MATHEMATICS IN SWEDISH MULTILINGUAL PRESCHOOL: HUMAN AND NONHUMAN ACTORS AND THE DEVOLUTION PROCESS

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Abstract

This article explores how a bilingual preschool teacher creates mathematical preconditions and socio–psychological premises that advance children's understanding of mathematical concepts, and considers factors such as language and materiality that influence mathematical activities in a multilingual Swedish preschool. Elements of situation theory (devolution processes) and of actor-network theory (materiality as mediator) interact. This article highlights whether some didactic contracts promote interactions between materiality and multilingual children in two mathematical activities, one planned and controlled by the teacher to introduce the concept of shapes and the other spontaneous, in which the teacher follows the children's desires.

Keywords: Devolution process, didactic contract, materiality, mathematics, multilingual, preschool teacher

Introduction

Recent studies around the world indicate that students with different cultural and linguistic backgrounds display significantly lower levels of mathematics achievement than do peers who speak the majority language (Clements and Sarama 2011; Denton and West 2002). The gap in reading and mathematics skills is already there when children begin preschool. Children starting with the lowest performance display the lowest mathematical development from kindergarten to third grade (Bodovski and Farkas 2007).

Simultaneously, many studies (Clark et al. 2010; Doverborg and Pramling Samuelsson 2011; Duncan et al. 2007) demonstrate that early investment in child development that offers early mathematics experience as well as high-quality mathematics didactics have a major impact on children's learning, increasing their later-life opportunities more than intelligence or memory abilities (Krajewski 2005). Early education programmes can help prevent or reduce the development of mathematical learning difficulties of children (e.g., of immigrant background) at risk of lagging their peers (Clements and Sarama 2011; Cross et al. 2009; Jordan et al. 2009; Korat 2005; Magnuson et al. 2004).

Lack of majority language skills is often seen as explaining why children cannot participate in mathematics teaching while some studies (Saunders 2001; Valero 2007; Valero et al. 2008) show that it is instead the vision of language and way of using it that affect student achievement in mathematics. Researchers have recently found that when multilingual children use all their languages as resources, this can increase their confidence in mathematics (Adler 2001; Chronaki 2005; Drury 2013; Norén 2010; Moschkovich 2002; Ni Riordáin 2011; Planas and Setari-Phakeng 2014; Poisard et al. 2014; Setati 2005). Researchers in linguistics, developmental psychology, pedagogy, and social sciences agree that the support students receive for knowledge acquisition in their first language is crucial for personal development and success in school (Swedish Research Council 2012). Results show that even though language cannot completely form and determine mathematical thinking, it exerts some influence and facilitates our thinking and perception. We learn better in the language we have better mastered (Lindberg 2002), and in a multilingual environment, children can use all their languages to solve mathematical problems and to discuss thoughts with their teachers and peers.

Theoretical analysis

In every mathematical activity, the teacher has a clear picture of the mathematical concepts of which the children are to develop their understanding. The Swedish preschool curriculum (Ministry of Education 2018) defines these mathematical concepts. The teacher's task is not only to communicate these mathematical concepts to the children; rather, teachers must create situations (or engage in play) leading to particular learning objects. The teacher introduces the mathematical concepts in a particular context and helps the children to build useful and well-established mathematical understanding by investigation and discovery. The mathematical situations created must be thought out and the didactic learning environment must be challenging for the children to 'own' the concepts and create meaning.

The teacher is expected to create the mathematical preconditions and socio–psychological premises that advance the children's understanding of new concepts, and he/she must determine when the children have understood these concepts. In didactic situations, the teacher tries to give the children instructions about what they are expected to do. These expectations are specific to the subject being taught. The relationship between the teacher, children, and topic can be described as a didactic contract, which becomes the framework for what happens between the teacher and the whole group, between the teacher and individual children, and between the children themselves (Blomhøj 1995; Brousseau 1988; Delacour 2013, 2016).

> The didactic contract is the rule of the game and the strategy of the didactical situation. It is the justification that the teacher has for presenting the situation. But the evolution of the situation modifies the contract, which then allows new situations to occur. (Brousseau 1998, 31)

The didactic contract always exists in and determines the teaching situation. In a given situation, some determining factors are more active at some moments while others take over at other moments (Sensevy 2007). Although the researcher cannot consider all the factors affecting the teacher's actions, one must be open and not intentionally ignore the external factors determining the contract.

