were. We were surprised to see that many of the component tasks of teaching require mathematical knowledge apart from knowledge of students or teaching. For instance, deciding whether a

method or procedure would work in general requires mathematical knowledge and skill, not knowledge of students or teaching."

Ball et al., thus, view SCK as a form of mathematical problem solving used in the work of teaching that requires no knowledge of students or teaching.

Research on knowledge for teaching is an applied research field and we should ask ourselves what this research could contribute to teacher education. A model of PCK development would provide us with a basis for the improvement of teacher education. Hypothesizing new constructs like SCK raises questions as to their role in the knowledge development process. By splitting up the realm of 'mathematical knowledge for teaching' in a subject matter knowledge domain, that contains among others SCK, and a PCK domain, Ball and colleagues diminish the value of the C(ontent) within PCK. Defining PCK as just a familiarity with students' conceptions and ways to react to these conceptions excludes from the definition the special content knowledge that is necessary for understanding the ideas that students bring into the classroom and for developing good examples that can be used to explain the topic at hand. It is therefore not surprising that Ball et al. (2008, p. 404) observe that: "it can be difficult at times to discriminate specialized content knowledge from knowledge of content and students."

Conclusion

Kansanen observes that the increasing use of PCK may likely show the way to a more heterogeneous usage of this concept in the future. For empirical research of PCK, however, it is important to reach consensus on the conceptualization of PCK. In order to improve teacher education, we have to be able to describe and analyse case studies of PCK and to identify the different factors that influence the development of PCK.

The paper by Kansanen addresses a number of relevant issues concerning the nature of PCK. The discussion of these issues, however, appears to be rooted in an understanding of PCK that is not compatible with Shulman's, and this raises the question as to how the considerations that are presented can help us find the core of PCK. The paper by Ball and colleagues makes a valuable contribution to our understanding of PCK. But more practice-based studies on other subjects are necessary to clarify the notion of PCK further.

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EXPLORING MATHEMATICS TEACHER KNOWLEDGE FOR TEACHING: MATHEMATICS TEACHERS IN ENGLAND, FRANCE AND GERMANY

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Abstract: *This article explores mathematics teachers' knowledge for teaching, in the Anglo/American, French and German 'scene', and how this may relate to teachers' beliefs and practices as a 'teacher of mathematics'. Using a socio-cultural framework a particular concern was what it meant to be a mathematics teacher in England, France and Germany, and in which ways their knowledge construction was influenced, or shaped, by this. The findings are based on twelve teacher case studies, four in each country, and additional interviewing of 30 teachers, ten in each country. Results show that teacher knowledge for and in teaching was different, in the sense that teachers needed different kinds of knowledge to become effective within their systems and classrooms, and even similar kinds of knowledge (for example, subject knowledge) appeared to be differently perceived in the different educational 'spheres'.*

Key words: *mathematics teachers' knowledge for teaching, teachers' beliefs and practices*

Introduction

In recent years researchers have, again, paid an increasing amount of attention to teacher knowledge, that is teacher knowledge for and in teaching. Professional knowledge of teachers has been investigated from different angles. It is accepted that what teachers know is one of the most important influences on what happens in classrooms. The conceptual tools that teachers posses in order to deal with their work situation depend to a large extend on the cultural and systemic traditions of the educational environment in which they work (Stigler & Hiebert, 1999; Hiebert et al., 2003; Pepin, 1999a). However, there is no consensus on what teachers need to know in order to ensure that student learning is taking place.

In mathematics there is evidence (e.g. Bennett & Turner-Bisset, 1993) that insufficient and poor mathematical knowledge has a negative impact on teaching, and researchers argue about the nature of that knowledge. On the other hand, work

at King's College London has found no link between teachers' subject knowledge, measured in terms of academic qualifications, and effective teaching (Askew et al., 1997). Many researchers show that mathematics as knowledge to practice mathematics is distinct from that for teaching mathematics. Ball (2003) argues that mathematics-for-teaching is unlikely to be neither 'more of' or 'to a greater depth than' the knowledge expected of students, but that it is qualitatively different.

> "…knowledge for teaching mathematics is different from the mathematical knowledge needed for other mathematically-intensive occupations and professions. The mathematical problems and challenges of teaching are not the same as those faced by engineers, nurses, physicists, or astronauts. Interpreting someone else's error, representing ideas in multiple forms, developing alternative explanations, choosing a usable definition—these are all examples of the problems that teachers must solve. These are genuine mathematical problems central to the work of teaching." (Ball, 2003, p. 6/7)

Ball and Bass (2003) argue for mathematics-for-teaching to become a distinct branch of mathematics, and there is a growing area of research concerned with this. They argue that mathematics knowledge for teaching is not a watered down version of 'real' (university) mathematics, but a demanding area of mathematical work.

> " …the mathematical knowledge needed for teaching must be usable for ***those*** mathematical problems. Mathematical knowledge for teaching must be serviceable for the mathematical work that teaching entails, from offering clear explanations, to posing good problems to students, to mapping across alternative models, to examining instructional materials with a keen and critical mathematical eye, to modifying or correcting inaccurate or incorrect expositions. The mathematical knowledge needed for teaching, even at the elementary level, is not a watered-down version of 'real' mathematics. Teaching mathematics is a serious and demanding arena of mathematical work." (Ball, 2003, p.7)

From my own research (e.g. Pepin, 1999, 2009; Pepin & Haggarty, 2003), that of colleagues and larger-scale studies such as TIMSS (e.g. Hiebert et al., 2003) it is clear that the work of teaching differs from country to country (e.g. Cogan & Schmidt, 1999). Whilst the quantity and quality of teachers' mathematical knowledge has been an area of great concern (e.g. Ma, 1999), it is, however, less clear how to measure teacher knowledge, what it consists of and how it is comparable across countries. Comparisons of, or simply 'looking into', different knowledges may develop deeper understandings of what we mean by 'knowledge in/for teaching'.

Over more than ten years I have studied mathematics teachers and their curricular practices in mathematics classrooms in different countries, in particular in England, France and Germany. The goal of these studies has been to develop a deeper understanding of what is going on in mathematics classrooms at lower secondary level, especially with respect to teaching and learning mathematics with understanding, and the influence and nature of curricular materials, such as

texts used in classrooms. The comparative perspective has helped to highlight particular features of teachers' pedagogic practice, to discover alternatives, and in turn develop a deeper understanding of those features and practices, in addition to stimulate discussion about choices within teachers' immediate environments and countries.

Specific models

In order to set the background for how teacher knowledge may be perceived in different educational 'spheres', I now outline and identify the relations between, some of the most influential models of teacher knowledge in the Anglo/ American, the French and the German scene. These will subsequently be used, as a background, to develop a better understanding of the teachers studied in the three environments.

One of the most influential models of teacher knowledge, in particular in the Anglo/American scene, has been provided by Shulman (1986a, b). He asserts that 'where the teacher cognition programme has clearly fallen short is in the elucidation of teachers' cognitive understanding of the subject matter content and the relationships between such understanding and the instruction teachers provide for students'. His interest is mainly in the realm of teachers' subject matter knowledge and the role it plays in teaching, whilst acknowledging that teachers need to possess a 'specialised understanding of the subject matter, one that permits them to foster understanding in most of their students' (Wilson, Shulman, & Richert 1987). Shulman (1987) proposes a framework for analysing teachers' knowledge that distinguishes between different categories of knowledge, and he mainly distinguishes between three kinds of knowledge: subject matter knowledge; pedagogical knowledge; and curricular knowledge. The important part of Shulman's work is the acknowledgement on 'pedagogical content knowledge' which, he claims, helps to fill the gap of the 'missing paradigm'. He describes 'pedagogical content knowledge' as that knowledge 'which goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching'.

Shulman's classification of teachers' knowledge has been proven to be very stimulating for research into teachers' cognitions. For example, Bromme (1994) who worked in Germany on mathematics teaching and learning took up Shulman's suggestions, but extended them by two further concepts: the 'philosophy of content knowledge'; and by distinguishing between the knowledge of the academic discipline and that of the subject in school, which includes goals about school and general education. By the 'philosophy of school mathematics' Bromme refers to 'the epistemological foundations of mathematics and mathematics learning and about the relationship between mathematics and other fields of human life', in other words teachers' perceptions on the nature of mathematics and its teaching. Ball et al. (2008) have further developed Shulman's idea of content knowledge for teaching by refining the concept and identifying discernable subdomains such as *specialised content knowledge* which is said to be distinct from *common content knowledge.*

Ernest (1989) explores teachers' knowledge in mathematics teaching, and his model includes teachers' attitudes and beliefs. What is notable in Ernest's model is the importance ascribed to teachers' beliefs, in particular those concerning the nature of the particular subject (mathematics), and concerning the process of teaching and learning the subject. He tries to develop a more fundamental understanding of how mathematics teachers' knowledge, beliefs and attitudes provide a basis for classroom teaching approaches.

Although this model is more detailed than that of Wilson, Shulman and Richert (1987), it shares many of its components with Shulman's model. The comparison provides some measure of support for Ernest's model, since there is evidently a great deal of overlap. Ernest's pedagogical knowledge refers to Shulman's knowledge 'which a teacher uses to transform and represent knowledge of mathematics for teaching' or pedagogical content knowledge (Wilson, Shulman, & Richert, 1987). A key difference between Shulman's and Ernest's models is the apparent neglect of attitudes and beliefs in Shulman's model. However, it seems that beliefs about subject matter are to some extent incorporated into Shulman's 'knowledge of subject matter'.

Brown and McIntyre (1993) developed a model based on the assumption that 'over a period of time experienced teachers have acquired substantial practical knowledge about teaching, largely through their classroom experience rather than their formal training' (p.12). Underlying this approach is the notion that teaching is a craft (rather than a science-based technology) and that experienced teachers have 'craft knowledge' which is accessible to others. They found out that teachers commonly judged their teaching in terms of 'the achievement or maintenance of states of pupil activity which they took to be normally desirable for particular phases and types of lessons (Normal Desirable States-NDS)' and each teacher had their own NDSs for their lessons and for phases of their lessons.

In continental Europe teacher knowledge is part of *Didaktik*, and didactics are often presented in the form of a triangular model (e.g. Houssaye, 1994). Although this model is likely to be limited, it nevertheless allows to establish more clearly the objectives of the study of didactics.

In the French research on the didactics of mathematics there are two distinct, but interrelated, theoretical fields: the theory of *didactical transposition*, based on the work of Chevallard since the 1980s (Chevallard, 1991); and the theory of *didactical situations*, developed by Brousseau (1986) since the beginning of the 1970s and subsequently developed by other researchers. The didactics of mathematics is seen here as the study of the issues of the preparation of mathematics for students.

The two theoretical approaches concern fundamental but different levels of didactical analysis. The concept of the *transposition didactique* (Chevallard, 1991) concentrates on the analysis of the processes that are based on the *savoir savant* (scientific/reference/scholarly knowledge), and how this can be 'transposed' to the *savoir enseigné* (taught knowledge). It is assumed that there exists some identifiable knowledge (*savoir savant*) against which the mathematics taught in schools could be judged or 'legitimised'. Therefore, by adopting the *didactical transposition*

approach, one acknowledges the institutions at the source of knowledge.

There has been much criticism of the vagueness of the notion of *savoir savant* (Freudenthal, 1986). Is there a recognised group of professionals (*savants*) who can produce knowledge which is considered 'knowledgeable'? Chevellard (1991) examined relations between the social practice of research in mathematics and that of institutionalised teaching/learning of mathematics in school. In principle, the theory of didactical transposition aims to identify and emphasise the constraints the different actors are subject to, and thus claims to uncover the apparently 'scientific decisions' made (by various decision-makers) as elements of a system following its own rules.

Brousseau's (1986) theory, the theory of didactical situations, is situated at the classroom level. It aims to model teaching situations so that they can be developed and managed in a controlled way. At the basis of this theory is the assumption that 'knowledge exists and makes sense for the cognising subjects only because it represents an optimal solution in a system of constraints' (p. 368). According to Artigue (1994) it is based on a constructivist approach and operates on the principle that knowledge is constructed through adaptation to an environment that appears problematic to the student. Brousseau's theory aims to become a theory for the control of teaching situations in their relationship with the production of mathematical knowledge. The didactic systems are therefore made up of three mutually interacting components: the teacher, the student, the knowledge. The aim is to develop the conceptual and methodological means to control the interacting phenomena and their relation to the construction and functioning of mathematical knowledge in students (e.g. Winslow, 2007).

Like in the French didactics literature, a German core concept in the development of didactics has been the *Didactic triangle* with its three components of the content, the learner and the teacher, in order to structure the field of didactic research and theory. The 'curriculum' tradition is often contrasted to the German didactics (e.g. Kansanen & Pepin, 2005; or Gundem & Hopmann, 1998). Didaktik in Germany has always been a form of philosophical thinking, theorising and the construction of theoretical models (Kansanen & Pepin, 2005), based on 'philosophical traditions of its own with names such as Kant, Herbart, Schleiermacher etc.' (Kansanen, 1995). Kansanen (1995) asserts that

> "*Didaktik* is mainly intended for teacher education and the models are based on a philosophical conception of man and on the nature of research concerning his education. The empirical research results are not a prerequisite for model building, but are used in a corrective way when they are in conflict with the model variables. Research on teaching reflects an empirical tradition and that is why its models are mainly inductive by nature and based directly on research results. Practical conclusions can, of course, be drawn from these models and thus they can also function in teacher education" (Kansanen, 1995, p. 348).

The emergence of research on what constitutes teachers' knowledge in a particular subject has created the *Fachdidaktik* (subject didactics) which denotes

the pedagogical transformation of factual content for the purposes of teaching, taking into consideration all factors of the teaching-learning process. The didactics of mathematics became the scientific discipline related to research in mathematics education and the research-related development work (Biehler et al., 1994).

There are at least two conclusions that can be drawn from the comparison of existing representations of knowledge in teaching in the Anglo/American, the French and the German educational scene. Firstly, there appears to be a commonality amongst representations on knowledge in teaching in the sense that it is not seen as static, but as a process of development, that it grows and changes, and that experience in the classroom contributes to its growth and change. Secondly, there seem to be differences in traditions within the research into knowledge of teaching. The German (and French) educational research into teaching appears to be traditionally concerned with philosophical thinking, theorising and the construction of theoretical models, the *Didaktik* (which is nevertheless informed by empirical research). The Anglo/American educational research is to a large extent based on empirical studies, in order to identify and be able to determine factors that are influential for teaching (and learning) and to develop an understanding of the processes involved in teaching and learning (Pepin, 1999c).

Teacher knowledge and 'situatedness' of knowledge

The research literature (e.g. Putnam & Borko, 2000) claims that a 'fundamental shift' in thinking has taken place initiated by the key work of Lave and Wenger (1991). Ideas about the nature of knowledge, and learning, have moved towards what is known as the "situated perspective" (e.g. Greeno, 1997; Lave & Wenger, 1991; Wenger, 1998). Whilst this work largely examined learning in informal settings, it has been influential in mathematics education. Work of Boaler and Greeno (Boaler, 2002; Boaler & Greeno, 2000) show that situated perspectives on learning may offer a different interpretation, representing knowledge "not as an individual attribute, but something that is distributed between people and activities and systems of their environment" (Boaler, 2002, p. 1).

Most of this work has attended to student thinking, and perhaps less to teacher knowledge and learning. Putnam and Borko (2000) have advocated a situated perspective on (teacher) cognition- that is that knowing is situated in physical and social contexts, social in nature, and distributed across persons and tools. They support Ball's argument that the contexts in which students, and teachers, learn and in which we assess what they know are inextricable aspects of their knowledge- thus knowing (and learning) are situated.

> "This professional knowledge is developed in context, stored together with characteristic features of classrooms and activities, organised around the tasks that teachers accomplish in classroom settings, and accessed for use in similar situations." (Putnam & Borko, 2000, p. 13)

Interestingly, using the situated perspective as an analytical tool to view teaching as a distributed activity, Cobb et al. (2003) situated teachers' instructional

practices within the institutional settings of the schools (and districts) in which they work. In particular, they emphasise three types of interconnections between various communities of practice within a school or district that involve "boundary encounters, the role of brokers, and the coordination of activity around common boundary objects" (p. 22). The analytic approach that they propose focuses on "teachers' interpretations and understandings while simultaneously treating those interpretations and understandings as situated in and at least partially constituted by the institutional settings in which they work." (p. 13)

Boaler (2002) has taken a situated view that views knowledge as something that is distributed between people and activities and context. Boaler (2000) contends that

> "What is fundamental to the situated perspective is an idea that knowledge is co-produced in settings, and is not the preserve of individual minds. Situated perspectives suggest that when people develop and use knowledge, they do so through their interactions with broader social systems. This may mean that they are learning from a book (written by others) or teacher, or engaging in individual reflection of some socially produced ideas. But the different activities in which learners engage co-produce their knowledge, so that when students learn algorithms through the manipulation of abstract procedures, they do not only learn the algorithms, they learn a particular set of practices and associated beliefs." (Boaler, 2000, p. 3)

Thus, she proposes to shift from a focus only upon knowledge, to one that attends to the inter-relationships of knowledge, practice, and identity. She uses the 'didactic triangle' (not explicitly) with knowledge, identity and practice at its vertices.

Cross-cultural and international studies have tried to explore what and how people know, as a result of learning (Nunes, Schliemann & Carracher, 1993; Stigler & Herbert, 1999; Ma, 1999). These studies highlight the existence of cultural differences, but seemed unable to answer the question of '*how* the cultural shaping of learning takes place' (Sfard & Prusak, 2005, p. 15). Different classroom environments and cultures, constraints and affordances, provided by different settings and opportunities for developing particular mathematical practices, are likely to influence teachers' perceptions of what it means to teach, and learn, mathematics with understanding; and what kinds of knowledges are needed to do that. Teaching mathematics successfully means identifying with and applying the norms of the classroom community which is likely to be different in different contexts, whether they vary from school to school, or from country to country (e.g. Stigler & Hiebert, 1999), and teachers need knowledge of those norms.

The study

In a previous study (Pepin, 1997; Pepin, 1999b, 2002) I have analysed mathematics teachers' work using an ethnographic framework and developed an understanding of the ways teachers worked in their classrooms in England, France and Germany. It emerged that national educational traditions are a large determinant and influence on teachers' pedagogies in the three countries. In a more recent study I (together with Linda Haggarty) investigated mathematics textbooks in the three countries, and connected to that, the ways they were used, by teachers, in English, French and German lower secondary mathematics classrooms (Pepin & Haggarty, 2001; Haggarty & Pepin, 2002). This not only supported some of the earlier findings, but also suggested that the use of curricular materials (such as textbooks), together with the selection of (mathematical) tasks, impacts to a large extent on the mathematical 'diet' offered to students, which in turn is likely to influence students' perception of what mathematics is and what it is to behave mathematically.

For this chapter I have re-analysed some of the data collected over the years in terms of teacher knowledge for and in teaching. The selected data (for this study) consisted of extended lesson observations and interviews with twelve teachers, four in each country, plus shorter observations and interviews with an additional ten teachers in each country. I re-analysed the data on the basis of my understandings of teachers' work, and using a socio-cultural approach to gain new understandings about teacher knowledge in and for teaching.

The main questions asked were:
- What does it mean to be a teacher of mathematics in England, France and Germany?
- In which ways does mathematics teacher knowledge influence/shape the identity of teachers, as teachers of mathematics, in the three countries?

In terms of analysis a procedure involving the analysis of themes similar to that described by Woods (1986) and by Burgess (1984) was adopted. Moreover, at one level I tried to maintain the coherence of the teacher cases through a holistic story of the case that is response validated by participant teachers, and anchored in their own interviews and my observations; at another level , I analysed across teacher cases using my conceptual framework of 'teacher knowledge in/ for teaching', testing the hypotheses offered by the different kinds of literature, and building explanations and theorisations grounded in the data; and at a third level looking for similarities and differences of teacher knowledge across country cases. However, due to the additional cross-cultural dimension, it was important to address the potential difficulties with cross-national research, in particular issues related to conceptual equivalence, equivalence of measurement, and linguistic equivalence (Warwick & Osherson, 1973; Pepin, 2002). Particularly important were the findings of Delaney et al. (2008) who compared teacher "mathematical knowledge for teaching" across the US and Ireland, highlighting the value of validity checks of constructs in both contexts. In this respect it was important to

locate and understand teacher pedagogic practices and the classroom cultures in England, France and Germany, and it was useful to draw on knowledge gained from earlier research which highlighted the complex nature of teachers' work and classroom environments in the three countries, in addition to potential influences (e.g. systemic developments and educational traditions).

Contextual factors – the system and schooling

In **Germany** mathematics teachers at lower secondary level work in a tri-partite system where 40% of the children of any age group go to the local grammar school (*Gymnasium*) and the remainder is distributed amongst the other school forms, i.e *Realschule*, a technical middle school, and the *Hauptschule*, a secondary modern equivalent. There are also a number of children attending comprehensive schools. Compared with England and France, they represent a low percentage of pupil intake. Anecdotal evidence suggests that the reasons for choosing the Gesamtschule are varied (Nentwig, personal communication). Whilst many pupils find the *Gymnasium* too academically orientated and do not want the practically orientated education of the *Haupt-* or *Realschule*, there are at the same time parents who make a positive decision of sending their children to that school type (because they expect a larger variety of courses and less academic approaches, for example).

Teachers teaching in the different school types have different number of teaching hours, i.e. approximately 25 school hours (each hour is 45 minutes long) for grammar school teachers; and approximately 28 school hours for secondary modern school teachers. The teaching responsibilities are also different for the different school forms. Whereas the grammar school teacher is regarded as the subject specialist teacher for two or three subjects, and is responsible for the teaching of those, the secondary modern teacher is likely to teach many more subjects and has more pastoral care responsibilities. Both are civil servants and paid under different pay spines.

In Germany the class is seen as a unit (albeit within a tri-partite system), rather than promoting a school ethos. Different streams, in different school forms, appear to develop different identities, which is reflected in a different curriculum (for each school type) and in different approaches to the academic and affective in different streams.

In **France** mathematics teachers work in a comprehensive system (*college*, or *lycée*). Depending for which level teachers are educated (*certifié* or *agrégé*), they have different numbers of teaching hours. For example, a 'normal' mathematics teacher (*certifié*) teaches 18 periods per week (where each period has 55 minutes). The main responsibilities for a French mathematics teacher lies with the preparation, teaching and assessment of the mathematics. French teachers are civil servants, and their pay varies with the number of years taught and the assessment by the inspectors which puts teachers on different 'ladders' to go slower or faster up the pay spine.

In France the class is also seen as a unit, rather than the school, and it is perceived that all pupils are entitled to the same curriculum (same textbook for one year group, etc).

In **England** the majority of secondary schools are comprehensive schools, catering either for the 11-16 age range or 11-18. There is also an independent sector with its traditional (selective) prepatory and grammar schools. Mathematics teachers typically work 23 out of 25 hourly periods, and they have many responsibilities beside the teaching of their subject. These can be in terms of pastoral care (of a particular year, for example), or in terms of leadership, i.e. head of the mathematics department.

In contrast to France and Germany English secondary schools try to develop a particular whole school ethos, which is in part influenced by the specialist nature of the school. Teachers feel they have to attend to the needs of the individual child, and setting in mathematics is common practice from year 7 onwards. This means that different mathematics is taught to different groups (sets).

In France one can distinguish between three potential 'routes' as mathematics teachers, and these are linked to teachers' educational background. Firstly, the most esteemed teaching qualification for a French mathematics teacher is the *Agrégation* (concours after Bac +4 or *Maîtrise*), the highest possible degree for teachers of the *collège*, *lycée* and post-secondary institutions. The *professeurs agrégés* are the specialist subject teachers, they are the **experts (de maths)**, i.e. experts in terms of mathematical knowledge. They have to effect only one year of teacher education, they have the lowest number of teaching hours and rarely any pastoral care commitments. Second, most mathematics teachers in France are *certifiés* (concours after Bac+3 or *Licence*). They are also specialists in their field (and not teaching other subjects), but have to teach more hours than the *agrégés*, in addition to taking on some pastoral care duties. These teachers see themselves as **profs de maths**. Third, and this is a minority, there are those who work with the teacher education institutions (*Institits Universitaires de Formation de Maitres*-IUFMs) as part-time teacher educators, or with their local authority (*académies*), perhaps on text books, to name but one area. These teachers have been carefully selected by the inspectorate, on the basis of their excellent teaching, and they see themselves as **expert teachers.**

In Germany, the professional routes a mathematics teacher could potentially develop are related to the system of schooling, the tri-partite system, and the associated teacher education. Firstly, the grammar school teacher is the subject specialist (in two subjects) and educated to the highest level in terms of their subject. Perhaps more importantly they are educated at the university (and they are preparing students for university entry) – implying that they have acquired 'Bildung' which is the traditional ideal of Humboldt's 'gebildeter Mensch'- they are the **specialists**. Second, at the *Realschule* teachers are attending to the skill side of mathematics education, in particular technically orientated- they are the **(technical) skills teachers**. Students in the *Hauptschule* mainly prepare for apprenticeships, in addition to those who need a lot of support and pastoral care, for various reasons (e.g. asylum seekers who do not speak German). Thus, and thirdly, these teachers see themselves as **basic skills teachers** and/or **pastoral carers**. However, there is also a minority of teachers who work as *Fachleiter* (subject mentors) in schools and

in teacher education at the *seminarium*. They are often seen as **expert teachers**, in whichever school form they are working.

