Becoming a Teacher in Mathematics and Science – a Study of the Transition from Initial Teacher Education to School Practice

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ISBN 91-7305-715-0 ISSN 0283-9997

**Abstract**

This study follows student teachers from initial teacher education into their first teaching jobs, with the aim of gaining insights how student teachers become teachers of mathematics and science. The study has two stages. In the first part the focus is on the beliefs and conceptions – termed here as 'personal didactics' – that student teachers have about teaching and learning mathematics and science. These are captured by open-ended interviews on completion of initial teacher education. Stage 1 is thus subject specific. Findings indicate that student teachers have an applied approach to mathematics and science. Findings of the study challenge teacher education to develop mathematics and science as a more democratic, moral and cultural enterprise. It is suggested that closer connections are needed between different parts of initial teacher with a continued discussion about how and in what areas subject teaching can develop in teacher education. The second stage of research - two years later – involved data collection through observation, field notes and post-observation interviews. This stage is a follow-up study building on the stage 1 and has a more sociological emphasis inspired by Bernstein’s concept of educational codes. The research shows how the structure of schools influences teachers and their possibilities to enact teaching that is consistent with their understanding of mathematics and science as school subjects. Schools have different codes and teachers’ practices were constrained by the opportunities that each school offered as well as each teacher’s personal didactics. Most of the teachers in the study worked in schools organised in such a way that new teachers have considerable autonomy over their own teaching. After two years of practice teachers generally felt freer to organise science teaching and put more planning and preparation of science lessons as compared to mathematics. The overall study illuminates the relationship between initial teacher education and school practice, and suggests an enhancement of initial teacher education and professional development as a unity.

**Key words:** initial teacher education, mathematics and science teaching, personal didactics, educational codes, school practice.
Acknowledgements

I am grateful for the possibility of learning which I have gained in the department of education through this research experience - to look at teaching from another perspective than my own. My own teaching background – from comprehensive school and from initial teacher education - formed a starting point to this study.

There are many people over the years that I owe gratitude to and I hope that everyone understands that I haven’t forgot you even if I do not mention your name!

I entered research with a loved colleague. Together we were going to ’knit a sweater’, which was our metaphor for the research we were going to create and conduct. Unfortunately we could not do this together, but we made the foundation together, we knitted the first part and we made it careful - thank you Ann-Kristin. Then I had to perform the rest myself. The sweater I was going to knit became a ‘slip-over’= this licentiate thesis.

Luckily there are other people to support in the research process. In the department of education there is a long tradition of postgraduate studies and I enjoyed participating in the foundation course. The seminar group and its leader have been of much help with discussions, reflections and opinions.

The one who has supported me the most is Gaby Weiner, my supervisor. Her ambition, her critique, her accuracy, her experience, her language support and her back up helped me through this work. The co-supervisor Daniel Kallós engaged in some really entertaining and intellectual moments. Thank you both!!

Of course this work could not have been done unless I had teacher students/new teachers to interview, observe and get information from. Thank you for letting me take part of your thinking and visit your classes. The work involved travelling throughout Sweden from the north to the south - by car, plane, bus and train - and in that process also gained much knowledge about Sweden. I considered it a privilege to be able to take part in these meetings and was welcomed into classrooms. I have learnt a lot!
In the process of my own learning I have met fellow teachers, teacher educators, students, pupils…who in different ways and in different times have added aspects to my beliefs, conceptions and understanding of what it means to learn and to teach.

Last but not the least, thanks to my supportive husband Hans, who I also think, learnt some aspects of research in another field than his own! Also thanks to the growing families around our children.

Umeå in August, 2004
Margareta Wolf-Watz
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Background, aims and context

This thesis explores teacher education in Sweden with a special emphasis on its relation to schools. It focuses on new teachers of mathematics and science, their understanding of the teaching and learning of these subjects from initial teacher education and their possibilities to enact their understanding in their practice in schools. Student teachers becoming teachers are thus the topic of this study.

In this introduction part, I first present a contextual background including some of my own experiences as a teacher and teacher educator. I also elaborate on some issues and introduce topics, otherwise not mentioned in the texts (papers 1, 2 and 3). The focus here is on the context of teacher education in Sweden and in Umeå, what it means to learn to teach and on the study itself.

Aims of the thesis

The main aim of this thesis is to increase knowledge of student teachers’ understanding of mathematics and science teaching and their possibilities as new teachers to enact this understanding in relation to curricula and national standards. An additional aim is to illuminate the relationship between initial teacher education and school practice.

Background

Teachers are important agents in developing learning in pupils (SOU, 1999). But how do we prepare teachers to do this? There have been different ways of thinking about what it means to educate teachers. This thesis deals specifically with teachers who received their initial teacher education under the Swedish 1988 teacher education reform.

Teachers’ educational processes are of interest to teacher education; thus for this study my own has been important. I was a teacher in the comprehensive school for more than twenty years and after that, a teacher educator for eight years. Looking back on my professional experiences, I have often thought that my own teacher education was too technical in the sense that it neither adequately prepared me for the profession nor did it enable me to achieve comfort with, and accommodate to, pupils learning. My own learning process has involved supportive colleagues, collaborative parents and of course, pupils. For me it was difficult to accept that as a teacher, I could not teach content and at the same time assume that the pupils...
were learning as planned. I was confronted with this notion on an in-service course, which emphasised that ‘a teacher cannot teach a pupil anything!!’ This was a revolutionary, interesting and important ‘lesson’, with which I have been struggling ever since, both as a teacher and latterly as a teacher educator.

After some years of practice in schools, I wanted to develop my own expertise in certain subjects and became involved with in-service education in mathematics and science. What was really valuable about this, I suggest, was that it took place over an extended period, and provided opportunities for me to try out new aspects of teaching. It also gave me time to internalise new knowledge. The engagement with in-service training made a link to teacher education, which I entered as a teacher educator after twenty years of school teaching.

As a teacher educator in the university I met expectations of research expertise (Ds, 1996) as well as the need to draw on my experience from schools. Different forms of activity, locally as well as nationally, were at that time being organised to support research. Together with people from different teacher education departments, I became engaged in further studies in the field of mathematics and science education1. For me, this also led to taking up postgraduate studies.

My own experiences have thus helped frame the study of how student teachers become teachers of mathematics and science. As a teacher I reflected on my own practice, as well as that of my fellow-teachers, and on the content and general issues in everyday school life. I came to realise that some teachers focus more on subject content and less on general educational issues such as learning, group-work, assessment, co-operation, gender patterns and so on, while for others the reverse is the case.

Another experience, which forms a background to my research, is that of teacher education itself. The form of teacher education with which I was involved as a teacher educator in the 1990s, was different from the one I experienced as a student teacher in the 1960s. ” The new teacher education” of 1988 onwards was an attempt to merge two traditions – that of the ‘seminar’ and the Academy (Prop. 1985).

1 As a result of this a colleague and I published two articles on mathematics and science in teacher education (Nyström and Wolf-Watz, 1996, 1998).
Changes in the Swedish curriculum have also had an impact on my thinking. In the 1994 national curriculum, mathematics and science teaching and learning were given an emancipatory element aimed at empowering all citizens\(^2\). It further emphasised the democratic foundation of the Swedish curriculum (Ministry of Education and Science, 1994).

Initially I wished to explore to what extent the then new curricula of mathematics and science ‘for all’ had made an impact on student teachers, and if so, to what extent they were able to enact the new curricula in their classrooms. As the research progressed, this aspect came to include the moral and democratic impact of the new curricula, as well as subject content and teaching strategies.

