Primary school teachers' beliefs about teaching mathematics

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The main aim of the study was to investigate the beliefs about the purposes and methods of teaching mathematics in primary school teachers with different teaching experience. The sample consisted of 103 practicing teachers and 26 pre-service teachers. It was shown that teachers with different teaching experience were concordant in their evaluations of the purposes of teaching mathematics – they evaluated the purpose of acquiring knowledge higher than the purpose of the development of personality. Also, all groups of teachers valued formalist teaching methods the least. However, teachers with different teaching experience held different beliefs about using traditional, formalist and social teaching methods.

Beliefs about the effectiveness of different teaching methods and their suitability to use in different age groups are related to conceptions of development and learning. It is widely acknowledged in developmental and cognitive psychology that already young children are active knowledge constructors, and that learning also includes the restructuring of current knowledge and changing concepts besides acquiring new knowledge (e.g. Carey, 2000; Chi & Roscoe, 2002). Additionally, children do not construct and re-construct their knowledge independently, but in cooperation with adults (mainly teachers and parents) and peers (e.g. Nelson, 2003; Valsiner, 2000). Teachers' beliefs are influenced by their own school experiences, theoretical knowledge received from university or college, their practical experience in classrooms, and feedback from their students' achievement. It is important to learn about teachers' beliefs because beliefs influence behaviour, and through this, the

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students' academic and social outcomes (Pehkonen & Törner, 1995; Thompson, 1992). Also, these beliefs have to be taken into account in in-service training and in designing new textbooks and other teaching materials because beliefs influence the way teachers interpret new information (Thompson, 1992). So far, there are several studies on the beliefs of mathematics teachers (e.g. Gales & Yan, 2001; Handal, 2003; Kupari, 1998; Pehkonen & Törner, 1995, 1998; Thompson, 1992). These studies have provided evidence that what teachers know and believe about mathematics is closely linked to their instructional decisions and actions (Thompson, 1992). Beliefs about teaching mathematics have been studied less in primary school teachers. Thus, the purpose of the current study was to investigate the beliefs about the purposes and methods of teaching mathematics held by Estonian primary school teachers with different teaching experience.

Concepts of learning and teaching mathematics

In understanding learning, two approaches can be distinguished – the behaviouristic (teacher-centred) and the constructivist (learner-centred) approaches (Pollard & Triggs, 1997; Shuell, 1996). The specifics and forms of both approaches for teaching mathematics are depicted in figure 1.

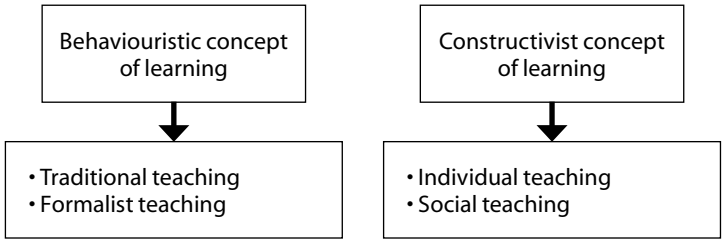

Figure 1. *Two concepts of learning*

When learning is conceptualized as accumulation of knowledge, the role of the teacher is that of active knowledge provider and the role of the learner passive knowledge receiver (metaphorically, as an 'empty vessel' to be filled with knowledge). In line with this conception, behaviouristic teacher-centred teaching methods were developed. In teaching mathematics, this so-called traditional teaching means a focus on acquiring skills of calculating and variation, and stress on practice rather than comprehension (Dionne, 1984; Pollard & Triggs, 1997). In

mathematics, additionally, formalist teaching is distinguished from traditional (Dionne, 1984). Here, the strictness of the subject is set foremost. Formalist teaching values the verbatim acquisition of definitions, using the terminology, correct use of language and symbols and it presupposes strict rules of formulation. Another feature of this method is frequent systematic assessment of learning results.