In England the potential routes for mathematics teachers are not strictly related to their educational background, in the ways they are in France and Germany. There are those teachers who follow the route of curriculum development and leadership within the mathematics department. This can be done by either taking on particular leading responsibilities within the mathematics department (i.e. head of department), or as Advanced Skills Teacher, a newly developed route that allows salaries to go up to £53'000 per year. These teachers regard themselves as '**skilled (mathematics) teachers'**. The second main route is typically taken by those mathematics teachers who are involved in and want to pursue the direction of '**pastoral carer'**. This means that they may become head of year, or head of House, where they have a number of children 'to look after' in terms of their well being in school. Thirdly, there are those mathematics teachers – **'experienced/expert (mathematics) teachers'** - who work with national or regional organisations (e.g. QCA, QAA, local authority) or as mentors with the universities in teacher education.

Looking across the three countries there are different routes that mathematics teachers can take, and these are to a large extent influenced by the context in which teachers work and study. Interestingly, in France it does not seem to be possible to develop a route as a teacher of mathematics that is not strongly related to the subject matter knowledge. Whether teachers are *agrégé*, *certifié* or expert teachers, also involved in teacher education, the expectations by the system emphasise a heavy reliance on their expertise in terms of mathematical subject knowledge. This is quite different in Germany and England, where teachers can develop and follow a *pastoral carer* route, and the system allows for that in terms of remuneration.

Content knowledge for teaching

When talking about mathematical knowledge for teaching, most people would probably argue that content knowledge matters for teaching. Much research has gone into this, and concepts such as pedagogical content knowledge (Shulman, 1986) have been further developed and refined (e.g. Ball et al., 2008). When asked explicitly about which knowledge is necessary for teaching mathematics, most teachers in the study emphasized mathematical content knowledge (see Fig.1). However, how they 'defined' this was different. English teachers claimed that it means "mathswise to be confident and competent", which includes having sufficient knowledge "if kids go off on a little bit of a tangent which has relevance". They also talked about knowing how to make the mathematics 'digestable' for the pupils/group they teach, to 'adapt any topic in a hundred different ways according to what children (one is) teaching'.

French teachers also pointed to subject knowledge, and interestingly linked it to the ability to 'step back' from the mathematics content. Teachers emphasised the 'distance' (*recul*) that a teacher needs to have, with respect to his/her subject.

> "… to have enough knowledge of the subject, of the mathematics, in order to have enough distance in terms of what one teaches" (Teacher 3, France – my translation)

> "At the pedagogic level one has to accept to step back, in terms of mathematical knowledge …" (Teacher 1, France – my translation)

This is an interesting notion which certainly involves a process of reflection. This reflection is likely to involve consciously thinking about one's experiences with the mathematics, turning ideas over in one's head, looking at things from a different perspective, stepping back to review things, and consciously deciding what one is doing and why. This process is likely to increase knowledge of the subject.

In Germany the *Hauptschule* teachers in the study emphasized the importance of subject knowledge, and elaborated on it in terms of 'conveying the content correctly', whereas *Gymnasium* teachers highlighted aspects of 'logical thinking' in connection with it. Logic was seen as the basis for their mathematics teaching and learning, and teachers worried that pupils often had problems with logic and reasoning. The second most important knowledge aspect was knowledge about the children, in the sense that **all** students must be heard (and not only those with their hands up). In particular the *Hauptschule* teachers stressed the 'background knowledge of the children' in order to 'be able to act educationally sound in problem situations, not only through negative sanctions." (Teacher 1, Germany – my translation)

Thus, it appears that even similar kinds of knowledge, commonly referred to as mathematics 'subject' or 'content' knowledge, are perceived differently in different educational environments. This is most 'visibly' illustrated by the German case teachers who worked within one country and *Land*, but within that *Land* in different school types. This also implies that they have gone through different teacher education. Teacher education for *Hauptschule* teachers shares the patterns of primary school teacher education; it may be argued that it also shares its 'philosophy', that is the 'education of the child' which would explain teachers' discourse and emphasis of pastoral responsibilities in terms of teacher knowledge. *Gymnasium* teacher education focuses on the subject matter (and its teaching), which may explain the emphasis on logic and reasoning in their explanations of subject knowledge.

English teachers	Subject knowledge: Mathematical content knowledge How to make the mathematics 'digestable'/ Adaptation of mathematics according to ind./group
French teachers	Subject knowledge 'Stepping back' from the content (*recul*) Multiplicity of ways of solving a problem and teaching a topic
German teachers	Subject knowledge: HS: to be 'correct' GS: to think logically To know the children: HS: pers. background GS: common problems connected to logic and reas.

Figure 1: Mathematics knowledge in/for teaching

Teachers' beliefs about mathematics and their pedagogic practice

There were three dimensions in terms teachers' beliefs about mathematics, and these underpinned their practices: **importance of conceptual links; process integration; and completeness of pupils' mathematical experiences**.

Teachers in all three countries were concerned about, and concerned with, the coherence of the mathematics taught, in order for a better understanding to be developed. This first dimension was concerned with conceptual links, the inter-connectedness of concepts, and the coherence of mathematical concepts taught. This is supported by the literature, Hiebert and Carpenter (1992) for example, who contend that it is important to be concerned about:

> "…the way information is represented and structured. A mathematical idea or fact is understood if its mental representation is part of a network of representations. The degree of understanding is determined by the number and strength of the connections." (p. 67).

For French teachers, what was essential for facilitating student understanding involved a number of principles, amongst them that understanding can be characterised by the kinds of relationships or connections that have been constructed between ideas, facts, procedures, for example.

Ma (1999) compared Chinese and US elementary teachers' mathematical knowledge. She found that Chinese elementary teachers perceived mathematical concepts as interconnected, which was in contrast to US colleagues who perceived these concepts as arbitrary collections of facts and rules. She developed a notion

of 'profound understanding of fundamental mathematics' (PUFM), an argument for structured, connected and coherent knowledge (Ball et al., 2001), which is 'deep', 'broad' and 'thorough' (Ma, 1999, p. 120) and this was seen as one of the factors for student enhanced mathematical performance. Her PUFM consists of four properties of understanding: basic ideas; connectedness; multiple representations; longitudinal coherence.

> "When it is composed of well-developed, interconnected knowledge packages, mathematical knowledge forms a network solidly supported by the structure of the subject." (Ma, 1999, p. 120)

The second dimension identified concerned a process dimension in teaching mathematics, which was either neglected (as in Germany) or was seen as integral to the learning of the mathematics (as in France). The whole idea about logical thinking was generally also part of that dimension. For example, in France teachers emphasised the process element by preparing cognitive activities for pupils. The idea of 'letting pupils discover' was linked to the teaching of the content, and therefore combining process and content. In England investigations appeared to be done separately, as a separate issue which seemed to be almost like another area of content.

This also resounds with the research literature. Kilpatrick et al. (2001) give a comprehensive view of what they regard as successful mathematics learning. They coin the term "mathematical proficiency" to capture what they think it means for anyone to learn mathematics successfully. Amongst their five strands, *adaptive reasoning* is the 'capacity for logical thought, reflection, explanation, and justification' (Kilpatrick et al., 2001).

Thirdly, teachers were concerned about the coherence of pupils' mathematical experiences. For example, in Germany and in France pupils were expected to reach certain levels at the end of every school year, otherwise they had to repeat the year. On the other hand, in England pupils reached levels of the National Curriculum and some progressed further than others within the same year. This led to a particularity which was not evident in France and Germany, in the sense that English pupils could leave school after year 11 whichever level they had reached. This dimension goes hand-in-hand with the system of schooling and the grouping of pupils within that system, e.g. in the case of England the practice of setting in comprehensive schools. Several studies (e.g. Boaler, 1997) have shown that setting does not enhance achievement, but it means that some students are provided with a different 'mathematical diet' than others, within the same year group.

Teachers' beliefs about mathematics was related to their pedagogic practice, and it may be fruitful to look at 'vignettes' of lessons in each of the three countries, to see how their pedagogic practice relates to knowledge and beliefs. There were certain features in each country that made it characteristic for the teachers.

In previous studies (e.g. Pepin, 1999b), I identified characteristic 'profiles' of classroom situations in England, France and Germany. Teachers assigned significance and value to particular practices which are commonly concerned with

pupil engagement and assessment of understanding. For example, in the English classroom, the main aim was to (relatively briefly) explain a particular mathematical notion and let pupils get as much practice as possible. Of particular importance was that pupils were attentive during teacher explanations and subsequently worked on their own whilst teachers attended to individual pupils' needs. The French teachers regarded their main aim as facilitating mathematical thinking by initiating tasks and helping pupils to think around a particular concept, in whole-class conversation, as individuals, or in groups, followed by practice. Thus, of particular importance was that pupils would discover the concept with the help of selected cognitive activities. The main objective in the German mathematics classrooms was to discuss mathematical content. Teachers initiated tasks or discussed exercises from the homework in a conversational style, before giving pupils exercises to practice on their own. They particularly valued that most pupils would be involved in a teacher-led discussion about the mathematical content.

Moreover, there appeared to be particular 'conventions' that all teachers adhered to. For example, teachers in all three countries ask pupils to work on exercises from textbooks for a considerable amount of time, so that pupils can practice what has been explained and teachers can monitor understanding. However, in England, many pupils at Key Stage[2] 4 and almost all at Key Stage 3 had not been issued with a textbook to use in school and at home; they only worked from textbooks during lessons under teacher guidance. Thus, it is likely that the majority of these pupils only ever had access to the textbook in class and consequently had to rely entirely on teacher guided input. In France, the situation was quite different: every pupil had a textbook provided by the school to be used in school and at home. In Germany, pupils had to buy their own textbooks which were selected by schools/teachers from a ministry approved range. Thus, already at the outset there are differences in the roles and importance assigned to textbooks, and for students in terms of access to textbooks.

Looking across the three countries and considering teachers' beliefs about mathematics and their pedagogic practice, it appears that these could be placed on a spectrum, ranging from specialist/professional emphasizing the mathematics (and its teaching and learning) on the one end of the scale, to the pastoral carer prioritizing the well-being of the child on the other end. French teachers' beliefs and practices can then be positioned on the 'mathematics professional/specialist' side of the continuum, considering their involvement with the mathematics, their beliefs in terms of coherence of pupil mathematical experiences and the associated practices. Whereas German *Hauptschule* teachers' beliefs and practices may be placed on the pastoral carer side of it- reflecting their involvement with the 'whole child' and their upbringing. The German grammar school teachers' beliefs and practices may be closely positioned to a French mathematics teachers'. English mathematics teachers' beliefs and practices appeared to be more linked to the skill side of mathematics education and the organization of pupils in their classrooms.

2   In England, compulsory schooling is divided into four key stages. The teachers in this study taught pupils in Key Stage 3 (age 11-14) and Key Stage 4 (14-16).

Conclusions

Considering teacher knowledge and the dimensions that contributed to their knowledge as teachers of mathematics, it is argued that teacher knowledge is 'distributed' across the different dimensions, and relational. This implies that to dissect it into individual components does not reflect the character of it, indeed the very process of dissection may distort it. To give an example: looking across the different teachers' knowledge and their practices (across countries), it cannot be said that teachers knew more, or less, or students learnt less, or more, in any particular classroom. But they taught, and students may have learnt, different mathematics. This means that our understanding of teacher knowledge has to go beyond knowledge, to, for example, their pedagogic practice and the associated beliefs concerning mathematics teaching, and the *relationship between these*. Thus, the site of knowledge production shifts from residing in the teacher to be distributed, in this case to the mathematical practices and the mathematical activities in which they engage students in classrooms.

Looking at teachers' practices across the three countries, it can be argued that teachers tried to establish a personal 'balance', and their practices can be viewed as a personal response to a set of institutional and societal constraints, to a set of teaching traditions –experienced during their time in the system of schooling, and/or in teacher education- and a set of perceptions concerning the teaching and learning of the mathematics.

Furthermore, we contend that different kinds of pedagogic practices, and activities chosen and mediated by teachers, reflect different dispositions (of teachers) towards mathematics, thus shedding light on their relationship with the discipline of mathematics (emerging through the pedagogical practices). These are supported, and perhaps 'produced by', the different educational environments. Looking at the models of teacher knowledge, it could be argued that the German grammar school teacher, the 'pedagogue', can be associated to Ernest's 'Old Humanist', whereas the *prof de maths* in France may be seen as a 'mixture' of Ernest's 'Industrial trainer' and the 'Progressive educator' (Ernest, 1991, p. 138-139).

Moreover, it appears that the three different educational, and cultural, contexts create different contexts for teaching, and learning, of mathematics. It is argued that teacher knowledge in and for teaching was different in the English, French and German classrooms studied, in the sense that teachers needed different kinds of knowledge within their respective environments. Even similar kinds of knowledge (for example, subject knowledge) appeared to be differently situated in the different culturally figured environments. Whereas in one context (England) content knowledge was seen to serve the adaptation of the mathematics to become 'digestable' for the students- a practical consideration, in another (France) the emphasis was on the development of the knowledge residing within the teacher, and reflection (stepping back) was necessary for that. The German cases also illustrated the influence of context and environment on the knowledges perceived to be appropriate for teaching mathematics: in one context (HS) subject

knowledge was about the 'correctness' of the mathematics; in another (GS) about 'thinking logically' – different natures of subject knowledge.

It may be interesting to consider to what extent the context in which the teachers work, perhaps the systemic features of the three countries here, may allow mathematics teachers to shift and develop different 'knowledges', associated with their developing beliefs and practices, without running the risk of becoming less effective. Under which conditions would teachers be able to develop new 'knowledges', as teachers of mathematics? What kinds of knowledge are needed to redefine oneself, to enable, or scaffold, a transformation process? If change is desired, these seem to be pertinent questions for every policy maker to consider.

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ON THE DYNAMIC NATURE OF PHYSICS TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE

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Abstract: *This study focuses on the role of teachers' pedagogical content knowledge (PCK) in transforming subject matter in physics instruction (at lower-secondary school). The purpose of the present study is to investigate the nature of teachers' pedagogical content knowledge. Video recordings were analysed of 27 lessons taught by 8 lower-secondary school teachers on the topic "composition of forces". A typology of content representations was developed inductively. The findings show that teachers use various types of content representations. These illustrate the dynamic nature of teachers' pedagogical content knowledge, which is documented using the example of a teacher who combines various types of representation flexibly when introducing the concept "composition of forces".*

Key words: *content representation, pedagogical content knowledge, physics teaching, video study*

Introduction

The present study contributes to the body of research on teachers' *pedagogical content knowledge* (PCK), which is one of the most prominent fields of Anglo-American educational research (see Kansanen; van Dijk; Pepin in this issue). In the context of a European research tradition, this field is known as the study of *didactical transformation* – in German *didaktische Transformation* (Kansanen, 2002). The study of physics teachers' PCK is embedded in a broader research project – the *CPV Video Study of Physics* – which is carried out at the *Educational Research Centre, Faculty of Education, Masaryk University* in Brno, Czech Republic (see Najvar et al. 2009; Najvar, Najvarová & Janík in this issue).

This study is aimed at the role of teachers' PCK in transforming subject matter in physics instruction (at lower-secondary school). Video recordings of 27 lessons taught by 8 teachers on the topic "composition of forces" were analysed within the *CPV Video Study* project that aimed to document and describe everyday teaching of

Physics in Czech lower-secondary schools. A typology of content representations was developed inductively. The findings are used to illustrate the dynamic nature of teachers' PCK.

Theoretical background

Shulman (1986; 1987) succeeds in demonstrating that teachers have a specific form of knowledge which is different from that of a subject-matter expert. This distinction dates back to Dewey, who points out that a scientist's knowledge of the subject matter is different from the specialized understanding of the subject matter of the teacher, who is interested in "how his own knowledge of the subject matter may assist in interpreting the child's needs and doings, and determining the medium in which the child should be properly directed" (Dewey, 1902, p. 286, cited in Tsu, 2004, p. 52). Recent research confirms Dewey's insight, which is reflected in a study by Grossman, Wilson, and Shulman: "While some of what teachers need to know about their subjects overlaps with the knowledge of scholars of the discipline, teachers also need to understand their subject matter in ways that promote learning. Teachers and scholars have different primary goals. Scholars create a new knowledge in the discipline. Teachers help students acquire knowledge within a subject area. These differing goals require related but distinct understanding of subject matter" (1989, pp. 24-25). The specific kind of knowledge the teacher has, is PCK – the category, which is "most likely to distinguish the understanding of the content specialist from that of the pedagogue" (Shulman, 1987, p. 8). This knowledge is what distinguishes a chemistry teacher from a chemist, a mathematics teacher from a mathematician.

Shulman sees PCK as a specific category of knowledge, "which goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge for teaching" (1986, p. 9). PCK is the basis for teaching expertise. According to Shulman, teachers' expertise lies "in the capacity of the teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and backgrounds presented by the students" (1987, p. 15). PCK represents "the blending of content and pedagogy into an understanding of how particular topics, problems, and issues are organized, represented, and adapted to the diverse interests and abilities of learners and presented for instruction" (Shulman, 1987, p. 8).

In this special form of teacher's professional knowledge and understanding, there are two crucial aspects: a) knowledge of representations of subject matter, b) understanding of specific learning difficulties and student's preconceptions (cf. Driel et al., 1998). Marks (1990) extends Shulman's model by including *knowledge of subject matter per se* and *knowledge of media for instruction* in PCK. Cochran, DeRuiter and King (1993) take the constructivist view of teaching and prefer the term *pedagogical content knowing (PCKg)* to *pedagogical content knowledge (PCK)*. They point out the dynamic nature of *pedagogical content knowing,* which they define as "... a teacher's integrated understanding of four components of pedagogy,

subject matter content, students characteristic, and the environmental context of learning" (Cochran et al., 1993, p. 266). According to Fernández-Balboa and Stiehl (1995) PCK consists of five components: subject matter, the students, instructional strategies, the teaching context, and one's teaching purposes.

As pointed out in the study by Driel et al. (1998, p. 677), there is no universally accepted model of PCK. On the other hand, all the authors cited accept Shulman's two key elements (knowledge of representation of subject matter and understanding of specific learning difficulties and student preconceptions).

Pedagogical content knowledge – ways of knowing how to represent the content

A teacher's knowledge and understanding of the content to be taught is a prerequisite of effective teaching. Teacher's *pedagogical content knowledge* is demonstrated in various ways, such as "the most powerful analogies, illustrations, examples, explanations, and demonstration – in a word, the ways of representing and formulating the subject that make it comprehensible to others" (Shulman, 1986, p. 9). To illustrate what is ment by PCK we present teacher's knowledge about a commonly used analogy in science education. As Loughran, Berry, and Mulhall explain, the reason for presenting an analogy is to draw parallel between new ideas and specific/similar situation. For example, "although something may appear to be made up of one thing – like a pipe is made up of one piece of metal – it is really the combination of lots of small things. This can be analogous to a jar of sand. From a distance it looks like one thing, but up close you can see the individual grains of sand" (Loughran, Berry, & Mulhall, 2006, p. 34).

The dynamic nature of PCK is manifested in how the teacher approaches pupils of different ages when teaching particular subject matter, how he manages to take students preconceptions and learning difficulties into account etc. The success of teaching also depends on means of communication that the teacher deploys in managing interaction with students. These include common language means or symbolic tools: figures, formulae, specific motoric activities (e.g. in art or sport), drawings, diagrams, etc. – *content representations. Content representations* play an important role in introducing, demonstrating, explaining, and manipulating content to be taught. There are differences among individual subjects as well as among individual teachers of a subject in what content representations are used in instruction (Leinhardt & Smith, 1985).

The meaning is to be interpreted by the student from the content representation. The result of this interpretation is that the student should be able to grasp the content. Once the student recognises the relationships between content representation and meaning, i.e. he can use his own representation to express, convey and think about the content, he demonstrates his *knowledge*. The teacher should formulate his representation in such a way that the student understands the content – he grasps the meaning correctly and without serious difficulties. The teacher must take the accuracy of the content into account. As shown in Fig. 1,

teacher's content representation need to be in accordance with (1) analogical content representation of an *expert* in the field and it should respect (2) *student's* predispositions and learning possibilities (cp. van Dijk, Kattmann, 2007).
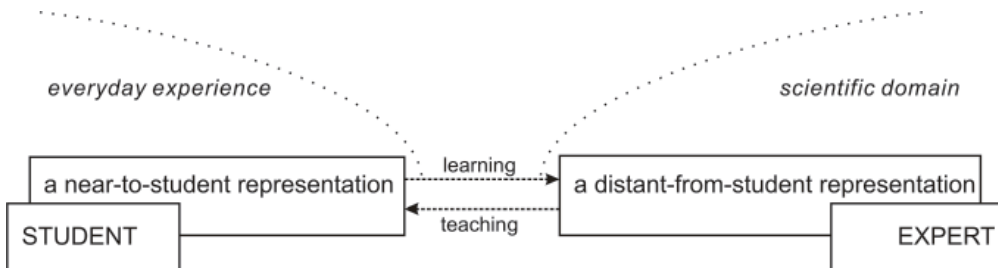

Figure 1: Learning-teaching, student-teacher and content representations

The nature of a teacher's pedagogical content knowledge

Much of the current research on teachers' knowledge focuses on its nature. Despite a lack of consensus about the nature of teachers' PCK, there is some evidence that this knowledge is *value-laden* (Gudmundsdottir, 1990). Values in knowledge operate as a kind of filter which plays a role in decision making as to what is important in teaching, what questions should be asked etc.

Gudmundsdottir (1995) demonstrates the *narrative nature* of a teacher's PCK. Teaching is seen as an interpretative and reflexive activity in which narration (as a specific way of knowing) plays an important role. Narration makes it possible to understand the world in a new way. A study of experienced teachers has shown that they intuitively use narratives to bring order to what they consider a disjointed curriculum (Gudmundsdottir, 1991). Teachers use narratives as a tool for structuring subject matter. According to this author, the teacher's experience is transformed into his PCK through the narrative dialogue of reflection and interpretation. "The study of teachers' stories and narratives brings us right to the heart of pedagogical content knowledge, in all its varied and richness" (Gudmundsdottir, 1995).

In a study by Driel, Veal and Janssen (2001) attention is paid to the *integrative nature* of knowledge. In a number of other studies evidence is presented that *PCK* is *implicit* and of *practical nature* (Driel et al., 1998).

One of the distinctive features of the *dynamic nature* of this knowledge is manifested in how the teacher approaches pupils of different ages when teaching particular content, how he manages to take pupils' preconceptions and learning difficulties into account etc. The quality of a teacher's PCK lies in its regard both to the content and to its possible pedagogical representations with regard to the pupils. The dynamic quality of PCK is due to the growth in teacher's capacity to communicate content because they know their subject and students better. An experienced teacher is able to see the "curricular potential" of learning material, and so has a number of possibilities for how to deal with the content pedagogically

– how much time is spent on particular aspects of the content; what the timing is when the content is introduced and elaborated; how it is (re)presented, what questions are asked, what the students' role is etc. Wilson, Shulman and Richert (1987) speak about the teacher's "150 different ways of knowing the content". These open up to him when he is pursuing the "didactic analysis of subject matter" (Klafki, 1958). If a teacher understands the subject matter pedagogically, he is able to take students' needs into consideration. He is "able to elucidate subject matter in new ways, reorganize and partition it, clothe it in activities and emotions, in metaphors and exercises, and in examples and demonstrations, so that it can be grasped by students" (Shulman, 1987, p. 13).