At the start of the research there were some fundamental issues that I wished to investigate, for example, regarding the conception of how we learn (see also paper 1 and 2). The present official Swedish curriculum requires pupils to construct their own knowledge, which means teachers having to adjust their teaching according to the needs of different pupils. While working with students in initial teacher education and with teachers participating in in-service courses in mathematics and science, I have noticed that they engage in the same struggle about learning that I did as a school teacher. This struggle was explored, in particular, in a project focusing on teachers of science\(^3\), which showed that teachers develop their understanding of ‘how we learn’ in a parallel process to that of pupils.

In determining the research agenda, there was also a discussion about whether to incorporate both mathematics and science into the study. For example, at a Nordic conference on research on mathematics education in 1996 Mogens Niss, the Danish mathematics educator encouraged me to include both mathematics and science in my study, since the subjects often are combined for teachers. Later in the same year, at a symposium on mathematics and science educational research in Vasa, Finland, Ole Björkvist, researcher in mathematics and science, likewise suggested that ‘it would be innovative to inquire into both mathematics and

\(^2\) The idea of mathematics and science for ‘all’ has several different origins. One is the need to increase the amount of science and mathematics for all children, not only for those aiming to go into higher education (see for instance Fensham, 1988). Another is the democratic requirement of Swedish curricula to be accessible to ‘all’ (National Agency of Education, 2000 b).

\(^3\) The project took place over a three-year period and focused on teachers of science (see Gisselberg and Wolf-Watz, 2001).
science' (personal communication). Bengt Johansson and Jonas Emanuelsson (1998) argue however that teachers' experience mathematics differently to science, but they also note that both subjects would benefit if teachers were able to incorporate aspects from each in their teaching. Another argument for exploring both subjects is that student teachers in Sweden are expected to specialize in both subjects simultaneously. Thus, as a consequence of the discussion as above, it was decided to focus on both subject areas in the study.

Setting the context of the research

Teacher education became part of universities in Sweden since 1977. It was substantially reformed in 1988 (Prop.1985) to meet the requirements of the school reforms that had begun 25 years earlier in 1962 with the introduction of the comprehensive school system4.

1988 teacher education

The 1988 reform integrated earlier separate teacher education programmes for different age groups5 (Askling and Jedeskog 1994). Its central features were the reinforcement and extension of subject-based training for the lower levels of schooling, and a broader preparation for discipline-based teaching and content coverage for the upper grades. Within the study programmes for schoolteachers, various alternatives were offered for specialisation with regard to grades 1-7 and 4-9. The aim was to orient comprehensive schoolteachers towards a group of subjects with an overlap between grades 4-6 (for children the ages 10-12 years). Generally, prospective teachers of the lower grades studied a range of subjects over a period of 3.5 years, with a choice between two subjects groups; Swedish and social sciences or mathematics and science. Prospective teachers for grades 4-9 were provided with a more in-depth preparation in fewer subjects, which involved one and a half years’ study of major and one year of minor subjects: making together a total of four and a half years (Askling and Jedeskog, 1994; Ahlström and Kallós, 1996).

The revised programme of 1988 thus brought together two different traditions (seminar and academic) in order to get the best from both. The so-called academic teacher education tradition was regarded as lacking professional orientation while the seminar tradition was seen

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4 For more detailed discussion of the traditions and directions of teacher education in Sweden, see Erixon Arreman (2001)
5 Earlier there was a more general, classroom-based teacher education program for grades 1-3, another for grades 4-6 and a more subject-oriented teacher education program for grades 7-9.
as a-theoretical and lacking a research base. Thus shortcomings were seen in both traditions. The new order in teacher education of 1988 may be regarded as a clear break with past organisational traditions (Kallós, 1996). As it was being implemented and all courses, reorganised⁶, a lively debate emerged about its content and aims.

The 1988 education program had two major components: subject studies and courses in theory and practice of teaching⁷ with a compulsory written dissertation linking the two components. However, the most significant change was that subject studies became more important. Previously based on academic disciplines, subject studies were seen to have a weak association to corresponding school subjects. Subject studies had been, it was argued, rarely adapted to the specific needs of initial teacher education (Kallós, 1996).

The concept of ‘didactics’ was introduced both to solve this problematic relationship and to bridge the gap between (university) subject studies and school subject areas. On the one hand, it was recognised that the relationship between academic disciplines and corresponding school subject(s) was not a straightforward one. For example, which aspect of an academic discipline might be regarded as most relevant to the preparation of teachers in the related school subject? On the other hand, it was also accepted that prospective teachers needed to be able to select content and method of teaching as appropriate, and also to adapt to the needs of different pupils. Questions were thus raised concerning the ‘what’ ‘how’ and ‘why’ of didactics which included the extent to which the aims of teacher education corresponded to the goals of the national curriculum (to attain and to strive towards), as well as whether didactics was attuned to the moral and value requirements for content (National Agency for Higher Education, 1996).

Didactics also has a personal dimension (‘personal didactics’) which recognises the different experiences that individual student teachers bring to their learning, arising, for example, from themselves as individuals, their educational backgrounds and notions of what it means to be a teacher and how learning takes place. In the research literature, this personal dimension of didactics has been variously labelled ‘private theories’, ‘implicit theories’, ‘personal practical

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⁶ A study of the 1988 teacher education reform, carried out by Carlgren, Beach and Andersson, used different approaches and perspectives. Generally, findings pointed towards an ‘universitification’ of teacher education, i.e. more teacher education took place in the academic tradition. Thus there was a fear that the professional orientation of teacher education would be rejected (Ahlström and Kallós 1996).

⁷
knowledge’ and ‘images’ (Bullough, 1997). I argue in this thesis that ‘personal didactics’ needs to be taken into consideration in debates concerning the role and values of teaching (see also pages 11, 14-15)

Generally, the relationship between initial teacher education and teachers’ work in schools has been seen as weak in Sweden as in most countries (Kallós, 1999). For example, there is no national induction program in Sweden for new teachers, nor is there a structured series of activities to facilitate entrance into teaching, as in Britain. The lack of coherence between different elements of teacher education (pre-service and in-service) and its fragile research-base are also clearly visible in Sweden, again as in other countries (Sander et al, 1996).

Teacher education in Umeå University.
As already mentioned, teacher education at Umeå University was reorganised following the 1988 reform. This involved the following. For grades 1-7, mathematics and science education became the joint responsibility of teacher education and academic subject departments, although mathematics and science departments taught only a minor part of the overall 50 credits\(^8\) allocated to the two subject areas. Teacher education also offered courses in Social Science, Swedish, English and Aesthetics subjects. For grades 4-9, the subject focus was stronger. Approximately two thirds of mathematics education was taught by the mathematics department and the remaining third, by teacher education. Similarly science education was primarily the responsibility of the science subject departments. However, to bridge the gap between academic and school subjects, shorter courses in subject didactics relating to biology, physics and chemistry were offered within teacher education (Board of Teacher Education, 1988). Significantly, teacher education courses had lower status than subject studies, and the methods aspects of subject studies were later reorganised into didactics courses in biology, chemistry and physics. Teacher education mainly offered courses in the theory and practice of teaching (method) for prospective teachers of 1-7 and 4-9 grades.

\(^7\) Other analyses of teacher education in Europe generally refer to four components: subject studies, teaching methods, educational studies and supervised teaching practice (Buchberger at al, 2000).
Courses are measured in credits. One credit corresponds to one week’s full-time study. An academic year normally consists of 40 credits.\(^8\)

8
Initial teacher education was thus structured around level of schooling. Prospective teachers of lower grades were mostly taught within the ‘seminar’ tradition\(^9\) and teachers of grades 4-9 mostly within the disciplinary (academic) tradition (Board of Teacher Education, 1988). Thus although teacher education was the responsibility of the university as a whole from 1977, there has been an ongoing struggle between the two traditions within university initial teacher courses, which again is also the case in other countries (Sander et al, 1996).