One factor that can affect what happens between the teacher, children, and learning object is how use of the children's languages is regarded. Some studies (Adler 2001; Chronaki 2005; Drury 2013; Norén 2010; Moschkovich 2002; Ni Riordáin 2011; Planas and Setari-Phakeng 2014; Poisard et al. 2014; Setati 2005) show that if the school's attitude to the students' multiple languages is positive, use of their multiple languages will promote student engagement in mathematics teaching.

The devolution process

Some studies conducted in Canada, Switzerland, and France (Giroux 2013; Joigneaux 2009; Margolinas 2012; Margolinas and Laparra 2008; Margolinas and Wozniak 2014; Thouny and Catteat 2006) have examined how various mathematical activities organized at the micro-didactic level and how teachers' behaviour can help maintain or create inequalities among preschool children that are perpetuated in school. Although the researchers did not investigate multilingualism, their results are interesting as they illustrate the factors that contribute to inequalities. These researchers argued that inequality among children when it comes to understanding mathematical concepts is not due to psychological or mental processes or to the children's backgrounds, but instead depends on how the teacher helps the children. They observed dysfunction of the didactic contract because of the 'topaz effect' – i.e., the teacher tells the children what to answer. The topaz effect can be described thus: When the teacher wants the students to act or to find an answer and they cannot, the teacher disguises the expected performance or answer using different behaviours or attitudes without providing it directly. To help the student give the expected answer, the teacher covertly 'suggests' it, hiding it behind progressively more transparent didactical coding (Brousseau 1997, 26); in the related 'Jourdain effect', the teacher assumes knowledge acquisition by the children when this is not the case. 'In order to avoid debating knowledge with the student and possibly acknowledging failure, the teacher agrees to recognize the indication of an item of scientific knowledge in the student's behaviour or answers, even though these are in fact motivated by ordinary causes and meanings' (Brousseau 1997, 26).

The teacher tries to help the children understand a specific mathematical concept by undertaking various activities or tasks. When some children do not succeed, the teacher tries to help by allowing them to undertake the same task several times. Teachers will tend to simplify the task for these children to be successful, but such success is short-sighted. The teacher makes most of the cognitive effort that should have been the children's, letting them simply perform different task (Vincent and Mary 2010). The use of step-by-step guidance towards the correct answer gives both the children and teachers an illusory sense of success that the children have acquired knowledge. The help that the teacher gives in a desire to see all the children succeed in a task hinders their ability to create their own strategies and acquire knowledge, and they do not give the children the time they need to understand mathematical concepts in their own way. The focus is instead to help the children perform a task. The teacher uses a lot of material to support the children's understanding of mathematical concepts, but when the explicit goal is to experiment with the material in the 'right way', the implicit goal – understanding a particular mathematical concept – becomes invisible to the children (Giroux 2013).

In a didactic situation, the teacher has the didactic responsibility to choose or pay attention to the learning object and help the children build their skills. The children must see the mathematical problem as their own and work to resolve it. The teacher must therefore delegate the responsibility to the children. Brousseau (2000) called this the ‘devolution’ process.

To enable the child to acquire knowledge, the teacher plans an appropriate activity. For the activity to be a learning activity, the child must be exposed to new knowledge. If the child already knows what the teacher wants to teach, there will no longer be a learning situation. If the teacher, for example, organizes an activity in which he/she introduces various plastic shapes and asks the children to name them, there will be no learning situation because the children must already know the names of the shapes to answer the question. Suppose a child has already learned to name the triangle, square, rectangle, and circle. If the teacher asks the child to name these shapes, the situation is just a way to control what the child can do but does not help the child understand what a shape is. There is a big difference between solving a problem by adapting to the *milieu* and by adapting to what the teacher wishes. For a child to see the solution to a mathematical problem as necessary regardless of the teacher’s desire, there must be a deliberate cognitive epistemological construction. Brousseau (2000) said that the power must shift for the child to take control of the problem. When the teacher transfers responsibility for solving a mathematical problem to the child, this is called the devolution process.

Actor-Network Theory– Latour

To advance our understanding of what happens between the teacher, children, and learning object – here, a mathematical concept – I will use concepts from actor-network theory (ANT) as defined by Latour (2005). How these concepts are used and understood is debated, but according to Latour himself, it is up to everyone to use ANT and distort it beyond recognition (Latour 2005). Thus, I will use parts of the ANT in my own way.

