Spectrums of knowledge types – mathematics, mathematics education and praxis knowledge

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Abstract

Knowledge in different research paradigms is discussed: mathematics, mathematics education and a paradigm of practical knowledge. I argue that the three paradigms as distinct, different, and significant in practice. They try to cope with entirely different types of knowledge, all relevant for mathematics teachers.

While mathematics is deductive and mathematical education is evidence based, practical knowledge is a type of knowledge that professionals in any profession develop by experience and by exchange with other professionals. It is based on experience more than on written text. It is well known that it to a large extent is difficult to articulate. Such knowledge is also essential in important types of mathematical knowledge. We discuss the role played by vagueness in mathematics. We also discuss linguistic mathematics knowledge which typically is present but mostly unformulated, as the mother tongue.

I argue that mathematics, pedagogy and mathematics education suffers from drawbacks by being strongly rooted in the positivist tradition, in which knowledge can always be expressed in words – otherwise it is not knowledge. Central aspects of teacher's day-to-day profession are too complicated to be captured in words. However, work has been done to allow such practical knowledge to be formulated among professionals. I would like to sketch a possible more fluent cooperation between the paradigms, in which the advantages of all the different knowledge types may interact and become increasingly useful to each other.

For such an idea to reach reality, an efficient meeting form is needed. The Dialogue Seminar is developed precisely to study and communicate difficult-to-articulate practical knowledge among experienced professionals from different areas, using analogue and metaphor as catalysts. Furthermore, it provides a possibility for mathematicians, mathematics education researchers, mathematics teachers and teacher students to listen in depth to each other, and to have a dialogue.

Introduction

In order to improve mathematics education, are our efforts well spent? Are there possibly other ways of work that may lead to more significant improvements? This is an extremely basic issue for an applied science, which lies at the bottom of this paper. It is a question that directly concerns how three

professions form and perform their work: mathematics education research, teacher education, and teaching.

This paper tries to use a viewpoint of the teacher profession as a profession among professions. When comparing to non-teacher professions, one particularity of the teacher profession stands out: its relation to *knowledge*. It has particularly strong relations to knowledge in two ways. The first is that its main purpose is the learning of certain subject knowledge for other humans. The second is that there is a long knowledge tradition about how teaching and learning can be done: pedagogy and didactics – in later years promoted to education science. Knowledge is essential in all professions, but for teachers it is the very material of work, and there is a lot of written knowledge on how this particular profession works – since the school is so important in society.

This strong knowledge tradition concerning the teacher profession has been developed in a positivist tradition – which was the dominant tradition in the previous century. In this tradition, knowledge is what can be formulated in words (Johannessen, 2006B, p. 273), a type of knowledge that can be called *propositional knowledge*. This viewpoint neglects much of practical knowledge, a fact that is not changed by propositional knowledge that has practical knowledge as focus (such as partly this article). Practice is different in essence from propositional knowledge. For example, it is very much possible to be an expert in every possible aspect of listening dialogues, without being able to take part in one. Another person may often engage in valuable dialogues with students, but unable to describe what a dialogue is and how it works in depth.

Despite the strong knowledge traditions in the teacher profession, difficult-to-articulate practical knowledge is important in all professions – also in the teacher profession. Practical knowledge enables a professional to act in appropriate ways in unforeseeable teacher situations – it develops intuition. It is a knowledge that enables skill – the ability to *perform* the profession. This ability is distinct from knowing.

In terms of action research, for example, pedagogy and mathematical education are searching ways to handle teachers' reality and practical knowledge. However, it is not easy to allow teachers' to fully express their views of their teaching situation if it contradicts established paradigms. This problem is one main focus of this article. The philosophical foundations of practical knowledge (Johannessen, 2006A) may also contribute to the understanding of propositional knowledge, both its limits and its values.

We will describe the Dialogue Seminar, which may be seen as a meeting form designed to formulate or visualize practical knowledge that is essential to perform the profession – according to the professionals themselves. The Dialogue Seminar is developed at the Royal Institute of Technology (KTH),

Sweden, primarily by Bo Göranzon and Maria Hammarén (Göranzon, Hammarén, 2006).

The Dialogue seminar shares many traits with Donald Shön's work about the reflective practioner (Shön 1983), (Shön 1987). Shön criticizes the dominance of the positivist "technical-rationality" and defines reflection-in-action (thinking on our feet) and reflection-on-action. The Dialogue Seminar can be thought of as a meeting form designed to allow reflection-on-action about reflection-in-action. Furthermore, professional performance skills characteristic for actors and artists are inspirations both for Donald Shön and for the Dialogue Seminar. Shön writes about knowledge inherent in practice that can be understood as artful doing. This is shared by the Dialogue seminar group, which frequently invites actors to meet university teachers, for example.

