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Measurement activities and teaching interaction in early childhood education

Abstract

The measurement of geometrical magnitudes, such as length, area and container capacity, constitutes an interesting aspect of mathematical training in early childhood education. The course of familiarization with the measurement process is a complex intellectual task that incorporates various features: Initially, the measurement processes take on meaning through the projection of the conceptual features that make up each separate case of measuring. Furthermore, the ability to use transitive reasoning, as well as the introduction into the measurement process by corresponding numbers to quantities are important aspects that make up a successful measurement course.

This study will explore the ability of early childhood education pupils to respond to processes involving the measurement of capacity. The research team aspires to highlight the important role played in this by the social framework which reinforces pupil autonomy and contributes to the acquisition of new knowledge.

The sample of the study consisted of 20 subjects aged 5–6, all coming from two Greek state kindergartens.

The research was conducted in three phases (pre-test, teaching intervention and post-test). During the pre-test and post-test, the subjects' reasoning was recorded through personal interviews, each of which lasted 15-20 min. In the pre-test we attempted to check whether the *children could carry out direct (using just the containers) and indirect (using a common measure) comparisons between container capacity. In the teaching intervention we proposed activities to small groups of children which aimed at creating the kinds of frameworks that would allow them to compare the capacity of containers and to elaborate on the concept of capacity. Finally, in the post-test, we evaluated the influence of the teaching intervention.*

Our findings highlight the important role of the communication framework in teaching, as it reinforces the pupils' autonomy and contributes to the acquisition of new knowledge.

Introduction

The measurement of geometrical magnitudes, such as length, area and container capacity, constitutes an interesting aspect of mathematical training in early childhood education. The course of familiarization with the measurement process is a complex intellectual task that incorporates various features: Initially, the measurement processes take on meaning through the projection of the conceptual features that make up each separate case of measuring. Furthermore, the ability to use transitive reasoning, as well as the introduction into the measurement process by corresponding numbers to quantities are important aspects that make up a successful measurement course (Clements & Stephan, 2004).

Reasons to have to measure dimensions are drawn from the natural or man-made environment. Thus, the role of suitably designed activities may be important in the activation of psychological and pedagogical parameters that will arouse the child's interest in dealing with scientific concepts such as the measurement of dimensions. Within such a teaching context, the child is led to the mastering of a functional definition of scientific terms and to a familiarization with unknown concepts and meanings (Davydov, 1999; Leontiev, 1978; Oers, 1996; Vygotsky, 1978).
This study will explore the ability of early childhood education pupils to respond to processes involving the measurement of length, area, and capacity. The research team aspires to highlight the important role played in this by the social framework which reinforces pupil autonomy and contributes to the acquisition of new knowledge.

The concept of measurement: psychological approaches and didactic perspectives.

The ability of measuring, in piagetian researches, is ascertained by the comparison of two quantities. According to J. Piaget and his collaborators "measure is to take out of a whole an element, taken as a unit, and to transpose this unit on the remainder of a whole: measurement is therefore a synthesis of *sub-division* (of the whole) and *change of position* (of the selected unit)" (Piaget et al. 1960, p. 3). The comments in the brackets and the italics belong to the writers of this paper. This procedure, although it may seem simple at the stage of the final equilibration, is in fact a result of a complex genetic process.

The acquisition of the measuring concept, in the piagetian theoretical context, will be built at the stage of a child's intellectual development, which is characterized by the use of a mediated measuring tool. A distinctive characteristic of this stage is an operational use of the measuring procedure which is expressed by the transitive reasoning, like: if A=B and B=C, then A=C, or if A>B and B>C, then A>C.

However, there is a large number of experimental facts, both from the field of the psychology of learning, as well as the approaches from the field of the didactics of mathematics, which shows that children who begin school don't have such limited abilities concerning mathematical concepts, as Piaget claims. These researches stress that the presentation of the mathematical object in a way that makes sense to the child and the provocation of social interaction, are factors, the contribution of which is significant to the learning process (Donaldson, 1991; Hughes, 1986; Zacharos & Ravanis, 2000).

From natural objects to the mathematical concept of measurement.

