Displaying Mathematical Literacy – Pupils' Talk about Mathematical Activities

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Abstract

The aim of the study was to exemplify pupils' mastering of mathematical literacy. The study is a comparative multiple case study. In pupils' talk of mathematical activities aspects of mathematical literacy are discerned. A distinction is made between pupils: (1) pupils in mathematical difficulties, (2) pupils with another mother tongue than Swedish or (3) pupils without mathematical difficulties. The study was performed as a comparative multiple case study. The "cases" were constituted by the three groups of pupils, and these were compared. Seventy-two pupils in grade 5 in six different primary schools in Sweden participated: twenty-four pupils in mathematical difficulties (twelve girls and twelve boys), twenty-four pupils with another native language than Swedish (twelve girls and twelve boys) and twenty-four pupils without mathematical difficulties (twelve girls and twelve boys). After each of the performed lessons in which the activities were carried out the pupils were interviewed (groupwise in the above defined groups) about their experience of the activities. In the analysis of the results three ideal types were described, one for each group of pupils. The ideal types were discussed with relation to mathematical literacy.

Keywords: *aspects of mathematical literacy; comparative multiple case study; mathematical difficulties; mathematical literacy*

1. Introduction

Many international studies of pupils' achievements in mathematics have been carried out. In the PISA study, the concept mathematical literacy was introduced (OECD, 2010). They define that the mathematical skill that is desired for future citizens is multifaceted and can be linked to linguistic development. The question is then if all pupils have equal opportunity to get stimulance to developing mathematical literacy. In order to find out more about this it is necessary to take an interest in pupils' own experiences of different kinds of mathematical activities.

The aim of the study was to exemplify pupils' mastering of mathematical literacy. In the study we account for which aspects of mathematical literacy are mentioned when pupils talk about their experiences of different common mathematical activities: (a) tasks containing numbers, (b) mathematical problems and (c) math story problems. We distinguish between pupils: (1) pupils in mathematical difficulties, (2) pupils with another mother tongue than Swedish or (3) pupils without mathematical difficulties. Secondly, we account for if/how the different aspects of mathematical literacy are shaped in the pupils' dialogues about the mathematical activities.

PISA defines mathematical literacy as: "an individual´s capacity to formulate, employ, and interpret mathematics in a variety of contexts. It includes reasoning mathematically and using mathematical concepts, procedures, facts, and tools to describe, explain, and predict phenomena. It assists individuals to recognize the role that mathematics plays in the world and to make the well-founded judgements and decisions needed by constructive, engaged and reflective citizens." (OECD, 2010, p. 4). Also, the importance of the context is pointed out: "An important aspect of mathematical literacy is that mathematics is engaged in solving a problem set out in a context. The context is the aspect of an individual's world in which the problems are placed. The choice of appropriate mathematical strategies and representations is often dependant on the context in which a problem arises" (ibid., p. 21).

Swedish pupils' achievement in mathematics have deteriorated since the 1990ies. In the TIMSS-studies the Swedish pupils were among the least successful in the 2007 study, in comparison with the 1995 study (Skolverket, 2008). In the PISA study it was established that the performance in mathematics of fifteen year old pupils had decreased both in comparison with the OECD average and in comparison with previous Swedish results (Skolverket, 2010).

The deterioration of Swedish pupils' achievements in mathematics has been studied from different perspectives. Hansson (2011) investigated how groups of pupils are composed and teachers' responsibility for the teaching. She used data from the TIMSS studies and she found that it affects the pupils in a positive way if the teacher guides the pupils; at the same time she pointed out the importance of letting pupils make their own reflections and solve problems independently. She means that pupils with another native language than Swedish, and with limited knowledge in the Swedish language are particularly dependent on the teacher's encouragement of interaction and also providing mathematical explanations. Also, speaking of pupils with another native language, we must be aware of the fact that another native language also means another cultural affiliation to some extent; Jablonka (2003) has drawn attention to this when pointing out that mathematical literacy has a cultural component: "It is not possible to promote a conception of mathematical literacy without at the same time – implicitly or explicitly – promoting a particular social practice" (p. 75). Jablonka (2011) has also observed that pupils who take initiative to posing constructive questions are favoured in mathematics teaching compared to more passive pupils. When the teacher gives answers to individual pupils the mathematical context is highlighted for some pupils, whereas the specific details in the context is emphasized for others. Jablonka means that a dynamic is thus created that becomes a self-fulfilling prophecy in which pupils' assumpted mathematical capacity is confirmed.