Things as participants

> Consider things, and you have humans. Consider humans, and you are by that very act interested in things. Do technology, and you are now a sociologist. Do sociology, and you are obliged to be a technologist. (Latour 2000, 20)

Children are constantly busy investigating the world through things, and things have always helped children make the world intelligible. To help younger children understand mathematical concepts, the teacher enlists the help of various items. Language is not enough to communicate abstract concepts, especially when it comes to children who do not always completely understand the language spoken by the teacher. Abstract concepts must be concretized using materials – games, toys, books, colours, movement, drama, etc. In situation theory (ST), material is a lifeless background to the situation and is understood in terms of symbols and representatives. Brousseau regarded the material as passively serving people and having a transitional, or intermediary, function. In ANT, the material is regarded as an active mediator that creates. The material can, like the teacher or children, change a state and exert influence. This does not mean that the material determines what will happen, according to Latour (2005), but that researchers should look at the durability and sustainability of various actors, human and nonhuman. They should ask themselves whether or not the material exerts influence within the framework of the other agent. Interaction is something that occurs between different units without transforming them.

> An intermediary, in my vocabulary, is what transports meaning or force without transforming: defining its inputs is enough to define its outputs. Mediators transform, translate, distort, and modify the meaning or the elements they are supposed to carry. (Latour 2005, 39)

The tendency to see materiality as an intermediary that can help children understand a predetermined mathematical skill is challenged by the vision of materiality as active and constructing new knowledge – i.e., as a mediator. Based on ST, learning objects are already culturally represented, and children are allowed to experiment with materials and exchange ideas to understand the mathematical concept of interest. Based on ANT, many different human and nonhuman actors can form a network and produce new knowledge. We cannot escape the fact that mathematical concepts are already predetermined in our society, but by letting ST and ANT form networks, new approaches can be produced highlighting what actors support children's understanding of mathematical concepts.

ANT does not treat the material as autonomous and as representing or speaking for a social activity, although it can initiate a social practice. A puzzle can draw the child's attention to a high shelf but cannot jump down by itself; it has no autonomy. The child might like to complete the puzzle, but is prevented because of where the teacher has placed it. A chair can draw the child's attention but it cannot go to the child; it has no autonomy. The child can move the chair, climb up on it, and take down the puzzle. Things can create some opportunities and prevent others: the chair can create the opportunity for the child to reach the puzzle, while the shelf can hinder the child from reaching it. Another scenario is that a didactic contract has hindered the child, puzzle, and chair from interacting. For example, certain rules may state that children in a preschool may not take down games by themselves, should not climb up on chairs, and can only play with puzzles between 12:30 and 14:30. Because materiality is not autonomous, it can be hindered by a didactic contract.

> Educational practices are then considered to be a myriad of actors that must relate to one another, and that are affected by one another. Big or small, alive or dead, complex or simple, "artificial" or "natural". (Hultman 2011, 32, own translation)

When we define actors as entities that change a situation by exerting influence, we see a mathematical activity as many actors coming together and negotiating. Actors can be various heterogeneous things such as curricula, language, time, rules, adults, children, toys, the playground, and tables. These actors can define the didactic contract that arises. ST defines everything that contributes to a specific mathematical activity *milieu*. The meeting place, if it is important for the ongoing mathematical situation, becomes part of the *milieu*, while the window somewhat farther away is not unless it represents and reinforces the mathematical concepts that the teacher is trying to convey to the children. In ANT, human and nonhuman factors acquire agency when they communicate and make suggestions. When they stay in the background and have no figuration, they are actant. If a human or nonhuman actor does not join the other actors, he, she, or it is not an actor but can be an actant in anticipation of becoming part of a network.

> An invisible agency that makes no difference, produces no transformation, leaves no trace, and enters no account is not an agency. Period. (Latour 2005, 55)

In a mathematical activity, many items of different forms that are parts of the *milieu* can, according to ANT, be actors when they leave traces, or actants if they are included in a mathematical network but are passive. The children, the meeting place, the shapes, the curriculum, and the teacher can become actors by linking themselves and interacting in a network producing knowledge. By seeing whether items are actors or actants, we can see whether or not materiality that the teacher thinks as part of the milieu interacts with the children to produce knowledge. We can also see this in the didactic contract in which the materiality can act. In a network, it is never clear who is acting as an actor, and an actor never acts alone. There are actors and actants that can only act by associating themselves with others (Latour 2005).

The nonhuman factors in the form of materiality are notably present in mathematical activities in preschool but may not necessarily be actors. This study attempts to capture the assemblage that affects the establishment of the didactic contract and to reveal the activities in which the materiality has the greatest opportunity to be an actor and interact with the children in various mathematical activities to produce new knowledge.