Methodological considerations

When Shulman introduced his concept of PCK, there were relatively few demonstrations of what PCK was or what it looked like. Research in the 1980s and 1990s is primarily of an exploratory character and aims at identifying, documenting, and portraying teacher's PCK in different school subjects, in different types of schools and at different levels of schooling; comparative studies exploring PCK in teachers-beginners and teachers-experts are common (e.g. Gudmundsdottir & Shulman, 1987). More recent research focuses on characteristic features of this knowledge – specificity, narrativeness, implicitness, adaptability etc. (e.g. de Jong, 2003). Gradually, longitudinal research is also beginning to develop, the aim of which is to monitor and document the evolution of the teacher's PCK (Seymour & Lehrer, 2006). Related to attempts at evaluating the teacher's professional competence, methodological techniques have been developed recently which enable the measuring of the level of PCK (Krauss et al., 2008).

As for approaches, methods and techniques applied in the research of PCK, the breadth of their spectrum corresponds to the complexity of the phenomenon examined. Besides quantitative approaches (primarily based on psychometric methods), there has been clear development in qualitative approaches (particularly those of an interpretivist or hermeneutic nature). Most of the research is based on the use of combination of several methods (eclectic methodology), and this serves to meet the specific character of PCK. For example, methods based on the observation of teaching offer only a partial view of the teacher's PCK, as this is an inner construct which can only be gathered to a limited extent from its external manifestations. It is therefore necessary to ask the teachers questions – examine their articulation of the knowledge. Furthermore, PCK is quite an implicit matter – teachers often lack vocabulary to express it, hence research is often based on a combination of direct or video-based observation, stimulated recall and narrative interview. Since the teacher's PCK forms a certain conceptual structure, techniques like conceptual mapping and concept structuring are employed (Loughran, Berry, & Mulhall, 2006).

In studying PCK a number of methods, techniques and instruments have been used (e.g. Baxter & Lederman 1999; Loughran, Mulhall, & Berry 2004). As our

intention was to investigate teacher's PCK as it is demonstrated in real teaching (PCK-in-action), methods based on qualitative analysis of lesson transcripts and video recordings are considered suitable for our purposes. In this study, we try to identify teacher's PCK "beyond" the *representations of content* (analogies, illustrations etc.) that a teacher uses in teaching. Content representation can be *observed* and *recorded* (e.g. by means of video). Video recordings of content representation become *fact*, which can then be analysed within a specific *theory*.

Present study on the pedagogical content knowledge of physics teachers

Purpose and research questions

The present study focuses on the nature of a teacher's PCK. The purpose is to analyse one of the features of this knowledge, i.e. its dynamic nature. Video recordings of lessons given by Czech lower-secondary school teachers of physics have been used for purposes of analysis. The research questions are: What types of representations of the concept "compositions of forces" are used by teachers and what can be inferred concerning their PCK? How is the dynamic nature of teacher's PCK demonstrated in teaching? From a methodological point of view, the focus lies on illustration and discussion of the potential of video case study as a means of presenting teacher's PCK.

Method – data collection and analysis

The research of PCK is a part of the *CPV Video Study of Physics* (Janík, Miková, Najvar & Najvarová 2006). This is based on analysis of video recordings of 27 lessons on the topic "composition of forces", taught by 8 teachers at lower-secondary schools in Brno, Czech Republic (see Table 1). Following the lead given by the TIMSS and IPN video studies (Jacobs et al., 2003; Seidel et al., 2005), lessons were recorded using a standardised procedure with two video cameras. One camera captured the activity of the teacher and his/her interaction with the immediate surroundings (the blackboard, the first row of students), while the other camera aimed to capture the activity of the class (the majority of the students).

Following Shulman's definition of PCK as comprising the "most useful forms of representation of these ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations-in a word, the ways of representing and formulations the subject that make it comprehensible to others" (1987, p. 8), we identified those teaching situations in which various representations of the concept "composition of forces" could be observed. We used Videograph software (Rimmele, 2002).

Table 1: An overview of lessons analysed

Teacher			Pupils		Subject matter		
Teacher codes	Teaching qualification	Teaching practice in years	Year	Number of students	Topic	Number of lessons	Lesson codes
A	FY/MA	2	7.	20	Composition of forces	4	FyS_A1, FyS_A2, FyS_A3, FyS_A4
B	FY/MA	17	7.	18		4	FyS_B1, FyS_B2, FyS_B3, FyS_B4
E	FY/TE	27	6.	21		2	FyS_E1, FyS_E2
H	FY/TE	4	7.	23		3	FyS_H1, FyS_H2, FyS_H3
I	FY/TE	3	7.	16		3	FyS_I1, FyS_I2 FyS_I3
J	FY/MA	28	7.	29		3	FyS_J1, FyS_J2 FyS_J3
L	FY/MA	7	7.	27		4	FyS_L1, FyS_L2, FyS_L3, FyS_L4
M	FY/MA	3	7.	23		4	FyS_M1, FyS_M2, FyS_M3, FyS_M4

Using an inductive approach combining open coding (Strauss & Corbin, 1999) and qualitative content analysis (Mayring, 1983) a typology was developed for the representation of "composition of forces". Table 2 gives authentic examples of PCK-in-action which were identified in the lessons analysed. Finally, we present a case study providing an insight into the dynamic nature of PCK (Table 3).

Table 2: Types of representations of "composition of forces" identified in lessons

Types of representations				
Experimental	Pictorial	Schematic	Symbolic	Verbal
T: What did you discover? P: Using the dynamometer, we found out that the weight was pulled by a force of three Newtons. T: Hm, so when you used the dynamometer here, the big one, then it did not work, it was the wrong determination of the measuring instrument, right? Well, and now we'll replace these two tiny weights with just one. And the deflection is? (FyS_J1_16:20)	T: Which fairy tale tells us about composition of forces of equal direction, Martin? P: The enormous turnip. T: Yes, The Enormous Turnip. Grandpa was happy because he had grown an enormous turnip, but he wasn't able to pull it up. I don't remember now who became involved in the harvest, I guess it was grandpa, grandma, some grandchildren, then the dog, the cat and the mouse. The mouse being the decider. (FyS_L1_12:40).	T: To represent it graphically, I need to set a scale. P: Five millimetres is equal to half a Newton, perhaps. T: Suppose so, right. So half a centimetre is equal to half a Newton, or, to make it simple, I'd say one centimetre is one Newton. I'll take a ruler and represent the two forces graphically. It means they both have a sphere of activity and a direction. Is the latter the same for both? PP: Vertically downwards. T: Vertically downwards, so I'll draw force F1 and see that it measures ... ? P: Half a centimetre. T: Half a centimetre precisely. I'll do the same with force F2, which measures two centimetres. Well, how do you, in the same way, represent graphically the result you see now? P: I know. Connect it to the arrow and calculate it. T: What will the direction of the force be? PP: Vertically downwards. T: How big will it be in centimetres? PP: Two and a half. T: Perfect. And that force F consists of force F1. Z: And F2. T: Of force F1 and force F2. It is a composition of forces. The resulting force F, and we'll call it resultant. (FyS_I1_31:10).	T: Force F1 plus force F2 equals resultant F. We'll frame this because it's important. (FyS_I1_37:00).	T: If we compose two forces of the same direction, then the resultant, we know now what resultant is, the resultant will be of the same direction, and its dimension equals the total… P: The total of the two forces. T: Of the dimensions of the two forces. T: Right. Let's underline it. P: Of the same direction. T: Of the same direction, excellent. Resultant, of the same direction, total (FyS_I1_35:00).

Results

Which representations of the concept "composition of forces" are used by physics teachers and which PCK can be identified in them?

In individual lesson phases different representations of "composition of forces" were used. Representations were frequently found in the lesson phases *developing new content, securing/practicing* and *applying/intensifying* (for definitions see Seidel, Prenzel, & Kobarg, 2005). Based on analysis of the video recordings a typology of representations was developed (Table 2), comprising the following types of representation: experimental, pictorial, schematic, symbolic and verbal.

Various representation types differ in the degree to which they are abstract. Experimental representations arise from the real interactions of teacher and pupils; in pictorial and schematic representations imagination is used more; in symbolic representations another symbolic system is used (e.g. mathematical symbols), which is more demanding on pupils' abstract thinking (cf. Bruner, 1968). Verbal representations are typically definitions enabling the learner to grasp abstract concepts.

1. **Experimental representations** (experiments) were in most cases demonstration experiments performed by the teacher. In the lessons observed we did not find a single situation where the introduction of the concept "composition of forces" was performed by the pupils themselves in the process of independent or directed heuristic exploration of the phenomena. Demonstration experiments were in all cases accompanied by the teacher's verbal commentary (exposition); only rarely did teachers provide an opportunity for pupils to comment in their own words on what was going on during the experiment (dialogue with the class). Differences among representations were brought about by different kinds of teaching aids, the design of the experiment and the procedure for its performance.

2. **Pictorial representations** were mainly in the form of pictures (e.g. tugging the turnip; dogs pulling a sledge; tug-of-war). The teachers drew these on the blackboard or used pictures from the textbook. These pictorial representations enhance the building up of images of the object under investigation. A real object perceived with the senses by a number of redundant features (shape, colour, etc.) is simplified in the picture and the main system features of the phenomenon are emphasised. Some pictures were also used for motivation, such as tugging the turnip (see Table 2). Pictorial representation also had substantial potential for creating variations, which was exploited in lessons to a greater extent than experimental representations. The reason for this may be that choosing a picture in a textbook or drawing it is less difficult and time-consuming than designing an alternative experimental apparatus for the pupils.

3. **Schematic representations** appeared in teaching in the form of graphic illustration (e.g. composition of vectors). These representations are the step which follows the examination of a specific natural object or phenomenon to its abstract idea (model). What they require of pupils is a higher level of abstraction.

4. **Symbolic representations** are the most abstract way of depicting an object or phenomenon. The law of composition of forces is represented in the most concise form using the mathematical symbols of vector algebra – addition of vectors (see Table 2). The teachers in our investigation respected the pupils' level of abstraction in the authentication of vector symbols and therefore did not use the symbol of vector force as it really is.

5. **Verbal representations** principally took the form of definitions or descriptions of phenomena. The following statement is an example of a definition: "The resultant of two forces in the same direction equals the sum of their magnitude" (see Table 2). This is caused by a high density of abstract concepts, which are often new and not very well established (e.g. "resultant, force, sum, equality, magnitude" in our example). In the lessons observed we were most aware of the deductive method, which leaves little space for pupils' own exploratory activities. Descriptive verbal representations are used chiefly for reports of experiments, the procedure of quantity measurements (e.g. measurement of force) etc. Teachers did not devote the same attention to these representations as to representations of verbal definition. However not all teachers' verbal comments can be considered as verbal representation: very often they are merely comments, which do not function as representations as such but are used to accompany demonstrative experiments, schematic illustrations or to deduce mathematical relationships etc. A specific role is played by narration, which is used by teachers as an instrument to structure subject matter (see Gudmundsdottior, 1995) and as a motivation technique.

How is the dynamic nature of teachers' PCK demonstrated in instruction?

In lessons FyS_J1, FyS_J2, FyS_J3, given by the teacher Jana (see Table 1), various representations of the concept "composition of forces" were combined flexibly. This particular teacher fell in the category of *expert teachers*[3] and she volunteered to participate in the follow-up study. We carried out a stimulated-recall interview with her about a selected situation. There we played a video recording of short situations in her lessons and her task was to comment on them. The aim was to get a better insight into her thinking about the content, thoroughly examine the relationships among representations that she used in her teaching, and to improve our understanding of her PCK.

We presented the episode as a video case study (see Table 3), providing evidence
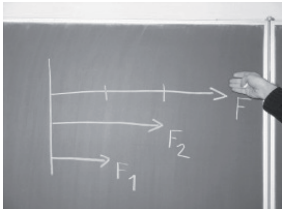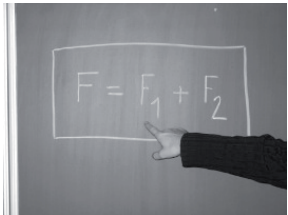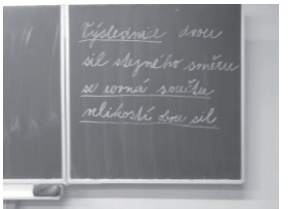
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3   Criteria for identifying teacher expertise included: more than five years of teaching practice, respected in the group of peers, indicators of performance etc. (e.g. Palmer et al., 2005).

of demonstrations of the dynamic nature of PCK (the middle column), which is based on the use of different representations of the concept "composition of forces" (left-hand column). The transcript of the interview (right-hand column) gives us a glimpse of the teachers' PCK.

Table 3: Video case study of teachers' PCK

<table>
<tr><td colspan="3" align="center">Video case study "Different ways of knowing how to teach the topic of composition of forces"</td></tr>
<tr><td>Representation – examples</td><td>Teachers' PCK beyond...</td><td>From interview with teacher Jana</td></tr>
<tr>
<td>
Experimental</td>
<td>Teachers' PCK as experimental demonstration (made by teachers and/or pupils).</td>
<td rowspan="5">RESEARCHER: When we had looked through your lessons, we found different ways of speaking about the force. You began with an experiment followed by fairy tale The Enormous Turnip. What was your purpose of including the fairy tale?

TEACHER. …it was motivation, and making use of a thousand-year-long experience, and essentially making use of the cooperation in the tale.

RESEARCHER: Then the vectors got into it, functioning as?

TEACHER: It is graphical representation of composition of forces, and numerical and verbal. It is assembled here from several points of view. … the pupil should visualize all those pictures when speaking about composition of forces. When they write this formula, or I write it, or wherever they see it, they should instantly verbalize this sentence and visualize these oriented line segments, vectors. We don't call them vectors for now, not until secondary school. For us, it is now the oriented line segment.

RESEARCHER: And now the pupils' task was to interconnect the different ways, or realize that they are interconnected in some way…?

TEACHER: … that we can describe the situation physically. That is the physical expression of the situation, of the tale. This is how physicists describe it, and physics does not go without mathematics, so it's for them to see the relation between the physical action and its mathematical formulation, and the mathematical formulation can be expressed by a sentence.

RESEARCHER: Is there anything you would like to add?

TEACHER: Well, it is about how many ways we manage to complete in a lesson.</td>
</tr>
<tr>
<td>
Pictoral (narrative)</td>
<td>Teachers' PCK as the story "The Enormous Turnip".</td>
</tr>
<tr>
<td>
Schematic</td>
<td>Teachers' PCK as a figure of vector addition.</td>
</tr>
<tr>
<td>
Symbolic</td>
<td>Teachers' PCK as symbolic formula $F = F1 + F2$.</td>
</tr>
<tr>
<td>
Verbal</td>
<td>Teachers' PCK as the definition "The magnitude of the resultant of two forces of the same direction equals the summation of the magnitudes of the original forces".</td>
</tr>
</table>

Conclusions and discussion

If the knowledge of teachers seems to be to a certain extent implicit (see Kansanen in this issue), the potential for professional sharing knowledge is limited. That implies a question: How can we turn a teacher's knowledge into words – how can we verbalize it? In this study we attempt to illustrate means by which to capture and portray the teacher's PCK. The search for suitable methods of *PCK* research is motivated by the effort "to develop codified representation of practical pedagogical wisdom of able teacher" (Shulman, 1987, p.11) and thus contributes to the developing of a knowledge base for teaching. Video seems to be a powerful tool for capturing *PCK* because of its dynamic and practical nature.

In the lessons studied, various representations of "composition of forces" were found (experimental, symbolic, verbal, pictoral, schematic). Representations were frequently found in the phases *developing new content, securing/practicing* and *applying/intensifying.* A teacher knows various ways (representations) of teaching a particular concept, which is a prerequisite for him to adjust the content to the students' abilities. The individual types of representations were often integrated into more complex wholes. The representations appeared in classes in various combinations, from which the dynamic nature of the teacher's PCK can be concluded. The dynamic nature of PCK – the teacher possesses different skills for teaching a particular concept, which enables him/her to adjust the content to the students' abilities. However, further research into other possible manifestations of this dynamism is desirable.

Based on their education and their experience teachers have a PCK which determines the repertoire of specific concept representations they use. Different types of representation seem to be interconnected in the teacher's mind, which enables him to employ them flexibly in teaching and thus support the student's understanding of the content. This, too, shows the dynamic nature of the teacher's PCK. When teaching, teachers employ multiple representations of the content – this was also proved true of Czech teachers in the *1999 TIMSS Video Study* (Roth et al., 2006). These are mostly *various* representations of *the same* content (Table 3). Through this finding, we are confronted with a very interesting problem from the pedagogical point of view, the problem of *synonymy* in (re)presenting content. In multiple representations, different ways of knowing the content are intertwined. To use multiple representations in the lesson is to acknowledge different student's learning styles (visual, auditory, kinaesthetic). How the teacher's sensitivity to student's learning styles influence his choice of different content representations? How the teacher's own learning style influence his choice of representations for teaching specific content? These are relevant questions for a reserach study focused on the interaction between teachers' content knowledge, PCK, knowledge about students etc.

During this study more questions emerged that should be paid heed to in the future. What is the spectrum of representations used by different teachers under comparable conditions and circumstances in the same forms? What is

the spectrum of representations used by one teacher under different conditions and circumstances? What is the mechanism by which a certain representation is launched, and which factors determine its rise? How does a certain representation develop, and which factors influence changes within it? What is the influence of certain representations on the fulfilment of teaching objectives? If we want to start looking for answers to these questions, first we have to create an adequate research methodology. Our experience has shown that analysis of video recordings of lessons can play an important role in this methodology. What are the merits of using the methodological technique presented here, and what are its constraints when studying and documenting the teacher's PCK? From our experience we can formulate the following conclusions. PCK is a practical knowledge (Driel et al., 1998) – teachers' PCK is brought to light in action – which is why we use video to examine PCK from its genuine manifestations in teaching (which include representations of the content). This is where analyses of transcripts or video recordings of lessons can be used to good effect. The video case study seems to be a powerful form of representing and communicating teachers' PCK. This tool makes it possible to capture the accumulated wisdom of teaching practice, and supports the transfer of research knowledge between researchers and teachers.

Acknowledgements

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THE MODIFICATION OF SUBJECTIVE THEORIES WITH VIENNESE TEACHER TRAINEES: RESULTS FROM A TWO-YEAR STUDY BETWEEN THE FIRST AND THE FOURTH SEMESTER OF STUDY

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Abstract: *Following Shulman and Bromme a lot of attention was paid in the 1990s to the "hidden knowledge in teaching practice" – above all in the scientific disciplines. The investigation under discussion, carried out at the State College of Education Vienna (now the University of Education Vienna), is to be seen as an attempt to identify possible modifications of subjective theories with teacher trainees in the course of study for future lower secondary teachers over a period of four semesters of study. Teachers' subjective theories are understood in such a way that their thinking can be considered an implicit theory which is relatively stable, structured, and influences their behaviour; teacher trainees, however, may reveal different findings. The main results of the analysis are: modifications of the perception of the students' own role (from students to teachers) in connection with self-related cognitions and self-efficacy, the perception of the child, that is the perception of the child in his/her role as a pupil; teaching issues in connection with the student's own role as a teacher as well as the pressure to act in critical situations, and their increasing realization of the teacher's job of bringing up children as well as a shift in the view of the schools' mission from mere cognitive learning to social learning.*

Key words: *subjective theories, teacher education, teaching practice, long-term study, self-related cognitions, self-efficacy, perception of the child/the pupil*

Theoretical positioning

Teacher students[4] professionalize themselves by producing their own patterns of perception and knowledge components in the course of testing their first skills. It seems that the constellation in which these patterns of perception are acquired is of particular importance. If these patterns of perception are acquired without scientific reflection, then skills and knowledge come into being that may be professionally typical, but not justifiable in relation to a professional science of teaching.

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4   Student/s is used when talking about teacher trainees; pupils is used with reference to the ten-to-fourteen-year-olds in class.

In the context of the expert-novice paradigm the implicit knowledge of experts, the routines, are of great significance. What is meant here is knowledge that can be used in new contexts, even though this knowledge often cannot be explained.

Discussing routines one comes upon concepts such as "tacit knowledge" (Polanyi, 1967), "knowing how" (Ryle, 1949), "knowing in action" (Schön, 1983), "intuitive action" ("intuitives Handeln"; Dreyfus & Dreyfus, 1987) and "tacit knowledge" (Bromme, 1992).

In relation to the professionalization of teachers the emergence of routines is not irrelevant: routines may develop from imitation of a model; the actions carried out in this context, however, may not have been the subject of the teacher's attention. Rules carried over from such patterns of activity cannot or can hardly be verbalized, as the adoption remains unconscious. This assumption involves a massive objection to forms of "teaching practice" that see themselves as a trade, rather than theory-based elements of curricula (see Haider, 2000).

Routines, however, also arise when learners pay attention to new patterns of activity while learning; in such cases they are able to verbalize the rules they followed (see Seebauer, 2006, p. 21ff.).

In this context the self-efficacy of teacher trainees is of special importance. Following the basic statements of the theory of self-efficacy (among others Bandura, 1997), we learn that psychological changes and changes in behaviour are conveyed through a change in judging one's personal skills and by the expectation of future personal effectiveness. Self-related cognitions of this kind set cognitive, affective and motivational processes in train – as to the implementation of knowledge and skills in action – and control them. Together with the expectation that a certain action will result in a particular outcome (expectation of contingency) such self-related cognitions exert a significant role in the regulation of self.

When discussing teacher education such expectations of self-efficacy are of interest – to the effect that through expectations of self-efficacy the teacher's (teacher trainee's) optimistic conviction is or may be expressed that they will be provided with the necessary resources to handle difficult situations.

According to Bandura (1997) the objective resources are not in the foreground in such cases, but the belief in them is: "Perceived self-efficacy is concerned not with the number of skills you have, but with what you believe you can do with what you have under a variety of circumstances" (Bandura, 1997, p. 37). These beliefs are followed by multiple consequences – they determine motivation, emotions and behaviour. According to Bandura (1997) the conviction to be able to use skills practically – besides the skills, of course – forms a prerequisite for the successful mastering of complex demands: "Effective functioning requires both skills and then efficacy beliefs to use them" (Bandura, 1997, p. 36).

Various publications (see Schwarzer & Schmitz, 1999; Schwarzer & Jerusalem, 2001) even suggest that people with high efficacy judge their chances of success with problems that objectively can't be solved, and with which they have had no experience, higher than people with a lower degree of efficacy: they try very hard to get a solution and are less frustrated by failures.

In view of the study presented here it can be assumed that teacher trainees with high self-efficacy also express their self-efficacy verbally (in a projective way, with self-references in their statements) and that there is an increase in self-efficacy between the beginning of their course of study in the first semester and the end of the fourth semester (end of the investigation period).

Targets of the investigation and the concrete problems

This study focuses on changes in the subjective theories of teacher trainees from the beginning of the first to the end of the fourth semester (three survey phases); the following categories (see Shulman, 1986; Bromme, 1992) of changes will be examined:

Bromme (1992) following Shulman (1986)	Categories adapted for this study:
subject matter knowledge	Knowledge about the subject[*] (2 Items[**])
curricular knowledge	Knowledge about general goals/objectives (2 Items). Teaching aids (2 Items)
general pedagogical knowledge	Knowledge about pupils (1 Item) Knowledge about other factors that influence pupils (parents, peers, etc.) (2 Items)
pedagogical content knowledge/„blending of content and pedagogy"	Knowledge about classroom management (2 Items)

The following questions have been formulated against the background of this concept:
1. What are the characteristics of the subjective theories of the teacher trainees (total sample) at the beginning of the first semester, at the end of the second and at the end of the fourth semester in terms of the following categories: knowledge about the subject, knowledge of general goals/objectives, teaching resources, knowledge of the pupils – of factors that influence pupils (parents, peers, etc.) – knowledge of classroom management?
2. Do the subjective theories of the teacher trainees reveal any changes from the beginning of the first to the end of the fourth semester of study? – If so, what kind of changes are these (quantitative/qualitative)?

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*   Bromme generally uses the term „Wissen" for „knowledge"; in current terminology we would use „competence" in this case.
** The Items contributing to the four categories refer to the survey material called Completing sentences (see chapter Description of the survey material and methodology).

3. Do the subjective theories – with progressive study experience (practical experience) – increasingly prove the prospective teachers as players?

Description of the survey material and methodology

Data were collected in written form, by means of projective techniques (projection of partly conscious, partly unconscious thoughts, ideas, values, desires). The projective technique was chosen to avoid the effects of test management (rationalizations and cognitive control).

The following techniques were applied (for details see: Seebauer, 2008):

- *Completing sentences* (11 sentences, contributing to the categories as described above, and
- *Mind Mapping* of the terms *school*, *education*, *tuition/teaching*, which allow a visualization of the elements of knowledge, of the underlying knowledge structures and knowledge systems.