A difference appears to be that in the Dialogue Seminar interpersonal knowledge is focused to a larger extent than in Donald Shön's work – knowledge that is formulated much more elaborately in a dialogue among professionals than by single experienced professionals. The method focuses *dialogue*. One person's thoughts and views may be seen as a provocation for another – provocation for formulation. Analogy-inspiring texts are used, which means that they initially may appear not to be relevant for the issue in question.

Both lines of work have predominantly philosophical backgrounds, involving for example work by Michael Polanyi and Ludwig Wittgenstein on tacit knowledge and praxis knowledge.

There has been a lot of work on situated cognition the last decades, one example is (Lave, Wenger 1991). In this work it is described how all learning takes place in and is formed by a *community of practice*. Such a community can be described as a group of interacting persons with a certain "local culture" and a common understanding of what and why they are doing. The group and its workings, which can only be partially conscious, are highly relevant for most aspects of the learning that takes place for the individuals in the group. In the present paper, the properties of different communities of practice are important, but not the main focus of study. We focus mainly ways that professionals may meet to ensure a fruitful dialogue, and different contrasting epistemological paradigms in mathematics.

A different but related serious problem for research in mathematics education is that it serves two goals that are rather conflicting. One is to help teachers; the other is to fulfil the requirements for research. The second goal is a long term goal that makes results more reliable, but tends to make results inaccessible for teachers. In effect, a researcher must choose between reaching teachers or reaching researchers. Some ambitious researchers have written popular versions of their research, more accessible for teachers and decision makers. This should

be mandatory for an applied science. We need to leave behind the fact that "popular" writing sometimes is seen as negative among researchers.

One purpose of this paper is to find ways to discuss and illuminate the non-propositional components of mathematical and mathematics education knowledge, which take many different forms. It is also to suggest ways in which the knowledge traditions can cooperate, develop and stimulate each other. For this, the professional reality experienced by mathematics teachers need to be a well developed starting point, from which mathematics education research provides a resource.

Differences between paradigms, research questions

A Dialogue Seminar is an organized dialogue between professionals, to be described later in this text. By taking part in Dialogue Seminars with other teachers, a rather obvious observation has become clear to me. It is that a teacher professionally faces a complex teaching situation with many different parts to be handled well. Such parts are subject knowledge, how to present subject knowledge, to understand students present level of subject knowledge, how to respond to students questions and actions, correspondence to neighbouring subjects, how to plan future lessons, etc. etc. These parts need not only to be handled well; they also need to be balanced into a reasonable whole. I argue that from an epistemological viewpoint, mathematics education generally provides solid information about one or a few of the different parts at a time, but rarely addresses the balancing act that a teacher needs to handle. On the other hand, from the viewpoint of practical knowledge, the balancing act naturally attracts focus, since here active teachers formulate their needs and views. On the other hand, in the praxis paradigm solid evidence based results are rarely produced, as is more typical for mathematics education. Results in mathematics education are usually more solid and general. We have a trade-off between generality and authenticity.

These two paradigms have different and complimentary roles to play. In praxis research, a group of teachers plays the main role in problem formulation as well as in reformulation and development. Mathematics education research results are founded in evidence and theory, which to some extent limits which problems that may be studied. Mathematics education results tend to be more reliable, less dependent on local culture; however the depth typically means a larger distance from teachers' experiences. If we compare with mathematics, one may claim that the overwhelming reliability of mathematics lies in that here extremely limited problems are studied – so limited that they allow a very high degree of certainty.

Following a line of praxis knowledge, I argue that there are fundamental categories of knowledge that are vital for teachers and that cannot be accessed by traditional analytical approaches. The Dialogue Seminar can be seen as a

respectful and well developed means, mainly using analogy, metaphor and dialogue, often taking advantage of areas as history, philosophy, mathematics education, to put practical knowledge in motion that is particularly useful for teacher's education, and that provide an answer to the following fundamental question:

How can the sources of knowledge and skill that experienced teachers possess become available for teacher students, as described by experienced teachers themselves, and in ways that teacher students find valuable, supported by mathematics education results?

This is one of the main research questions in this paper. Related questions addressed here are:

Which types of knowledge are relevant in the mathematics teacher's profession? Which types of knowledge are important in subject knowledge in mathematics? How can the different knowledge types be handled in successful ways?