**Research-base for teacher education**

A problem for teacher education in Sweden as well as in other European countries is its under-developed link to research (Sanders et al, 1996). Thus, in Umeå as well as nationally in Sweden, various attempts have been made to strengthen the position of research within teacher education. This process has not been an easy one and progress has not come without struggle.

Nationally, the need for a broader scientific basis for teacher education was identified (Ds, 1996) and a three-year research program launched to achieve this. Locally, this meant that courses for teacher educators in Umeå were organised, so that they could enter postgraduate studies\(^{10}\). In the late 1990s, the need for a specific scientific base for teacher education – in effect, research and graduate studies – was emphasised yet again (SOU 1999).

Local attempts to strengthen research in teacher education led to the decision by the University to establish a Faculty of Teacher Education (2000) and later to create research and doctoral studies for all departments involved in teacher education. This meant that departments involved primarily with practice and methods courses and/or focusing on the preschool, aesthetic subjects etc. were provided with increased research funding and a new subject discipline ‘teachers’ work’ (pedagogiskt arbete) (Erixon, 2002).

Subject departments also began to establish research and doctoral programmes specifically aimed at education. As a consequence the Department of Education (Pedagogik) began to lose its dominance in regard to research and doctoral studies focusing on teacher education and teachers’ work. Thus, the research base in teacher education at Umeå University currently has three components - teacher education, educational studies and subject disciplines.

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\(^9\) Although within university, teacher education departments were not regarded as fully ‘academic’ because of lack of a research base.

\(^{10}\) Together with other teacher educators, I gained my academic training in the Department of Education (Pedagogik).
Knowledge of curricula.

The socialisation of teachers into different educational practices is likely to be influenced by their own school education and the conjunctions or disjunctions in their own educational socialisation in pre-, compulsory- or secondary school (and university) (Bernstein, 1971). In relation to this, the Swedish National Curriculum has also to be taken into account in the study especially since the influences from teachers’ own schooling may be different from existing curricula. National policy documents are of importance to teachers and teacher education. It should be noted that the Swedish curriculum document is a legal ordinance, which articulates the right of access to knowledge for school students. Thus it is mandatory for teachers to understand its requirements.

Table 1 below provides an overview of when different changes occurred, thus indicating the relationship between the national curriculum and teacher education.

Table 1: Development of national curriculum and teacher education.

<table>
<thead>
<tr>
<th>Comprehensive school</th>
<th>Teacher education</th>
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<tbody>
<tr>
<td>1962 new national curriculum for the comprehensive school</td>
<td>1946, 1950, 1952…seminar tradition in colleges and academic tradition in universities</td>
</tr>
<tr>
<td>1969 first revision of “</td>
<td>1977 teacher education becomes part of the university</td>
</tr>
<tr>
<td>1980 second revision “</td>
<td>1988 attempts to merge seminar and academic traditions to meet the need of the comprehensive school</td>
</tr>
<tr>
<td>1994 third revision of national curriculum which introduced goal and result steering</td>
<td>*</td>
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<tr>
<td></td>
<td>2001 new teacher education programme with emphasis on research</td>
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* 1996, the year when participants in this study completed their initial teacher education.
Student teachers’ own educational background is termed their ‘personal didactic’, by which they bring specific beliefs and values into their teacher education programmes. This influences their views of teaching, learning, subject matter and students (Richardson, 1996). This focus on ‘personal didactics’ suggests the need for teachers to have greater understanding about curricula and how they are constructed, especially as existing curricula may be different from that of their own schooling. As Goodson (1994:111) argues, curriculum needs to be understood as a multifaceted concept, which is:

constructed, negotiated and renegotiated at a variety of levels and in a variety of arenas and... we must embrace fully a scholarly focus on curriculum as social construction, first at the level of prescription itself, but also at the levels of process, practice and discourse.

Thus what is prescribed by a curriculum is not necessarily carried out, and what is planned does not necessarily happen. Curriculum is negotiated and realized in relation to the specific context of teachers and pupils in their classrooms. What pupils learn can vary according to teacher, time and space. This study addresses mathematical and science teaching and learning; so the construction of these school subjects is of considerable interest. Goodson and Marsh (1996) present an overview of school subjects in different countries, mainly in the UK, USA and Australia though it is claimed that conclusions are applicable to other Western countries. Goodson and Marsh argue that school subjects are socially and politically constructed in an endlessly shifting terrain. By studying the history of school subjects, it is possible to identify periods of conflict and conformity. Such struggles underpin the fact that the taken-for-granted, normative aspects of school subjects are often much contested (Goodson and Marsh, 1996).

Thus, in science, Goodson and Marsh identify a struggle between single science subjects and a general science approach dating back to the beginning of the nineteenth century: a struggle that emerges in the current divide between academic ‘subject’ scientists and teachers who see school science as for all students (op cit: 77). The single subject and ‘science-for-all-students’ positions are also evident in the Swedish science curriculum of 1994. I return to this in papers 2 and 3.
Goodson and Marsh find a historical tension in mathematics between abstract, purist and practical, utilitarian positions. The abstract position depends heavily on ideas of Euclid, which ‘sharpened the intellectual power of mind and at the same time decontextualized knowledge away from the things of life’ (Goodson and Marsh, 1996: 8). After the launch of Sputnik by the Soviet Union in the late 1950s, an increased interest in ‘new’ mathematics spread throughout the Western world. Mathematics curricula were renegotiated in many countries and in both the UK (in 1988) and USA (in 1986) new subject standards were introduced. At the same time student-centred mathematics curricula, emphasising the ‘real world’, was in retreat from modes of assessment, which tended to focus on technical solutions (Goodson and Marsh: 92). These tendencies could also be seen in the Swedish mathematics curriculum of 1994 (see also, paper 2).

Falkevall and Selander (2002) claim that Swedish academic subject disciplines and school subjects ‘live their own lives’. School subjects, they argue, develop from different origins drawing on academic subject disciplines, curricula and teachers, and learning aids such as books, hands-on-activities, CD ROMs etc. Similar to Goodson and Marsh, Falkevall and Selander highlight the changing nature of curricula.

Emphasis on democratic values has also been a strong feature of the Swedish national curriculum. Thus, it is stressed that broad competences and the development of democratic skills should permeate all areas of school life and cannot be separated from everyday schoolwork:

\[
\text{Developing democratic values in young people is an educational task and the work of instilling such values presupposes that staff has the requisite knowledge and skills as regards both theory and practice in this area. (National Agency for Education, 2000 a: 8-9)}
\]

The 1994 national curriculum had a significant influence on the content of teacher education. Professional obligations were emphasised and also that teacher educators were to help becoming teachers to develop school activities in more independent and responsible ways. As Swedish education became more decentralised, there was more formal emphasis on teachers becoming more autonomous (Kallós and Nilsson, 1995). Teacher unions among others
contributed to a lively debate on the nature of teacher-professionalism in Sweden (Kallós, 1996).

**Learning to teach**

The transition from initial teacher education to school teaching is a process that begins early in teachers’ own experiences of schooling and education. When student teachers or indeed new teachers meet existing classroom practices, a complex reality emerges. As Ernest points out

> Theoretical knowledge is not enough for practical knowledge, which includes pedagogical knowledge of teaching mathematics [and science, my comment], curriculum knowledge, organisation management, context knowledge of school and pupils. (Ernest, 1989: 30)

One factor in learning to teach includes how teachers construct their own teaching in mathematics and science, and also their own assumptions about their teaching. Teachers’ and pupils’ attitudes and beliefs are important in understanding classroom practices and in enabling students and experienced teachers to develop their thinking and practice (Richardson, 1996).