In the first school grades, such as preschool and first school grade, it's important for children to be introduced to a big variety of environmental objects and materials, for which measurement can come up as a matter for speculation. Measurement offers us possibility to approach maths in a natural way. However, the pupils' interest in carrying out activities in the direction that the educator desires is not automatically led by the influence of the educational material.

The role of the educational material in the teaching process is defined by the pupil's specific activity, which lends the material in question a specific content. Dealing with measurement aims to lead to forms of mathematisation that are related to measurement; to the devising of methods of measurement of geometrical magnitudes; as well as to the acquisition of desired generalisations. The psychological function of the educational material consists in the role of the support and the substratum of the child's external actions (Leontiev, 1978).

Measurement process

There is a similarity in all cases of measurement. However, the principles of measurement could be more obvious in some cases than others: for example, we can add two lengths directly, placing the one next to the other, edge to edge. We can also classify four children, and refer to their heights, but the comparison of three objects in terms of their capacity requires logical conclusions, which presuppose the acquisition of the transitivity reasoning.

The measurement process must also lead to the development of the ability to construct suitable measurement tools. These measurement tools may resemble established measurement tools, but they may also be arbitrary devices and constructions by children that facilitate the successful completion of the measurement. Each measurement tool has the advantage that it can be applied to a variety of cases, while it also mediates in and supports the construction of new knowledge (Stephan et al., 2001).

According to Nunes and Bryant (1996), the measurement tools provided each time play a structural role in children becoming familiar with the concepts of measurement. This is because "the structuring of the children's action was not independent from the tool they had at their disposal in the problem-solving situation" (p. 308). Moreover, it is noted that the measurement process can be more effective when the units of measurement of dimensions such as length, area or capacity correspond to the dimensions being measured (Nunes, et al., 1993). Thus, oblong tools are used to measure length, while capacity and volume are measured by tools that facilitate the "filling" of objects.

In the case of volume, besides the three dimensions of space, there are other additional "dimensions" that are related to the particular form of the container and that is one reason to distinguish between *volume* and *capacity* (Dickson, et al., 1984, Freudenthal, 1983). More specifically, the term 'capacity' is used to describe the ability of hollow objects to contain something, such as liquids or materials characterized by fluidity (for example sand, rice etc), while 'volume' is an abstract geometrical magnitude which refers to the space occupied by an object.
In order to study the magnitude of 'volume' in the first school grades, J. Piaget and his collaborators (1960) used containers of equal capacity with different dimensions (base area and height). After transfusing an amount of liquid from one container to another, they checked whether children could understand that the quantity of the liquid remains the same, despite the difference in the containers' level. What they observed was that the youngest children of the sample tended to focus on one dimension, mainly the height, while the oldest ones were able to give correct and justified answers.

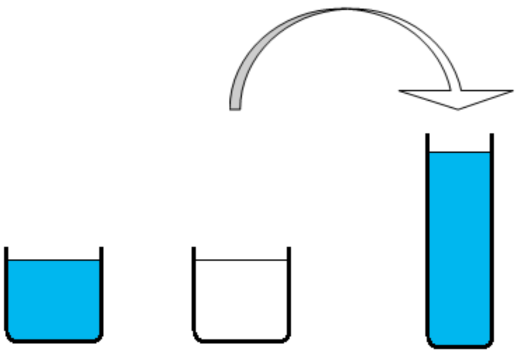

Fig 1. Volume experiment (J. Piaget, 1960)

However, the interpretation of the results of J. Piaget's experiments has been doubted by later researchers in the field of mathematical training (e.g. Dickson, et al., 1984, Freudenthal 1983) who claim that it's the concept of 'quantity conservation' and not the magnitude of 'volume' which is actually examined in this kind of experiments. This is something that can be easily seen in the type of questions posed to the children, since they are frequently asked "is it the same?", a question that clearly relegates to the concept of 'quantity reservation'.

Based on the remarks mentioned above, we judge that it would be didactically fertile to distinguish between volume and capacity. Therefore, we approach the capacity of an object as the total space occupied or enclosed by the object. In this case, what is used is the mediation of natural objects and materials which have fluidity and can fill the interior of the objects being measured (water, sand etc).