When learning is conceptualized as active knowledge construction, it also means that learners' preliminary knowledge, values, motivation and personality influence their activity, and, accordingly, the learning process and the achievements (Aronson, 2002; Carey, 2000; Covington, 2000; Merenluoto & Lehtinen, 2004). Accordingly, the roles of the teacher change, and she/he acts more as the students' supporter and supervisor (Dionne, 1984; Pollard & Triggs, 1997; Shuell, 1996). In line with this conception, constructivist learner-centred teaching methods were developed. In mathematics, individual constructivist teaching emphasizes independent raising, analysing, and solving problems, finding different solutions, and creative thinking. Social constructivism has brought about group work, research projects and the overall use of project learning. Students should experience that the result may be attained in various different ways, they are encouraged to find different ways of finding the solution, and discuss these during lessons. Co-operation is valued as well as using elements of games (see Geary, 1994; Handal, 2003). Both constructivist approaches value the development of the student's personality and knowledge comprehension instead of gaining 'pure' (factual) knowledge. Contemporary methods of teaching mathematics focus on the process of acquiring knowledge and skills in mathematics, not giving packaged knowledge; it means that constructivist approach is more valued than behaviouristic one (Geary, 1994; NCTM, 2006).

However, using pure constructivist child-centred methods did not gain hoped results (e.g. Geary, 1994). Without enough time for discussions and teacher's guidance in this process, misconceptions may arise (e.g. Bergqvist & Säljö, 1994). It is now acknowledged that behavioristic methods are specifically important for building basic skills and procedures in mathematics (see Geary, 1994). Just learning of the procedures requires extensive practice on variety of problems. Learning basic skills and procedures starts form the first grades, i.e., this form of practicing is of importance already in primary grades. Conceptual understanding also requires experience, although not so much drill (Geary, 1994). For a deep understanding of the ways of solving problems and their theoretical background, using constructivist methods (discussions, encouraging to use different ways of solving the same problem etc.) has additional value besides traditional methods.

Teachers' beliefs

Despite many educational reforms, which have been driven by conceptualising learning as active and have stressed the value of active learner-centred teaching methods, several studies have shown that a large number of teachers still perceive teaching mathematics in behaviouristic (traditional) rather than in constructivist terms. Handel (2003) gave an overview of studies about the beliefs of the mathematics teachers of various countries. He found that students attending teacher education institutions held beliefs mostly in accordance with traditional (behaviouristic, formalistic) approach. For example, they thought that mathematics learning in school should be based on memorising facts and rules. Beliefs of in-service teachers showed more variety. Some studies and teachers showed the preference for traditional, others for constructivist methods. Still, studies showed quite concordantly that more teachers favoured the traditional than constructivist model.

In Estonia, beliefs of mathematics teachers have been studied by Lepmann (1998, 2004). She differentiated between three approaches to teaching mathematics: the traditional, the formalist and the constructivist approach (she did not differentiate between individual and social constructivist learning, see figure 1). In accordance with Handel (2003), she found that although mathematics teachers valued constructivist teaching methods to some extent, they still did not fully favour these. The strictness in mathematical facts and formulae, and the high level of students' procedural and factual knowledge were also important to these teachers.

In accordance with trends in other countries, the constructivist teaching methods have been promoted in Estonia at least in the past 15 to 20 years. This has been done by means of national curricula design (Põhikooli ja gümnaasumi riiklik õppekava, 2002). Today, the new Estonian national curriculum is being developed. However, the working group of the mathematics curriculum has found that Estonian school mathematics in general and teaching techniques especially have primarily been based on the behaviourist approach to learning. The stereotypes of teaching and assessment tend to put extremely strict demands on all of the students (Ainevaldkond "Matemaatika", 2006).