A frequency analysis of the notions that were associated with *school*, *education*, *tuition/teaching* was carried out and as a follow-up the notions were categorized (e.g. characteristics/features/functions of school/of education/of teaching – players – characteristics of the players – actions of the players…). The texts (from the subtest *Completing sentences*) were ascribed to the respective categories, analysed quantitatively and visualized; examples typical for each of the categories were listed. Particular subcategories (e.g. should-statements, teaching resources, educational/ methodological issues, actions/ activities of the pupils) were dealt with in the knowledge categories. To answer question 3 the "direct surrounding of the text worthy of interpretation" (Mayring, 2002, 118)[5] was the focus of consideration. The text was scrutinized with the help of the search function of MS-Word ® and with the help of TextSTAT 1.52, a concordance program by Matthias Hüning (freeware, Free University Berlin).

Characterization of the sample

The survey was carried out on a group of teacher trainees in the course of study for future lower secondary teachers over a period of four semesters of study (English as a first subject) following the curriculum 2004 to 2007.

In the first survey and in the second round (October 2004 to June 2005) 28 students took part (7 male, 21 female); because of students taking a semester abroad, changing to other institutions or dropping out, there were just 20 students available for the third survey.

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5   In the original language: „…direkte[s] Textumfeld der interpretationsbedürftigen Stellen".

Summary and interpretation of results

The presentation of the results[6] follows the categorization according to Shulman and Bromme as described above.

- ***Goals / Objectives***

Transfer of knowledge/transfer of knowledge of a subject is regarded as the most important task of the school by college entrants, and at the same time knowledge (of a subject) is what the school should provide the children with.

The subjective theories of the college entrants seem to be fed by experience gained from upper secondary schools (general stream, vocational stream) and are projectively reflected.

Changes – at the end of the first semester of study – are being reflected in such a way that social behaviour/social skills (in the broadest sense) are regarded as more important.

The importance of teamwork and manners (good behaviour) are articulated as further tasks of the school, which can be explained by increasing school experience – in the sense that deficits observed are being reworded as "a task of the school".

Further experience – picked up during the experience of "practical studies/ teaching practice" in the second academic year – complements the range of what schools should impart: neat appearance, politeness, orderliness, punctuality, positive attitude to work, etc.It is assumed that in classes in which the students could observe these properties in the children, teaching and learning proved to be more successful than in classes in which the absence of these properties was observed.

Preparing for life – as *the* task of the school – is regarded as being of great importance even in the first semester and increases with the progression of studies as revealed by the frequency of the students' statements.

Teaching multicultural classes in Vienna – until the end of the second academic year – brings about a further change in the perception of the role of the school: tolerance/ acceptance of people of other origins gains significant importance.

- ***Teaching resources***

Media – throughout the total investigation period – are ascribed great importance.

While the college entrants stress the importance of media in relation to the children or pupils ("Students learn easily by means of various media"; "… so that all students are addressed, and not just those who learn well acoustically …"), the statements of students at the end of the second semester link the use of media with their own teaching

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6 For reasons of clarity the results will be presented according to the categorization of Shulman and Bromme. The reader will be fully provided with the answers to the research questions as formulated in chapter 2 without explicitly referring to them.

("…teaching in an entertaining, interesting way"; "inspiring tools that grind the classroom"; "variety in teaching …"). Only at the end of the fourth semester of study do the statements of the students address the use of media as didactic components – for example, that "these are useful and should be applied in various ways"; "… media should not demand too much of the children"; "…should be adjusted to the children …".

The analysis of Mind Maps (stimulus word "tuition/teaching") suggests a narrowing regarding the possibilities of the use of media. While the college entrants at the beginning of the first semester named twelve different media (projector, CDs, slides, film, etc.), the number of media decreases at the end of the fourth semester of study: worksheets, real objects, overhead projector, posters, videos and blackboard – in other words, those teaching aids are listed that actually were used or were available in the classes. Textbooks are ascribed the function of "guide, support, assistance, guidance", with increasing importance of these aspects between the first and fourth semesters.

While college entrants consider textbooks to be a means for reading, for repetition, etc, students in the fourth semester increasingly criticise the textbooks (partially not useful, useless…).

At the end of the fourth semester of study this critical perspective is often followed by a justification of the criticism – for example, that textbooks offer just a few exercises for differentiated and independent learning, and usually are not up to date.

- **Subject**

First-year students (after the *initial block* of teaching practice) address the "principle of fit" in English classes, as well as the good explanations offered by the teacher, the sequence of exercises carried out from simple to difficult, and the media.

It can be assumed that the type of lesson planning and structuring experienced during the "initial block" of teaching practice forms a contrast to the students' own experience of teaching in the upper secondary schools. With advancing studies, however, such principles of teaching are taken for granted and are no longer mentioned.

With increasing first-hand teaching experience (planning and implementation of individual lessons) beginning with the second semester the curriculum framework and the related (personal) freedom of the teacher in the planning of lessons gains special significance. With increasing first-hand teaching experience the knowledge of the pupils is described as "unsatisfactory", "weak", "insufficient", "bad", etc, but also as "depending on the teacher".

During the first academic year, the allocation of attributes such as "weak" or "poor" remains as a finding, while at the end of the fourth semester such attributions are followed by numerous statements that demonstrate "ways of improving their knowledge": "The knowledge of the pupils differs a lot, therefore you have to pick it up with the children there, where they are." – "The pupils' knowledge depends on

the teacher, on his/her motivation, on the teaching resources, on the class climate and on the pupils' learning conditions".

"The knowledge of the pupils depends on whether or not I address the pupils directly with my topics, everything I offer them should be connected to their world …"

In the same way the numerous "should-statements" uttered by the students in the first and second semesters are replaced by concrete measures.

In the fourth semester the students investigated not only express demands: their subjective theories regarding their "knowledge about the subject" reflect specific and concrete measures dealing with various challenges. With increasing experience picked up in various schools in Vienna the students – for the first time at the end of the second academic year – refer to the "good knowledge of the children", e.g. "The knowledge of the pupils is sometimes quite good, you can teach them a lot when you make them practise hard. That's not a question of their cognitive abilities".

It is likely that such comments result from positive experience with their teacher trainers and from their own successful teaching.

The analysis of the notions associated with the stimulus word "school" (in the Mind Maps) proved the availability of an elaborated specialist terminology – in contrast to the beginning of the first semester when the students just used everyday language.

- **Pupils**

Overall, the students revealed a positive view of the pupils. The college entrants describe the pupils as "inquisitive, curious, eager to learn", and "individual personalities and adolescent people." The other attributes allocated to them generally have positive connotations; statements such as "difficult to control, uninterested, unpredictable" are the exceptions.

With ongoing practical experience, the number of statements such as "inquisitive" clearly decreases; the perception of the pupils as "autonomous, independent beings" and as "individual personalities" takes its place.

The associations of the college entrants with the test word "pupils" (Mind Maps) clearly show that the students are still rooted in their own role as pupils.

Associations such as: "I think the teacher is nice, fantastic", "I tell my Mom what I've heard/learned; I eat my snack in secret; I start to draw; I copy everything at the end of the lesson; I prepare a cheat sheet; I become careless; I engage myself because it's interesting …"; the assumption that the students are still rooted in their own role as pupils is boosted by the use of the verb in the first person singular.

By the end of the second academic semester and increasingly up until the end of the fourth semester a shift in perspective takes place and the students regard themselves as "teachers" – the reference to different types of learning as well as to educational activities underpins this change: "speak, practise, repeat, cooperate, self-directed learning …".

Whereas at the beginning of the first semester educational activities are seen

from a cognitive angle ("acquire knowledge, do one's homework..."), this view clearly decreases by the end of the fourth semester and social learning takes its place: "acquire social skills, do one's duties, cooperation of pupils, teachers, parents ...".

- **Other factors that influence pupils (parents, peers, etc.)**

Future teachers think that parents want to delegate the upbringing of their children (especially "manners") to the teachers. In almost a quarter of the students' statements the pupils' behaviour and manners are regarded as bad. The external image allocated to teachers by the children's parents conveys the feeling that teachers work too little or not at all.

This negative "expected external image" of teachers is complemented by numerous statements that refer to an unfair assessment/grading; they refer to the teacher as "a smart aleck", as "a smart ass" who is blamed for the poor performance of the children.

In the second and fourth semesters the students investigated increasingly express criticism of the parents, among other things that parents do not consider school and education as important. Overall, the future teachers reveal a feeling of being left in the lurch by parents, especially in their educational work, but also as far as teaching is concerned and they complain about a general unfavourable image of teachers.

Although the teacher trainees are encouraged to participate in parent-teacher meetings, in parent forums, etc, teacher trainees have little experience of contact with parents. It is therefore assumed that the "teacher-parent relationship" depicted above has been fed and shaped by the attitudes and opinions of the supervising teachers.

The "school heads" are primarily attributed three functions: an integrative function (integration of concerns of teachers, pupils, parents), an organizational/planning function as well as a social function. While the organizational/planning function is largely characterized by a broad constant of statements (40 % from the first to the fourth semester), the frequency of statements that can be allocated to the integrative function decreases clearly.

An increasingly realistic perspective of the school as an institution, including its players, seems to explain these findings, since these functions of the school heads can scarcely be perceived or experienced during the practical training period.

The social function of the school, on the other hand, is increasingly regarded as very important: "Establishing a constructive working environment, open, honest communication in every direction, recruitment of competent teachers ...".

- **Classroom Management**

Increasing teaching experience of the teacher trainees seems to imply that the future teachers regard the children (as the recipients of teaching and education) less often as "children" but more often in their roles as "pupils".

At the end of the second academic year the view of the "child as a personality and individuality" returns to the students' minds – on an equal basis with their

role "as a pupil". What future teachers "do not mind" can – at the beginning of the first semester – be assigned to the category "behaviour" ("…when children are noisy, bluster, jabber, romp around …") and – by the end of the second semester – gets shifted to the category "teaching/lessons" ("…if the lesson plan proves to be insufficient …").

It can be assumed that students in the second semester direct their attention to "teaching issues"; that does not mean, however, that this shift to the field of "teaching" implies behavioural issues ("discipline").

Students in the second semester are concerned with putting their well-planned lessons "on stage" in the best possible way – very often disregarding the behavioural component.

Between the beginning of the first semester and the end of the second academic semester future teachers become more and more aware of themselves as agents ("players") in classroom management; they increasingly become aware of their self-efficacy in teaching and in educational processes and find themselves forced into action ("I must try to make the material clear to the pupils with the help of other methods; I make other pupils explain the material"), which – until the end of the fourth semester – slightly decreases to make room for more general statements. The subjective theories of class management – over the investigation period – are characterized by references to concrete educational measures.

- ### *Self-efficacy*
Throughout the investigation period an increase in self-related statements and references to self-efficacy could be observed in the three areas of "knowledge of the subject", "knowledge about the pupils" and "knowledge about classroom management". The increase in statements concerning "classroom management" – from the beginning of the first semester to the end of the second academic semester – was significant (+ 57.15%). The pressure to act in the field of classroom management as referred to above becomes evident. The category of the "subject" seems to allow the students room for personal development; "… to design really meaningful lessons", to "implement own priorities": one student regards himself as a body for the allocation of educational opportunities ("When I, as a teacher – from the very beginning – say 'not too much input', then I deny all children the possibility of being capable of anything.")

In the category of "knowledge about the pupils" we learn that the teacher trainees regard the pupils as *the* reason for their own professional decision (primarily expressed by second semester students); the pupils are described as people to whom they may/shall/will impart knowledge (primarily expressed by students in the first and the fourth semester). It seems that some of the students investigated have not found an answer to the question of having chosen an adequate career until the end of the second semester. The "child, sometimes anxious and in distress …, as the centre of teaching", "children as important personalities I would like to teach" are mentioned at the end of the fourth semester.

In the category "classroom management" the problem of "discipline" is

rudimentarily recognized from the beginning of the first semester; this problem continuously bothers the teacher trainees until the third survey at the end of the fourth semester. By the end of the second academic semester, "lesson planning/ scheduling" is added as a further concern.At the beginning of the first semester statements with a self-reference were identified – in such a way that students regard themselves as the responsible party when some children have not understood the material ("I have not provided sufficient information"; "… the reason is my teaching method ...").

Such statements gain ground until the end of the second semester and remain relatively unchanged until the end of the investigation period in the fourth semester; knowledge of subject matter methodology and its application in the teaching situations is articulated: different methods, tools, the use of classmates, repeated explanation, etc.Individualizing, the individual redress of gaps in the children's knowledge, as well as the reflection on reasons are added by the end of the second semester: "I'm trying to find out reasons; ... I wonder what's wrong and try to find solutions ...". In general there is some evidence that the reflective proportion in the statements – initiated and maintained through cross-disciplinary reflections on lessons and teaching – has increased.

The most significant changes throughout the survey period are these:

- Perception of the student's own role, i.e. the intense perception of his/her role as a (future) teacher – increasing tendency from the beginning of the first semester until the end of the fourth semester;
- The perception of the child as an independent personality (first semester), which is replaced by the perception of the child in his/her role as a pupil in the second semester – in order to gain a well-balanced relationship "child : pupil" toward the end of the fourth semester;
- The clear perception of educational aspects (teaching/ methodology) in connection with the students' own roles as teachers and the pressure to act and react to the requirements of the situation (end of the second semester) as well as the perception of an increasing self-efficacy – above all in the area of "classroom management";
- The understanding of the educational mission of the teacher by the end of the fourth semester and the general shift from a mere content-based mission to the more general educational and social functions of the school.

Consequences and prospects

The following table shows the results of the investigation – as hypotheses – and addresses possible consequences:

Evidence	Consequence
The development from the role of a student to the role of a teacher takes place progressively across the survey period (semesters 1-4).	„Personality Development" as a subject throughout the entire training period.
Lesson planning as well as a "perfect" implementation of the lesson plan determine the central expectations as to teaching of the second semester students.	*In the second semester:* Teaching exclusively of small groups (max. 8-10 pupils) in order to reduce complex educational demands. Ensuring of subject matter knowledge. Ineffective classroom management must not be included in the students' grading. A total refrain from grading for the benefit of intensive consultation would be preferable.
The perception of the child is primarily a positive one. At the beginning of the first semester the students' statements that focus on the child are: eager to learn, curious. Increasing practical experience during the second semester presents the child in his/her role as a pupil (in the sense of "object of teaching"). At the end of the fourth semester a relatively balanced view of the child as an individual personality and in his/her role as a pupil prevails.	Focus on developmental psychology (childhood, adolescence) including diversity and heterogeneity in the broadest sense. Proof of finishing two months' practical training (non-formal education) by the end of the third semester; intensive subject-related studies, ensuring of basic subject-related and methodological competencies as a precondition to enter the third semester of study.
A blocked practical training period of two consecutive weeks (in semester 3) expects too much of the teacher trainees because of the complexity of the educational situation – above all for students with weak subject knowledge – and ends in class teaching.	Intensive subject-related studies; broadening of the subject-related and methodological competences. Focus on educational psychology; classroom management. Documentation of the individual progression in practical teaching in a video-portfolio with comments.

The educative mission is – besides mere cognitive learning – not realized and is only partially fulfilled before the fourth semester ("from transfer of knowledge to social learning").	Intensive subject-related studies; further development of the subject-related and methodological competences. Focus on classroom management, communication and interaction. Documentation of the individual progression in practical teaching in a video-portfolio with comments.
With an increasing period of study teacher trainees articulate more self-efficacy – above all in the area of classroom management. High self-efficacy is to be seen in connection with high competence in the field of the subjects.	The students' system of self-concepts is to be built up. The subject-related and methodological competences are to be extended. Documentation of the individual progression in practical teaching in a video-portfolio with comments.
The (expected) unfavourable professional self-image of a teacher is replaced by increasing criticism of the pupils' parents.	Integration of students in parent forums, open days and other school events in which parents are involved. "Integration of parents" as a main area in educational sciences.
With an increasing period of study textbooks and blackboard and – at best – work sheets are the most current teaching resources.	The lessons planned and implemented in the course of the practical studies have to (demonstrably) reveal progressive complexity. Documentation of the complexity of lessons that could be managed by a documented video portfolio.

By investigations such as the one described above the responsible persons are allocated a series of duties; simultaneously further questions are raised by them. Further research in this highly complex and sensitive area of the exploration of "the hidden knowledge in practical teaching" concerns the investigation of students:

- throughout the entire training period of six semesters;
- studying different subjects (mathematics or German as a first subject);
- in different training systems;
- in a consecutive training system;
  as well as the investigation of the "hidden knowledge" of supervising teachers in comparison to the students' "hidden knowledge".

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UP TO THE GARDEN FENCE
OR THE WORLD AT PRIMARY SCHOOL

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Abstract: *Up to now only few empirical studies have focused on the development of children's spatial cognition. The study examines the map-drawing abilities of an international sample of ten-year-old children by examining the nature of world maps they have drawn. It explores the extent to which different factors of influence, e.g. the presence of media, travel activity, handling of cartographic media, individual interest and family or school factors of influence are correlated to the enhanced ability of the children to represent their spatial cognitive structure of the world as a drawn map. The paper discusses the implications of the findings for the creation of learning environments which support the development of map-drawing using both ways - the way "from local to global" as well as the way "from global to local".*

Key words: *experiences, factors of influence, geography, mental maps, cognitive perceptions, primary school, world*

Introduction

If one examines the field of experience of today's primary school children regarding Europe, foreign countries or the world, one can basically distinguish between five different fields:

1. Experiences from living together with people from different countries and cultures

In Germany, foreign citizens have led and continue to lead us to a multicultural society, where people from different countries with different ways of life[7] (e.g. ways of interpretation, attitudes, habits, religions, values) live. Children face these different ways of life in their everyday life, e.g. at local parties and events, at stores

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7 In 2007 the share of foreign nationals in Germany was 8.8 % and thus clearly beneath the average compared to most other European countries (see Statistische Ämter des Bundes und der Länder 2007; see also Eurostat. Statistisches Amt der Europäischen Gemeinschaften 2008a). In comparison to Germany the share of foreign nationals was 41.6 % in Luxembourg, 20.7 % in Switzerland, 19 % in Latvia, 17.6 % in Estonia, 15.2 % in Cyprus and about 10 % in each of Ireland, Spain and Austria (cf. Eurostat. Statistisches Amt der Europäischen Gemeinschaften 2008b).

with exotic-sounding (family)names, in their own surrounding area, through exotically dressed people as well as from what their parents, adults, friends and acquaintances have to say. But the multicultural society is not just felt in every-day life. In the field of school, strong traces can be detected.[8] The situation is very different on the different levels of schooling. Especially primary school, as an educational institution common to all, has a large number of foreign children.[9] In 1991, the average number of children of foreign backgrounds at German primary schools was 8.8%[10]. By the year 2000 the number had increased to 11.8%.[11]

Due to this fact, primary school children are part of our multiculturally compounded society and experience this in their everyday lives. In their so-called "sub-communities", e.g. kindergarden, day-nursery, school, sports associations and their neighbourhood, they gain first impressions of different cultures as well having their first experiences of them. Büker's statement from the year 1998, where she says that living together with people from different cultural backgrounds is *normality* (see Büker, 1998, p. 68) for today's children, remains valid today.

2.   Growing mobility and increased travel among the population

In 2006, every German travelled by plane or train (at least one overnight stay) an average of 2.3 times. 43.8% of these flights or journeys by rail headed to European countries abroad. Passengers flew from German airports to European countries abroad 41 million times. The most frequent destinations within Europe were Spain (with 9.9 million flights altogether), the United Kingdom and Northern Ireland (with 4.9 million flights) and Turkey (with 4.4 million flights).[12], [13]

Regarding the consequences of increased travel for pupils' spatial knowledge,

8   In quantitative terms the most significant country of origin is Turkey; in the year 2000 almost 502,000 pupils in Germany had Turkish nationality, accounting for almost 43.4% of all foreign pupils. Another 195,000 (16.9%) came from the member states of the European Union; Italians – with almost 92,000 (7.9%) and Greeks with 43,000 (3.7%) were the biggest groups amongst them. With a total of 149,000 (12.9%), the states of the former Yugoslavia account for a huge proportion of foreign pupils in Germany; of this amount of more than half – 84,000 (7.2%) – are from the former Yugoslavia. Of the remaining pupils whose nationality is not German, 24,000 (2.1%) are from Poland, 78,000 (6.7%) are from other European States and 207,000 (17.9%) are from states outside Europe (see Sekretariat der Ständigen Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland 2002, p. 12).

9   See Analyses from Büker for the year 1990.

10 Asylum seekers and German emigrants who returned to Germany long after World War II are not part of statistics of the KMK (Conference of Ministers of Education and Arts). Due to this fact, one has to assume that the actual number of pupils with different cultural backgrounds in primary schools is a lot higher than the statistics the KMK gives. [Comment of the author.]

11 See Sekretariat der Ständigen Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland 2002, p.11, tables.

12 See Statistisches Bundesamt Deutschland.

13 Journeys by other means of transportation such as bus and/or car are not integrated into the statistics of the German Federal Office of Statistics. One has to assume that the number of real trips to European countries abroad is much higher than the statistics say. [Comment of the author.]

studies show that growing primary experiences through travelling, besides individual and experience-based influences, has an influence on the spatial imagination of primary school pupils (see Schmeinck, 2007a, p. 181; Schniotalle, 2003; Halocha, 1998). Related to this, interviews would show that besides the primary experiences they have in countries in which they spend their own holidays, children have great access to a wide range of travel experiences through their classmates, parents and grandparents (see Schniotalle, 2003, p. 200). Due to this the growth in travel seems to have a crucial role in class with regard to a global dimension.

3.   Influences of the different (mass)media

Nowadays the media are *the* information medium for foreign countries and cultures because they can give one an impression of and an insight into the past and the future, the *here* and the *there*, the great diversity of human ways of life and behaviour, where personal encounters are not possible (see Büker 1998, p. 73cf.). Therefore, television has a pre-eminent role in the lives of children.

According to the KIM-study from the year 2005, television is still the most important medium for children. Almost half of children have their own set, and 78% watch television almost daily (See Medienpädagogischer Forschungsverbund Südwest 2006, p. 19). The computer is an important medium at primary-school age, too. In the year 2005 83% of households with children had a computer or laptop and 12% of children already had their own equipment. 63% of children use a computer at least once per week (see Medienpädagogischer Forschungsverbund Südwest 2006, p. 26). Besides television and computers, children's print media such as children's books (e.g. Pipi Longstocking, Emil of Lönneberga, etc.) and special magazines for children (e.g. Mücke, Geolino, etc.) provide impressions of foreign countries, nations and their cultures. Judging by this one can assume that even children of primary-school age have a media-generated knowledge and experience of foreign countries and the world.

4.   Increasing European and international consumption

As early as 1989 Bausinger detected that Lacoste and Benetton were often firm terms associated with the youth (see Bausinger, 1989, p. 7) and also Büker found that the clothes that originated from different nations and the typical ways of dressing were becoming more and more mixed-up, crossing over into folklore and becoming more and more part of international fashion. Examples of this development are kilts, traditional costumes and Norwegian pullovers (see Büker, 1998, p. 72). But not just in the area of fashion are we confronted with Europe and different countries of the world. Danish bed depots, Swedish furniture shops, Italian furniture design, French, Italian and Polish makes of cars, Italian ice cream and pizza, Spanish paella, Turkish doner kebab, Dutch tomatoes, Greek olives, Spanish grapes, etc. have become a big part of our daily lives and within this a big part of the (daily) reality of primary-school children. Therefore children grow up

with an international range of goods on offer which seems natural to them. Given that this is so one has to assume that these enormous amounts and all the special offers are not viewed as such through the eyes of children. One should be aware that children are not aware of the foreign origins of certain products because they were not yet born when international goods were integrated into the local network of supply (see Büker, 1998, p. 72).

5.   Officially supported programmes for the support of the growing together of Europe

Especially in recent years there has been an increasing range of officially supported programmes for the support of the growing together of Europe, even for primary schools. Supportive measures from the European committee surely are of particular importance for this growing together. So not only partnerships between schools are supported (e.g. COMENIUS projects), but also the forming of networks for partnerships between schools. Numerous European competitions for pupils of all ages are advertised and organized by the Centre of European Education, the Council of Europe, the Federal Ministry of Education and Research, the Department of Foreign Responsibilities of the KMK and/or the German-French Youthclub.[14]

To summarise, children nowadays can fall back on extensive experiences of different kinds with regard to their idea of seeing the world. With reference to Negt (1998, p. 22) the understanding of the changes in the world as well as the detection of aspects concerning one's own personality are not just superfluous luxury, but essential requirements. The necessity of the implementation of a European or rather global dimension in class has been emphasized for years not only at a political level but in primary-school-related didactic discourse.[15]. Analysing the current guidelines and school curricula of Germany, we detect in most of the federal states of Germany an orientation towards the principle "from close to far" (see in detail Schmeinck, 2008). In spite of the different decisions from the Council of Ministers for the education system, the resolutions of the KMK on the topic "Europe in class" or rather "Teaching Europe in school" from the years 1990 and 2008, the reports of the Gesellschaft für Didaktik des Sachunterrichts (GDSU) in their "perspective frame general sciences" as well as different didactic discourses and the ministerial declaration of intent from 1992, to integrate the European dimensions into the new school curricula (see Büker, 1998, p. 38), in many federal states region-related learning is still taking place in the home region.