How to teach mathematics has been discussed internationally for several decades, and there is disagreement in particular between the idea that traditional teaching best benefits mathematical knowledge since it guarantees good numerational skill, and the idea that conceptual knowledge is developed through a reformed teaching for better understanding and insight in how and in which contexts strategies can be applied (Kilpatrick, 2001; Boaler, 2009).

According to Samuelsson (2010) procedural skill is still focused in Swedish classrooms despite the fact that different abilities are stressed in the most recent curricula in mathematics, in which a more diverse teaching of mathematics is highlighted. Swedish mathematics teaching has also been criticized for giving too little creative stimulation. In Skolverket (2011) examples are given of how to stimulate creativity using math story problems.

Sjöberg (2006) interviewed pupils and found that many pupils start experiencing difficulties when aged around ten. The difficulties often start with anxiety and strain together with negative expectations of mathematics. According to Sjöberg pupils in mathematical difficulties claim that they often get more useful explanations from classmates than from teachers. This can be interpreted in different ways – either as if the pupils are satisfied with getting an explanation for solving the immediate task or as if pupils do actually, better than the teacher, understand possible misunderstandings/ways of thinking. Both interpretations imply that pupils are better than teachers in putting mathematical problems in a plain context. If so, this is an example of the aspect of mathematical literacy that concerns the importance of the context.

Concerning difficulties in mathematics Linnanmäki (2002) has drawn attention to the fact that bad self-confidence can be one fundamental reason for assessing pupils as being in need of special support. The author claims that mathematics has a special status as a school subject in that it evokes strong reactions and that pupils worry more about their achievements in that subject than in others. Magne (1999) also emphasizes the special status of the subject by noting that it has a specific research area concerning anxiety, so-called math-anxiety. It is also known by the so-called attributional theory that it is a pattern for the behaviour of low achieving pupils to attribute their own ability when failing (Weiner, 1980; 1986), whereas high achieving pupils instead attribute failure to not trying hard enough.

Norén (2008) means that there is a barrier for learning, not only in mathematics but in general, for pupils with another native language. It is well-known that what is difficult in mathematics for these pupils is often the understanding of single words (Parszyk, 2009). However, the major difficulty is not "uncommon words"; these words are often explained by the teacher. No, the difficult words are those that have both a general meaning and a specific meaning for mathematics. Such words become treacherous, since the pupil can presume that a word has a general meaning and thereby not "see" the difficulty. A pupil may for example think that "odd" numbers imply something weird (Skolverket, 2011). Both Parszyk (2009) and Norén (2010) stress that pupils with another native language need substantial support in order to understand mathematics. Of course it is important that the teacher challenges all pupils' mathematical thinking, but this applies in particular to pupils with another native language and insufficient knowledge of the Swedish language.

2. Performance of the Study

The study was performed as a comparative multiple case study. The "cases" were constituted by the three groups of pupils, and these were compared. In order to make sure that all groups of pupils were talking about the same thing they all performed "the same" mathematical activities and after that group interviews were carried out immediately after the lesson. Seventy-two pupils in grade 5 in six different primary schools in Sweden participated in the study. The pupils' teachers were asked to pick out and make contact with the pupils: twenty-four pupils in mathematical difficulties (twelve girls and twelve boys), twenty-four pupils with another native language than Swedish (twelve girls and twelve boys) and twenty-four pupils without mathematical difficulties (twelve girls and twelve boys).

The study was carried out in six substudies, in which the comparability was controlled by following a written template, indicating how the study was to be performed. This is to say that the three mathematical activities were carried out as similarly as it is possible in different classrooms and also that the interviews were carried out using identical questions and as similarly as possible. The three lessons in which the activities were carried out were observed by a researcher/master student (in order to make sure that the activities were performed similarly), and after each performed lesson the pupils were interviewed (groupwise in the above defined groups) about their experience of the activities.