The analysis of beliefs is a valuable and necessary form of educational research (Pajares, 1992) and has become a part of studies on teachers’ thinking processes. There are several concepts that have similar meanings to ‘belief’ in the literature, e.g. attitudes, conceptions, theories, understanding, practical knowledge, and values (Green, 1971). In this thesis, two terms are used in particular; ‘beliefs’ and ‘conceptions’. Beliefs and conceptions are created by means of a process of social construction through enculturation (processes through life), education (formal and informal learning) and schooling (teaching and learning). Beliefs and conceptions about teaching are well established by the time children go to school, and are unlikely to change unless they prove unacceptable or are challenged (Pajares, 1992). The study of beliefs and conceptions is important in order to raise the level of consciousness of teachers so that they are clear about their own value positions and the origin of their personal belief system (Cooney and Shealy, 1997).
The importance of the student teacher as an individual is also highlighted by Gran (1995) in an assessment of the Swedish teacher education reform of 1988. Here it is pointed out that among other aspects, individuals should be the focus of teacher education, in particular their values, ethics and early experiences. The learning of the student teacher should thus be characterized as a seeking for personal knowledge, critical reflection, creativity, flexibility, context and an open mind towards society and humankind. Teacher education should likewise draw on the same set of principles that underpin comprehensive schooling and its curricula (Gran, 1995).

The study

The main aim of this study is to gain greater insights – by means of investigation, analysis and interpretation – into teachers’ thinking and practice in mathematics and science. It seeks to contribute to such deeper understanding by the use of better contextualised data, clearer insights into human thinking and richer description of phenomena. Research about teachers has shifted in recent years from the study of teachers’ behaviours to focusing on their thinking (Lemar, 2001; Scott Nelson, 1997). Through examining prospective teachers’ beliefs and conceptions, the aim of the study was to gain insights into the thinking of beginning teachers and an increased understanding of their practice in school. Since beliefs and conceptions require assessment of what individuals intend, say and do (Pajares, 1992), related verbal expressions, action and teaching behaviour were all targets of the study. According to Pajares, traditional, closed belief inventories provide only limited information and are of little value since they are context free. Open-ended interviews are accordingly to be preferred. Observations on teacher behaviour provide further data for the study. The stages of the research design were as follows.

Table 2: Research design

<table>
<thead>
<tr>
<th>Research stages</th>
<th>Data collection</th>
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<tbody>
<tr>
<td>Stage 1</td>
<td>a) Questionnaire to all student teachers (90) specialising in mathematics and</td>
</tr>
<tr>
<td>On completion of initial teacher education</td>
<td>science – in 1996</td>
</tr>
<tr>
<td></td>
<td>b) Sub-sample of 16 student teachers interviewed in depth – later in 1996</td>
</tr>
<tr>
<td>Stage 2</td>
<td>a) Telephone contact with the above sample after one year – in 1997/98</td>
</tr>
<tr>
<td>On the entry into teaching</td>
<td>b) Observations of, and interviews with remaining 9 teachers in their school settings-</td>
</tr>
<tr>
<td></td>
<td>in 1999</td>
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</tbody>
</table>
In order to select participants for stage one of the study, a questionnaire was distributed to all prospective teachers specialising in mathematics and science on the completion of their initial teacher education at Umeå University in October 1996 (i.e. after 3.5 years for grade 1-7 teachers and 4.5 years for grade 4-9 teachers). 86 out of 90 of potential respondents completed the questionnaire. The aim of the questionnaire was to identify a sample of student-teachers, who represented the broad experiences of the population with respect to education, university studies and work experiences. As a consequence, 16 respondents from different backgrounds were chosen for in-depth interviews. They all agreed to participate and were duly informed about the ethical framework of the project (HSFR, 1990). At the beginning of each interview participants were informed about how the interview was to be organised. The questionnaires and interviews together form stage one of the data collection.

Stage two of the data collection comprises observations and follow-up interviews with nine teachers of the original sample of 16, carried out after two years of teaching. From telephone interviews at the end of their first year, reflections were gained on their first experiences of teaching. For information on the seven who dropped out, see paper three, page 4.

Participants received detailed information about what would be expected from them several weeks before the stage two meetings took place and were also provided with earlier interview transcripts. Head-teachers, colleagues and pupils were also provided with information about the project. I considered it a privilege, as researcher, to be able to take part in these follow-up meetings and to be welcomed into a variety of classrooms. I saw it as an opportunity to gain deeper understanding of the different conditions and traditions under which teachers work. The schools were welcoming and the pupils also appeared interested in my presence. All in all, this proved a positive experience and learning situation for me as well, I hope, for the teachers involved.

11 The questionnaire identified student teachers’ experience of: a) their studies b) Mathematics and Science in relation to different school levels c) evaluation.

12 The interview was structured in four different parts with a pause. The first part consisted of open questions on mathematics and science. Here each participant also gave more information drawing on the initial questionnaire. The second part consisted of a mathematical problem and how teachers might deal with that in their teaching. The third part illuminated a science problem and how teachers might deal with it. The fourth part was a ‘think aloud’ passage through statements on teaching.
Data collection (for stage two) involved sets of interviews, and observation and field notes which provided information on the settings in which the teachers worked. The observations provided an opportunity to understand teachers’ lives in the classroom from an insider perspective (Henriksson and Månsson; 1996). They were open-ended and without pre-selected categories. The focus was on how teachers carried out mathematics and science teaching. The observations were used as a starting point for the interviews, which took place immediately afterwards. As researcher, it was necessary to understand positioning in the classroom from at least two different directions; first, as an insider and experienced teacher with insights on the contextual settings of the classroom and a readiness to understand practice, and second, as someone who was able to look critically at the data and maintain a distance from familiar settings (Adler and Adler, 1994). In the distancing process, theories helped to create ‘lenses’ for the data analysis. For example, Östman’s didactical typologies (1996) were chosen to aid understanding of the nature of school subjects (see papers 1 and 2), whilst Bernstein’s discussion of educational codes (1971) contributed to the analysis of school contexts and how these affected teachers’ work (see paper 3).

The structure of the thesis

Having thus provided an introduction to the overall thesis, I now turn to details of its structure and organisation. The next section contains three papers that have been presented and published in various forms. Paper 1 was published in the Journal of In-service Education (Wolf-Watz, 2000); paper 2 was presented at the 2001 Nordic Educational Research Association meeting (NERA) in Stockholm (Wolf-Watz, 2001); and paper 3 was presented at the European Educational Research Association (EERA) Conference in Lisbon 2002 (Wolf-Watz, 2002) and published in Education-line (www.leeds.ac.uk/educol/).

Paper 1, Student Teachers’ Beliefs about Science focuses primarily on science, drawing on stage 1 of the data collection. The findings are presented at a group level. Its main focus is the nature of science as a means of developing thinking and in relation to teachers’ knowledge. It draws on Östman’s didactic categories to argue for an emphasis on democratic and moral scientific perspectives in teacher education and schools. In conclusion, it is argued that deeper understanding is needed of students’ taken for granted assumptions about science and the beliefs and conceptions that teachers’ hold.
Paper 2, *Developing pupils’ mathematical thinking: Student teachers’ beliefs and conceptions of mathematics education at the end of their initial teacher education* take up parallel issues to those of paper 1, but in relation to mathematics. The paper likewise draws on stage 1 of the data collection. Here, focus is on the contradiction between prospective teachers’ early experiences of mathematics when at school, and their perceptions as they complete their teacher education.

