Prospective mathematics teachers' metaphors for mathematics, teaching, and the teacher's role

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This study sheds light on Finnish preservice mathematics teachers' ($n = 16$) views of mathematics, teaching, and the teacher's role. Data was gathered via metaphors at three time points during teacher students' pedagogical studies, in academic year 2011–2012. The analysis was conducted inductively, but based on categories found in previous studies. The results indicated that prospective mathematics teachers' metaphors for mathematics mostly involved picturing the self-existent quality of mathematics. Their metaphors for teaching referred to the ups and downs in teaching, and their metaphors for the teacher's role were involved with the characteristics of the teacher's personality. One possible explanation for these results centres round mathematics student teachers' life situations. They have studied mathematics as their major at the department of mathematics for 2–3 years just before they started their pedagogical studies, and they have just experienced their very first and overwhelming lessons as teachers.

Teachers' beliefs about mathematics, its learning and teaching are reflected strongly in the way they teach. Reflection is assumed to play a key role in change of practice and many researchers see a cyclical relationship between changing beliefs and changing practices. (Kagan, 1992; Lerman, 2002; Wilson & Cooney, 2002). A number of recent studies have focused on elementary teachers' beliefs (c.f. Allen, 2010; Hannula, Kaasila, Laine & Pehkonen, 2005, 2006). Still primary teachers' views of mathematics can differ from prospective specialised mathematics teachers' views. Primary teachers in Finland very often consider mathematics as difficult, repugnant or even frightening (Pietilä, 2002). It is therefore important to study how Finnish mathematics student teachers describe their views of mathematics and its teaching. One way to explore these views is with the help of metaphors.

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In the Finnish context there has been data gathering in the form of metaphors for novice teachers and experienced teachers, but not so much for student teachers. Reflection is an essential part of teacher training and metaphors can be used as a reflective tool in different stages of pedagogigal studies. The main interest in this study is to collect metaphors for mathematics, metaphors for teaching, and metaphors for the role of mathematics teachers. The novelty of this research is that it combines all these three aspects. The research questions are:

1. What metaphors do prospective mathematics teachers use when they refer to mathematics?
2. What metaphors do prospective mathematics teachers use when they refer to teaching?
3. What metaphors do prospective mathematics teachers use when they refer to the role of mathematics teachers?
4. Is there continuity between the student teachers' metaphors for mathematics, metaphors for teaching, and metaphors for the role of mathematics teachers?

About metaphors

The word "metaphor" has its roots in Greek and is based on word *metapherein*, meaning to transfer or carry. That means that something is carrying across, and thus by metaphor we denote that something is, in some sense, something that it literally is not. As metaphors focus on similarities, they can be used to express views of the nature of mathematics. While they provide a way of talking about current views of mathematics, metaphors can open up new ideas of thinking about these perceptions (Lakoff & Núñez, 2000; Sterenberg, 2008).

Metaphors are not mere words or expressions, instead they are ontological mappings across conceptual domains. Also a metaphor is not just a matter of language, but of thought and reason. They involve understanding one domain of experience in terms of a different domain of experience (Lakoff, 1993). Therefore metaphors can allow students to understand and express abstract matters in concrete ways (Sam, 1999). Noyes (2006) points out that metaphors can reveal hidden beliefs of mathematics and help teacher educators to create conflict situations that might shift the meanings of mathematics. Reeder, Utley and Cassel (2009) argue that if experiences in teacher education programmes are to bring about meaningful transformation for pre-service teachers, teacher educators

must provide opportunities for students also to critically examine their own thinking and beliefs about teaching and learning.

Mathematics as ...

Ernest (1989) proposes three viewpoints for the nature of mathematics. Firstly, the instrumentalist view that mathematics is an accumulation of facts, and skills to be used, and mathematics is a set of unrelated but utilitarian rules. Secondly, the Platonist view of mathematics as a static but unified body of certain knowledge, where mathematics is discovered, not created. Thirdly, the problem solving view of mathematics where mathematics is seen as a dynamic, continually expanding field of human creation and invention, a cultural product. These three viewpoints can also be seen in metaphors for mathematics.