The aims and hypotheses of the study

The main aim of the study was to investigate the beliefs about the purposes and methods of teaching mathematics in primary school teachers with different teaching experience. So far, mainly the beliefs and opinions of middle and high school mathematics teachers have been studied (e.g. Handel, 2003; Lepmann, 1998, 2004). The beliefs of primary school

teachers may be different due to the aims of primary education, but also due to the peculiarities of the educational system of primary grades and the children's age. The role of the primary school teacher is crucial in building the base for acquiring and comprehending knowledge of mathematics further, in helping to develop students' views on mathematics as a science, and in forming their attitudes towards studying mathematics. Primary school teachers who teach several subjects have better opportunities for integrating mathematics with other subjects than middle and high school teachers who teach mathematics only. Using problems from daily life and other school subjects enables them to show students the possible area of applying mathematics. First-grade students are generally interested in learning (e.g. Stipek & Ryan, 1997). However, children of this age are not always able to work independently for a long time, to find and compare different ways of solving problems. Also, due to their limited skills of group work, teacher's guidance and help is of specific importance (e.g. Azmitia, 1996).

Firstly, we studied the purposes of teaching mathematics. Namely, we analysed to what extent primary school teachers stress the importance of acquiring knowledge and to what extent they value the individual development of personality. According to the current Estonian national curriculum, the main objectives of teaching mathematics are to develop the creativity of the students on the basis of intuition and logical thinking as well as to provide the students with sufficient mathematical skills necessary in everyday life (Põhikooli ja gümnaasumi riiklik õppekava, 2002). Lepmann (1998, 2004) has shown that middle and high school mathematics teachers value the accumulation of knowledge, but we assumed that primary school teachers value individual development of students at least as highly as knowledge acquisition.

Secondly, we studied teachers' beliefs about the importance of using specific methods for the effective teaching of mathematics. A questionnaire was developed to represent traditional, formalist, individual, and social teaching methods (see figure 1). We expected that behaviouristic methods (traditional and formalist) are higher evaluated than constructivist methods.

Thirdly, we compared the beliefs of teachers with different teaching experience. We hypothesized that students and novice teachers would evaluate the elements of constructivist learning higher and teachers with long teaching experience would value behaviouristic methods more than students and novices. Students and novices study or have studied in university in the time when constructivist theory has been valued and teachers with long experience when the behaviouristic approach was taught. We also expected that teachers with medium experience would value different teaching methods.

Method

Sample and procedure

The sample consisted of 103 practicing teachers from 35 schools in different parts of Estonia and 26 fourth or fifth year university students of primary teacher education. Twenty-nine teachers had taught in school for less than 10 years, 32 teachers for 11 to 20 years, 21 teachers for 21 to 30 years, and 21 teachers for over 30 years. All the participants were female.

Questionnaires were distributed to practicing teachers by contact persons. Teachers filled in the questionnaires at home and returned to the contact persons. Of the 120 questionnaires distributed, 103 were returned. Students filled in the questionnaires in the university during a lecture. All the students returned the completed questionnaires.

Questionnaire

The questionnaire was developed in order to assess how relevant are different purposes and methods of teaching mathematics as considered by teachers. The introductory text of the questionnaire read as follows:

> The curriculum of basic school mathematics should be treated as one system. Topics studied in primary grades form the basis of school mathematics. It depends greatly on the primary school teacher, how strong a foundation is built. There are different ways of gaining and sharing knowledge, and no exact recipe for achieving the best results. We would like to know your opinion about the effective teaching of mathematics in primary grades.

Next, descriptions of different purposes of teaching mathematics (part I) and methods of teaching (part II) were described. Teachers had to assess their importance on the five-point Likert scale (1 – not important, 2 – not very important, 3 – neither important nor unimportant, 4 – important, 5 – very important).

In the first part, 7 purposes of teaching mathematics were described. In selecting items, we based on the Estonian national curriculum (Põhikooli ja gümnaasumi riiklik õppekava, 2002). Three of the descriptions were focused on personality development, four on knowledge acquisition (see table 1).