But what ideas do ten-year-old children have of the world? Which kinds of influences on the development of three-dimensional ideas of the world are of crucial importance? What does "distance" mean to the primary-school children of

14 The list of programmes and measures is just an example, not an attempt at completeness [Comment of the author.]

15 See Schmeinck 2008, also see Amtsblatt der Europäischen Gemeinschaft 1976 and 1988, Sekretariat der ständigen Konferenz der Kultusminister der Länder in der Bundesrepublik Deutschland 1978, 1990, 2008 and Gesellschaft für Didaktik des Sachunterrichts 2002.

today and the future? Which preconditions are needed by learners in the future? Empirical research on the origins of the three-dimensional ideas of primary-school children are rare. But an overview of children's ideas of the world, how these ideas are created and under which circumstances they change, would be very important.

The study presented in this paper therefore examines how ten-year-old primary-school pupils perceive the world, the cognitive map they have in their minds and which factors may have an influence on the development of their perceptions. The paper discusses the implications of the findings for the creation of learning environments that support the development of pupils' spatial representation.[16]

Theoretical background

The necessity of helping children to develop spatial perceptions of the world and an understanding of the ways in which societies and environments are connected has long been recognised as desirable (see Gould & White, 1974). Previous research has therefore focused attention on children's perceptions of the world as well as on the development of spatial cognitive structures (see Cohen & Schuepfer, 1980; Tanner, 1999; Bourchier et al., 2002).

Despite the fact that recent research has focused attention on children's perceptions of the world, we know relatively little about children's perceptions and the reasons for their development. Nevertheless, this aspect of geography education is highlighted as very important by Holloway and Valentine (2000, p. 7) who refer to the "small, but significant literature about children's spatial cognition and mapping abilities." Likewise, the manner in which travel experiences, exposure to cartographic media, personal interest as well as familiar and school influences interact in the development of spatial cognition and mapdrawing ability is not fully understood. Thus Poria et al. (2005) identify this as an area where additional research is still required.

In 1950 Piaget concluded that children aged 7 to 11 are at a 'concrete operational' stage of development. According to Piaget children at this stage use symbols to represent objects and can solve problems that have a concrete, rather than an abstract basis. In terms of examining children's spatial awareness of the world Piaget's work suggests that at the age of ten children are still developing the ability to represent in maps things like countries and places that they may not have visited and of which for that reason they may have only an abstract knowledge.

In the last few decades arguments have raged in respect of exactly when children develop the ability to represent their spatial cognition of the environment or the world as a map (see among others Blaut, 1997a, 1997b, 1999; Catling, 1979; Cook et al., 1998; Goodnow, 1977; Newman & Newman, 1978, Rivlin et al., 1985). Some authors report the development of this ability in children as young as four (see Blades et al., 1998). According to Blaut even children as young as three can make maps with

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toys (see Blaut, 1997a; Blades & Cooke, 1994; Blades & Spencer, 1990). Other authors confirm the statement that a basic requirement for the understanding of maps – the understanding of symbolical representations and/or the understanding of objects as representatives of other objects – is already developed at the age of three (see e.g. DeLoache, 1987, 1989, 1991, 2000; DeLoache, Miller, & Rosengren, 1997; DeLoache, Uttal, & Pierroutsakos, 1998). Children who are five years old can both reorientate maps that are not aligned correctly (see Blades & Spencer, 1990) and interpret aerial photographs (see Sowden et al., 1996). Nevertheless, some authors still assert that only when children have entered the 'concrete operational' phase can they start to represent their spatial cognitive structure of the world in the form of a (mental) map (see Towler & Nelson, 1968; Towler, 1971; Stückrath, 1963).

Aims of the study

Bruner states that new knowledge (in or out of school) is taken up and memorized significantly (see Bruner, 1960). In order to avoid placing excessive or insufficient demands on pupils it is necessary for teachers to become aware of the knowledge and the personal and individual experience of their pupils. The understanding of how children develop cognitive structures of the world and a profound knowledge of their ability to represent these structures in maps is required to help develop effective pedagogical strategies for the teaching at school of mapping skills and spatial abilities. Additionally, an understanding of how children's spatial cognition of the world grows may also help deepen knowledge of how operational thought develops in children.

In order to be able to examine the different factors of influence (e.g. school or cultural influences), in addition to the German sample corresponding international samples were taken. The results of these smaller studies offer explanations as to whether the results of the German study deviate from those of other countries, or whether they can also be confirmed at an international level. In accordance with this the aims of the present research were to:

- identify representative samples of ten-year-old children from Chile, Germany, France, the UK, the US, Spain, Sweden and Switzerland;
- collect data from the sample regarding ability to represent spatial cognitive constructs of the world in mental maps;
- collect data from the sample in respect of previous travel experiences, personal interests, school and family influences, out-of-school-experiences and exposure to cartographical media.

In order to address the overall aim the following research questions were investigated:

- How do children represent the world in a mental map?
- Were there observable differences in the mental map-drawing abilities of the children?
- What influence do different experiences have on children's ability to represent the world in a mental map?

Method

Sample

The sample for this study comprises 724 ten-year-old primary-school children from Chile, Germany, France, the UK, the US, Spain, Sweden and Switzerland. In the selection of the countries various criteria were taken into account:

- geographical boundaries (e.g. UK) vs. political boundaries (e.g. Switzerland)
- special settings of the countries (e.g. Australia = country and continent)
- role of geography in the school system
- curricula differences

Table 1: Numbers of children from each country in the sample

Country	Number of children[*]		
	Boys	Girls	**Total**
Germany	188	191	380
Switzerland	43	39	82
France	33	38	71
Spain	34	28	62
United Kingdom	31	20	51
Sweden	12	10	23
Chile	19	14	33
USA	10	12	22
Total	**370**	**352**	**724**

* Whilst the data set may be unduly influenced by the variance in sample size between each country, it should be noted that analyses between countries are not attempted within the data set. With regard to the purpose of the study it would have been desirable to be able to collect data by randomly chosen, homogeneous and identically sized samples. However in conjunction with the actual data acquisition in the international parts of the study this proved to be unrealisable because even the identification of comparable schools and/or classes turned out to be a practically unsolvable task. Given the fact that the international parts of the study were performed mainly for purposes of comparison and examination, the results of the underrepresented countries (Chile, the USA and Sweden) are also considered in the analysis of the results.

The last two points in particular appeared to be highly relevant, as it was assumed that the framework of a separate subject or an early start in the teaching of geographical or cartographical input accompanied spatial abilities and/or mental map-drawing abilities. To ensure the best possible comparability of the data local contacts were asked to select schools that might yield a sample representative of their educational system and which were based in an urban location with an associated population of between 10,000 and 25,000. In addition the schools had to have a roll of between 200 and 240 students. The classes selected for study were composed of ten-year-old students. The number of students per class in the classes selected was in the range of 20 – 25. Therefore, schools were not randomly selected

for involvement in this project and a convenience – rather than probability – sample albeit with specific design parameters, was selected for the study. However, within the schools a full study of all fourth graders (age 9/10) was accomplished. Table 1 presents the numbers of children from each country in the sample.

Instruments

For the collection of the different data from the sample the pupils were asked to draw a mental map of the world. This data was gathered from a free map-drawing exercise with no reference to cartographic media. This technique was developed from methods previously reported by Schniotalle (2003), Matthews (1992) and Gould and White (1974). The children in the study sample were assigned the following task:

> Draw a world map.
>
> Draw and write on your map anything you can think of with regard to the world.

The mental maps drawn by the pupils were interpreted by a method of coding. This was done in order to allow comparisons to be made within the data set. Codes were developed on the basis of criteria that described the nature and qualities of the mental maps. These codes resulted in each map being assigned a numerical score. Increasing scores were awarded to maps of increasing complexity and quality (see figure 1 and table 2).
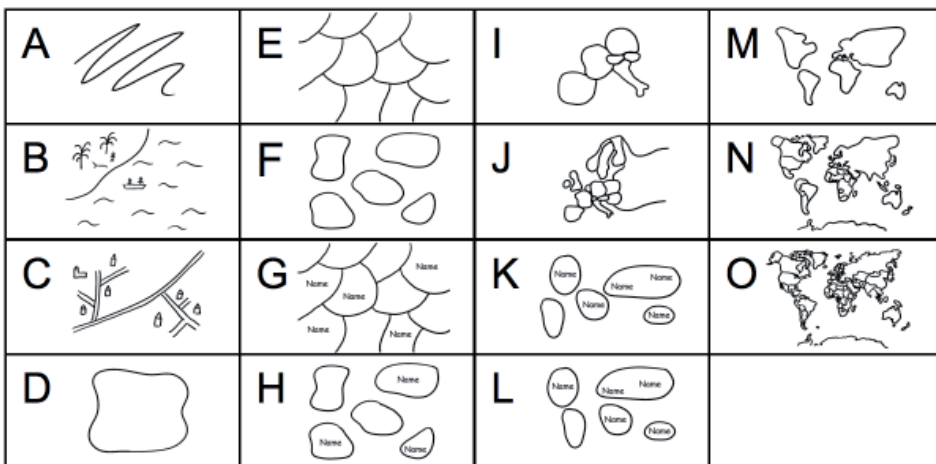

Figure 1: Qualitative categories for the maps shown in characteristically ideal form (source: Schmeinck, 2007b, p. 37)

Table 2: Index of the quality of the mental maps drawn (Schmeinck, 2007a, p. 178-183)

Type A	No classification possible	0 points
Type B	Picture of a situation; frequently pictures of houses, humans, plants and animals	1 point
Type C	Regional maps, e.g. single towns with streets and houses	2 points
Type D	Single isolated country island surrounded by water or without surroundings	3 points
Type E	Continents stuck together; randomisation; no labelling of the countries; no land and water discrimination	4 points
Type F	Isolated islands; randomisation; no labelling of the countries; no relationship between the countries; with land and water discrimination	5 points
Type G	Continents stuck together; randomisation; with labelling of the countries; no land and water discrimination	6 points
Type H	Isolated islands; randomisation; with labelling of the countries; no relationship between the countries; with land and water discrimination	7 points
Type I	Single countries identifiable by size, shape, labelling or distributions	8 points
Type J	Parts of the world identifiable by size, shape, labelling or distributions	9 points
Type K	World map identifiable by labelling of the continents; continents partially misrepresented	10 points
Type L	World map identifiable by labelling and location of the continents	11 points
Type M	World map identifiable by labelling, location and shape of the continents	12 points
Type N	World map identifiable by labelling, location, shape and size of the continents; parts of the world map are represented in detail	13 points
Type O	World map identifiable by labelling, location, shape and size of the continents; most parts of the world map are represented in detail	14 points

To give valuable clues as to the correlation between the mental maps drawn and the different factors of influence related to the development of spatial conception, additional data were collected in the form of specially developed questionnaires from the children, their parents and the teachers. Both the children's and the parents' questionnaires combined open and closed questions with *a range of*

possible answers, with the closed clearly outweighing the open because of their higher objectivity (see Bortz & Döring, 2002, pp. 194f). The cognitive capabilities of the children were measured both by the estimation of the class teacher and by the awarding of school marks (Mathematics, German, General Studies {Sachunterricht in German}).

In accordance with the objectives of the present study the children's questionnaires were divided into two parts. In the first part the focus was set on the different factors of influence and awareness of foreign countries and continents. The answers are used to investigate which factors of influence have a notably positive impact on the perceptions of the children and which sources of information are used by the children. Within the questionnaires the following content areas were pursued:

a.   social statistics
b.   travel experience
c.   out-of-school factors of influence
d.   school factors of influence
e.   familiar factors of influence
f.   individual factors of influence
g.   impact of cartographical media

The second part of the children's questionnaire focused more on the perceptions and competences of the children. The following content areas took centre stage:

h.   competencies in working with cartographic media
i.   awareness of one's own country and continent affiliation

The questionnaires were developed, examined and optimized beforehand in numerous pretests and by two different methods of cognitive laboratories regarding the cognitive processes during the question-answer process: on the one hand by the use of the retrospective-think-aloud method, in which after answering the question the respondent is asked to explain why he/she chose that particular answer (Prüfer & Rexroth, 1996, p. 105), on the other hand by the methodology of paraphrasing, where the respondent is asked first to answer the question and then to reproduce and/or formulate the question in his/her own words (Prüfer & Rexroth, 1996, p. 108). The finished children's questionnaire contained 20 questions from the various areas mentioned above. In order to assign questionnaire data according to family, class and country affiliation whilst respecting privacy, all questionnaires were completely coded and completed anonymously.

In the available survey, for the children's and teachers' questionnaires a response rate of 100% was achieved. However, in this respect this is not surprising as all the students' surveys took place during a school day. With 81.3% for the German survey and 73.7% for the survey as a whole[17] the response rate for the parents' questionnaires is pleasingly high.

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17 In general the response rates of corresponding surveys are between 10% and 90% (see Bortz & Döring 2002, p. 257).

Data Analysis

Non-parametric statistics were used to analyse the data. This decision was justified on the basis of the following factors:

- Samples were not randomly selected from countries and the sample size from each country varied.
- Although the data set for quality of world maps was numeric in nature, the scale developed was non-parametric.
- The use of weighting factors in the development of index scores meant that it was appropriate to use non-parametric statistical analyses.

For the reasons given the use of non-parametric statistical analyses was less likely to give anomalous results of positive correlations as a result of the statistical processes. The Kruskal-Wallis test, a non-parametric equivalent to ANOVA, was therefore used to determine statistical differences between the sample means. Kendall-Tau-b and Spearman-Rho tests were selected to explore evidence of correlation between variables.

With the aid of cluster-analytical proceedings, additional enquiries about the markedness of the groups' characteristics were conducted to test how groups with the same or similar characteristics were perceptible within the survey. Afterwards an analysis was performed to discover whether conclusions about the quality of the mental map drawn, gender or nationality could be drawn on the basis of membership of a cluster based on markedness of characteristics.

Results

The results of phase one of the mental mapping exercise show that the children did not produce a uniform spatial cognitive representation of the world as a map. The maps drawn present different and individual spatial cognitive representations of the world. The Data presented in figures 2 and 3 show the number of children who drew a map of each type in the German and French sample. Figure 2 indicates that about 89% of the German children were not able to draw a world map at all. 6.1% drew holiday pictures, regional maps or single countries (type B to type D). The majority of the children (74.2%) drew world maps in the form of countries, continents or cities that were stuck together randomly or were represented as isolated islands without any relationship to one another (type E to type H). Another 17.1% drew parts of the world in the form of single countries which were stuck together in the right form and were identifiable by size, shape or distribution (type I and type J) or islands that could be identified as the different continents (type K and type L). Only 2.1% of the German children were able to draw identifiable world maps with identifiable shape and/or more or less detailed information (type M to type O). In contrast to this data, the results of the French study show that all children were at least able to draw maps (type E). Furthermore more than half of

the French children were able already to draw world-similar maps (see Schmeinck, 2007a, pp. 156-157).
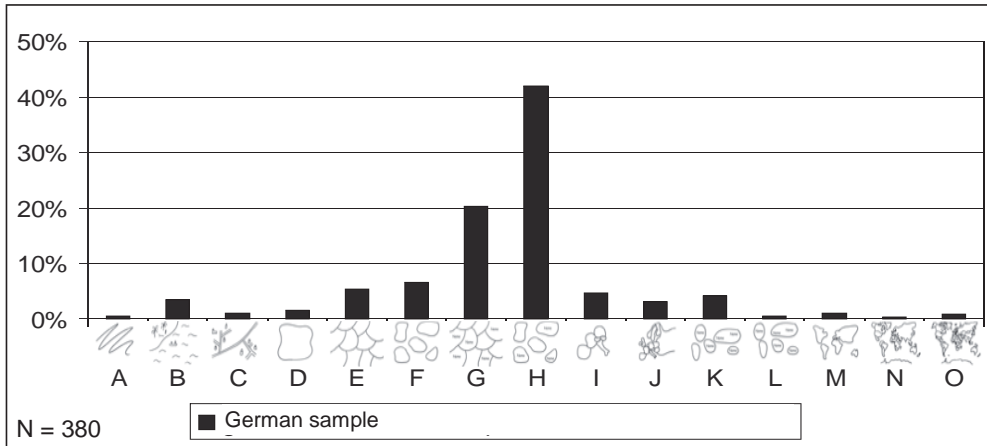

Figure 2: Distribution of the map categories in the German sample (Source: Schmeinck, 2007a, p. 157 – original in German)
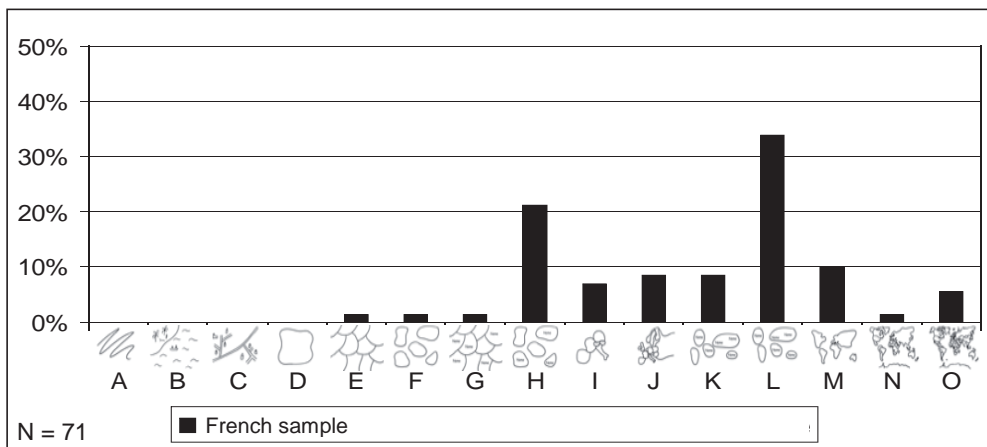

Figure 3: Distribution of the map categories in the French sample (source: Schmeinck, 2007a, p. 158 – original in German)

Also in comparison with the other European sample groups of the present study the average quality of the German world maps is much lower (see table 3). Thus age-related development in the form of common map representations could be diagnosed neither in the context of the study nor in the pilot survey with around 600 children from kindergarten to university (see Schmeinck, 2004).

Table 3: Average quality of the world maps (see Schmeinck, 2007a, p. 159)

Country	Average	N
France	9.73	71
Sweden	9.00	22
United Kingdom	8.02	49
Spain	7.94	62
Switzerland	7.68	82
Germany	6.71	379
Chile	6.44	32
USA	6.41	22
Total	**7.36**	**719**

Additional analysis of the data set of the German sample using the Kruskal-Wallis test indicated that the average mapping abilities of male students were significantly better than those of female students in the sample (x^2 =11.8, df=1 and p=0.001). To examine the meaning and effectiveness of the different factors of influence for the development of spatial imagination, index-results of the different aspects of influence were calculated out of the questionnaires' results. In particular the fields of travelling, the use of cartographical media, interest, family influence, school, knowledge and abilities in dealing with cartographical media and a consciousness of one's own country and continent were considered. The survey's results show that the development of space-imagination is very complex and influenced by several factors. On the basis of the data gained it was not possible to identify one single factor out of all those examined and thus to draw a decisive conclusion.

For the index-results that have been acquired through the analysis of children's interest, school, cartographical competences, influence of media and travelling it was possible to prove connections between the quality of the *Mental Maps* drawn, but they were only weak or moderate. Even intensive or numerous experiences in one of the fields do not as a rule lead inevitably to a corresponding development of spatial imagination. The clearest correlations were proven in the cartographical competence index, where the connection between the *Mental Maps* drawn and the index-results was comparatively the strongest. For the index family however, it was not possible from a statistical point of view to prove connections, so that it is necessary to assume that family influence is insignificant for the development of spatial imagination (see Schmeinck, 2007a, p. 231).

The analysis of the "competences concerning maps" index indicates that boys have more experience of and more competencies in working with cartographic media than girls and additionally get more benefit from this experience and these competencies. In contrast to this, girls get more benefit out of their experience of travel than boys, whilst their interest in foreign countries affects the quality of their mental maps less strongly than those of boys (see Schmeinck, 2007a, pp. 174-209).

With regard to the question, "To what extent can different types be distinguished within the study by the markedness of their characteristics?", it was possible to identify three different types with the help of cluster-analytical processes. The first type distinguishes itself by particularly low results in the field of cartographical competence. Beyond that, children show only average results in the other index-results; it is likely that as a rule they have less extracurricular access to or contact with cartographical media, less experience of travelling, only an average interest in the world or in foreign countries and received only average exposure about foreign countries at school or used cartographical media in the classroom. 50% of this type's children draw Mental Maps of types G and H, meaning maps within which the land areas are situated absolutely arbitrarily and which with regard to their legend do not show a town-county-continent hierarchy. Furthermore this cluster also shows a great number of extreme values and mavericks, and hence both children who drew plainly better and plainly worse maps. Regarding gender, it is generally possible to say that children from the first cluster tend to be girls. Children of the second type tend to produce lower results than the children of type I, when one discounts cartographical competence. Hence do those children have as a rule both less extracurricular access to or contact with cartographical media and less experience of travelling than the children from the first cluster. They have not heard much about foreign countries at school nor have they used cartographical media, and they show very little interest in foreign countries or the world. Compared to children from the first cluster, type II children show as a rule plainly more cartographical competence. Half of the children of this type draw maps of types G to I, where illustrations are plainly available that show the first countries situated correctly. Type III children tend to have very high results in all fields of index. They have as a rule both extracurricular access to and/or contact with cartographical media, a great interest in foreign countries and the world, have heard a lot about foreign countries at school and/or have used cartographical media, and they have a broad cartographical competence. But even they have not had distinctive experience of travelling. 50% of the children of this type draw maps of types I to L, hence maps in which at least individual countries are situated correctly in relation to one another, with the continents partly shown in the correct positions. Regarding gender it is possible to determine within this type that the children here tend to be male. With regard to the membership of countries and clusters the study's results show, the countries differ significantly regarding the arrangement of established clusters. Especially with girls membership of a country tends to have a greater influence on spatial imagination and/or on the quality of the Mental Maps drawn, whereas locally-available or lack of school influence seems to matter more than the country itself (see Schmeinck, 2007a, pp. 231-233).

Discussion

With regard to the question, "To what extent have primary-school children already developed spatial ideas about foreign countries?" and individual conditions

of learning in this field, as well with regard to the extent to which primary-school pupils are able to deal with foreign countries and/or remote areas and to depict these if applicable in the form of maps, the results of the current study – especially those of the partial studies in France, Czech Republic, Sweden, Great Britain and Spain – show that children at the age of ten are very well able to do this. Also with regard to the knowledge, imagination and interest of the children in the field of spatial learning, the results of the current study show that these are neither restricted to one's own garden, neighbourhood or village nor to one's own country. The results prove rather that the children already know many countries and that their knowledge of countries is not at all restricted to single continents or to communities of states such as the European Union. The perception of remote areas is often regarded as being too abstract; but with the development of the infantile view of the world already starting at primary school (probably even earlier), it should be picked up, supported, used intensively and developed in the framework of a purposeful teaching unit. The view that an understanding of abstract spatial coherence is not yet developed sufficiently at primary school and remote areas could be reasonably covered from a developmental-psychological point of view first at secondary schools seems to be unreasonable (see Schmeinck, 2007a, p. 233).

Based on the present research figure 4 shows a suggested model for the development of spatial conceptions at primary-school level. The individual strands represent different areas, which are – in the context of the spiral curriculum – repeatedly taken up, extended and deepened.

Actual geographical proximity or distance cannot necessarily be equated with pupils' emotional and/or personal proximity or distance. For this reason, the organization of the areas cannot be exclusively bound to real geographical distances. The different areas must be defined individually in relation to the subjective experiences and conditions for learning of the children. Constant movement between areas and perspectives at increasingly complex levels is important for the development of spatial conceptions. Therefore teachers need to provide pupils repeatedly with experience of the different spatial dimensions and with perspectives other than their own. In order to enable an emotional and personal relation between the individual strands, it is crucial that new information always connects to pupils' already acquired knowledge and/or cognitive structures.