In this paper I introduce four different studies where metaphor theory and metaphors for mathematics were used. (1) In Sam's (1999) study to explore the images of mathematics of a sample of adults in the UK, the participants were asked open-ended question about their images of mathematics and learning mathematics and could give their answers in the form of descriptions, and metaphors or analogies. Only 27 % of the respondents expressed their images of mathematics in the forms of metaphors. (2) In Noyes's (2006) paper he reports how metaphor theory was used to explore pre-service mathematics teachers' beliefs about mathematics and the learning and teaching thereof. At the start of their secondary school mathematics teacher education course the students are required to submit an assignment, where they are expected to write about their experiences of learning mathematics, both in school and in their lives more generally, about teaching and their understanding of the nature of mathematics. The data in Noyes's study was selected from around 50 such assignments. Using a grounded approach the metaphoric expressions were identified and mapped. (3) Schinck, Neale, Pugalee and Cifarelli (2008) reported on an exploratory study of the mathematical beliefs of a group of 34 ninth and tenth grade students in the United States. Students were given a homework assignment to identify a metaphor for mathematics and describe how the metaphor represents mathematics. (4) In Sterenberg's (2008) study four elementary teachers were selected to participate in the research project, where these teachers wrote a story based on their study of the history of mathematics and created and implemented a series of corresponding lessons. The teachers in her study used metaphors to express how they were making sense of their experiences with mathematics.

One of the common themes that are likely to come up in these metaphor studies is metaphor for mathematics as a *journey* (Noyes, 2006; Sam, 1999; Schinck et al., 2008). According to Sam (1999) mathematics can be "a challenging journey and you get rewarded by arrival at your destination" or "learning mathematics is like an easy stroll" or "running uphill". Journeys include "places and timings, obstacles and short cuts, dead ends and all too often, going around in circles" (Noyes, 2006, p. 904). These metaphors are most often expressing experiences or the process of learning mathematics.

Mathematics as a *skill* is closely linked to a utilitarian view of mathematics (Sam, 1999). Noyes (2006) uses the word *toolkit* and describes it as a bag of rules, methods and conventions that we can use to model, interpret or change the world around us. Schinck et al. (2008) propose that 38 % of the metaphors contained codes referring to mathematics as a *tool*. That category included metaphors like duct tape, instruction manual, and a pencil.

The third category in Sam's (1999) study was mathematics as a *game* or a *puzzle*. This category is closely related to the problem solving views and in those metaphors mathematics was viewed as something to be solved. It reflected the fact that learning mathematics is fun and challenging. Schinck et al. (2008) use a category *structure* and included metaphors like mathematics as a game in that category. In the study by Schinck et al. (2008) it was the second most prevalent theme and structure codes were found in 82 % of the metaphors. The theme was divided into two sub-themes; an *interconnected structure* (44 %) and a *hierarchical structure* (41 %). Their argument was that in metaphors like a jigsaw puzzle or Rubik's cube mathematics was viewed as many separate pieces that are connected together by the student, and in metaphors like a video game and a castle of cards mathematics is understood "one level at a time and that skipping levels would expose the student to danger" (Schinck et al., 2008, p. 329). Noyes (2006) also uses a category called structure, but his reasoning is based on mathematical ontology.

Both Sterenberg (2008) and Noyes (2006) also found a category called *mathematics as a language*. When mathematics is considered as a language it is assumed to have properties of internal logic and it is also seen as useful for describing and communicating with people. Some teacher students consider mathematics to be the international language or the universal language. Moreover, it encouraged a consideration of the humanistic dimensions of mathematics, and "maths is all around us" (Noyes, 2006, 902) was seen as a feature of the self-existent quality of mathematics.

Teaching as ...

There are two categories for metaphors for teaching mathematics, as can be seen in Sfard (1998). Acquisition metaphors describe teaching as delivering the knowledge to be acquired. In the participation metaphor the teacher is seen as a co-participant and preserver of discourse. In this paper I introduce three studies where metaphors for teaching were used. Reeder, Utley and Cassel (2009) studied a group of 200 preservice elementary and early childhood teachers in a teacher education programme. Data for their study was collected at three different points in the teacher education programme. The participants were asked to construct a visual metaphor for mathematics teaching and learning, and describe their metaphor in writing. The categorization in this study is based on Kliebard's work which identifies three metaphors for learning and curriculum, namely production, journey, and growth. In Cassel's and Vincent's (2011) study they collected metaphors from 47 preservice elementary education majors during the students' mathematics or science methods course on the first day of class. The assignment was open: the students were handed a sheet of paper with the sentence "Teaching math/science is like ..., because ..." (Cassel & Vincent, 2011, p. 321). The researchers found five categories: End-product, End-product/process, Process, Overwhelming, Unclear. Martínez, Sauleda and Huber (2001) studied the reflections of 50 experienced elementary teachers in an in-service course on instructional psychology. The metaphors in their study were constructed by collaboration in small groups. The results were then compared with metaphors formulated by 38 prospective teachers without classroom experience participating in a course on curriculum design.