Paper 3, “*I have not found my way of teaching yet*. A study of new teachers of mathematics and science* uses Bernstein’s sociological concepts of ‘classification’ and ‘framing’ to explore new teachers’ possibilities to enact their understanding of mathematics and science in their teaching. This seems especially problematic in the case of mathematics. It is argued that Bernstein’s work is an important theoretical source for this kind of research. The paper draws on stage 2 data collection, i.e. observations and follow-up interviews. Findings are presented both at a group level and from the individual perspectives of three teachers.

The final part of the thesis is a concluding section which reflects on and extends the ideas contained in the three papers, and then provides recommendations for future policy and action.

Thus the three papers are sandwiched between the introductory and concluding sections, which form together the ‘kappa’ for the thesis.
References


Board of Teacher Education (1988) Local Plan of Teacher Education 140-180 points, Umeå University


Ministry of Education and Science (1994) The curriculum for the compulsory school, the preschool class and the afternoon school centre Lpo 94. Stockholm: Fritzes


Wolf-Watz, Margareta (2000) Student Teachers’ Beliefs about Science. *Journal of In-Service Education*, volume 26, number 2. 403-413

http://www.educ.umu.se/gaby/paper2_mww.doc

www.leeds.ac.uk/educol/guide.htm

Discussion and reflection

The complexity of teachers’ work is not easy to grasp. However this study has attempted to identify some key factors in following teachers from initial teacher education into their first teaching post. This final part of the thesis first provides a short overview of the overall study and its findings, then a discussion of the main themes that have emerged. It also refers to the literature that has helped illuminate the study. This is followed by a reflection on the research methods used and how appropriate they were. Attention is drawn to a need to strengthen the link between initial teacher education and teacher education as a whole. Finally a vision is presented of how teacher education might develop, derived mainly from findings of the study but also from my own experiences as a teacher, teacher educator and researcher.

The study

As we have seen, the research study was carried out in two stages. First, a questionnaire was distributed to all student teachers at the end of their initial teacher education at Umeå University (in 1996) who had taken mathematics and science as main options. Following this, a sample was selected for in-depth interview, chosen on the basis of a variety of factors (e.g. job experience, school and university studies). Papers 1 and 2 report on the first stage of the research, focusing on the subject specific elements of the study and drawing on theories from mathematics and science education. Two years later, a follow-up study was carried out of the remaining nine left in the sample that was still working in schools. Paper 3 reports on this second research stage and has a more sociological emphasis. It attempts to explain how the organisation of schools influences teachers and their possibilities to enact teaching that is consistent with their understanding of mathematics and science.

Overall, there are six main findings of the research.

1. Student teachers bring their beliefs and conceptions (i.e. personal didactics) learnt at school about what it means to be a teacher of mathematics and science into their initial teacher education and later, into the schools where they begin their professional lives.
2. Student teachers are interested in developing pupils’ thinking processes and learning in science and mathematics, rather than merely transmitting content.
3. Student teachers are aware that the quality of their teaching (of mathematics and science) is dependent on the pedagogical content knowledge.
4. Student teachers emphasize mathematics and science ‘for understanding’ and in connection to ‘real life’. Thus generally they have an applied approach to science and mathematics.

5. Schools in Sweden tend to be organised so that new teachers are have considerable autonomy over their teaching.

6. New teachers have greater autonomy in their teaching of science (which is not a core curriculum subject) as compared to mathematics (which is)

Discussion of Main Themes

This section draws on national and international research with the aim of locating the findings of the present study as above. Papers 1 and 2 indicate that at the end of initial teacher education, prospective teachers have a good understanding of how to carry out mathematics and science teaching in relation to national standards contained in the Swedish curriculum. On taking up their first professional post, they are able to exert considerable autonomy over their teaching. Even so, they seem dissatisfied with their abilities to enact teaching that is consistent with their individual ‘personal didactic’. It is argued that previous beliefs and conceptions continue to exert great influence on teachers’ own learning.

Personal didactics

A recurrent theme thus is the importance of the beliefs and conceptions that individual student teachers bring to their future professional role. Entwistle (1988) suggests that approaches to teaching reflect student-teachers’ experience of learning when they themselves were pupils. According to Posner et al (1982), it is therefore more important to address these preconceptions in teaching, than in other professions. Student teachers are insiders in the sense that they have first hand experience of schools and therefore may find it difficult to change their beliefs about familiar classroom events. Reflection on their often hidden assumptions about what it means to be a teacher is one way of challenging this inherent conservatism.

Constructivism, as we have seen, suggests that student teachers transfer their early beliefs and conceptions about learning, teaching and subjects when at school into their initial teacher education and into the schools they eventually work in. According to Pekhonen (2001) such beliefs are hidden factors that nevertheless steer the quality of mathematics (and science)
teaching and learning. Thus ‘how to learn’ affects not only new teachers’ own learning but their perceptions of their pupils’ learning. Initial teacher education clearly needs to address this ‘pre-understanding’ (Richardson, 1996). Magnusson (1998) further suggests that teachers’ knowledge is related to the teacher as a person. He refers to teachers’ pedagogical ‘tacts’ described as the meeting point between the individual and contextual framework. Thus,

... pedagogical tacts are not just differentiated in the sense of being person-related. They are in addition, created in the interchange between specific traits within the individual and specific characteristics in the contextual framework of teacher activities. (Magnusson, 1998: 226)

A Swedish research overview suggests that the single most important factor that influences pupils’ learning is teachers’ competence (Gustafsson and Myrberg, 2001). Other aspects such as class size and resources are seen as less important. Moreover, as Kupari (1997) points out in relation to teachers of mathematics, individual beliefs and conceptions are not easily changed and so cannot be expected to be transformed by a single event or course of training. Development of teaching, at whatever level, needs to occur from within rather than imposed from above. Teacher educators, thus, need to engage in the process of helping student teachers to become reflexive and self-conscious about their own beliefs and conceptions.

The changing nature of curriculum (Goodson and Marsh, 1996; Falkevall and Selander, 2002) is also an important issue for teacher educators and teachers. Student teachers need to be encouraged to reflect on what it means to be a ‘teacher’ of mathematics and science. Louks-Horsley et al (1998) argue that building on new understandings through active engagement is relevant to all learners, of whatever age.

The idea of building new understanding through active engagement in a variety of experiences over time, and doing so with others in supportive learning environment, is as necessary for adults as it is for young people (Louks-Horsley et al, 1998: 36)
Learning to teach

During the learning process, student teachers (as well as teachers, teachers educators, school pupils) strive to integrate their views about mathematics and science into their understanding of specific subject areas (Povey, 1997). Approximately half the student teachers in the study mentioned that by the end of their training, they wanted to teach in a more pupil-centred way. This might involve, for instance, the development of communicative skills using meaningful open-ended questions derived from a particular content area, with the aim of providing different perspectives which engage the pupils in responsible ways (Boman et al, 2002). The student teachers in the study had an awareness of open- and problem-solving approaches and also mentioned other teaching strategies such as inquiry-oriented group work, and practical activities connected to real life. As we have seen, many student teachers enter their initial professional education with a non-constructivist view on learning (Hewson et al, 1999). However, internalisation of constructivist perspectives on learning offered in their courses seems to have had a profound impact on their practice for most. For some new teachers, their ability to enact their understanding of teaching and learning was inadequate. Scott Nelson (1997: 5) claims that to understand how learning takes place, a shift is needed towards constructivism, in which:

- There is a view of learners as having a capacity to pose questions, develop solutions to problems and construct their theories and knowledge, rather than vessels to be filled
- The focus is on the development of students’ thinking rather than ‘covering the text’

The influence and authority of teachers, it is argued, is less important than their ability to encourage rigorous argument in their classrooms. However, the possibility of teaching in accordance to the conditions above is difficult to fulfil within current forms of initial teacher education in Sweden where the practice element is often short, and over-filled with other demands.