Besides the development of topographical knowledge and competences which allow orientation in the world, the development of spatial ideas described in the model comprises the ability to form critical opinions and the children's development into mature citizens. Therefore a positive attitude towards other people is important. The aim of the present examination – as well as those depicted in figure 4 – and of the framework of a spiral curriculum should be to develop spatial dimensions and the consciousness of the children with regard to their own relationship to the world.
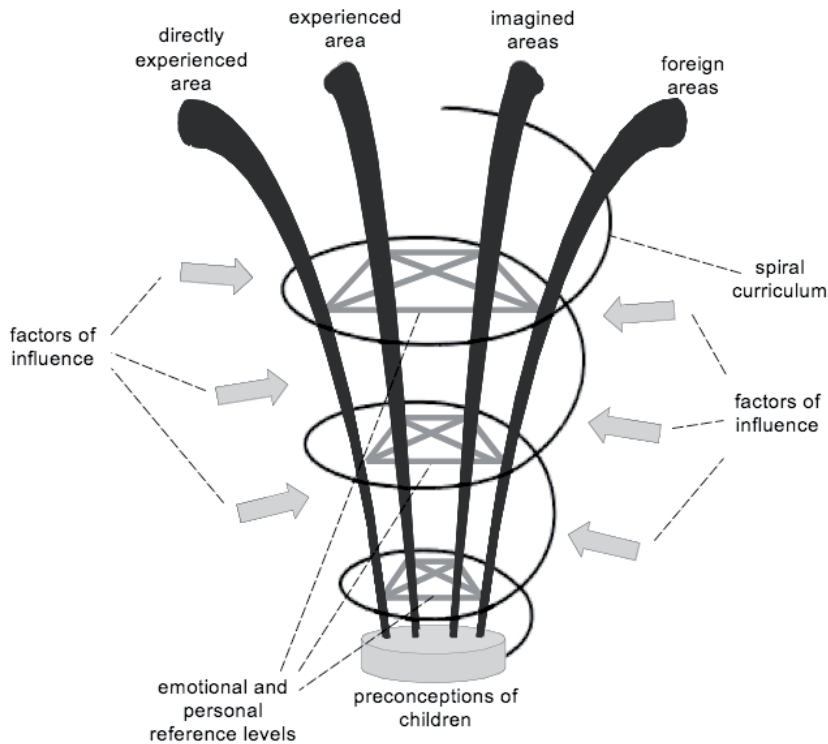
Figure 4: Model for the development of spatial conceptions in primary school (source: Schmeinck, 2007a, p. 237)

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PUPILS' UNDERSTANDING OF MAMMALS: AN INVESTIGATION OF THE COGNITIVE DIMENSION OF MISCONCEPTIONS

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Abstract: *The investigation of misconceptions among children is a favorite kind of investigation among researchers. It is possible to meet with the term "cognitive dimension of preconcept". Misconceptions about animals have been reported in various research reports on pupils of different ages. This cross-age study is focused on finding misconceptions about mammals among elementary-school children of various ages (from 10 to 15). A questionnaire consisting of 35 multiple choice and open-ended questions was used. This questionnaire was administered to 468 children from 6 elementary schools. We divided the questionnaire items into five categories according to their character. We focused on finding the differences in results between the gender and age of the respondents. We found numerous misconceptions across all age groups. Our study provides implications for teaching biology/science especially in the field of zoology.*

Key words*: misconceptions, mammals, pupils, questionnaire*

Introduction

Children come into schools with their own ideas/conceptions about the world. Children have developed conceptions about the natural world about them. They have experiences of what happens when they drop, push, pull or throw an object, and in this way they build up conceptions about the world around them (Driver, Squires, Rushworth, & Wood-Robinson, 2008). Some conceptions are correct and some are incorrect from a scientific point of view. The term "conception" denotes a mental representation of some features of the external world or of theoretical domains.In this paper we will present the results of research which has focused on the investigation of pupils' ideas about mammals. The research was carried out among elementary schools pupils aged between 10 and 15. Some of the children had been taught about animals and some had not. This is the reason why the investigation was of interest; as some children could be influenced by the surrounding world and some by using their knowledge base.

Theoretical background

Definitions of misconception

The conceptions could be divided into two groups: preconceptions and misconceptions. Preconceptions are those conceptions that result from informal experiences in everyday life, whereas misconceptions are misunderstandings that are induced through prior formal teaching (Duit, 1996). Many things play an important role in the preconception's creation, for example social, economic, and religious factors. This group is called exogenous factors. Also, we know of endogenous factors, which come from the individual psychological and biological characteristics of each individual. The preconceptions are structured in a very complex manner; they are not only knowledge and understanding (Richardson, 1999). Preconceptions have one important attribute; they are interactions with other preconceptions (Nicoll, Francisco, & Nakhleh, 2001).

Škoda and Doulík (2007) suggested on the basis of investigations the following characteristics of preconcepts. They used three descriptive categories:

1. cognitive dimension
2. affective dimension
3. conative dimension

For our purposes the most important is the first category, which is characterized by the content and extent. Every pupil has a founded cognitive level of concept, which is defined as the information's quality and quantity.

A very important thing is that children's preconceptions are stable. They persist even after meeting with facts which contradict the children's incorrect preconceptions. They do not start to diminish until after multiple occurrences of the situation in which the incorrect conception was not proved. The change from incorrect conception to correct conception happens very slowly.

Children obtain information through all senses. Every new experience contributes to the concept's creation via some concrete phenomenon or object. Children have the tendency to view objects/phenomena/situations only from their own view. This fact influences children's conceptions, because conceptions are represented by the experiences of children. Gradually children have an interest in the conceptions of other people. They have the need to share their own ideas with other people, mainly with those, who are in the close environment (Wenham, 1995).

Wenham's (1995) definitions of preconceptions are as follows:

- preconceptions working from experiences, not from imagination or fantasy,
- they are connected with a reality which was the basis for their creation, they are less applicable for other situations, but what is interesting is they are used as analogies for explanations of different phenomena
- preconceptions consist of a small amount of information which is necessary for the creation of complex explanations
- they are connected with specific situations and are therefore impossible to apply to similar situations

- preconceptions can be influenced by other information, not only that connected with one's own experiences
- preconceptions are expressed in a scientific way, but whose meaning is incorrect.

There are lots of definitions for what misconceptions are. We refer only to the information about misconceptions which is connected with our study.

Misconceptions refer to ideas formed as a result of the incorrect assimilation of formal models or theories. Misconceptions reflect situations in which students provide mistaken explanations of events on an intuitive basis and according to their daily experience, lacking any informal instruction. On the other hand, a misconceptions can be a situation in which, following formal instruction, students still do not understand a scientific idea and they provide a mistaken explanation (Driver & Easley, 1978).

Misconceptions are created by misunderstanding or wrongly understanding curriculum content. These things happen when a pupil is creating a symbiosis with a new curriculum content. Part of the knowledge from a new curriculum is understood correctly, part is connected to a previous preconception and part of the pupil's knowledge remains unchanged. This last part impedes future learning.

Vosniadou (1991) demonstrated the importance of prior knowledge in the acquisition of new information. The individual's ability to learn something new depends on the interaction between the information that currently exists in the knowledge base and the new information to be acquired. And when there are gaps in the knowledge base or when the prerequisite information has not been activated, the result is failure in communication and in learning.

Also, misconceptions could be created from one's own experience, incorrect articulation or from mistakes in a text (Betkowski, 1995). Through teaching or learning the interesting situation can occur that pupils receive a parallel understanding of phenomena or ideas. One understanding is for school and one is for everyday life (Gilbert, Osborne, & Fensham, 1982).

The next problem is when a pupil still believes their own preconceptions and does not accept the teacher's explanation (Minstrell & Smith, 1983). Similar reasons are denoted by Duit (1996). Firstly, teachers sometimes have inaccurate conceptions because they were not well-trained and are unfamiliar with their subject-matter area. Secondly, inaccurate ideas survived for generations because they were taken for granted and passed on, without any critique, from one generation of teachers to another. Lastly, students interpret what the teacher presents to them in a totally different way from the one the teacher intended.

The probing of misconceptions is not simple. There are two forms of diagnostic. First is the task of teacher. He comes across different forms of the pupils' understanding of the curriculum. The second comes from the pupil. He discovers if his understanding of the curriculum is correct. Teachers can use a pupil's work. A teacher can observe the procedure of a pupil's work. Teachers can investigate a pupil's outlines, drawings, written records, calculations etc.

Hewson (1981) created a set of principles which could be used in the misconceptions' elimination process. The principles are as follow:
1. The teacher must introduce a contradiction with the original idea in the mind of the pupil. The pupil must be made aware that his original idea was wrong.
2. The new theme must be clear and comprehensible for the pupil. The pupil must understand the curriculum in order to be able to think about it.
3. The explanation of the curriculum must be believable, plausible and acceptable for the pupil. When these conditions are fulfilled, there is the presumption that the pupil will start to accept new ideas.
4. The new curriculum must be useful and usable for pupils. The new information must be better for the pupil for problem solution.

Lazarowitz and Lieb (2005) stipulate that meaningful learning will occur when a new concept to be learnt will be integrated with the relevant ideas and concepts which had previously been learned. Students have to integrate new ideas or a new concept into their existing cognitive structure. Without this integration, rote learning will take place, the memory will be short lasting and transfer skills will not be mastered.

Misconceptions have some important characteristics: they are found in males and females of all ages, abilities, social classes and cultures; they are often resistant to conventional teaching approaches; they interact with knowledge presented by teacher; they resemble the ideas of previous generations of natural philosophers; they serve a useful function in the everyday lives of people; they are the product of direct observation, everyday language, the mass media and peer culture and they are found frequently among teachers as well as students (Mintzes, 2003).

Research in the field of misconceptions

Nowadays there is a lot of research connected with misconceptions in zoology. The study which focused on the investigation of misconceptions about mammals was by Kubiatko and Prokop (2007). The authors were focused on finding misconceptions in age related differences in knowledge of mammals. Other studies are oriented towards the classification of animals, a knowledge of the anatomical structure of animals, life cycles of insects etc. For example Shepardson (1997) found problems with the determination of insect life cycles. Similar research by Tamir, Gal-Chappin and Nussnovitz (1981) focused on life cycles, but in this case on butterflies. They found pupils had the correct ideas about life cycles, but pupils believed that a pupa was dead, when it was without any manifestation of movement. Barrow (2002) investigated pupils' ideas about insects. The author found several misconceptions. For example pupils drew an internal skeleton for an insect. Pupils knew only the adult phase of an insect's life cycle.

Other research has been aimed at finding the ability to differentiate between vertebrates and invertebrates. They found that when an animal has a head,

extremities and an external skeleton, it is a vertebrate. An external skeleton was assigned to vertebrates by 7- and 9 year-old pupils. A frequent feature with this group of pupils, which is related to vertebrates, is the occurrence of a carapace. This age group of children classified eels and snakes as invertebrates. The reason is that the body of these animals is able to twist (Braund, 1991; Ryman 1974 a, b; Trowbridge & Mintzes 1985).

Braund (1996) found in his research that pupils do not have a problem with the identification of large mammals like elephants as vertebrates. But pupils in his research have problems with the identification of birds. Many children consider birds to be invertebrates because they have light bodies and are able to fly.

Tunnicliffe et al. (2008) found an ability to classify animals at kindergarten age and the first year of compulsory education for children. The percentage of children able to classify animals corresponded corrrectly with age. Kindergarten children had problems in classifying spiders, dolphins and ladybirds. More than half of the children wrote that they were not animals. It is interesting that the authors discovered that pupils thought that the dolphin was not an animal but a fish. This finding is connected with the work of Carey (1985) that marine life is isolated and distinguished from the other animals because their natural habitat is in the sea.

Similar research was carried out by Braund (1991) into the classification of vertebrates and invertebrates. The highest level of response for "vertebrate" occurs for animals with a well defined head and limbs or having a body that is rigid. This feature of rigidity is also more often referred to by younger pupils. The association with invertebrate is strongest for those instances lacking appendages (snail and earthworm). In Braund's study, penguins are often misclassified as mammals while some pupils identified a penguin as a fish. The justifications used by younger children for classifying the penguin as a mammal are split between body covering, viviparity, and homoithermy.

Kattmann (2001) found that classifying animals by habitat was the most common for pupils from all grades of study. The second significant criterion was the different types of locomotion. Morphological and anatomical criteria played a minor role in the classification of animals.

Randler et al. (2007) found an increase in knowledge about animals with the age of respondents, but in their research there was no significant difference in results between genders.

Yen et al. (2004) showed that pupils and students had problems with amphibians and reptiles in their research. The turtle was classified as an amphibian by a significant percentage of students; the reason was due to its aquatic and terrestrial habits. A crocodile was considered to be an amphibian too by students of all age levels. This misconception was due to students' perceptions of the external morphological features of crocodiles, especially segmentation, body covering and appendages. Some vertebrates were classified as invertebrates because they lack obvious external segmentation and limbs.

Methods

Purpose of study

This study investigates of pupils' misconceptions about mammals. In the strict meaning our investigation could be classified as an investigation of the cognitive dimension of preconceptions according to Škoda and Doulík (2007), but we were inspired by science articles focused on this area of research which were written in English. The pupil verifies a cognitive level of the preconcept with their own view and with the adjusted level of a pupil's knowledge and understanding. It means that the cognitive dimension of preconcepts can include incorrect information. Diagnostic tools have to be able to discover these incorrect ideas. A similar study focusing on the influence of age on pupils' knowledge about mammals has already been published (Kubiatko & Prokop, 2007), so the main aim is to focus on finding differences between gender in pupils' knowledge of mammals. The aims of our study were as follows: What are pupils' ideas about mammals in elementary school[18]? How much do children's ideas about mammals change from fifth to ninth grade? Are there any gender differences in ideas about mammals?

The instrument

The measurement tool consists of 35 open-ended and multiple-choice items. In open-ended items we expected one word answer or short sentences. Only in the question "Why do beavers gnaw trees?" did we expect a relatively longer answer in comparison with the others. Not all of the multiple-choice questions had the same number of possibilities. The number of possibilities were from two to five. Only one possibility was correct. Before the administration of the questionnaire, it was checked by experts in zoology (two professors of zoology from different universities) and two biology teachers. Questions in the questionnaire were divided into five categories, namely: 1. Animal classification and phylogeny; 2. Food; 3. Foraging strategies; 4. Parental care; 5. Senses, morphology and anatomy. The answers were binary coded. Incorrect answers were marked by the number 0 and correct answers by the number 1. The questionnaire included demographic variables like gender, class and age. The time for filling in the questionnaire was no longer than 30 minutes. The full version of the questionnaire can be provided by the authors on demand.

Participants

We obtained 468 completely filled questionnaires from pupils of six typical elementary schools in Slovakia. All grades were included in the investigation. The numbers of grades were as followes 5th grade (n = 83), 6th grade (n = 86), 7th grade (n = 112), 8th grade (n = 86) and 9th grade (n = 101). The age of pupils varied

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18 According to ISCED – lower secondary education.

from 10 to 15 (n = 468; X = 12.62; SD = 1.47).

The number of boys (n = 229) and number of girls (n = 239) was similar.

Statistical procedure

After recoding the obtained data, we evaluated the items of the questionnaire by percentage. Then we calculated the average and standard deviation and summary score for each dimension. For finding the differences in results between genders we used the Pearson chi-square test (χ^2) and the MANCOVA test. We presented the differences among grades in our previous study, and therefore, did not explore this in this study. Our focus was on presenting pupils' interesting ideas about mammals and showing the results between genders. On the measure of reliability of the questionnaire, Cronbach's alpha calculation was used. The values of Cronbach's alpha close around 0.7 or higher, which generally indicate that results are consistent (Nunnaly 1978).

Results

Statistical evaluation of categories

Based on the distribution of correct and incorrect responses, we found out the maximum number of points acquired from the questionnaire was 34 and the minimum was 8. The average score was 22.84 (n = 468; SD = 4.22). The value of Cronbach's alpha was α = 0.67. This value indicates that the questionnaire marginally reaches the appropriate reliability.

The descriptive statistic for the mean success that pupils acquired from the questionnaire is shown in Table 1.

Table 1: Basic statistics of questionnaire categories

Categories	Number of questions	N	X	%	SD
Animal classification and phylogeny	9	468	5.66	62.89	1.64
Food	9	468	6.46	71.78	1.45
Foraging strategies	3	468	2.01	67.00	0.77
Parental care	4	468	2.49	62.25	1.01
Senses, morphology and anatomy	10	468	6.61	66.10	1.44

N – number of respondents
X – average number of points
SD – standard deviation

The highest average score was found for the category "Food". Only in this category was there found a percentage success higher than 70 %. The lowest score achieved was in the category "Parental care", where the percentage success was 62.25 %.

We found pupils of the 8th grade achieved the highest average score in animal classification and phylogeny; parental care and foraging strategies dimensions. Pupils of the 7th grade achieved the highest average score in the two remaining categories. A statistically significant difference in the results between the ages of students was found in the following categories: Animal classification and phylogeny; Food and Parental care. More detailed information about the influence of age on misconceptions about mammals is in our previous study (Kubiatko & Prokop, 2007).

We focused on the differences in results between genders. For this we used the MANCOVA test. Gender was used as an independent variable, the category results as dependent variables and age as a covariate. The total influence of age on results was not statistically significant ($F = 1.54$; $p = 0.17$; Wilks' $\lambda = 0.98$) and we found out statistically significant differences in results between gender ($F = 7.41$; $p < 0.001$; Wilks' $\lambda = 0.93$). A more detailed view of results shows that in some categories there was no statistically significant difference in results (foraging strategies and senses, morphology and anatomy) between genders and in one category the influence of age on results was significant, specifically in parental care (table 2).

Table 2: Detailed results of a multivariate analysis of covariance (MANCOVA)

Categories	F(gender)	F(age)
Animal classification and phylogeny	**14.94***	1.78
Food	**5.18***	2.42
Foraging strategies	1.68	0.59
Parental care	10.73**	4.64*
Senses, morphology and anatomy	1.78	0.00

* statistically significant difference $p < 0.05$
** statistically significant difference $p < 0.01$
*** statistically significant difference $p < 0.001$

Gender differences

In figure 1 we are able to see that boys achieved higher scores in almost all categories. Only in the last category named "Senses, morphology and anatomy" did girls achieve a higher average score in comparison with boys. A statistically significant difference in results between genders by the use of the Pearson chi-square test in the items was found only in four items. In all four categories girls achieved a higher score than boys. Two of them belong to the category "Food". In

the first we asked pupils what was the dominant component of hedgehogs' food. We found a statistically significant difference in the results between genders ($\chi^2 =$ 8.86; $p < 0.01$). The total number of correct answers was relatively high - 81.84 % of all answers were correct, whereby pupils wrote down that a hedgehog's food included worms, snails, etc. In the next question, belonging to the category "Food", we were interested in why beavers gnawed trees. We expected the main reason to be the building of barriers, a source of food, teeth corrosion. We found that 90 % of all answers were correct and we found a statistically significant difference in the results between genders ($\chi^2 = 4.07$; $p < 0.05$). The next statistically significant difference in the results was found in the item relating to the flying squirrel. We wanted to know how well pupils would be able to identify this animal; the possibilities were a mammal, a bird and an amphibian. Only 42.95 % wrote the correct answer that the flying squirrel was a mammal, and the majority of incorrect answers was that a flying squirrel was a bird. A statistically significant difference in the results was with the girls ($\chi^2 = 6.22$; $p < 0.05$). In the item where we asked, which of following animals: a whale; a penguin; a flying squirrel, does not belong among the mammals, we found a statistically significant difference in the results between genders ($\chi^2 = 4.15$; $p < 0.05$). The penguin was correctly identified as the animal which belongs to another group of animals by only 32.91 % of respondents. The majority of incorrect answers were assigned to the flying squirrel. These two items belong to the category "Animal classification and phylogeny".
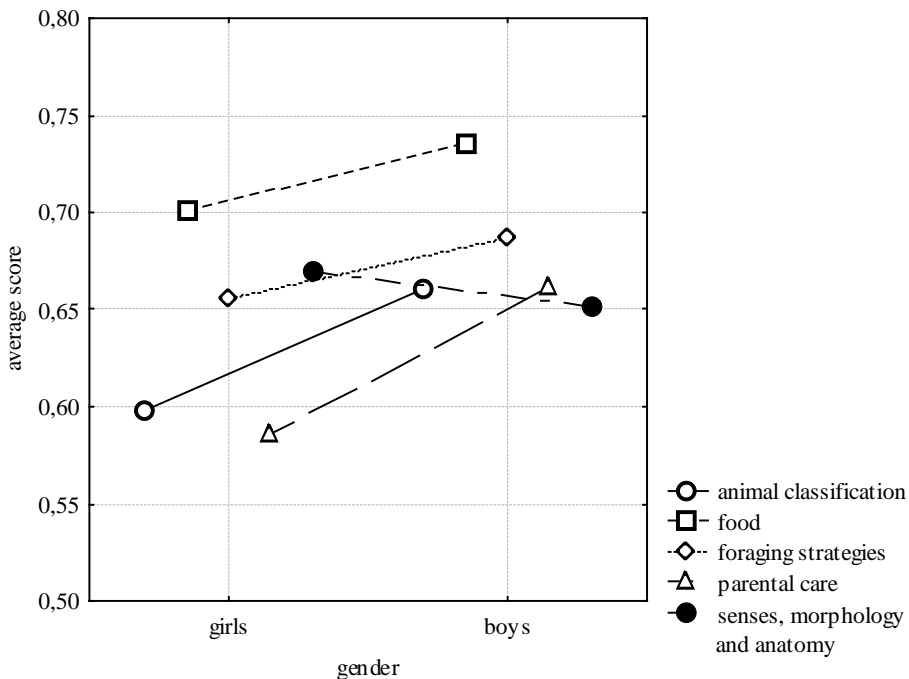

Figure 1: Average score of dimensions

The most problematic questions

When we focused on the responses of some items in the separate categories, we observed some interesting results. In the first category, respondents had problems with the identification of animals relating to dinosaurs. Only 40.69 % of all respondents wrote the correct answer that birds are most closely related to dinosaurs. The majority of pupils (50.85 %) considered mammoths for the animals as being most closely related to dinosaurs. Children had problems with the name of a female deer, 48.93 % of all children named a female deer correctly – a hind. The most quoted incorrect answer was doe (female roe deer) – 42.74 %.

In the category "Food", respondents had considerable problems with the food of wild boars. Only 21.58 % of pupils gave the correct answer that wild boars are omnivores. We found a spectrum of incorrect answers, for example wild boars are herbivore animals or they feed on acorns, potatoes or roots of plants. Pupils had fewer problems with the food of whales' young. Approximately half of respondents answered correctly that the young of whales suckle milk and a similar number of pupils wrote plankton as a source of food.

In the category "Foraging strategies", pupils had problems with how lions hunt. Less than half of respondents wrote that lions hunt in groups, which is the correct answer. The majority of pupils thought that lions hunt prey alone by stalking. The next question, which belongs in this area, was similar to the previous one. We asked about the typical behavior of a lynx when hunting. Approximately 2/3 answered correctly. The lynx grab the prey from behind. According to 1/3 of children, the lynx hunts prey alone by stalking. Pupils did not have problems with identifying animals which hunt in groups. From the following possibilities: a fox, a lynx, a wolf, a bear, 90.60 % correctly marked a wolf.

In the category "Parental care", pupils had the biggest problem with who takes care of a deer's young. More than half of children wrote the female, which is the correct answer. But 41.88 % showed both parents. There were problems with a similar question when we asked about a wolf's parental care, where 56.84 % of children wrote both parents take care of the young. It was the correct answer, but the majority of incorrect (37.61 %) answers attributed this task to the female wolf.

In the last category pupils had problems with the reason for brown bears hibernating. Only approximately half of respondents wrote correctly that it is due to lack of food. Other responses, which were incorrect, of course, were different. Pupils wrote down cold, exhaustion, because it has to, as reasons for brown bears hibernating. The next problem item was to answer how a horse steps when it is walking. The horse steps on the last phalanxes of the hoofs was the answer of 39.10 %, which was correct, but the majority answered incorrectly, that the the horse steps when walking on the whole hoof. Pupils did not have the right idea about how dolphins breathe. Approximately 1/3 showed that dolphins breathe through lungs. The incorrect answers were distributed among branchias, lung sacks and air sacks. The biggest problems pupils had with camels was specifically with the contents of the camel's hump. Only 19.66 % of all pupils wrote that there is fat

in the hump, while others wrote that the hump contains water, which is a typical misconception.