Methodology

To investigate the didactic contract formed when teachers teach mathematics in a multilingual environment and to highlight the interacting human and nonhuman factors, I used an ethnographic approach. Before the fieldwork, interviews were conducted individually with ten teachers working in different preschools. Four teachers were followed for about 25 hours each. I took pictures of the learning environment and activities. I sometimes made video-recordings when permitted by the teachers, the parents, and children. My respondents had been told who I was and about the purpose of my study. The preschool teachers, parents, and children received a consent form and an information sheet explaining the consent, confidentiality, and use requirements. Participants were allowed to withdraw from the study at any time without stating a reason. The participants' names have been anonymized. All the data collected have been stored in a secure place.

In this article, I analyse two activities directed by one of these teachers, 'Evin'. She grown up multilingual, using two languages at school and at home, a third at work in her country of birth, and finally Swedish when she moved to Sweden.

The analytical processes

I conducted a microanalysis of two mathematical activities, one planned by Evin and one emerging spontaneously as the children played. By iterating between the activities, interviews, field notes, video, theories, and my own knowledge, I tried to discern what factors inside and outside the activities could determine the different didactic contracts formulated for the two specific activities and whether these contracts in turn affected the possibility of nonhuman factors interacting with children and leaving mathematical traces. With a focus on what could influence the formulation of various didactic contracts, different categories and subcategories emerged. In this article I highlight only the analyses of the two activities.

Analysis of the planned activity

Evin gathered five children between four and five years old around a table. All were multilingual, with four of them speaking the same languages as the teacher (i.e., Arabic and

Swedish) and one of them speaking Albanian. The children could understand and speak Swedish at different levels. Evin prepared the activity to incorporate materials such as leaves, branches, and straws as well as images representing different seasons and pieces of paper representing rain and snow. She planned to tell a fairytale to introduce mathematical shapes. A small plastic hare was involved, and the teacher moved him around during the reading. The hare wanted to build a house, the parts of which have different shapes. She started to read the book and put the material on the table to illustrate what she was reading and to create a landscape and house for the hare. The children sat on chairs around the table and listened to the teacher. Sometimes Evin asked what some of the things are called in Arabic, but otherwise she spoke Swedish. At the end of the fairytale, the hare had a house but still got wet when it rained. Evin asked the children why, at the same time as she let pieces of paper representing rain fall into the house. One child answered that the house did not have any roof. Evin asked the children to make a roof using three straws. She showed them what the roof should look like and that this shape is called a triangle.

The teacher retains responsibility

The teacher manipulated the material while telling the fairytale. The mathematical problem to be solved was that the hare has forgotten to build a roof for his house, and it is raining inside. The teacher wanted the children to understand that a roof should be built in the shape of a triangle. The teacher translated some words into Arabic, showed with the pieces of paper that there is no roof, and showed with her hands what a triangle should look like, what the roof should look like, and where it should be placed. No responsibility was left to the children to find their own strategies to solve the problem. As Brousseau (1997) explained, the teacher must delegate responsibility to the child to build his/her understanding regardless of what the teacher wishes. This power shift, called the devolution process, must occur for the child to take control of the problem. In this case, there is a 'topaz effect' in which the teacher tells the children what to answer. To help the children to give the expected answer, the teacher 'suggests' the answer, hiding it behind progressively more transparent didactical coding (Brousseau 1997). There is also a 'Jourdain effect' in which the teacher sees signs of the acquisition of an item of scientific knowledge in the children's behaviour or answers when this is not the case (Brousseau 1997). The activity thus became a linguistic activity rather than a mathematical one. The didactic contract dictated that the teacher should control all the activity and the children sat in their chairs, listening, answering questions about what some of the objects are called in Arabic, and following the instructions about how to build a roof with straws that looks like a triangle.

Materiality: agents or not

In situation theory (ST), the material is regarded as passively serving people and having a transitional, or intermediary, function. In this activity the material helped Evin present and illustrate the fairytale, making a triangle visible to the children. But was the material used in the activity as an active mediator that could exert influence, intermediate, and help the children understand what a triangle is? In this case, the plastic hare, leaves, branches, and pieces of paper representing rain and snow interacted with the teacher and helped her illustrate the fairytale she told the children. They even interacted with the children, helping them understand the fairytale and develop their understanding of the Swedish language. We can say that the material left traces and influenced both the teacher and children when it came to understanding Swedish, but it did not intermediate the learning object, which was the understanding of a mathematical concept. At the end of the fairytale, the children were asked to use straws to build a roof, which must be triangle shaped. One at a time, the children had to take a straw and place it where the teacher told them. My interpretation is that the didactic contract dictated that the children had to sit on their chairs, wait for the teacher's instructions, and not experiment with the material to solve the problem by themselves. This situation created obstacles or opportunities that left traces when it came to understanding a mathematical concept. The chair interacted with children but was not autonomous and could not act by itself. The materials used by the teacher when telling the fairytale interacted too. The chair, hare, and pieces of paper were all parts of a network that constituted, in this situation, an obstacle stopping the children from moving around the room and interacting with the materiality, as they were expected to watch but not touch. When the teacher spoke Swedish to ask the children what some objects were called in Arabic, she was not encouraging the children to be multilingual and use the languages they wanted to. She instead signalled that Swedish should be used and that Arabic and Armenian should not be interacting with humans in this situation. Multilingualism was allowed no agency.