Nevertheless, the student teachers in the study had an awareness of the importance of their own role in pupils’ learning e.g. that individual pupils think and learn in different ways - which enabled them to focus on the different teaching methods needed. The contextual aspects of specific groups of pupils were also mentioned as in teaching and learning situations.
Teaching content.
Swedish curriculum guidelines state that teachers should achieve goals of ‘science for all’ and ‘mathematics for understanding’, which underpin a concern for wider democracy and empowerment of citizens (National Agency for Education, 2000). The emancipatory phrase ‘for all’ has been a clear influence on the teachers in the study, as we have seen.

The study shows furthermore that student teachers are interested in developing an applied approach to mathematics and science education (see also paper 1 and 2). If, as Englund (1996) argues, there is a distinction between education for the private good and education for empowerment of members of a democratic society, the applied approach to teaching content found, points towards teachers’ understanding of mathematics and science as mainly for the private good, that is for individuals to be able to cope with everyday life. To develop strategies, which also empower citizens, teacher education needs to give greater emphasis to democratic and moral approaches, and to provide student teachers with experiences, which enhance engagement with such values.

School influence
The main findings from stage 2 of the study suggest that school structures and organisation have a significant influence on newly qualified teachers. Schools have specific frame factors such as cultures and traditions with which new teachers are confronted. This is partly captured in Bernstein’s concept of ‘educational code’. Using the concepts of ‘classification’ and ‘framing’ taken also from Bernstein, it has been possible to explore in detail, the different contexts within which each beginning teacher worked. Strong classification restricts the teacher while weak classification allows for greater teacher autonomy. Mostly, classification in the schools included in the study could be portrayed as weak in the sense that the teachers themselves could teach mathematics and science according to their own knowledge and framing, and could take responsibility for planning and evaluating their teaching. Interestingly however, teachers’ own strong framing at the micro level of the classroom meant that pupils were not encouraged to engage in classroom planning nor influence curriculum content nor have a say in how lessons were to be conducted. It was rarely the case that teachers’ framing was flexible enough to provide possibilities for pupils to exert control over their everyday school lives.
In her study of science education, Morais (2002) similarly used Bernstein’s theoretical framework to argue that weak framing creates a context where children are able to question, discuss and share ideas; e.g. pupils are invited to influence the conduct of lessons – a position supported by Swedish curriculum principles mentioned earlier. Morais further claims that evaluation criteria at the macro level should be clear, i.e. that the aim of content needs to be made clear to pupils and that teachers need to develop a overview of curriculum objectives and underlying assumptions about choice of content. Indeed, many of the participants in the study seemed to understand that teachers need to have good knowledge and understanding of curriculum issues. Teacher education in Umeå University may thus be considered ‘effective’ in Morais’ terms as cited below.

The crucial move lies on teacher training – teachers’ competence can create classroom social contexts in which the aforementioned [weak framing and pacing] characteristics are present. This new approach is dependent on teachers changing their pedagogic principles and ideology. Effective training of teachers that makes them aware of the meaning and effects of their actions, and gives them the opportunity to change their practices, may also be expensive but would be more efficient than increasing indiscriminately the time allowed for acquisition.

(Morais, 2002: 561)

Morais emphasises the importance of teacher education in creating social context and meaning in the classroom, thus enhancing the relationship between initial teacher education and school practice so that they are able to build on each other. Morais also challenges the reluctance of science educators to accept sociological insights into content by arguing that Bernstein’s framework offers a significant contribution to scientific knowledge (of science education).

One finding from stage 2 of the study is that there were different approaches among teachers towards mathematics as compared to science. Mathematics was seen as more restricting, while in science teachers felt freer to act in a way more consistent with their understanding of the subject thus putting more effort into, for example, lesson planning. One reason might be that in Sweden, mathematics is a core and perhaps more pressured subject, while science is not. Another could be that in initial teacher training, teaching in science and mathematics is produced as different pedagogically. Thus in science, students are encouraged to “try
anything you want”, while in mathematics, students are expected to adapt more to the demands of the teacher. As a consequence the student teachers in the study, reported more experience of developing their own practices and pedagogies in science, than in mathematics.

Reflections on findings
Zeichner & Tabacnik (1981: 117) make an important point, also of interest to the study:

*It has become commonly accepted within teacher education community that students become increasingly more progressive or liberal in their attitudes towards education during their stay at the university and then shift to opposing and more traditional views as they move into student teaching and in-service experience.*

They ask whether the ‘effects of university teacher education are “washed out” by school experience?’ The findings of the study suggest, however, that new teachers know what is expected from them, but that it is not always easy for them to put this into practice. Their knowledge is not ‘washed out’ but, rather, difficult to achieve which makes them feel guilty that they are somehow not doing things in the right way. Disparities between understanding of teaching mathematics and science and daily classroom reality are reported as a source of discomfort for the teachers (see also Hargreaves et al 2001). What might be the reason for this? A number of possible factors may be considered, for example, that newly qualified teacher’s own experiences of mathematics and science education while at school, is often too technically-oriented, especially concerning mathematics. As one research participant put it:”*It was not ‘now we shall learn how to think and how to learn mathematics’, but just sitting down and doing calculations’.*

In their initial teacher education, student teachers reported the tendency likewise to be informed about curriculum content rather than about how to recognised and understand the impact of the differences between ‘older’ and ‘newer’ curricula. They were not encouraged to work with their own beliefs and conceptions of ‘old curricula’ in relation to the expectations of new curricula. Thus one finding from the study is the importantance of linking practice to theory (i.e. within teacher education, linking mathematics and science subjects, pedagogical approaches and schools practices) so that there is a consistent view of teaching and learning.
According to Goldsmith and Shifter (1997), a stronger connection is needed between thinking, talking and doing in teaching. This leads to questions concerning what kinds of experience stimulate teachers and teacher educators to reflect on their practice and develop their teaching? What beliefs enhance or constrain the possibility of change?

As we have seen, mathematics in Swedish schools seems more problematic than science, reflected in the various efforts to promote mathematics for understanding and problem-solving. Indeed, as a facilitator for mathematics education in-service courses in the 1990s, a main task was to enhance mathematics teaching in the comprehensive school drawing on a resource centre specifically to support mathematics teaching, created in Gothenburg in 1999. Later, in 2003, an investigation into mathematics in comprehensive and upper secondary levels was carried out, which pointed to difficulties, but which also provided evidence of definite, if uneven, improvements in mathematics teaching (Skolverket, 2003). About the same time, (January 2003), a committee for school mathematics was set up in order to change attitudes towards mathematics, increase interest in the subject, and improve mathematics teaching at all levels, from early childhood to university education. All these activities suggest that there is a deep concern in Sweden currently, about the state of mathematics education if it is to meet the needs of pupils and society more generally. Science does not seem to have attracted the same kind of sustained efforts, although some curriculum initiatives have been generally supported e.g. the Science and Technology project (in Swedish, NOT-projektet) to increase students’ interest in science and technology in different ways. Resource centres to support chemistry and physics teaching and learning have also been created.