The purpose of the paper is to put forth underestimated types of knowledge, to give a general view of the epistemological landscape, and to suggest ways to design this landscape. This proposed design is to professionally take advantage of existing experience by allowing different knowledge traditions to meet systematically and constructively. Teachers will not acknowledge the value of their own resources of experience unless researchers emphasize these resources and try to find ways to develop them.

Propositional and professional knowledge

In (Hudson, 2002), Shulman's (Shulman, 1987) model of categories of knowledge of teachers' knowledge is used. It contains the following categories, where I in parenthesis have added counterparts/characterizations relevant for the discussion in this paper. It illustrates well the balancing act that teachers constantly face in their profession:

- Knowledge of subject matter (mathematics)
- Pedagogical content knowledge (mathematics education)
- Knowledge of other content (knowledge of the educational program)
- Knowledge of the curriculum (course knowledge)
- Knowledge of learners and their characteristics (student culture)
- Knowledge of educational aims (political and school knowledge)
- Knowledge of the educational context (school culture)
- General pedagogical knowledge (pedagogy, classroom management)

Parts of these knowledge categories can be formulated in words, a knowledge type that may be called *propositional knowledge* (Göranzon, p. 19). Two types of

knowledge that cannot easily be expressed in words are also part of most of these categories. These are *practical knowledge*, which is knowledge that contains experiences from having been active in a practice, and *knowledge of familiarity*, that is built by interaction with collegues about examples of practice. These two may together be called *professional knowledge*. This is knowledge with special properties, described by Kjell S. Johannessen (Johannessen, p. 229) as follows:

"Professional knowledge is essentially characterized by two basic traits: (a) It is acquired over a relatively long period of time by individuals; and (b) attempts as articulating it in some reasonably satisfactory way all fall short of even elementary standards of plain speech."

These two properties disqualify professional knowledge as knowledge from a positivist standpoint. In a positivist view, knowledge that is individual is not knowledge. Furthermore, knowledge that cannot be articulated is not knowledge. Here are Johannessen's perhaps more nuanced words (ibid.):

"Both of these traits stand out as inherently provocative to the adherent of the received and positivistically tinged view of knowledge that is predominant in our time. The first trait threatens to make knowledge dependent on individuals; and the second more than indicates that some kinds of genuine knowledge may in basic respects be resistant to verbal or notational articulation and thus be beyond the reach of language."

Is such professional knowledge, difficult to formulate and perhaps to study, important for mathematics teachers? Well, a famous and experienced research mathematician has once claimed:

Logic is very important in mathematics, but it has never been used to find a proof.

Mathematics students attempt to solve mathematical problems, which is a counterpart to mathematician's search for proofs. Inherent in the statement is the recognition of the vague concept of "intuition", which is addressed by Davies and Hersch (Davies & Hersch 1995, p. 435) in the following way:

(1) All the standard philosophical viewpoints rely in an essential way on some notion of intuition.
(2) None of them even attempt to explain the nature and meaning of the intuition that they postulate.

(3) A consideration of intuition as it is actually experienced leads to a notion which is difficult and complex, but it is not inexplicable or unanalyzable. A realistic analysis of mathematical intuition is a reasonable goal, and should become on of the central features of an adequate philosophy of mathematics.

These are strong words about the role in mathematics on something so vague and undefinable as "intuition". Personally, I look forward to the "realistic analysis of mathematical intuition". Probably a very metaphoric and poetic language, far from traditional mathematical language, is required to develop this analysis – which would shed light on this very language.

Vagueness and knowledge

Epistomology and linguistics are firmly related to mathematics education, and have during later years found increasing attention. This is described by Paul Ernest in the preface of (Rowland, 1999, p. x (in foreword)). He describes that the lack of attention to linguistics may depend partly on the focus of mathematical thought over talk. He continues to write that it may also depend on absolutist epistemology of mathematics, in the light of which language serves to describe absolute logic. Spoken mathematics is imprecise and has limited value in this perspective. This diverts the attention from students' actual mathematical thinking.

On the importance in mathematics of the opposite of preciseness, vagueness, Ernest writes in the same preface to (Rowland, 1999):

> Precision is the hallmark of mathematics and a central element in the "ideology of mathematics". Tim Rowland, however, comes to the startling conclusion that vagueness plays an essential role in mathematics talk. He shows that vagueness is not a disabling feature that detracts from precision in spoken mathematics, but is a subtle and versatile device which speakers deploy to make mathematical assertions with as much precision, accuracy and confidence as they judge the content and context warrant.

Thus, vagueness need to be restored as a valuable compliment to precision for good mathematics learning. Certainly, vague descriptions may lead to misinterpretations, but that is also possible for precise descriptions. Essential is that descriptions are to the point, and that the teacher has an idea of how students interpret. A better dialogue is required to understand each others interpretations – vague or not.