In the second part, methods in teaching were described. The items were formulated to represent four approaches to teaching mathematics – the traditional, the formalist, the individual and the social approach

(see figure 1), in developing descriptions we based on the earlier studies (Lepmann, 1998, 2004) and theoretical assumptions (Dionne, 1984; Pollard & Triggs, 1997; Shuell, 1996). At first, the questionnaire included six descriptions of traditional, formalist, and individual constructivist teaching methods, and seven descriptions of social teaching methods. As the preliminary factor analyses showed that three of the items (two of the formalist and one of the traditional methods) loaded on several factors, three items were excluded from further analyses. Consequently, the second part contained 22 items (see table 2).

Data analysis

First, we carried out exploratory factor analyses separately on two parts of the questionnaire, with the Principal Component Method and Parallel analyses for determining the number of factors both for purposes and methods. Second, differences between evaluations of different constructs were compared with paired-samples *t*-tests. Third, differences between evaluations of teachers with different teaching experience were compared with the ANOVA and the LSD test in post-hoc analyses.

Results

Purposes of teaching mathematics

Exploratory factor analysis was run for seven items. Parallel analysis showed two factors. The loadings of all the items are given in table 1. All in all, 48.5 per cent of the variance was explained by the variables. Internal consistencies (Cronbach's α of the scales were .53 and .56, the item-total correlations were higher than .30 for both scales. As scales contained only three and four items, these values may be considered acceptable (Field, 2005).

As expected, the first factor (loadings higher than .57) describes purposes related to the development of the individuality of students, i.e. *personality development*. The purposes characterising this factor were developing students' creativity and problem cognition, the individual development of every student, moulding independence, persistence and patience. The second factor (loadings higher than .43) describes *knowledge acquisition*. This factor includes the following purposes: acquiring basic skills of calculating with natural numbers, guaranteeing the ability to use mathematical knowledge and skills in everyday life, developing general skills and abilities, as well as promoting interest in learning

Table 1. *Evaluations of the purposes of teaching mathematics*

Item No	Purpose	Personality development	Knowledge acquisition
7	Developing students' independence, profoundness, persistence and discipline	**.85**	-.14
6	Developing students' creativity and problem cognition	**.67**	.25
4	Individual development of each student	**.57**	.27
1	Acquiring the basics skills of calculating with natural numbers (algorithms of mental and written calculation, basic characteristics of arithmetic operations)	.12	**.71**
2	Developing ability of using mathematical knowledge and skills in daily life	-. 09	**.71**
5	Developing general abilities and skills (comparing, systematizing, classifying, logical thinking)	.32	**.60**
3	Raising students' interest in studying mathematics and maintaining pleasure in their work	.29	**.43**
	Cronbach's alpha	.56	.53
	Mean	4.53	4.76
	Standard deviation	.31	.43

mathematics. Mean scores of the evaluations of personality development and knowledge acquisition were compared. In general, teachers valued knowledge acquisition significantly more than personality development, $t(128) = 3.11$, $p = .002$.

Approaches to teaching mathematics

Exploratory factor analysis was run for 22 items. In accordance with theoretical assumptions, parallel analysis showed four factors. All in all, 43.6 per cent of the variance was explained by the variables. The loadings of all the items are given in table 2. The internal consistencies of the scales were .70, .68, .66, .66, and the item-total correlations were higher than .30 for all four scales. These values may be considered acceptable (Field, 2005).