Reeder et al. (2009) uses three categories: production, journey and growth, and their combinations. These go well with Ernest's (1989) three models of the teacher's role and intended outcome: (1) the teacher is an instructor and outcome is skills and correct performance; (2) the teacher is an explainer and outcome is conceptual understanding with unified knowledge; or (3) the teacher is a facilitator and outcome is confident problem posing and solving.

Metaphors categorized as *production* were most common in the data of Reeder et al. (2009, p. 293) and indicated that students passively receive knowledge from teachers for example, "the teacher is as a sponge full of knowledge, squeezing it out into the empty glass". In Cassel's and Vincent's (2011) study most of the mathematics students' responses (64 %) were placed in the category of *end-product*. This category consisted descriptive words such as complicated, challenging, outcome, right ingredients, get answers, and laying a foundation. For example "teaching

math is like building a house with bricks because it takes a lot of patience and many different components to make it whole" (Cassel & Vincent, 2011, p. 321). Also in the study of Martínez et al (2001) the majority of experienced teachers as well as prospective teachers shared traditional metaphors depicting teaching and learning as *transmission* of knowledge.

Metaphors categorized as a *journey* describe the teacher as a guide or leader of an adventure with the students actively participating in the journey. Some metaphors also indicate that the teacher continually learns together with her students as things are discovered (Reeder et al., 2009). Cassel and Vincent (2011) called this category *process*, and 23 % of the science students in their study were in this category. Some examples of their descriptive words were interaction, change, discover, exploring, and interesting; "teaching science is like watching a flower grow" (Cassel & Vincent, 2011, p. 322). Martínez et al. (2001) described this category as constructivist and only a small group of teachers in their study were expressing constructivist metaphors.

The third category of metaphors was metaphors for teaching as *growth*. These metaphors depicted the teacher as one who gives something to the students that they need but the students can use it in their own way. The teacher is more like a nurturer working with students, and the students are curious life-long learners (Reeder et al., 2009). A minority seemed to conceive teaching and learning as a *social process*, the name given by Martínez et al. (2001) for this category.

In Cassel's and Vincent's (2011) study the third category was different. The students (20 %) described teaching of mathematics or science with words as dark, intimidating, does not make sense, a lot of work, no understanding, and scary. These metaphors were labelled in the category called *overwhelming*. "Teaching math is like teaching another language because students may not understand a single word."

Teacher's role as ...

Metaphors for teachers' role can be categorized according to Manual for the NorBa Project (Löfström, Anspal, Hannula & Poom-Valickis, 2011), which is based on Beijaard's, Verloop's and Vermunt's (2000) tripartition teachers as subject matter experts, didactical experts, and pedagogical experts. These aspects are not exclusive and they refer to teacher's knowledge base. Löfström et al. (2011) developed the model further and included two extra categories: self-referential referring to teacher's personality and contextual referring to teacher's teaching environment.

Subject matter experts possess vast and detailed knowledge and they transmit information to their students. *Didactics experts* know how to

chop the content into comprehensible parts and facilitate students' learning. *Pedagogical experts* focus on caring and nurturing students' holistic development. *Self-referential* metaphors indicate the characteristics of the teacher's personality. They tell us who the teacher is. C*ontextual* metaphors on the other hand describe where or in what kind of setting or environment the teacher works.

Educational setting

In Finnish secondary school, teacher preparation is a 5-year programme (3 BA and 2 MA). The students major in one subject and minor in one or two other subjects (e.g. mathematics major, and chemistry and physics minor). This means that the students take education as minor and these teacher's pedagogical studies (60 ECTS) can be taken within one academic year. Usually the students do their pedagogical studies at the end of their BA-studies. The programme gives general teacher qualifications to teach children (7th grade, 12–13 years), young people (secondary school) and adults in educational institutions offering general, vocational and adult education. Moreover, aacording to programme objectives, the future teachers gain a starting point to develop into a professional who plans, implements, evaluates, and develops teaching. In pedagogical studies the student teachers have to combine content knowledge, knowledge related to education and different learners, pedagogical content knowledge (i.e. knowledge of how to teach, study and learn the subject), and knowledge about school practices into their own pedagogical practical theory.