Another issue arising from the study concerns the content of teacher education. After two years as teachers, the research participants identified deficiencies in their initial teacher education, particular with regard to communicating with parents about pupils’ progress and dealing with everyday conflicts. They would also have liked to have been more informed about how schools are organised. For example, a teacher in a small rural school wanted to know more about how to order books and financial management. Teachers of grades 1-7 pointed to a need for wider knowledge about the teaching of reading and writing, though seemed generally satisfied with the professional character of their initial teacher education. Teachers of grades 4-9 pointed to the gap between academic subject disciplines and school subjects, and the need for more help with subject teaching. Possible reasons for the
perceptions of initial teacher education as unsatisfactory by newly appointed teachers are as follows

- The existence of a gap between academic subject education and professional teacher education.
- The emphasis on subject teaching in initial teacher education, with less consideration of classroom practice.
- Too little time available in initial teacher education to develop sufficient knowledge about the professional nature of what it means to become a teacher.

As indicated earlier, the 1988 reform of teacher education aimed to merge two traditions in teacher education - ‘seminar’ and ‘academic’. Yet only two of the nine teachers in stage 2 of the research indicated that they had benefited from this combination of traditions. A teacher of grades 1-7 spoke warmly of the subject studies offered by the biology department and was also satisfied with the quality of the professional education that she received. A teacher of grades 4-9 claimed to have benefited from both traditions; i.e. aiming to meet pupils’ needs and to develop subject teaching skills.

The study also indicates that teacher education is generally structured to take into account, the specific conditions and traditions of a university, even if this does not accord with the government’s interpretation of what the education a teacher should receive. The Swedish curriculum is legally an ordinance, which means that goals can be interpreted as both the right of pupils to have access to, and the obligation of teachers to fulfil, the aspirations of the formal curriculum. More attention by teacher educators to government requirements and to the wishes of student teachers themselves, would lead, it is suggested by the study, to a better quality of mathematics and science teaching. Additionally a stronger link between teacher education and schools might encourage a greater focus on practice, and on how school subjects can be taught in more effective and productive ways.
Reflections on research methodology

In reflecting on the study and its methodology, it is evident that using a variety of methods – i.e. questionnaires, interviews and observation – was beneficial in terms of contextual information, richer possibilities for the description of phenomena, and achievement of deeper insights into how teachers think about and act out their teaching of mathematics and science. Although the aim was to use a variety of research methods in order to ensure breadth and depth of analysis, the research design could perhaps have been structured differently. For instance, fewer participants could have been chosen and followed more closely. However, this might have been problematic given the unpredictability of employment at the end of initial teacher education: indeed, the original sample ended up scattered across Sweden. In fact, the original aim was to study the participants over a longer period of time, but this was not possible for a variety of reasons.

In terms of validity, each stage of the research process was scrutinised: from the initial research question/problem, methods, theoretical framework, argumentation to interpretation and evaluation. Kvale (1989: 93) argues that validation is important to research because ‘validity concerns the justification of knowledge claims’ and therefore to question is to validate. Kvale claims that validity should be taken seriously throughout the research process, because it involves skills that the researchers need to develop in practice (Kvale, 1997) which include continuous checking of data and claims. As claimed earlier, beliefs and conceptions are important topics for educational research, since they involve analysis of what practitioners say, intend and do (Pajares, 1992). Thus by adopting the validity process of Kvale and the research methods according to Pajares (1992), it was hoped that the study would reach the research quality threshold.

Interviewing, as a research method, was problematic, however, for several reasons. Although trained in interview techniques, it was not always easy for the researcher to carry out the interviews in practice. For example, respondent ‘comfort’ levels differed. While most seemed satisfied with the way the interviews were conducted, one participant in particular was very reserved in the first interview at the university. Later when the location of the research moved to her school, she seemed more relaxed and was able to reflect on the reasons for her earlier discomfort. It seems that in the first interview, the researcher was seen more as an authority
figure, while in the second, was more of a critical friend. Thus inequalities in power and knowledge can be seen as embedded in the research process itself.

For the study, student teachers who later became school teachers, were the key informants of the research. Without their willingness to participate in the original questionnaire study, the interviews and without their agreement to open up their classrooms to scrutiny and observation, the research could not have taken place, underpinning the point that practitioners and researchers need to develop mutual good will in the interactive process of data acquisition. (Hamilton, 1994).

The time span for the research was extended over more than two years, allowing a range of factors to intervene. For example, unexpected events occurred between meetings and earlier interviews influenced subsequent research contacts with participants. There was also a leakage of respondents over time (Campell, Stanley, 1963) – in this case, seven of the original sample of 16 were not teaching two years after the original interviews. An additional aspect of carrying out research over a relatively long period of time concerns the development of the researcher. The longer time span can have both positive and negative effects. Positive factors include a longer period for planning and rethinking different aspects of the research - and hence a deeper overall understanding. More negatively, there may be a fragmentation in the research process and problems of sustaining an overview of the research.

Moreover, it became clear, following Denzin and Lincoln (1994) that it would be impossible to institute a value-free inquiry or hold to any single interpretation of truth. Messick (1989) likewise argues that there can be no value-free standard in validation. As a researcher, I approached my task with a specific set of questions that were to be investigated in a particular way, based on a set of ideas/framework/theories/ontology (Denzin, Lincoln, 1994: 11). My teacher background provided an insider perspective and a familiarisation with classroom activities. This again had both positive and negative implications: positive in terms of recognition of daily life in a classroom, and negative in terms of the ability to explore teaching in a distanced and analytical way. It is argued here, however, that for an experienced practitioner, the acquisition of ‘research glasses’ has enhanced rather than hindered understanding of life in classrooms.
Swedish teacher education.

In most European countries, the complexity of teacher education has been a constraint to action and change. As Buchberger et al, (2000: 10) points out,

\[\text{[Teacher Education] seems to be full of contradictions, tensions and paradoxes, and one of them lies in the fact that intentions expressed are not always succeeded by appropriate action.}\]

Teacher education which includes initial teacher education, induction, in-service training and postgraduate work is thus seen as weak in Sweden as in other European countries (Kallós, 1999).

As we have seen, the ‘new’ teacher education of 1988 tried to merge two Swedish traditions (‘seminar’ and ‘academic’) so that ‘the different sub-cultures together make a differentiated understanding corresponding to the multidimensionality of teachers work possible’ (Carlgren, 1997: 117). However, the research suggests that this has not been fully realised and that a possible strengthening could be achieved if different parts of teacher education could collaborate more closely, and build on each other’s expertise.

Additionally, schools that take in new teachers need, it seems, to make greater efforts to provide support for them in terms of their development of wider pedagogic perspectives and skills. For example, experienced teachers specialising in mathematics and science could take greater interest in the progress of new teachers specialising in the same subjects. School-leaders (and/or mentors, induction programmes etc.) are also important in supporting the professional development of newly qualified teachers (Bullough, 1997). In Sweden, this needs to be developed more systematically.

The research thus indicates that initial teacher education at Umeå University provides prospective teachers with a promising start as specialists in mathematics and science. It also showed that expectations of the new teachers in schools were in accordance with the national standards that they had worked with in their initial teacher education. This promising beginning however, needed to be further built upon in the school work place, so that the teachers might avoid reverting to their earlier understandings of school mathematics as ‘sitting and doing calculations’ or of science as ‘writing on the dotted line’. A UK study
highlights the enthusiasm of newly qualified teachers (NQT) about the expertise of co-ordinators who have supported them (Roden, 2002). It is suggested that such strategies are important.

*Schools must provide NQTs not only with sufficient and appropriate support to enable them to implement aspects of good practice, but must also provide the structure to enable the expertise NQTs bring to school to be built upon for the good of the whole school situation.* (Roden, 2002: 23)

The study also shows the first two years of teaching to be a period of struggle for new teachers. Schools, it seems, fail to provide opportunities for new teachers to develop their understandings of school settings in structured way so that the link between initial teacher education and the school workplace can be maintained and extended in a form of continuous development. This is unfortunate, especially as other research studies show that experiences from the first years of teaching have a tremendous impact on the personal and professional lives of teachers (e.g. Gold, 1996).