The mathematical activities had been constructed with respect to an assessment of pupils' results such as described in the comments to the curriculum (Skolverket, 2011). The first activity concerned basic arithmetic but mixed operations. In the second activity the pupils were asked to solve mathematical problems and in the third they were asked to construct their own math story problems. The two first types of activities had been constructed in advance in cooperation with an experienced maths teacher for grade 5 children.

The interviews aimed at finding out if/how the pupils described that the type of activity stimulated aspect/s of mathematical literacy: (1) reasoning mathematically and using mathematical concepts, (2) recognising the role that mathematics plays in the world, (3) making well-founded judgements and decisions and (4) solving problems set in the pupil's life world context.

When accounting for the result "ideal types" are constructed, based on the results of the study, for the groups of pupils, respectively. By ideal type is meant the analytical model that Weber (1949) constructed as a tool for describing and analyzing a certain unit. The ideal type means that certain traits are emphasized, and a hypothetic construction is formed in which the "type" becomes ideal in the meaning pure.

3. Results

At first we account for the pupils' talk about three activities concerning mathematical literacy, discerning the above defined four aspects of literacy. After that the presented result is summarized in the form of "ideal types" of how the three groups of pupils said that the activities stimulated mathematical literacy; in the ideal types we also indicate if/how mathematical literacy was created in the pupils' talk about the activities.

3.1 Pupils' Talk about the Basic Arithmetic Tasks

The pupils in mathematical difficulties meant that knowledge of mathematical concepts had been consolidated; one pupil said that s/he had used a stratagem for learning: "when doing multiplication I used the jingle". Typical for these pupils was that they stressed the fact that they had got the opportunity to learn basic arithmetic: "this thing with twenty-four, you can take 'how many times can you take four in twenty-four; then it is six'. This is something I have learned now". The pupils stressed that their knowledge development had been promoted by mixing basic arithmetic tasks.

The pupils with another native language than Swedish emphasized that they liked to work individually with basic arithmetic, preferably with more difficult tasks than these. At the same time, they said that the reason for these tasks being easy for them was the fact that they did not presuppose good linguistic skill. They stated that their knowledge development had not been promoted: "the tasks were too easy"; they wanted "bigger numbers and such". It appeared that they liked to "work on their own" and that they "liked counting". They did not have difficulties with making numeral calculations and they appreciated this kind of tasks, since they did not have to meet with the linguistic challenge. In summary, they said that these tasks had stimulated the first aspect of mathematical literacy: using mathematical concepts.

The pupils without difficulties in mathematics meant that they had learned mathematical terms (for basic arithmetic) and that the activity was fun. Symptomatic for these pupils was that they expressed themselves on a metacognitive

level: "Sometimes the teacher explains in a way that you cannot understand and then she does not understand either; sometimes she messes up for herself", and about their own learning: "it is good to repeat. Then you learn". So, also these groups of pupils said that this activity stimulated the first aspect of mathematical literacy, but they touched on the importance of mastering other aspects of mathematical literacy: mathematical reasoning – unlike the other two types of pupil groups.

3.2 Pupils' Talk about Solving Mathematical Problems

Typical for the pupils in mathematical difficulties was that they did not mention any aspect of mathematical literacy when talking about the tasks that concerned solving mathematical problems; they did not seem to experience these tasks as promoting either knowledge or linguistic development. The linguistic problems were expressed for example as follows: "[it would have been] easier if the text had been shorter". The cognitive challenge had been too big: "I did not understand what kind of arithmetic to use". One pupil said about the teacher's explanation: "I didn't understand anything", but s/he attributed her/himself the deficient understanding: "I don't think I would have understood even if s/he had explained in another way".

Characteristic for the pupils with another native language was that they did mention the first aspect of mathematical literacy, but only that the tasks had *not* implied stimulance of mathematical reasoning etc. The mathematical problems had been a linguistic challenge: "I was confused, so much text!". The pupils stressed that they had mastered the cognitive and linguistic challenges in the problem solving tasks thanks to getting help, in particular from classmates: "the teachers don't usually explain so clearly. For me classmates explain better, so that I understand". One interpretation of this is that it illustrates that it is easier for pupils than for teachers to relate to pupils' life world; this implies stimulation of the last aspect of mathematical literacy. The pupils also gave examples of meta cognitive skills: "the tasks weren't difficult, but it was more difficult because you had to think more"; they appreciated this: "it was fun […] you had to think more". This also means that one aspect of mathematical literacy was created: the aspect of making judgements and decisions.