A praxis paradigm

In the tradition of the Dialogue seminar there is not much fear of vagueness. Instead, the unformulated knowledge that is possessed in a group of experienced

professionals is focused. Unsuccessful computerizations of workplaces in the 80-ies were a starting point of this line of research. Reforms were related to a conviction that most or all of the relevant knowledge could be programmed in computers. Instead, groups of experienced professionals possess more knowledge that they are able to formulate in words. I have earlier described the knowledge categories *practical knowledge*, *knowledge of familiarity* and *propositional knowledge*. The two first develop while taking part in a professional practice, and interaction with colleagues, respectively. Such knowledge is not necessarily individual; it usually lives in a professional group. Sometimes the group is needed to find an appropriate action – for the knowledge to come alive.

The dialogue seminar is an arena for professional groups to find, formulate, characterize, stimulate and value their practical knowledge based upon experience, or in some sense (not necessarily with words) make it palpable or present. Analogue and example are important elements. Historical texts are often rich in these respects. Musicians, engineers and others may participate in the same sessions. Meetings with other professions incur no rivalry, and appear surprisingly often to be fruitful for all parts. The sessions work with writing as a method of reflection. All members prepares actively each session along a certain theme with a text to be read aloud and reflected upon. Then, each member is invited to comment verbally upon each text that is read.

The invitation to reflect from experience is central. It makes the sources of experience increasingly visible for each bearer of that experience. These sources may grow into resources of knowledge that deliver more and more. Associations to other persons experiences, which may be partly similar and partly different, is the tool for this discovery.

The dialogue seminar is an arena where mathematics teachers, mathematics education researchers, mathematics teacher educators and mathematicians can meet, listen to each other in depth, and learn from each other through dialogue. It appears as if mathematicians often experience dialogue with musicians as particularly valuable. This may come from the fact that intuition is important both in music and in mathematics, in somewhat similar meanings, as described above in (Davies & Hersch 1995), while musicians may have advanced longer than mathematicians in formulating their intuition.

Göranzon and Hammarén (Göranzon, Hammarén, 2006) describe the major goals of the dialogue seminar as follows:

The dialogue seminar method is a method of working that aims to
(i) create a practice of reflection
(ii) formulate problems from the dilemma
(iii) work up common language
(iv) train the ability to listen.

I remark that the ability to listen does not follow automatically from the ability to talk. In academia, the ability to talk is trained much more than the ability to listen. We learn in three ways: from reading, one-way-listening during lectures, and dialogue and reflection with others. Self-reflection is of course always a component. Reading is a form of listening, but without an opportunity of dialogue. The relative dominance of these learning modes in academia determines the corresponding degrees of training, and which abilities which develop.

How is a Dialogue Seminar organized?

To meet the goals described, a Dialogue Seminar is often a sequence of five whole day occasions. Although there is an overall plan of the five occasions, the basic theme on one Dialogue Seminar is typically affected by which questions turned out to be central in a previous one. This reflects again the idea that questions raised by *the participating professionals* should be allowed to dominate. There is often a different situation when mathematics education researchers meet mathematics teachers. Often the researchers formulate the agenda, while dilemmas experienced by teachers remain unformulated and unsolved. Such dilemmas require time and attention to become formulated.

A typical number of participants is eight to ten persons. A few weeks before each Dialogue Seminar, everyone receives one text (or a few texts), a so called *impulse text*. Everyone is required to read the impulse text and reflect on it ("read with the pen"), and write a one page *reflection text*, preferably about relevant professional experiences. The reflection texts are the basis of the Dialogue Seminar meeting, in that each participant read ones own reflection text aloud. After reading, everyone in turn has an opportunity to comment the reflection. Here a dialogue typically evolves around the reflection texts and the impulse text. Simultaneously, the dialogue is taken down in a protocol. This protocol is the output of the particular seminar.

This approach has a number of interesting consequences. The outlook of reading aloud a text about your own profession promotes care and reflection. All participants are strongly prepared in advance, which is rather unusual in academia. Furthermore, everyone is prepared in a specific direction of thought – the one pointed out by the impulse text.

A major requirement of an impulse text is that it is rich in analogy, to inspire reflections. An observation often made is the surprisingly wide scope of reflections done by different individuals on the same text. Issues that appear and reappear in reflections and in the ongoing dialogue are often fundamental professional dilemmas, although initially they may appear in disguise.

When lacking words for practical knowledge, metaphor and analogy may be important ways of expression. Metaphors may be misleading, but misconceptions may be pointed out by for example other metaphors, and it may turn out to be possible to express in part what previously could not be expressed at all.