Discussion

This study was concerned with finding misconceptions among pupils about mammals. The term misconception is generally used in scientific literature, but sometimes this term is substituted by the "cognitive dimension of preconcept" (Škoda & Doulík, 2007). And we are able to confirm that elementary pupils had serious problems with several mammals. In our previous study we focused on class differences in results (Kubiatko & Prokop, 2007).

We found that pupils of the 8th grade achieved the highest average score in animal classification and phylogeny; parental care and foraging strategies dimensions. Pupils of the 7th grade achieved the highest average score in the two remaining areas. Young children's biological knowledge is significantly affected by early experiences with live organisms or with themselves (Jaakkola & Slaughter, 2002). A statistically significant difference in the results between ages of students was found in these categories: Animal classification and phylogeny; Food and Parental care. In this study we focused on finding significant differences in results between genders.

We divided the items in the questionnaire into five different categories according to the character of items as follows: 1. Animal classification and phylogeny; 2. Food; 3. Foraging strategies; 4. Parental care; 5. Senses, morphology and anatomy. We found a statistically significant difference in the results between genders without an age influence. In summary, boys achieved higher score than girls. Only in the category Senses, morphology and anatomy did girls achieve higher score than boys.

By a detailed analyses the influence of age was presented in the category "Parental care" and no statistically significant difference was found in the two categories: "Foraging strategies" and "Senses, morphology and anatomy". Similarly statistically significant results between genders can be observed in studies of a similar nature (Randler, 2008).

A more detailed analyses showed us that pupils have problems in identifying mammals. There were problems with the identification of the flying squirrel. The majority of children mistook this kind of mammal for a bird. This finding confirmed the findings of other authors that use the criterion of locomotion for the classification of animals (Markham, Mintzes, & Jones, 1994).

In the studies which were concerned with the concept of animal the investigators were interested in the scientific meaning of the term. Students developed their own categories. Students' reasons for the classification or characterization of an organism as an animal were found to be that of distinguishing between mammals and other "creatures". Students used criteria like a habitat, or locomotion, or number of legs (Bell, 1981; Tema, 1989). The influence of habitat was presented by the questions about classifying whales, platypus or mammoths.

The children in our research had problems with the dolphin. Only one third of pupils knew that the dolphin breathes through lungs. There is the influence of habitat in identifying animals. Tunnicliffe et al. (2008), have had similar findings – In their investigation a number of children recognized the dolphin as an animal, but many respondents classified the dolphin as a fish, not an animal. This conception may have arisen from the teaching about fish in a separate context from being members of the animal kingdom (Tunnicliffe et al., 2008). Our respondents had problems with the contents of a camel's hump, where only 1/5 answered correctly that it is fat. Other pupils wrote water.

Pupils had problems with the foraging strategies question. The lowest problems they had were with animals which live in Slovakia (wolf, lynx) in comparison to animals which live in another continent (lion). Some pupils had problems with the reason for brown bears hibernating, hedgehogs' food, whales' youngs' food etc.

Many of these misconceptions are created in the preschool age of pupils. These mistakes are often created from pictures in book, from tales which are read by parents to their children. There is no problem to find a picture of fruit on a hedgehog's spines. Or we can read about a camel which crossed the Sahara because it had water in its hump. All tales about brown bears contain information that the brown bear must sleep all winter because it is cold outside with snow and frost, and halfway through winter the brown bear turns its body round on the other side. Children are influenced too much by incorrect information, which can arise from different media.

Tunnicliffe and Reiss (1999) found home to be one of the most important sources of information about animals for elementary aged children. Children interpret the world and physical phenomena for themselves and hold various representations of the world. Sources of animal knowledge apart from previous learning at school are out-of-school activities in terms of informal, free-choice learning which influences learning about animals. Such informal learning takes place in zoos, museums, parks and aquariums (Falk, 2005).

Solomon (1987) points out that a greater amount of information is culled from the media in an incidental, unintentional, casual fashion, where there is exposure to information through watching television programmes. Watching TV programs about animals and nature received almost a similar proportion compared to learning about animals in school (Bjerke, Kaltenborn, & Ødegardstuen, 2001).

Conclusion

In our research we focused on the investigation of pupils' understanding of animals, namely mammals. We found a statistically significant difference in the results between genders and evaluated items focused on finding which questions cause the biggest problems for students. We found several misconceptions in all of the categories. On the basis of these results we could suggest some educational recommendations:

- use more pictures in the teaching process because textbooks are predominately text-based as opposed to having photographs
- focus on atypical kinds of mammals (whales, bats, platypus) and bring attention to their attributes, why these kinds of mammals are classified as mammals
- the visual part of the teaching process is very important, children should be in contact with nature as often as possible.
- teach more about exotic mammals – due to children's better ability to picture mammals, show that in other countries there are mammals which may be different to Slovakian ones
- try to connect the present time with phylogenetic development, not only to teach about animals today, but also about extinct mammals
- since a knowledge deficiency within issues seems to continue throughout various educational levels, it makes good sense to develop appropriate techniques that help the students to improve their understanding of the curriculum (Bozkurt et al., 2005).

We believe that our study gives new information for the investigation of misconceptions and will help pedagogical workers in the teaching process.

Acknowledgement

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LESSON STRUCTURE IN DIFFERENT SCHOOL SUBJECTS IN THE CZECH REPUBLIC

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Abstract: *The paper presents the results of an analysis that was carried out within the CPV Video Study research project. It aimed to investigate differences in lesson structure in the every-day teaching of different school subjects in Czech lower-secondary schools. Video recordings of 249 lessons of physics, geography, English and physical education were analysed with respect to two dimensions: the organisation of classroom activities and the nature of the content. The findings show that there are manifest differences in teaching in the school subjects analysed. In classroom organisation, teacher-centeredness was found to be significantly greater in English than in geography and physical education. Concerning the purpose of lesson segments, the focus lay on developing new content in geography but on practicing the content in English and on applying the content in new situations in physics. Due to methodological limits inherent in the approach used, these findings must be interpreted with caution.*

Key words: *video study, lesson structure, learning and instruction, lesson signature, classroom research*

Introduction

Formal education in different academic disciplines has been shown to produce different effects on everyday reasoning. Lehman, Lempert and Nisbett (1988) investigated the effects on reasoning of graduate training in different disciplines. They found that training in psychology and medicine (representing probabilistic sciences) had a positive effect on statistical, methodological and conditional reasoning about problems of everyday life, while training in chemistry (representing deterministic sciences) did not seem to affect any of these kinds of reasoning.

If academic disciplines indeed require and therefore enhance different ways of reasoning then it is only reasonable to expect these different ways of reasoning to be reflected in the school subjects that represent these disciplines in schools. Stodolsky (1988) noted that "it is likely that certain types of knowledge and goals are associated (or even require) particular instructional approaches" (p. 4). She claims that school subjects differ from each other in perceived or inherent sequentiality, in their scope and coherence, and in their status within the school and larger community. Mathematics, for example, being a structured and sequential

discipline, is also – unlike many others – a highly structured and sequential school subject. She found evidence that *how* teachers taught depended on *what* they were teaching.

This paper presents the results of a video-based analysis of how teaching differs in different school subjects in Czech lower-secondary schools.

Theoretical background – Lesson structure

We see school subjects as complex phenomena the natures of which reflect the natures of their parent academic disciplines. We claim that differences between academic disciplines influence not only what is taught within the respective school subjects but in particular how teaching is organised. We seek to understand the aspects of teaching that are common to the whole range of subjects in the curriculum (domain-general aspects) as well as those that are specific to each school subject (domain-specific aspects).

Towards the end of the 20th century, many researchers began to abandon the strictly behaviourist perspective of concentrating on the form of instruction. Rather, they sought a balance between the form and the content of what happens in the classroom, investigating both of these dimensions (e.g. Kuusinen, 1991); the resulting analyses built on the concepts of *teaching patterns, teaching scripts, lesson patterns* or *lesson structure*. What is implicitly inherent in different approaches summarised below is that it is by analysing the structures of lessons that we come to understand the patterns of teaching.

Recent attempts to capture the complexity of classroom processes tend to focus among others on two distinct observable dimensions: 1) the way teaching is organised and 2) the nature of content being processed. Pointing out the complex nature of classroom processes, Průcha (1989) investigated 82 lessons taught in Czech lower-secondary schools with respect to a number of aspects of teaching. He measured the time pupils spent working individually to find great variability among the classes investigated (41% – 73%). To illustrate the findings concerning various temporal aspects of lessons, Průcha introduced the so-called lesson profile to summarise individual lessons. He also focused on the *kinds* of content processed, distinguishing *old content* (i.e. content introduced in previous lessons) and *new content* (i.e. content introduced in the particular lesson). He found that in regular basic schools 42% – 45% of lesson time was dedicated to *old content* while 21% – 28% of lesson time was spent on *new content*.

Hiebert, Stigler and their colleagues advocated a range of concepts at the turn of the century, from *lesson scripts* via *lesson patterns* to *lesson signatures* (Clarke et al., 2006c). The TIMSS 1999 Video Study, within which an international comparison of teaching was carried out, considered *structure of the lesson* as concept that comprised the coincidences of lesson length, time spent studying mathematics/science, role of mathematical/science problems and two important dimensions: grouping (whole-class, independent activities) and instructional purpose of

lesson segments (reviewing old material, introducing new material, practising new material) (Roth et al., 2006; Hiebert et al., 2003). The authors claimed that they identified significant culture-based differences in the structure of lessons between American, German and Japanese teaching scripts. In later work members of the team sought ways of quantifying these differences (Givvin, Hiebert, Jacobs, Hollingsworth, & Gallimore, 2005).

> "We focus on the purpose, classroom interaction, and content activity of lessons. Lessons were coded with respect to each of these three dimensions, and shifts were noted during the lesson sequence. This methodology allows us to examine the points in a given lesson when a particular feature had occurred and how many lessons exhibited this same pattern. We define the resulting 'pattern of teaching' as the duration and sequence of particular kinds of activities and events during daily classroom lessons" (Givvin et al., 2005, p. 316).

Some researchers however thought that this approach to international comparison was flawed in some respects. Clarke et al. (2006c) rejected the identification of nationality with culture and argued that variations within the teaching of individual teachers and within individual lessons make it very difficult for general patterns of teaching to emerge unless further aspects are addressed, such as the location of the lesson within the instructional sequence of topics, the independence of the dimensions of lesson structure and greater sensitivity in defining analytical categories. Moreover, the purpose of the comparison ought to be inspiration rather than evaluation.

Other researchers build on the approaches inherent in TIMSS Video Studies, often carrying out other large-scale video-based surveys of classroom practices. Within the IPN Video Study, for example, the stability of teaching patterns in teaching physics was investigated (Seidel & Prenzel, 2006). The authors considered three dimensions within a teaching pattern: 1) organisation of classroom activities (as an example of sight structures), 2) quality of teacher-student interaction, and 3) the students' perception of supportive learning conditions.

Building on these approaches, attempts have been made to justify the concept of teaching patterns by analysing the effects of particular teaching patterns on student achievement. Hugener et al. (2009) pose a question as to whether teaching patterns follow geographical boundaries or whether they are part of what they refer to as *pedagogical cultures of teaching*, which are independent of country boundaries.

However, analysis of teaching patterns – especially those based on video studies – have been so far carried out almost exclusively in mathematics and natural sciences (physics) classrooms. We feel that in order to develop the concept of teaching patterns, a wider perspective should be introduced. This paper draws on those analyses carried out within the *CPV Video Study* project that were aimed on the similarities and differences in lesson structure (in the sight structures) in different school subjects (physics, geography, English as a second language and physical education). In these analyses, lesson structure was considered as comprising two

main dimensions: 1) organisation of classroom activities and 2) the purpose of lesson segments with respect to the content.

Research aims, design and methods

The aim of the study presented here is to identify similarities and differences in lesson structure across the four school subjects analysed. The data presented here was gathered within the CPV Video Study project, which aimed primarily to document and describe the teaching of four school subjects – physics, geography, English as a second language and physical education – as taught in Czech lower-secondary classrooms. It also aimed to develop our understanding of the nature of similarities and differences in the teaching of different school subjects. Between 2004 and 2009, the Educational Research Centre (Centrum pedagogického výzkumu – hence CPV) at the Faculty of Education, Masaryk University carried out the *CPV Video Study of Physics*, *CPV Video Study of Geography*, *CPV Video Study of English* and *CPV Video Study of Physical Education* (Figure 1).
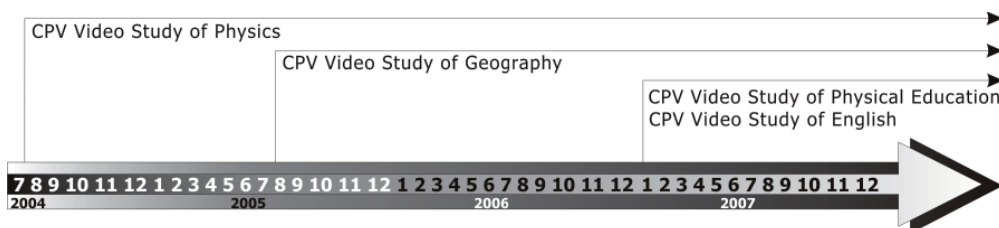
Figure 1: the CPV Video Study time line

CPV Video Study projects employ the video study approach to capture the complexity of teaching and learning processes in a classroom context. With recent advances in technology that have brought new ways of collecting, storing, managing and analysing data, video has become a powerful tool in large-scale classroom research (Ulewicz & Beatty, 2001; Najvar et al., 2009). The large-scale video study approach was introduced to a wider audience in the TIMSS 1995 and 1999 video studies (Stigler et al., 1999; Hiebert et al., 2003; Roth et al., 2006), which sought to analyse teaching practices in mathematics and science in different countries. A number of further research projects based on video studies followed – notably in the field of mathematics and science education (Seidel & Prenzel, 2006; Clarke, 2006ab; Klette, 2007; Labudde et al., 2007; for a review see Janík, Seidel, & Najvar, 2009).

To carry out analyses of such complex phenomena as classroom processes, the video study approach seems suitable and appropriate. Jacobs et al. (1999) show the advantages of using video data as opposed to direct observation techniques, especially when combining qualitative and quantitative approaches. The main advantage of video data over other types of data lies in the cyclic nature of analysis. While the conventional research is linear in nature, video data allow for cyclic

reanalyses, the reformulating of objectives and the applying of new codes which build on previous analyses (cf. Najvar et al., 2009).

In order to compare selected aspects of teaching in four different school subjects (physics, geography, English and physical education), an expert group was established, with one expert representing each school subject under analysis. Negotiations within the expert group were based on the observing of lessons in the four subjects and led to the establishing of a shared language to describe the phenomena observed. Only after a consensus on a particular aspect of teaching was reached could comparative analyses be carried out. The key principle that guided the work of the expert group was the combining of the comparative and the multi-perspective approaches (Najvar et al., 2009). The purpose of the negotiations was to describe, explain and justify inter-subject similarities and differences that occurred as results of the analyses (Figure 2).
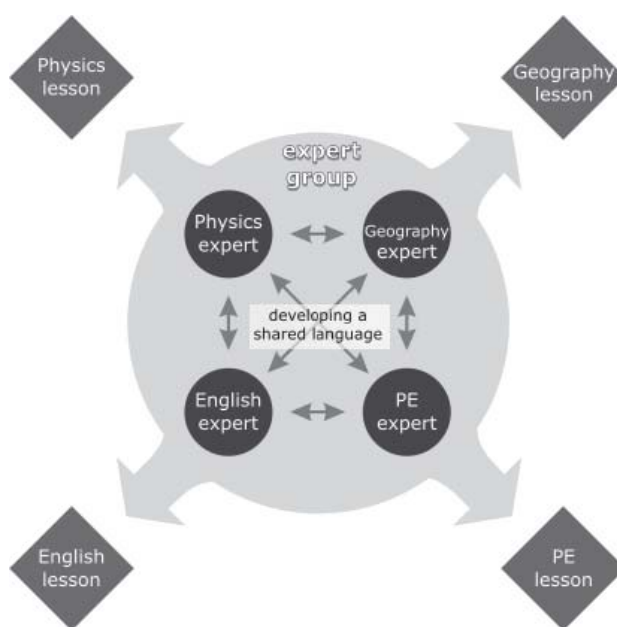
Figure 2: CPV Video Study Expert Group

Sample and data collecting

The research sample comprised a total of 249 video recordings of lessons taught in lower-secondary schools between 2004 and 2007. 62 lessons of physics were video-recorded in the school year 2004/05; these were taught by 13 teachers in Brno, Czech Republic who volunteered to participate in the *CPV Video Study of Physics* project. 50 lessons of geography were recorded in the school year 2005/06 taught by 6 teachers in Brno, Czech Republic who volunteered to participate in the *CPV Video Study of Geography* project. 79 lessons of English as a foreign language (taught by 25 teachers) and 58 lessons of physical education (taught by 20 teachers)

were video recorded in the school year 2006/07 in 21 randomly selected schools in the Jihomoravský, Zlínský and Olomoucký regions of the Czech Republic within the *CPV Video Study of English* and *CPV Video Study of Physical Education* respectively.

Employing experience obtained from the TIMSS and IPN video studies (Jacobs et al., 2003; Seidel et al., 2005), the lessons were taped using the standardized two-camera procedure. One camera (trained on the pupils) was placed on a tripod next to the board, so as to record what was happening in the classroom as a whole. The other camera (trained on the teacher) was operated by a trained cameraman, and it recorded the teacher and the zone of his/her close interaction with the pupils.

In the next step, video recordings were transcribed using Videograph software (Rimmele, 2002) according to standardized procedures (Seidel, Prenzel, & Kobarg, 2005). Various coding procedures developed in the Leibniz Institute for Science Education (IPN) at the University of Kiel in Germany (Seidel et al., 2005) were adopted and used to analyse the video recordings (Janík & Miková, 2006). The observation schemes relevant for the present analysis covered two areas: a) modes of classroom organisation; b) purpose of lesson segments. Video coding was carried out by trained coders on the basis of time sampling (analysis unit = 10 sec). Inter-coder reliability (Cohen's Kappa: Min = 0,6; Max = 1,00; percent direct observer consistency: Min = 71%; Max = 100%) met international standards.

System of categories – organization of classroom activities

Modes of classroom organisation are an important element in the organisational structure of the lesson. They represent an organisational framework within which the activities of the teacher and pupils take place with regard to the teaching goals. The responsibility for some organisational aspects of dealing with the content (such as pacing) may rest with the teacher or may be distributed differently. Wragg (1995) notes that "*if the class is being taught as a whole, then the teacher can take direct control over the speed at which material is covered; … when individuals and groups are working separately, the determination of pace is to some extent in the hands of the children themselves, and the teacher's role changes*" (Wragg, 1995, p. 209). Different classroom settings therefore provide different learning opportunities for students.

For the coding of organisation of classroom activities, a coding system introduced by Seidel, Prenzel, and Kobarg (2005) was adopted (Janík & Miková, 2006). For the purposes of the present analysis, four modes of classroom organisation were considered[19] (see Table 1).

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19 Other modes were coded (such as *more modes at the same time, transition, other*) but they were infrequent.

Table 1: Categories of organisation of classroom activities (P-C: pupil-centred; T-C: teacher-centred)

T-C	***lecturing by the teacher***	the teacher talked, dictated or demonstrated to the class
	teacher-class discussion	the teacher spoke with individual pupils in a whole-class setting
P-C	***individual work***	the pupils worked on a given task individually
	group work	the pupils worked on a given task in pairs or in groups

For the purposes of further analyses, lesson segments coded in the *lecturing by the teacher* and *teacher-class discussion* categories were sometimes referred to as *teacher-centred* lesson segments; segments coded in the *individual work* and *group work* were sometimes referred to as *pupil-centred* segments. This distinction reflects the distribution of responsibility for the speed at which material is covered.

System of categories – purpose of lesson segments

Different lesson segments are used by the teacher for different purposes (Hiebert et al., 2003, p. 49). In the TIMSS 1999 Video Study, three such purposes were distinguished: reviewing, introducing new content and practising new content. We think that such a set of distinctions fails to include one important purpose which teachers may have in mind and which aims to support pupils' learning in the cognitive as well as metacognitive dimensions. For the purposes of the present analysis, we therefore considered four categories of lesson segment purpose (see Table 2).

Table 2: Categories of lesson segment purpose

reviewing	included lesson segments in which content was reviewed which had been introduced in previous lessons; the aim was very often for the pupils to recall factual information
developing new content	comprised lesson segments in which new content was introduced, developed as well as motivational lesson segments
summarising	comprised lesson segment in which new content was summarised in an organised manner, often using summarising dictation or visual aids (e.g. the over-head projector)
practising	comprised lesson segments in which content was practiced, strengthened, intensified or applied to new contexts, and lesson segments devoted to testing

The original coding system that had nine categories and was based on a system for coding lesson phases introduced by Seidel et al. (2005) was later adopted by Janík and Miková (2006) for the purposes of the *CPV Video Study*. It distinguished for example two types of summarising: that of content, and that of the learning process. For the present analysis, these data were aggregated.

Findings

Below, the average percentages of 1) organisation of classroom activities and 2) purpose of lesson segments are given in overview. Lesson signatures are then composed for each of the school subjects under analysis.

Organization of classroom activities

For the purpose of presenting the results, the average percentages of the categories were calculated[20] for each subject and juxtaposed in stacked column graphs (Figure 3).
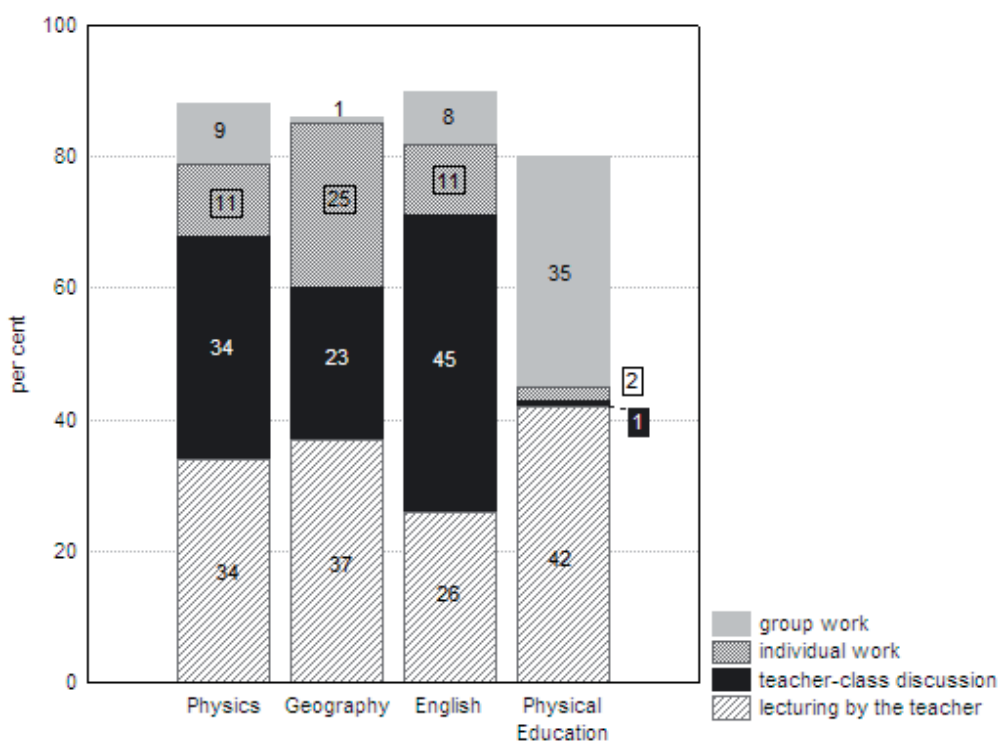

Figure 3: Organisation of classroom activities in the CPV Video Study

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Comparisons such as the one presented here help reveal similarities and differences in everyday teaching practices in different subjects. The analysis of organisation of classroom activities presented produced some expected findings, such as that which indicates that teacher-pupil discussion is rare in physical education while it is an important component of the teaching of English as a second language. Nevertheless other findings suggest more subtle differences, such as that which indicates that in geography, emphasis is laid on individual work – with maps and atlases, as other analyses show – whereas in the other school subjects, a group work setting is regularly introduced. There is the suggestion that physical education is exceptional in the sense that it provides pupils with significantly more time to work independently of the teacher than the other school subjects. The degree of teacher-centeredness found in English lessons was significantly higher than in physical education and also in geography lessons.