Method

Data for this study was gathered from 16 mathematics student teachers in three parts. The reason for this tripartite data gathering was to ensure that the student teachers in this study had been able to familiarize themselves with each issue, namely also in teaching. In addition student teachers were able to engage in reflective discussions of their views of mathematics, teaching mathematics and teacher's role in mathematics. Clearly, these discussions during the pedagogical studies were enhanced also by the use of metaphors as a strategy for revealing and challenging these images.

The first part of the data was metaphors for mathematics, and these were collected at the beginning of the semester before the students started their pedagogical studies and their mathematics methods courses. After studying for two to three years at the mathematics department, mathematics student teachers deepen their knowledge of mathematics,

and their views of mathematics have new ways of looking at the subject in addition to the previous ones in school context. The assignment was: the student teachers were asked to determine a statement "mathematics is", and to continue with an explanation of why it is so. They were also asked to identify themselves in their texts so that the answers could be put together later on.

The second part of the data was metaphors for teaching, and these were collected in the middle of the studies after student teachers' first practical classroom experiences. This ensured that all student teachers had gained experience of school and teaching mathematics. The assignment then was: the students were asked to complete a statement which started, "Teaching is ..., because ..." and to continue with an explanation for their statement.

The third part of the data dealt with metaphors for teacher's role. These metaphors were collected after the semester at the end of student teachers' pedagogical studies. Student teachers had now gained deeper experiences of working as teachers, of assessment and evaluation in school, and of how to develop their future profession. The assignment then was: the students were asked to expand the statement "As a mathematics teacher I am ..., because ..." and again to continue with explanations for their statements. Only the metaphors with students' permission to use all these three metaphors as data, was gathered for this study.

The analysis was made in two phases: firstly, a short description of categories was developed for metaphors for mathematics and metaphors for teaching following the data analysis used in the previously mentioned studies. Each metaphor was analyzed independently by the researcher and the assistance classifier. Once independent data analysis was complete the findings were compared for inconsistencies and worked collectively to reconcile some of the inconsistencies. Then the Cohen's kappa was calculated, although the number of metaphors was quite small.

Agreement was substantial (Cohen's kappa $\kappa \approx 0{,}733$) (see table 1) for the categorization of the metaphors for mathematics using the codes Journey, Tool, Structure, and Language. As it was for categorizing the metaphors for teaching using the codes *Production*, *Journey*, *Growth* and *Overwhelming* (Cohen's kappa $\kappa \approx 0{,}793$) (see table 2). When the metaphors for mathematics teacher's role were categorized using the NorBa –project's codes *Subject matter expert*, *Didactics expert*, *Pedagogical expert*, *Self-referential metaphors* and *Contextual metaphors* the agreement was also substantial (Cohen's kappa $\kappa \approx 0{,}813$) (see table 3). After the categorization all the results were cross-tabulated (see tables 4–6).

Results

Some of the metaphors were rather clear-cut, but some were opened up to various possible interpretations. Each metaphor was counted as one, but four of the students did write more than just one metaphor, and every metaphor was used. That explains why the total amount of metaphors is 19 in table 1 and table 2, and later in table 4 and table 6.

Based on the results of categorizing the prospective mathematics teachers' metaphors for mathematics (see table 1), the language metaphor was the most common metaphor (58 %).

Table 1. *Prospective mathematics teachers' metaphors for mathematics*

Metaphors for mathematics	*n*
Journey	2
Tool	1
Structure	5
Language	11
Total	19

A typical language metaphor expressed the self-existent quality of mathematics and included an aspect "mathematics is beautiful" or "mathematics is all around us". "Mathematics is like a flower. One cannot help but fall in love with *its beauty*" (Student 10). Mathematics as structure was the second most prevalent category. Structure-metaphors were found in 26 % of the cases. Typical metaphors in this category include "puzzles". "Mathematics is like a *house of cards*, the previous piece is always crucial" (Student 9). The third category was mathematics as a journey (11 %). Typical metaphors in this category handled "struggling and perceiving" or "problem-solving". "Mathematics is like hieroglyphics. *To start with* they are completely incomprehensible, *but as they open up*, they are an interesting world" (Student 7). The fourth category was mathematics as a tool. Only one metaphor (5 %) fell into this category. "Mathematics is like a periscope. *It enables special views*, but at the same time offers only one particular way of interpreting the world" (Student 15).