The pupils with no difficulties in mathematics mentioned all aspects of mathematical literacy when talking about solving mathematical problem. They meant that the tasks had implied a cognitive challenge, they gave examples of how the cognitive development could have been stimulated by concrete examples: "you could have used real money in bills and coins – that would have made it easier", and they described that they realized that the lesson had been linguistically difficult for some pupils. "I understood the words, but maybe not all the others? That word can mean something else in another context." Such comments from the pupils suggest that they were able to identify with other pupils' perspective. The pupils way of talking about the activity meant that several aspects of mathematical literacy was created: mathematical reasoning and concepts, understanding the role of mathematics and also to make judgements.

3.3 Pupils' Talk about Math Story Problems

The pupils in mathematical difficulties said that math story problems stimulated several aspects of mathematical literacy: mathematical reasoning and concepts: "you learn mathematics when you write math story problems", to make judgements and decisions: "it was fun, difficult, but it was really fun to do this together". It was emphasized that the activity was fun and connecting to their life world reality: "it was so easy to make a story about ... just an ordinary story, sort of about anything: tomatoes, elephants, potatoes". Additionally, the pupils meant that imagination and creativity was stimulated. They were proud of their stories and asked to read them out in class. However, also in this activity a pupil stressed his/her own lack of competence. S/he assured that the teacher had explained well, but that s/he still did not understand. S/he meant that the reason for this was mathematical difficulties: "I don't understand" [….] "maybe you get ten minus seven, then it is slowly backwards and then I get stuck on a number, then I start thinking and get very stressed".

The pupils with another native language described that math story problems stimulated several aspects of mathematical literacy: they emphasized mathematical reasoning and concepts: "you learn to cooperate and you learn different ways of calculating"; they mentioned making judgements, and they also mentioned stimulation of linguistic development: "[it was] good to get the opportunity to both write and talk. It was easy and you understand better when you are allowed to draw and write also". They also said that they had stimulated each other both linguistically and socially. They also emphasized that the task had stimulated imagination and creativity, and connection to their life world: "you were allowed to imagine; that is not always the case in mathematics". These pupils displayed insufficient linguistic understanding, when saying that they had had difficulties understanding the instructions for the activity.

The pupils without mathematical difficulties described that the activity had stimulated all aspects of mathematical literacy: mathematical reasoning and concepts: ”when it is complicated you may not manage on your own, but together you can help each other and manage difficult tasks that you are able to do but maybe not on your own” – ”it would have been possible to do this by yourself but that is not wise because then you cannot support each other and that is what I think is good with group activities”. These last comments also exemplify that the pupils reflected over learning as a sociocultural phenomenon. The aspect to make judgements and decisions was touched on, for example when one pupil connected “to talk mathematics” to playing chess. Connection to the pupils’ life world was mentioned in comments such as: “[it was] fun to sort of write a story of your own in mathematics. At first we thought like this ’one bear’, but it became difficult with twelve thousand bears, so then we took ants instead, how many in an ant-hill.” The pupils’ way of expressing themselves suggest both that they had been stimulated comprehensively by the activity and also that they could reflect over this. They showed mastering of all aspects of mathematical literacy.

3.4 Ideal Types

All pupils said that the basic arithmetic tasks stimulated one aspect of mathematical literacy (mathematical concepts and reasoning) and that math story problems stimulated all aspects of mathematical literacy comprehensively. In each ideal type below it is described what was typical for the different groups of pupils. The ideal types summarize and structure the result accounted for above.

3.4.1 Ideal Type for Pupils in Mathematical Difficulties

The most striking was that solving mathematical problems was not talked of as stimulating any aspect of mathematical literacy. When talking about math story problems these pupils shaped one aspect of mathematical literacy: understanding the role of mathematic. Significant for these pupils was that they displayed bad self-confidence and attributed themselves the responsibility for failure.