Analysis of the spontaneous activity

Evin noticed that the children were playing with a box of SmartMax magnetic rods and she joined them. She asked if they could make different shapes, and one child made a rectangle. Another child made a line, wanting to make it as long as possible. Evin was involved in asking questions: 'How long do you want it to be? Which one do you think is longer, me or the line?' A child guessed it was Evin, and she laid down beside the line. When the rods ran out, Evin suggested that they make a circle; the children made two circles instead. Evin asked, 'Which is bigger? How many people can fit in each?' Two new children joined the playing, and six fit in one circle and the teacher and one child fit in the other. Then the children kept building, first making a triangle, which became a letter 'A', which became a rectangle, which became a birthday cake with candles on it, which finally became spiders. Then the children wanted to build a structure as tall as possible. They tried to find a way to keep the rods upright; helping one another, they climbed up on a chair and then asked for help from two teachers who were taller. Evin talked mostly in Swedish and translated some words into Arabic, but the children mixed different languages. When they built a structure as tall as possible, the teachers went away, and the children continued to build for a little while.

In this case the children were given the responsibility to find their own strategies to solve the problem. The teacher made suggestions, but they were free to build what they wanted, how they wanted. A devolution process occurred when Evin transferred responsibility to the children to investigate which was longer, how to make different shapes, or how to build as tall as possible. In this didactic contract, the teacher encouraged the children to investigate and tried to guide them, but they were free to respond or not. According to a previous interview, Evin wanted to concentrate on shapes for several weeks, but in this activity the children wanted to investigate other mathematical concepts such as length, height, and volume, and they played and used their imagination when they built a cake or spider. The human (i.e., seven children and two teachers) and nonhuman (i.e., the SmartMax rods, chair, floor, ceiling, and languages) actors were all parts of a network that created, in this situation, the possibility of some of the elements interacting. This interaction between the human and nonhuman seemed to leave traces when it came to understanding mathematical concepts, when the children used materiality to build shapes or investigate length and volume. The language was mainly Swedish, but multilingualism had agency, and in this case, when the children were free to investigate, Swedish and different languages seemed to interact with materiality and provide enough support for the mathematical concept to be understood.

Discussion

In the planned situation, the didactic contract (the teacher exerts control, the children sit at the table and follow instructions, Swedish is the expected language, the activity has a clear beginning and end, etc.) hindered the devolution process and prevented the materiality and children from interacting and creating their own strategies to solve a mathematical problem. What was intended to be a mathematical activity became only a linguistic activity about learning the Swedish word 'triangle'. In summary, the didactic contract for this activity created obstacles to human–nonhuman interaction. An improving understanding of the Swedish language could perhaps be traced, but it is doubtful whether we can trace an understanding of a mathematical concept.

In the free play, a devolution process occurred when the teacher made the children responsible for solving the problem – although she made some suggestions. The didactic contract (the children take the initiative, everyone moves freely, different languages is used during the activity, time is relatively unlimited, etc.) seemed to allow the human and nonhuman elements of the network to interact. The mathematical concept that the teacher had in mind (i.e., shape) was not always in focus as the children let their fantasy and the materiality guide what happened, but they did come across other mathematical concepts. Some of the nonhuman actors such as the SmartMax rods, chair, and floor interacted with the human actors, leaving traces as the children apparently understood how to build a triangle, circle, and rectangle and how to compare length, height, and volume. The language was not interacting in a significant way as the children and teachers were able to explain and demonstrate the use of materiality. This activity was a mathematical activity.

In summary, when the didactic contract allowed the children to move and investigate in various directions, to follow their imagination and not remain stuck in what the teacher had in mind, to be multilingual, a devolution process occurred. The network of human and nonhuman actors easily created a situation in which most of the elements could interact with one another, leaving traces that highlighted mathematical concepts for the children.

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