The category overwhelming was the one into which the greatest number of teaching-metaphors were classified (37 %) (see table 2). Most common theme was "teaching is difficult, demanding and sometimes you succeed and sometimes not". "Teaching is like going to war! *No plan can endure* the contact of battle" (Student 9). Teaching as production was coded less frequently than overwhelming and was found in fewer metaphors (26 %). Production was further subdivided into two sub-themes:

Table 2. *Prospective mathematics teachers' metaphors for teaching*

Metaphors for teaching	*n*
Production	5
Journey	5
Growth	2
Overwhelming	7
Total	19

"teacher presenting" and "teacher transferring information". "Teaching is like playing the piano. You must master the basics before going on to more advanced things, and practice does make perfect" (Student 10). The categorization of the prospective mathematics teacher's teaching-metaphors further revealed that 26 % constructed a metaphor depicting a journey metaphor. The main theme in these metaphors was "counselling" or "guiding". "Teaching is like an expedition. You have to be able to bring information to *different personalities* and at the same time learn something about the others as well" (Student 11). "Teaching is like guiding a treasure seeker – all throughout their school years students seek "treasures" of knowledge as *the teacher guides them on the path of learning*" (Student 8). The growth metaphor for teaching was represented in the fewest number of metaphors being found in only 11 % of cases. A typical growth metaphor included aspect "taking care". "Teaching is like gardening. If you respect your plants and their needs, *you will find their deeper potential and allow them in bloom*" (Student 15).

When the students were asked to describe themselves as mathematics teachers the most common metaphor (44 %) used was categorized in the category self-referential (see table 3).

These metaphors merely described student teachers' personal characteristics or features. A mathematics teacher was portrayed as "excited like a foal" or "like a small plant in a precious garden" or "a ship in the fog".

Table 3. *Prospective mathematics teachers' metaphors for teacher's role*

Metaphors for teacher's role	*n*
Subject expert	0
Didactics expert	6
Pedagogical expert	3
Self-referential	7
Contextual	0
Total	16

"As a mathematics teacher I am like a small child. *I am excited to learn new things*" (Student 10). A mathematics teacher as a didactics expert was the second most prevalent category (38 %). Typical metaphors in this category include "a scientist testing new methods", "Navigator", or "compass". "As a mathematics teacher I am like a signpost. *I lead the way and ask questions that inspire* the students to choose a path and explore. There might be many various paths leading across: cycle paths, dead ends and short cuts" (Student 12). The rest of the metaphors fell into the category pedagogical expert. Metaphors like "chameleon" or "rainbow" were examples of this category. "As a mathematics teacher I am like a muse. *I try to get the students ideas into circulation*" (Student 16).

Table 4. *Prospective mathematics teachers' metaphors for mathematics and teaching*

Mathematics / Teaching	Production	Journey	Growth	Over-whelming	Total
Journey	1	-	-	1	2
Tool	-	-	1	-	1
Structure	-	2	1	2	5
Language	4	3	-	4	11
Total	5	5	2	7	19

When examining the cross-tabulation in table 4 three aspects can be considered important. Firstly, eight of the students who described mathematics as a language also characterised teaching either as production (4/11) or as overwhelming (4/11).

> Mathematics is *a universal language*. The language in which it is spoken and studied does not affect its understanding. [...] Teaching is construction of buildings. Work can be done with great care and professionalism, thus creating a solid foundation. On the other hand builders may make mistakes and can learn from them. *The teacher is a construction worker,* who is trying his best to develop students' knowledge and development. To build a firm foundation from which it is good to move on later.
>
> (Student 13, language and production)

> Mathematics is like *the air you breathe*. Everyone uses it, even without noticing. [...] Teaching is like wading through the jungle, *you might come across either the mouth of a lion or a fruit tree*.
>
> (Student 2, language and overwhelming)

> Mathematics is *a foreign language*. It has its own grammar and sentence structures, but after you have studied it you can understand the much larger number of people speaking. [...] Teaching is like composing a symphony. You can do it in your own style, *but if the orchestra does not keep up with you, the result will not be beautiful to listen to.* (Student 16, language and overwhelming)

Secondly, none of the student teachers, who pictured mathematics as a structure, described teaching as production at the same time.