The purpose of the dialogue is not to reach the same view, to reach "the truth". Conversely, true disagreements may be uncovered, which deepens the insight in the complexity of the profession and about different ways to handle it.

Teaching and *Bildung*

While mathematics education research often investigates different particularities in depth and in an evidence-based way, in the Dialogue Seminar the dialogue often focuses the whole picture of the teaching and learning situation. Teachers' ability to interact and improvise with students – teachers' presence – is then relevant. It may from this perspective appear natural that the Dialogue Seminar sometimes converges towards the concept *Bildung*, which is also discussed by Hudson (Hudson 2002).

Hudson describes differences between the Anglo-American curriculum tradition versus the German. In the first case the teachers are employees of the school system which has a strong formal control of teachers (Westbury). Professionalism is achieved by *training* and *certification*, to teach the curriculum. In the German tradition, the teacher is directed rather than controlled by the institutional framework. There is a larger professional autonomy for the teacher, for example in interpretation of the curriculum. This is related to the presence of the idea of *Bildung*. Klafki (Klafki, 1998) has specified three main elements of *Bildung*: (i) *self-determination*, to be enabled to make independent responsible decisions, (ii) *co-determination*, to be enabled to contribute together with others to the society, and (iii) *solidarity,* actions to help others.

Khalid El-Gaidi's doctoral thesis (El-Gaidi, 2007) *Teacher's professional knowledge – Bildung and reflective experiences* (my translation of the title, which was in Swedish only) was defended 2007 at the Royal University of Technology in Stockholm. Here teachers' skill at a technical university is examined. The dissertation starts with a case study in form of a Dialogue Seminar where university teachers participated actively in a series of meetings about their view of their praxis and of skill. The discussion on knowledge and skill based on this case study converged clearly towards *Bildung*. In this thesis *Bildung* is seen from many aspects, such as the ability to see the limits of the activity and to avoid misunderstandings. It is also seen as a standpoint involving judgement, sensus communis and taste (Gadamer 2004), a way to view knowledge in that we need to recognize the different forms of cultures we live in, and as a way of seeing the whole picture, intuition and as rhythm of thought and communication.

Conclusions

A mathematics teacher needs to acknowledge and understand all three knowledge types described in this paper. Mathematics learning processes (mathematics education), as well as positivist mathematical knowledge, and furthermore practical knowledge of the teacher profession that typically escapes words. To be able to exploit all learning opportunities, a multiple view of knowledge is important. They play different roles. Mathematical education knowledge makes it possible or easier to reach students where they are. Mathematical knowledge trains deduction and is of course the purpose of mathematics training. Professional knowledge may typically facilitate the organization of learning opportunities, the quality of leadership and presence of teachers, as well as the vividness of the dialogue of teachers and students. By metaphoric dialogue, difficult-to-articulate knowledge can find its way into the realm of words. Some metaphors disappear rapidly, while others are modified and gradually become more stable – and may finally become a part of our language.

Such processes are not very common in mathematics, since mathematics still is a subject with a low degree of dialogue. It is a culture where written communication dominates over verbal communication. The lack of dialogue is even more problematic since also mathematical subject knowledge, not only professional mathematics teacher knowledge, has important vague and tacit components.

Simultaneously, there is a division between mathematics teacher's culture and mathematics education researcher's culture that is dangerous from both perspectives: for the improvement of mathematics teaching, and for the relevance of mathematics education research. This division stems also from the differences in aims and history – on the view of knowledge. A dividing issue is the view of mathematics teachers role. If they are not involved in formulating mathematics education research questions, dilemmas, there is a risk that the research may be difficult to apply. On the other hand, researchers may be able to add relevant aspects to teachers' view on teaching. There is an urgent need for meeting opportunities where such exchanges are possible.

To bridge divisions, a complementary way to work is proposed in this paper. As a tool the Dialogue Seminar is proposed, which is designed and developed for the purpose of allowing experienced professionals to search and find difficult-to-articulated knowledge – or at least to find tangible knowledge resonances. Such seminars are verbal in nature, but works with both reading and writing as means of reflection.

The proposal is to apply this method for the benefit of mathematics education. Mathematics education research texts are natural starting points for the

participants, but the dialogue may focus dilemmas that mathematics teachers find crucial in their profession. By its construction it furthermore offers an opportunity for different groups – mathematicians, mathematics education researchers, mathematics teachers and teacher students, and others – to participate, to give their view of practical mathematics teaching problems, listen in depth to experiences and conclusions, and to have a dialogue.

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