The overloaded nature of initial teacher education curriculum and its limited period, among other things, lead to difficulties in meeting all professional demands. Professional development is thus essential in promoting life-long engagement among teachers, and a readiness to meet rapidly changing demands of teaching and the teaching profession (Buchberger et al, 2000). One strategy would be to provide a systematic programme of support (e.g. mentorship, induction) as currently in the UK. This would start from the end point of initial teacher education and enable new teachers to reflect on who they are and where they stand in relation to their students and colleagues. This could help to bridge the gap between the different parts of their teacher education and also promote life-long learning within the teaching profession. Preservice and in-service education clearly need to be linked, perhaps through adopting the criteria developed by professional development schools, which incorporate the full range of activities, as above (Bullough, 1997).

The research base of teacher education has previously been weak in Sweden as in many European countries, as noted earlier (Sander et al, 1996). The ‘universitification’ of teacher education started in Sweden when it formally became part of university system in 1977. This was followed by efforts to bring teacher education in line with the 1988 teacher education
reform. The latest set of reforms (SOU, 1999) has led to recognition of teacher education as a university research subject in its own right. The research outcomes, it is anticipated, will lead to new insights into teaching and teacher education (Lindberg, 2002), perhaps involving the following:

- Greater concentration in university subject departments on adapting their teacher education courses and research to the requirements of the school, rather than university, subject.
- A research base for teacher education departments
- Broadening of educational research within the university department of education (Pedagogik).
- Research collaborations involving different university departments involved in teacher education.

A promising start has been made at Umeå University involving these moves. Perhaps it is now possible for the different research domains to close the gap between academic and school subjects and to collaborate in discussing issues raised in this study. Thus, future research in initial teacher education might focus on the effectiveness of courses and pedagogies used in order to enhance curriculum content and teacher learning. Ernest (1989) argues that the mode of courses within initial teacher education have to attract greater attention in these aspects. And as already mentioned, Morais (2002) points to the central importance of teacher education and the evident need for more developmental work making student teachers aware of their own actions. Drawing on the findings of this study teaching, research, a recent concept ‘practice-near’ (or praxisnära) emanating from government, might offer a means of improving teaching strategies. The dissatisfaction with existing educational research is reflected in recent pronouncements from the mathematics committee (Ministry of Education and Science, 2003: 3) that ‘the results [of research, developmental work and evaluation] have only to a limited extent reached the classrooms’. More innovative approaches and collaboration between researchers and teachers might be useful in improving the quality of teacher education as well as of schools, thus reinforcing the importance of the link between the two.
Vision of a teacher education

To conclude this research report, it is argued that the understandings have been drawn from a wide set of phenomena and experiences;

- of being a teacher and teacher educator
- literature review and theories on learning and life-long learning
- literature review and theories on teachers’ professional development
- findings from the study

All these indicate a vision of a developmental approach to becoming a teacher, which makes closer connections between initial teacher education and school practice.

Significantly, initial teacher education is of substantial international interest currently with many countries in the process of re-thinking and reformulating education policy. The point made here is that initial teacher education needs incorporate the complexity of teachers’ work and draw on inquiry, research and reflection as fundamental tools in creating its knowledge base. Lindberg suggests that it could include the following.

_We could start to talk about teachers’ work as if it was a profession with communicative and deliberative characteristics seen in the perspective of citizenship in terms of belonging and participation and we could start to talk about education for teachers as if it was meant to create good conditions for becoming teachers to develop their capacity to make sound judgement in relation to their work by participating in critical, constructive and challenging dialogue._

(Lindberg 2002, p 243)

The vision put forward here is somewhat different from the newly implemented teacher education (SOU, 1999) in terms of funding and length of programmes. The argument is that initial teacher education is a period during which many ideas about teaching and learning are presented and discussed. Currently there is too little time available for student teachers to arrive at a deeper understanding of the nature of school subjects, in this case, mathematics and science, and too little time for working on these issues in school settings. Perhaps there are

too many demands on teacher education or that the demands are unrealistic? There needs to be a redistribution of financial resources so that it is possible for a period of induction and/or in-service teacher education for all Swedish teachers beyond the end of their initial training. If this were to happen, new teachers would gain support, for example, systematically to gather evidence of their work, perhaps in a reflective journal or personal portfolio. This would enable them later to review their experiences together with other teachers and teacher educators, in order to look critically into, and to distance themselves from, their immediate school context. Teachers, schools and teacher education would all, it seems, benefit from this. Loughran similarly argues for a linking of teacher preparation and teachers-in-practice.

Learning about teaching in teacher preparation, and learning about teaching through experience as a beginning teacher can and should be explicitly linked. They are not, nor should not be, independent of one another, but need to be linked in ways that make understanding about teaching a growing concern for teachers, the profession and the academic community, that supports and learn with them….Teachers in schools and Faculties need to continually work together to enhance the learning about teaching of our students of teaching.

(Loughran et al, 2001:22)

One step towards this is the increased emphasis on mentoring currently. Certainly mentoring was available to only a few in the study. Teachers already in the system in Sweden are able to take part in professional development through distance courses: however this arrangement does not include (or suite) all teachers. The vision presented here thus reflects a constructivist approach to learning, in which teachers are engaged in a lifelong learning process, which draws on their own starting points and professional requirements.

**Concluding remarks**

One of the outcomes of this study of the complex process of becoming a teacher of mathematics and science, is that it is possible to make a number of recommendations relating to initial teacher education and professional development. These include:

- greater emphasis on democratic and moral aspects of mathematics and science in teacher education and in schools.
• further investigation of student teachers’/teachers’ underlying assumptions about mathematics and science, i.e. their personal didactics.

• continued discussion about how, and in what areas, strategies could be shared since core subjects e.g. mathematics seem more restricting pedagogically for teachers than other subjects e.g. science.

• development of teacher education and professional development as a unity - from initial teacher education, induction and in-service, through to support for teachers’ long-term professional needs

• placing of such issues and developments at a structural level so that schools and teacher education are forced to take them seriously, and genuinely engage with the concept of continuing professional development and life-long learning
References


Goldsmith, Lynn and Shifter, Deborah (1997) Understanding Teachers in Transition: Characteristics of a Model for Developing Teachers. In Elizabeth Fennema and Barbara Scott
Nelson (eds) *Mathematics Teachers in Transition* Mahwah, New Jersey: Lawrence Erlbaum Associates Inc Publisher .19-54


Hargreaves, Andy; Earl, Lorna; Moore, Shawn and Manning, Susan (2001) *Learning to Change Teaching beyond Subjects and Standards* San Francisco: Jossey Bass


Kupari, Pekka (1997) Teachers Mathematical Beliefs – Four Teacher Cases. In Gunter Törner (ed) *Current State of Research of Mathematical Beliefs IV* Gerhard-Mercator-University, Duisburg. 79-85


Ministry of Education and Science (1994) The curriculum for the compulsory school, the preschool class and the afternoon school centre Lpo 94. Stockholm: Fritzes


Povey, Hilary (1997) Beginning Mathematics Teachers’ Ways of Knowing: the Link with Working for Emancipatory Change Curriculum Studies vol. 5, No. 3. 329-342


Roden, Judith (2002) Improving Science in Primary Schools: The Role of Newly Qualified Teachers Report from Canterbury Christ Church University College

Sander, Theodor; Buchberger, Friedrich; Greaves, Anthony E. and Kallós, Daniel (1996): From the first to the second generation of European action programmes. Editors' foreword. In Theodor Sanders et al (eds) Teacher Education in Europe: Evaluation and Perspectives