The two first factors characterise the constructivist concept of learning and teaching. Factor 1 (loadings higher than .36) characterizes *social*

Table 2. *Evaluations of the teaching methods*

Item No	Method	Social teaching	Individual teaching	Traditional teaching	Formalist teaching
4	Learning with concrete materials and through concrete activities	**.75**	-.09	.05	.13
5	Using the elements of games	**.68**	-.01	.02	-.20
3	Learning with visual aids	**.66**	-.03	.07	.06
21	Using group work	**.62**	.08	.22	.08
22	Using project work	**.52**	.27	-.05	.13
7	Motivating students	**.40**	.23	.16	.04
15	Taking into account students' experience, knowledge and skills	**.36**	.21	-.00	.12
8	Raising and analysing problems	.12	**.71**	.11	-.06
10	Differentiated and versatile practicing	.00	**.68**	-.09	.06
20	Showing the possibilities of using mathematical knowledge in daily life	.27	**.58**	.12	-.13
11	Guiding students to self-control when solving problems	-.11	**.54**	.26	-.01
14	Developing ability to work independently (e.g. working with literature. instructions)	.07	**.52**	.21	.22
16	Aiding multiple ways of solving problems	.12	**.50**	-.07	.20
6	Teacher's instruction and explanations	.09	.04	**.71**	.09
9	Intensive practicing and repetition of basic knowledge and skills	-.04	.22	**.68**	-.01
12	Assessing students' knowledge and skills regularly	-.01	.05	**.61**	.23
2	Sequential raising of the level of difficulty	.21	.06	**.56**	-.06
13	Systematic repetition of the material learnt earlier	.16	-.01	**.56**	.24
18	Teaching mathematical definitions and rules	.07	.20	.23	**.73**
17	Solving problems which develop skills of proving	.15	.18	-.02	**.69**
19	Learning definitions or rules verbatim by heart	.15	.00	.06	**.68**
1	Guiding learning exactly and rigidly according to the textbook	-.16	-.14	.23	**.58**
Cronbach's alpha		.70	.68	.66	.66
Mean		4.15	4.39	4.48	3.05
Standard deviation		.43	.43	.37	.64

teaching in which the teacher encourages children to participate in different activities and playing games, utilises group and project work while motivating children and taking into account their current knowledge and experience. Factor 2 (loadings higher than .50) characterises more *individual teaching* in which differentiated practice along with self-control is important, developing independent working skills, directing students into finding problems and analysing them as well as finding different ideas of solutions.

The next two factors characterise the behaviouristic concept of learning and teaching. Factor 3 (loadings higher than .56) characterises *traditional teaching*, in which the student is left a passive role and the teacher directs and explains, mediating knowledge in small bits as the level of difficulty is raised. Basic knowledge is practiced, systematically repeated and regularly assessed. Factor 4 (loadings higher than .58) characterises *formalist teaching*, valuing the teaching of definitions and regularities, acquiring definitions verbatim, developing the ability to prove theorems. The teaching process is guided strictly by aims on the basis of the textbook.

Mean scores of the evaluations of social, individual, traditional, and formalist teaching were compared by pairs. Paired-samples *t*-tests showed that teachers evaluate traditional teaching significantly higher than all the other approaches ($p < .001$), individual teaching higher than social and formalist teaching ($p < .04$), and social teaching significantly higher than formalist teaching ($p < .001$).

Teaching experience, purposes and approaches to teaching

An analysis of variance was carried out to determine differences between groups of teachers with different teaching experience. Five groups of teachers were compared: students, novices (with a teaching experience of 1 to 10 years), younger experts (with a teaching experience of 11 to 20 years), experts (with a teaching experience of 21 to 30 years), older experts (with a teaching experience of more than 30 years). Mean evaluations of teaching approaches in different groups are given in figure 2. The main effect of experience was significant for social teaching, $F(4,124) = 3.17$, $p = .016$, traditional teaching, $F(4,124) = 3.35$, $p = .012$, and formalist teaching $F(4,124) = 2.24$, $p < .001$, but nonsignificant for individual teaching and purposes (knowledge acquisition and personality development).

Post-hoc analyses with an LSD test showed that all groups valued traditional teaching and individual teaching higher than social teaching and formalistic teaching. However, just older experts valued traditional teaching significantly more than students, novices, and experts ($p < .05$), and formalist teaching higher than all the other groups.

Students valued social teaching significantly higher than experts and older experts ($p < .005$). Novices and younger experts valued formalist teaching significantly higher than students ($p < .04$).