The purpose of lesson segments

For the purpose of visualising the findings, the average percentages of the categories presented above were calculated[21] for each subject and juxtaposed in stacked column graphs (Figure 4).
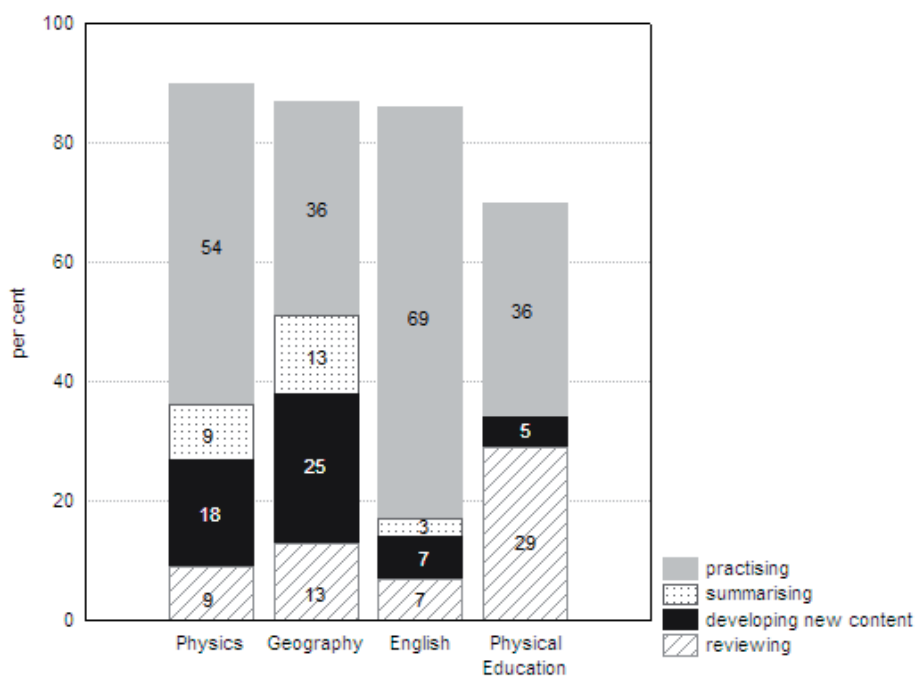

Figure 4: The purpose of lesson segments in the four school subjects

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21 All differences proved statistically significant for p ≤ .05; the Bonferroni test was used to determine the significance.

The results show (Figure 4) that different purposes are given different emphases in the school subjects under analysis. In geography and also in physics, a greater emphasis is laid on introducing and developing new content than is the case in English or physical education, whereas practising is the dominant purpose in English lessons.

Lesson signature: a complex view on the lesson structure

In an effort to illuminate the lesson structure typical of each of the school subjects under analysis, coincidences of the two dimensions of lesson structure were examined. Studying the coincidences of modes of classroom organisation and the purposes of lesson segments makes it possible to identify similarities and differences between the structures of lessons as they appear in every-day teaching across different school subjects. Overlaying the analysed lesson features of all the lessons of the school subjects on a timeline, lesson signatures (cf. Dalehefte et al., 2009; Hiebert et al., 2003) were acquired for the individual school subjects (Figures 5 to 8).
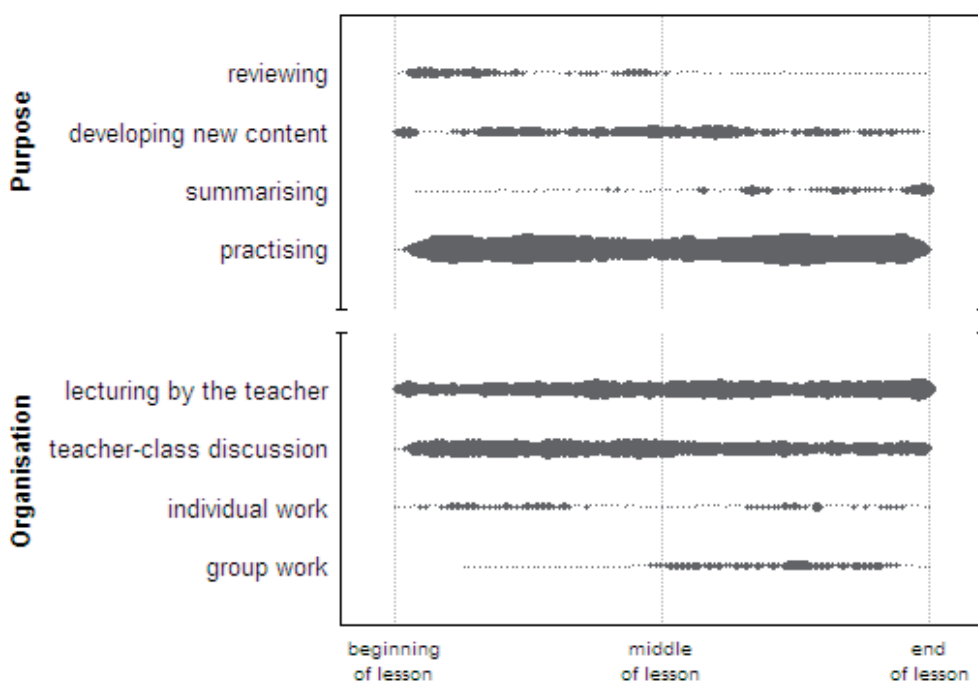

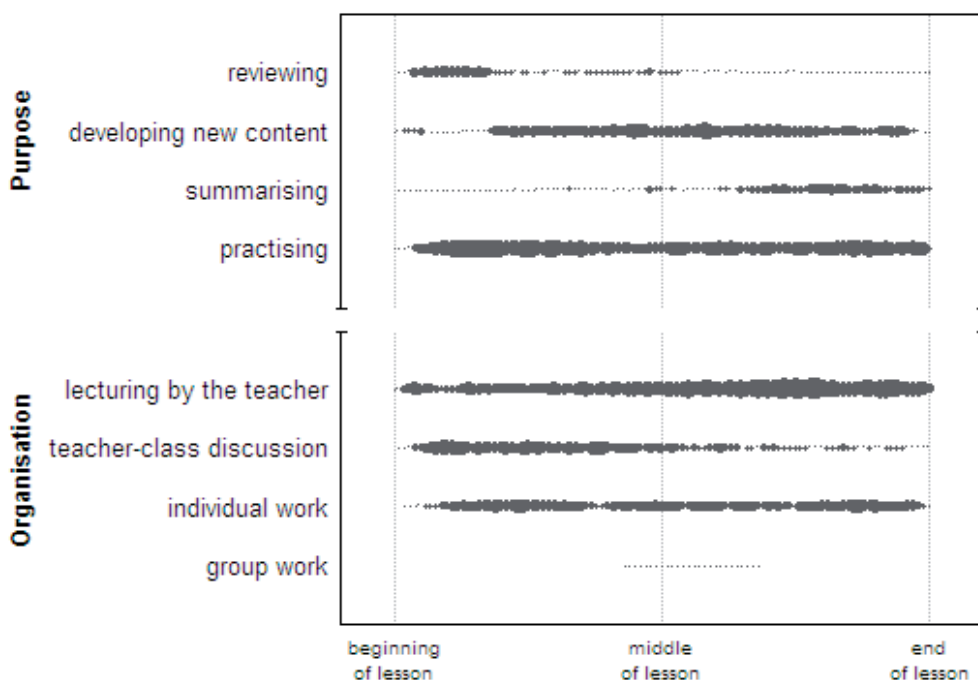Figure 5: Lesson signature for physics teaching

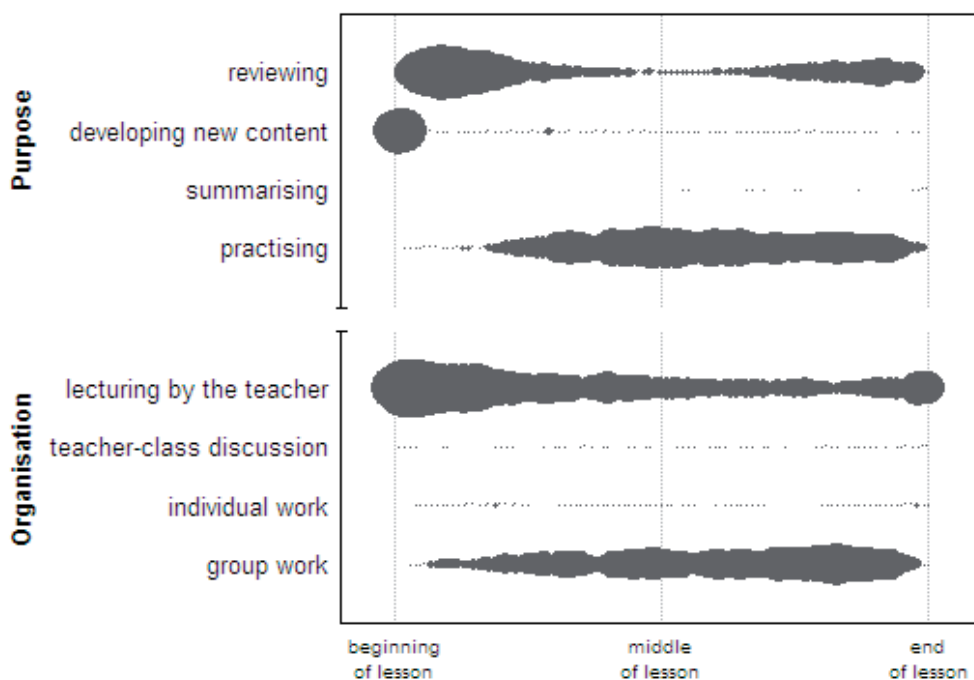Figure 6: Lesson signature for geography teaching

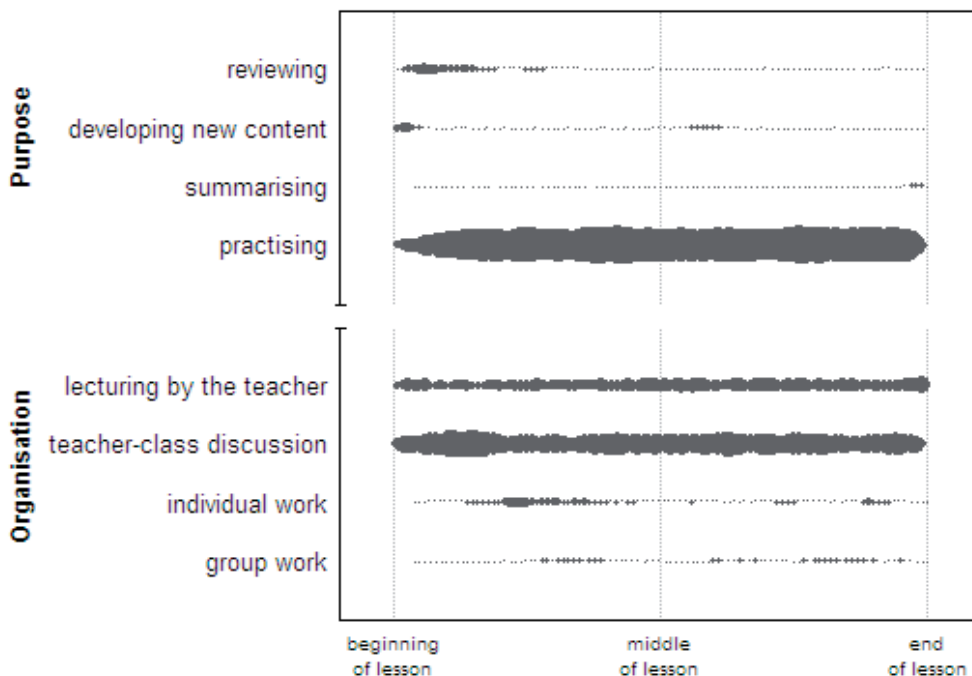Figure 7: Lesson signature for physical education teaching

Figure 8: Lesson signature for English teaching

The findings reveal manifest differences among lessons of the different school subjects under analysis. In physics and geography a coincidence was observed in the summarising of the content (purpose) by means of lecturing by the teacher (classroom organisation), which tended to happen towards the end of the lesson. The first third of a lesson was often devoted to reviewing (purpose) through teacher-class discussion (classroom organisation) or to testing (purpose) through individual work (classroom organisation). The dominant purpose of lesson segments in English was practicing in correlation with teacher-class discussion as an organisational mode.

Discussion and perspectives for the future

Using the concept of *lesson structure*, the practice of teaching physics, geography, English and physical education at lower-secondary schools in the Czech Republic was analysed within the *CPV Video Study* research project. The results indicate that teaching at lower-secondary schools in the lessons under examination is to a large extent teacher-oriented. This is in accordance with other analyses carried out on this sample which show that teachers speak on average four to six times more than all the pupils in the class put together. Due to methodological limits inherent in the approach used and the nature of the sample, however, these findings must be interpreted with caution.

Nevertheless, the results of the CPV Video Study are in conformity with the findings of other research projects (e.g. Roth et al., 2006), which point out the dominating role of lesson phases focused on work with subject matter already taught (practising, application) in lessons taught by Czech teachers. In contrast to this, German teachers of physics have been shown to spend most of their teaching time on work with new subject matter (M = 31.5; SD = 7.7), dedicating much less time to revision, practice and applications (Seidel & Prenzel, 2004). The comparison shows quite a number of similarities and differences. One of the similarities is the relatively strict control of the lesson exercised by the teacher both in Germany and in the Czech Republic.

Methodological discussions concerning the concept of *lesson structure* point to several issues that need to be resolved before any decisive arguments are accepted. Clarke et al. (2006c) argue for the interpreting of *lesson structure* in three senses: at the level of whole lesson, at the level of topic and at the level of constituent lesson events. They also call for an appreciation of the variation within the lesson of an individual teacher in order to understand variability in general *teaching patterns*.

It remains to be solved whether and how *patterns of teaching* translate from one school subject to another. It may be that there are *general didactic* aspects of teaching that take different forms in different *pedagogical cultures of teaching* (see Pauli & Reusser, 2003) and that are manifested across the boarders that separate school subjects in the curriculum. If content indeed serves as context of teaching (see Grossman & Stodolsky, 1995) then addressing these issues remains an important challenge for future research.

Acknowledgements

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REVIEWS

TOMÁŠ JANÍK & TINA SEIDEL (EDS.)
The Power of Video Studies in Investigating Teaching and Learning in the Classroom
Münster : Waxman Verlag GmbH, 2009.

The book *The Power of Video Studies in Investigating Teaching and Learning in the Classroom* displays the power of expertise of an international group of researchers who contributed to its contents. The publication was edited by Tomáš Janík from Masaryk University of Brno and by Tina Seidel from Friedrich Schiller University of Jena. Fourteen chapters threaded by the concept of video study are organized into three sections.

The introduction to the whole book was written by Tomáš Janík, Tina Seidel and Petr Najvar. First of all, the authors introduce observation as a method of social and educational research, which is followed by the role of video technology in current educational research. The introductory chapter also offers both an overview of recent large-scale video studies and a summary of recent research developments ranging from obtaining the descriptions of classroom practices to implementing research outcomes into teacher education programmes. Furthermore, the authors highlight what they perceive as the main powers of video studies: firstly, the possibility to deploy circular research design based on revisiting the original video data, and, secondly, the reversibility of complexity reduction, which allows the researcher to return to the raw data whenever needed. The introductory chapter is concluded by an overview of the three sections of the book.

Describing the dynamics of teaching and learning is both the title and the focus of *section one*, which consists of six chapters.

Kathleen Roth not only presents the results from the *TIMSS Video Study* of 8th Grade Science Teaching but she also gives reasons for using video-based methodology in an international comparative study and offers insights into its implementation. Apart from supporting the powers of video study stated in the introduction, this chapter provides a valuable example of a collaborative analysis of video data.

David Clarke, Cameron Mitchell and Peter R. Bowman uncover data generating processes in the context of *Learner's Perspective Study*. They advocate that the recent shifts in education theories on learning represent the driving force of technological developments. In order to illustrate this, three technical interludes, which reveal processes that a non-specialist in ICT can hardly imagine, are inserted in the text. The reader will appreciate that the chapter uncovers the potential of the technology by offering examples of analyses the technology enables to carry out in the area of investigating classroom practices.

Kirsti Klette introduces *PISA+ Study*, a video study of teaching and learning in Norway. The chapter shows how the complexity of video data may become a

double-edged sword: on the one hand, the reality of the classroom captured in its complexity, on the other hand, challenges for a research team to cope with both the quantity and complexity of the video data. The author's solution of the problem – being explicit about coding categories – is illustrated by selected findings of the *PISA+ Study*.

A team of researches, including Inger Marie Dalehefte, Rolf Rimmele, Manfred Prenzel, Tina Seidel, Peter Labudde and Constanze Herveg, presents *IPN Video Study*, German-Swiss physics study carried out in response to the results of TIMSS and PISA studies. The reader will become aware of the issues involved in conducting such a large-scale project, for example, carrying out surface structures and in-depth structures analyses and using low- and high-inference category systems. Besides yielding valuable results, the IPN Video Study illustrates how to benefit from intercultural and international comparison, i.e. from observing "next door".

The following chapter, written by Petr Najvar, Tomáš Janík, Marcela Janíková, Dana Hübelová and Veronika Najvarová, actually provides another example of benefiting from observing "next door" as the focus of *CPV Video Study* is on inter-subject comparison. The reader will certainly appreciate that apart from traditionally explored classes of physics, geography, English and physical education are subject to investigation. The authors conclude that in inter-subject studies of this type the research targets domain-general aspects; inevitably, some domain-specific aspects have to be sacrificed, e.g. content.

In the concluding chapter of section one the attention is turned to *Process-oriented learning in small groups in chemistry education* project. Maik Walpuski and Elke Sumfleth share their experience with video-based methodology. Furthermore, they introduce a process plot, a tool to analyse video recorded inquiry situations in chemistry education. The authors accentuate that attaining a high level of inter-rater reliability is an issue.

While previous studies provided insights into classroom teaching and learning, three chapters in *section two* are concerned with *investigating the effects of teaching*.

Eckhard Klieme, Christine Pauli, and Kurt Reusser report on *The Pythagoras Study*, which was aimed at investigating the effects of teaching and learning in Swiss and German mathematics classrooms. The complex research design was built on a theoretical model of basic dimensions of instructional quality and their effects on student learning and motivation. One of the core issues of the study is the concept of cognitive activation.

The following chapter brings the reader back to the *IPN Video Study*. This time Tina Seidel, Manfred Prenzel, Katharina Schwindt, Rolf Rimmele, Mareike Kobarg and Inger Marie Dalehefte present its findings regarding the effects of observed physics teaching practices on student learning. The design of the study represents a multi-method approach. Similarly to some of the previously mentioned chapters, the issue of inter-rater reliability is reiterated.

The last chapter in this section was written by Erin M. Furtak and Richard J. Shavelson, whose study explores the relationship between guidance and conceptual understanding during inquiry-based post-investigation discussions

held in classrooms of four middle school teachers of physics. The results of the study suggest that less extensive projects also contribute to understanding the effects of teaching. In this particular study it is the manner in which different types of discourse are used that makes the difference, rather than the type of discourse itself.

Section three titled *Using video in teacher professionalization* consists of four chapters, which provide different examples of utilizing the benefits of video in teacher education.

The authors of the opening part of this section – Tomáš Janík, Marcela Janíková, Petr Knecht, Milan Kubiatko, Petr Najvar, Veronika Najvarová and Simona Šebestová – summarize different purposes of using video in teacher education. They further present examples of video databases used in teacher education programmes. Apart from describing the *CPV Video Web* and its component parts, the authors also introduce the rationale for creating this e-learning environment as well as its prospective use in teacher education.

Kathleen Roth describes the *Science Teachers Learning from Lesson Analysis study*, which examined if upper elementary teachers in the U.S. could improve their teaching after engaging in a professional development programme, in which analyzing video recordings constituted a major part.

Tina Seidel, Manfred Prenzel, Katharina Schwindt, Kathleen Stürmer, Geraldine Blomberg and Mareike Kobarg present *LUV* and *OBSERVE* projects that use video to diagnose teacher competence.

The final chapter by Jennifer Jacobs, Hilda Borko and Karen Koellner discusses the use of video both in research and in professional development of teachers (*STAAR* and *iPSC projects*). In this part the process of establishing a community of teachers around video is described.

As it has already been implied in the above comments on individual chapters, the book fulfils what its title promises – it shows the power of video studies in investigating teaching and learning in the classroom and in teacher education.

Thanks to the carefully structured content the prospective reader will get an overview of major video studies as they were conducted in the area of education in the last fifteen years. The reader will surely realize how complex, technologically demanding and long-term projects video studies are, and how the results of one study inspire the design of another.

As regards the area of research methodology; the reader will become familiar with the main assets as well as challenges of video-based methodology, which the research teams were confronted with. The book itself is an evidence of multiple benefits of cooperation in educational research.

To conclude, all the presented studies have a sound theoretical background and, through the implementation of properly designed research, they provide unique insights into instructional processes that would not have been possible to obtain without video-based methodology. Undoubtedly, for such reasons the book has plenty to offer to professionals in the field of education.

Monika Černá

CONFERENCE REPORT

CONFERENCE: CURRICULUM AND INSTRUCTION IN CHANGING SCHOOL

Brno, 24th – 26th June, 2009

The topics of curriculum and instruction are in the focus of attention of experts in the Czech Republic and Slovakia, especially in the context of the current educational reforms. Research into these topics still brings new questions and challenges. The international conference "Curriculum and Instruction in Changing School" was organised on 24th – 26th June 2009 by the Educational Research Centre, Faculty of Education, Masaryk University, Brno, Czech Republic.

The aim of the conference was: (a) to provide an opportunity for presenting theoretical studies and research results on the topic of curriculum and instruction; (b) to provide an opportunity for exchanging experience and support discussion on current issues of the theory and research of curriculum and instructions; (c) to mediate cooperation within the educational research community.

The conference was connected with prof. Josef Maňák's jubilee, therefore the first conference day was held both as a celebration, and as an academical gathering. The opening plenary session was devoted to congratulations on prof. Josef Maňák's jubilee. The second part was represented by three contributions, in which prominent Czech and Slovak experts in pedagogy and psychology looked into issues which are considered significant and which should deserve our attention.

J. Maňák (Faculty of Education, Masaryk University, Brno, Czech Republic) explored an issue in his paper concerning the direction of education and how education should proceed with regard to the ongoing societal changes. On the one side, there is an effort to continue in the present extensive processes, on the other side, there are more attempts to search for new solutions because of the growing discrepancies seriously affecting education. It is essential to form a harmonious, healthy, creative, integrated personality and his or her moral profile, to integrate all pieces of knowledge, to connect theory and practice, and to conceive school as a centre of civil activities. The suggested views relate to the new conception of educational content emphasizing both critical thinking, and the new organisation of education. The open school should continuously transform into the school with whole day programme and should be of special interest and support from the side of family, community, and all citizens.

In search of further directions for school, prof. Zdeněk Helus (Faculty of Education, Charles University, Prague, Czech Republic) stresses that education cannot be derived only from logic and aims of the knowledge society. Obviously,

such efforts have their limits. Therefore, it is important to emphasize the education of "turnaround". The question is what the turnaround should direct to.

Prof. Peter Gavora (Faculty of Education, Comenius University, Bratislava, Slovakia) deals in his paper with self-efficacy – an important self-regulatory capacity of the teacher. The concept, originally elaborated by Albert Bandura, has important consequences in the field of education. It shows (1) how the teacher perceives his/her abilities to influence the pupil, and (2) how he/she judges the potentials of instruction to overcome unfavourable external factors, such as family environment. The paper presents data on Slovak adaptation of Teacher Efficacy Scale. Indication of weak construction validity of TES was proved due to the fact that the questionnaire rests on two constructs, Bandura's self-efficacy and Rotters' locus of control.

The second conference day consisted of three parts – the first section, presentation of posters and the second section. The first section involved contributions on the theoretical problems of the creation and implementation of curriculum, the realized curriculum research findings, and the particular subject curriculum analysis, i.e. textbooks also from the international point of view. The first section was followed by a presentation of posters in which both the Ph.D. students, and the experienced scholars presented their partial or general research findings. The second section was represented by contributions dealing with curriculum from the point of view of subject didactics. The papers presented involved presentations from Science subjects, Maths, Media Education, English, Arts and Philosophy of Education.

Contributions from the conference will be published in a collection of abstracts and on a CD-ROM with full texts, edited by the conference organising team.

Simona Šebestová

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