> Mathematics is a puzzle. A single piece does not say anything about the image. After patiently looking for every piece of its own place, you get a magnificent and intact piece of art. [...] Teaching is baking a cake. Yes it takes time, but when you work hard and you practice patience, you will enjoy the wonderful delicacy.
>
> (Student 14, structure and overwhelming)

And thirdly, only one of the metaphors (1/19) was categorized in the "mathematics as a tool" -category.

Table 5. *Mathematics student teachers' metaphors for mathematics and teacher's role*

Mathematics / Teacher's role	Subject expert	Didactics expert	Pedagogical expert	Self-referential	Contextual	Total
Journey	-	-	1	1	-	2
Tool	-	1	-	-	-	1
Structure	-	2	1	2	-	5
Language	-	3	1	4	-	8
Total	0	6	3	7	0	16

When examining the cross-tabulation in table 5 also three aspects can be considered special. Firstly, half of the students whose metaphors for mathematics (4/8) were categorized in "mathematics as language" were using teacher metaphors categorized in the self-referential category (4/7).

> Mathematics is a piece of art. Some believe that it can make sense, and others believe that it does not. But it always *evokes emotions and debate*. [...] As a mathematics teacher *I am a diary*. I collect experiences and blunders. I try to reflect on them with metaphors and sometimes without a plot; or with unconnected sentences, learning from them in the future. I also have book covers, and I keep secrets inside. Likewise mathematics has a certain face but the content may be surprising and dismantle prejudices.
>
> (Student 14, language and self-referential)

Secondly, three of those students whose metaphors for mathematics (3/8) were categorized in "mathematics as language" were using teacher metaphors categorized in the didactics expert category (3/6).

> Mathematics is a perpetual motion machine. It exists and is *constantly evolving*. [...] As a mathematics teacher I am a navigator. I *guide my students*. I give them options on how to proceed. But there will also be other alternatives for progression.
>
> (Student 6, language and didactics expert)

And thirdly, none of the teacher metaphors were categorized in the subject expert or contextual categories.

Table 3. Prospective mathematics teachers' metaphors for teaching and teacher's role

Teaching / Teacher's role	Subject expert	Didactics expert	Pedagogical expert	Self-referential	Contextual	Total
Production	-	4	-	1	-	5
Journey	-	2	-	3	-	5
Growth	-	2	-	-	-	2
Overwhelming	-	1	2	4	-	7
Total	0	9	2	8	0	19

When examining the cross-tabulation in table 6 two aspects can be considered important. Those students (4/5) who described teaching as production also described the teacher as a didactics expert.

> Teaching is a *tightrope dance*. A skillful dancer remains upright on the line and tough tricks seem easy for her. A skillful performer, however, always has the possibility to drop off. While practising with a thin tightrope the dancer is very fragile and weak. Successes in the smallest task can be a great experience and memorable. Also guidance and encouragement are needed. The trainee may experience hope and confidence and then the thread will strengthen. [...] As a mathematics teacher I am a squirrel eating pine cones. I am a curious and active participant, but also choosy and discriminating in my work. By eating or *capturing relevant information I get deeper layer by layer*, but all the layers cannot be known in advance.
>
> (Student 5, production and didactics expert)

Secondly, students (4/7), who described teaching as overwhelming, also described the teacher's role with a self-referential metaphor.