Discussion

The beliefs about the purposes and methods of teaching mathematics held by Estonian primary school teachers were studied. We found that teachers with different teaching experience were concordant in their evaluations of the purposes of teaching mathematics – they evaluated the purpose of acquiring knowledge higher than the purpose of the development of personality. Also, all groups of teachers evaluated the formalist teaching methods the least. Teachers with different teaching experience held different beliefs about using traditional, formalist and social teaching methods.

Besides teaching subject knowledge and skills, primary school teachers have greater role in socializing students than middle and high school teachers. According to Handal's review (2003) and Lepmann's study (1998, 2004), middle and high school mathematics teachers valued the accumulation of knowledge highly. In contrast, we expected that primary

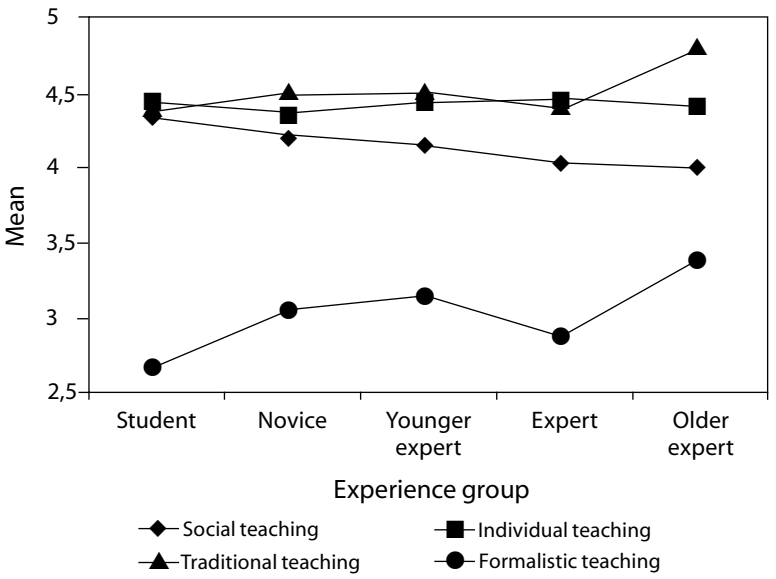

Figure 2. *Evaluations of teaching approaches in different experience groups*

school teachers evaluate the purpose of individual development of students at least as highly as knowledge acquisition. The results showed that although teachers – in spite of their experience – evaluated the acquisition of knowledge higher, another purpose – the development of personality – was evaluated highly as well.

While sometimes two – behaviouristic and constructivist – broad approaches of teaching are differentiated (see Handel, 2003), we could differentiate between four approaches – traditional, formalist, social and individual constructivist – which were evaluated differently in the whole group and in groups of teachers with different teaching experience. Our expectation that primary school teachers evaluate behaviouristic (traditional and formalist) teaching methods higher was partly confirmed. Great differences were found between evaluations of traditional as compared with formalist methods. Formalist methods – the verbatim acquisition of definitions, strict terminology, correct use of language and symbols, strict rules of formulation – were least evaluated in all experience groups. These methods seem to be more important to use in middle and high school (Handel, 2003; Lepmann, 1998, 2004). In contrast, traditional methods – focus on acquiring skills of calculating and variation, stress on practice – were evaluated the highest. The latter result is similar to earlier studies with primary, basic and high school teachers (Handel, 2003; Lepmann, 1998; 2004). Intensive practicing, repetition, sequential raising of difficulty as well as regular assessment seem to be an important part of teaching mathematics at all ages (cf. Geary, 1994).