3.4.2 Ideal Type for Pupils with Another Native Language

In this ideal type lack of linguistic understanding was displayed. Problem solving was *not* mentioned as stimulating mathematical literacy comprehensively; only that the aspect connection to their life world was accommodated by the help of classmates, not the teacher. As regards mathematical story problems they did not seem as familiar with this kind of activity as the other pupils; we do not know what lay behind their difficulties in understanding the instructions for the activity or their surprise at being allowed to ”imagine” when doing mathematics. It is possible that not only linguistic difficulties lay behind this but also cultural differences.

3.4.3 Ideal Type for Pupils without Mathematical Difficulties

This ideal type implied that these pupils talked about solving mathematical problems as an activity that stimulated mathematical literacy comprehensively; additionally, mathematical literacy was created when they talked about solving mathematical problems (mathematical reasoning and making judgements) and math story problems (all aspects of mathematical literacy).

4. Discussion

The pupils in mathematical difficulties said that it had been a good challenge that the rules of arithmetic had been mixed. ”Swedish” teaching in mathematics has been criticized, according to the deep analysis of TIMSS 2007 (Skolverket, 2010), for oversimplifying so that pupils are not challenged. Using only one arithmetic rule at a time may lead to numerical skill but does not challenge the other aspects of mathematical literacy. When talking about solving mathematical problems and also math story problems these pupils attributed themselves when they could not solve the tasks. This can be seen as an illustration of the behaviour formulated by Weiner (1980; 1986) in the attribution theory: pupils in difficulties (and with low self-confidence) attribute their own deficient capacity as the reason for the failure. When talking about math story problems these pupils shaped one aspect of mathematical literacy: understanding the role of mathematics. They even wanted to read out their story in class, which shows that this activity could counteract math anxiety and bad self- confidence.

The pupils with another native language than Swedish had no problems with the basic arithmetics – they appreciated that the tasks did not contain any text; however, thus they lost the important stimulation of language development (Parszyk, 2009; Skolverket, 2011). For these pupils problem solving offered linguistic difficulties, which shows that they needed to develop the Swedish language skills. They also mentioned that this activity stimulated mathematical literacy – when they got help from classmates the aspect connection to the pupils’ life world was shaped. They said that the math story problems had stimulated mathematical literacy comprehensively. This kind of activity is pointed

out as particularly important for pupils with another native language by Skolverket (2011).

The pupils without difficulties in mathematics talked about basic arithmetic in a way that they shaped good metacognitive skills/mathematical literacy. Their way of talking about pupils in mathematical difficulties illustrated the benefit of allowing pupil groups to be heterogeneous – it raises the (empathic, social and cognitive) competence in ”skilled” pupils – contrarily to when mainstreaming pupils; in that case the skilled pupils are deprived of the experience to meet a diversity of pupils. This is also said by Boaler (2009).

Metacognitive skills may be one reason that pupils are met with the kind of teacher response that stimulates mathematical literacy (Jablonka, 2011). Jablonka has pointed out that this may lead to self-fulfilling prophecies when it comes to pupils' performance capacity in mathematics. Only these pupils talked about solving mathematical problems as stimulating mathematical literacy comprehensively, and they also shaped mathematical literacy. The pupils said that math story problems stimulated their confidence in their own capacity. Such confidence can create “good circles” and counteract the vicious circles/self-fulfilling prophecies that Jablonka (2011) talks about.

When comparing the ideal types, the pupils without difficulties came forward as a ”wished-for norm”; these pupils both created and talked about mathematical literacy, in all types of activities. For the other two groups the situation was quite different; all types of activities did not seem to offer stimulation of mathematical literacy. This study gives examples of the nature of the difficulties for pupils with another native language and pupils in mathematical difficulties, respectively.

As regards pupils in mathematical difficulties it is easy to share Jablonka's (2011) concern about self-fulfilling prophecies and for pupils with another native language it seems important to observe the cultural aspect of mathematical literacy (Jablonka, 2003). If pupils without difficulties are the norm, pupils in mathematical difficulties and pupils with another native language run the risk of being made invisible when trying to stimulate mathematical literacy.

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