> Teaching is a steak. Ingested in appropriate chunks it is delicious and enjoyable. The quality of the steak depends upon *the group being taught*. [...] As a mathematics teacher *I am a small plant* in a prestigious garden. (Student 7, overwhelming and self-referential)

Discussion

Studying metaphors is addictive and at the same time challenging. Metaphors are personal and personalized and they are open to several interpretations. Some of them are too ambiguous and abstract to be interpreted; and some metaphors could be interpreted differently by different researchers (Sam, 1999). The fact that mathematics is seen to be a tool is in line with teacher belief research, where an instrumentalist view of mathematics and mathematics teaching (Ernest, 1989) is acknowledged to be prevalent amongst new trainees (Noyes, 2006). However, this study was a small and positive exception. The Platonist view is compatible either with the language metaphor or structure metaphor. In this study, 16/19 (84 %) of the metaphors were grouped under these categories. One reason for this might be that these particular students have studied mathematics as their major or minor for some two to three years before they started their pedagogical studies. The beauty of mathematics and its formalism are rooted deeper in them. Perhaps this is also contributing to the fact that only one of the students referred to the utilitarian view of mathematics as a tool. Surprisingly, none of the students with the mathematics as structure metaphor suggested a production metaphor for teaching. The problem solving view of mathematics (Ernest, 1989) can be referred to teaching as journey metaphors instead, where the process is seen as a necessary part of mathematics. Also this view was present in this study (26 %).

The metaphors for teaching after the first teaching practice in school were coloured by school experiences. Like Chang and Wu (2008) portrayed: at the beginning of his teaching career the teacher seldom notices the special incidents occurring within his classroom, and usually feels lost and does not know what to do. Then he only performs his teaching duties. Perhaps the teacher's working environment is not very well known after the teaching practice. The students have only 16–20 practice lessons (á 75 min) and that is not much. This could be the reason why there were no contextual metaphors for the teacher's role.

The second gradation in Chang's and Wu's categories is when the teacher reacts to the instructional problems occurring, but usually fails to solve them effectively. On the contrary the teacher recognize the huge gap between his own expectations and the school reality (Chang et Wu,

2008). The first experiences from teaching practice were perhaps the reason why so many of the students (37 %) used the metaphor "overwhelming" for teaching or self-referential metaphor for teacher's role. Anspal et al. (2012) suggest that while student teachers develop professionally, they shift from just thinking of themselves as teachers, or their survival in the classroom, towards concentrating on teaching methods and skills, and at the end *seeing* the pupils around them and concentrating on their pupils' learning.

In previous studies the most common metaphor for teaching was the production or transmission metaphor (Reeder et al., 2009; Cassel & Vincent, 2011; Martínez et al., 2001). In this study, production metaphor was used, in only 26 % of the teaching metaphors. Immediately after the pedagogical studies and method courses it is understandable that no subject expert metaphors were used and didactics expert metaphors were well represented (47 %), and only 4/9 of those students used the metaphor "teaching as production".

As seen, the material for the study in hand was small ($n = 16$), so the credibility of the study must be reviewed accordingly. Nonetheless, the study provides an *existence proof* that this can be the case. There was no explicit way of categorizing the metaphors either, even though a parallel classifier was used. Despite the difficulties with categorizing, and analyzing the metaphors they are nevertheless useful for teacher educators, while planning data gathering either in the form of metaphors or in the form of questionnaires. Metaphors are perhaps more powerful when participants have to choose one feature they want to emphasize, this is in contrast to the situation found when answering questionnaires, with metaphors they, can if they, wish value every aspect. By letting the students recognize their profession's metaphors, metaphors may "function as stepping stones to a new vantage point from which a teacher can look at his or her own practice from a new perspective" (Martínez et al., 2001, 974).

Was there then continuity or compatibility between the three metaphors chosen by the participants? To some degree, yes: only two participants had the combination "mathematics as language"-"teaching as production"-"teacher's role as pedagogical expert". The professional development of the student teachers in their study year was inevitably remarkable, and all the participants experienced it individually. Hence Complexity Theory could give a perfect theoretical frame for studying metaphors in the future. Metaphors are images of their time. They are continuously evolving in time and new associations are formed. The informativeness requires that the conditions, as presented in Davis's and Sumara's (2008) paper about Complexity Theory within educational research, are met

(c.f. Davis & Simmt, 2003; Davies, Sumara & Simmt, 2003). There must be internal diversity between the subjects. No two people have equivalent backgrounds or similar experiences. Moreover, there has to be internal redundancy; the subjects are much more the same than different: culturally, professionally, and educationally. According to Complexity Theory also neighbour interactions and decentralized control are needed. In a study of mathematics student teachers, they have a common language and shared representations to communicate and the assignments play a key role in bringing their knowledge into practice. Like Davis et al. (2003, p. 228) state: "the emphasis is not on what is, but on what might be brought forth".

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