While Handel (2003) in his overview found that it was students who valued traditional teaching methods and that more experienced teachers hold different views, in our study, students evaluated the constructivist approach as highly as the traditional approach, and gave specifically low grades to the formalist approach. They evaluated individual teaching specifically highly. Novice teachers (with a teaching experience of 1 to 10 years) stressed the importance of traditional methods the most but both constructivist methods as well. Younger experts and experts (i.e. teachers with a teaching experience of 11 to 30 years) evaluated traditional and individual teaching the highest but social teaching quite highly as well. So, social constructivist methods – group work, research projects, discussions, elements of games – were evaluated higher by students and teachers with less experience. Beliefs of teachers with teaching experience more than 30 years (i.e. older experts) differed from those of other groups. In particular, both formalist and traditional teaching approaches were evaluated higher by these teachers than by teachers with less teaching experience or by students. These results may be explained, taking into account that teachers' beliefs are influenced by their own school

experiences, theoretical knowledge studied in university, and their practical experience in classrooms. Actually, the participating students have studied in the university according to the curriculum where individual constructivist methods (e.g. discovery learning, project work) have been introduced and practiced specifically for teaching science. These experiences might have influenced their beliefs about the methods of teaching mathematics as well. Also, social constructivist methods are stressed as valuable for usage in school. Additionally, social constructivist methods are used in university teaching and these are also popular in in-service training courses. Older experts in particular have studied both in school and in the university at a time when traditional and formalist teaching methods were highly valued. If they do not take an active part in in-service training courses, their practical skills of using child-centred methods may even not be very high. These personal experiences and low skills in using constructivist methods might have influenced their preferences.

Across arithmetic and problem solving skills, conceptual and procedural competencies must be acquired (Geary, 1994). These skills must be taught and practiced; children need encouragement but also possibilities and time for the construction and reconstruction of knowledge. In the different stages of teaching, or in teaching different topic areas, various methods are used. Therefore, it is no surprise that Estonian teachers evaluated almost all the methods and approaches highly. However, teaching methods based on the behaviouristic approach (specifically, traditional methods) are more favoured (for older grades' teachers see Lepmann, 1998, 2004). The members of the committee engaged in developing the new national curriculum have also revealed reasons why constructivist methods are not widely used in Estonian schools (Ainevaldkond "Matemaatika ", 2006). According to their analysis, teaching methods based on problem solving take too much time to be effective. When little time is left for discoveries, discussions, and – specifically – for group work, it is students with lower skills and knowledge who are not able to gain understanding (cf. Azmitia, 1996). Additionally, constructivist teaching puts higher demands on teachers' knowledge and skills: the teacher has to integrate subject matter knowledge, pedagogical knowledge, student characteristics and the environmental context of learning (Leino, 1994). It has also been stressed earlier that learning some mathematical concepts and algorithms is more effective especially by means of behaviouristic methods. For example, when considering how to teach the memorisation of the multiplication facts, behaviourism may be a better option than constructivism since the aim is to remember rather than to understand (Zevenbergen, Dole & Wright, 2004).

It should be stressed that this investigation studied beliefs not behaviour. To determine which methods teachers really use in their teaching, classroom research is needed. As a limitation of the study, it should be mentioned that the sample size was quite small. In the future, teachers of different cultural backgrounds should be studied. Also, differences in the in-service training of teachers must be taken into account. Also, longitudinal studies have to be carried out to find out possible changes in beliefs due to experience.

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Sammanfattning

Huvudsyftet med studien var att undersöka uppfattningar (beliefs) om syftet med och metoder för matematikundervisning hos grundskollärare (primary school teachers) med olika undervisningserfarenhet. Undersökningsgruppen bestod av 103 verksamma lärare och 26 lärarstuderande. Resultatet gav att lärarna, trots olika undervisningserfarenhet, var samstämmiga beträffande syftet med att undervisa i matematik – de värderade syftet att utveckla kunskaper högre än den personliga utvecklingen. Dessutom värderades formalistiska undervisningsmetoder lägst av samtliga. Däremot visade det sig att lärare med olika undervisningserfarenhet hade skilda uppfattningar beträffande traditionella, formalistiska och sociala undervisningsmetoder.