The aim of this study is to examine the ability of pre-school children to measure geometrical magnitudes. In the part of the study presented here, we are going to focus our attention on the measurement of capacity. Through the introduction of suitable teaching situations, we are going to try to find out whether infants are able to cope with capacity measurement processes and whether they can use non-typical measuring units efficiently. Finally, we are going to examine whether young children can create and use measurement tools of capacity.

Method

The sample
The sample of the study consisted of 20 subjects aged 5–6, all coming from two Greek state kindergartens. None of them had ever before got involved in training activities involving the measurement and the comparison of containers' capacity.

The procedure

The set of activities (divided into three phases) is based on creating teaching situations of direct and indirect comparison of containers' capacity, as well as situations that introduce the children to the measurement of containers' capacity and to the construction of an appropriate measuring tool. However, it's the second and third phase of the study that are going to be presented and analyzed in this article.

Second phase; indirect comparison and introduction to counting

The researchers tell the children a story, in which a farmer uses two containers filled with corn. Every day, he gives each chicken a cup of corn (the researcher shows the children the cup). This leads to the questions: "How many chickens can we feed with each container?" and "Is it possible to feed more chickens with one of the containers?" Each group is given seven cups of equal size, the same as the one used in the story, plus two containers (of different shape and height) filled with corn. While the children work on their answers, the researchers intervene in order to help them deal with any insurmountable difficulties and to direct the children's activity and collaboration towards giving answers to the questions/problems posed.

Third phase; constructing a measure of capacity

In this phase, the teaching intervention aims at constructing a tool with which to measure capacity. A cylindrical, oblong container and a felt-tip pen are presented and the following question is posed: "How far should we fill this container to feed two, three, four, … seven chickens?" here the children are called upon to construct and grade a measure in order not to have to fill the container cup by cup each time. While they work on the task, we help them do tests and verify their measuring, and talk with them about shaping and stabilizing their mental constructions when these are deemed satisfactory.

The findings

Indirect comparison processes

As mentioned above, during this phase of the study, the children are presented with two containers of different shape and capacity filled with corn and with cups of equal size. Our goal here is to develop indirect strategies for comparing capacity through the use of small cups that function as units of measurement of capacity.
Already familiar with the process of direct comparison of two containers' capacity in the initial phase of the study, the children use similar practices to transfuse the contents of the containers by filling the small cups. The strategy of measuring the contents of the containers proceeds successfully and leads to the selection of the correct container. The following dialogue shows how the activity develops with one group of pupils.

> *R*: So here are the farmer's two jars filled with corn! Can we help him figure out how many chickens he can feed with the one and how many with the other? What do you think we should do? What do you think, Dionysia?
> *Dionysia*: I don't know…
> *Dimitris*: Let's empty the corn into the cups and measure it!
> *R*: Ah! Now there's a good idea! What do you say, kids? Shall we do it?
> *Children*: Yes!

A pupil undertakes to fill the cups, while another keeps reminding him that the corn must go "all the way to the top". The students measure the cups and identify the larger jar.

The construction of a measurement tool of capacity

The aim here is to encourage the children to construct a tool with which to measure capacity. The suggested teaching situation creates the appropriate framework so as the children's construction devices correspond to the requirements of the scenario. Each group is given a cylindrical tube, a cup that corresponds to feed for one chicken, a big bowl of corn and a felt-tip pen. Through the appropriate questions, the children are encouraged to construct a unit of measurement of capacity.

First question: If the farmer wants to feed one chicken, how far must he fill this container (the cylindrical tube)?

Second question: If the farmer wants to feed two chickens (the tube is emptied), how far must the tube be filled? Can we figure this out without using the cup each time?
Finally, in the cases in which the children do not proceed to the construction of a measure, there is a third question to guide them.

Third question: What if we marked the level of the corn each time we add a cup?

The interaction between the researchers and the children, as well as the interaction between the children, contribute substantially to the approach of our teaching goal. The next dialogue let us observe the role of interaction.

> *R*: Who can tell me how much corn we should put in this container in order to feed one chicken?
> *Martha*: One cup.
> The pupil fills a cup and pours it into the container.
> *R*: How many cups of corn should I put into the jar in order to feed two chickens?

John: Two!
R: So then, how many cups of corn should I add, since I've already poured one cup into the jar?
John is thinking.
Martha: One more!
R: And why is that, Martha?
Martha: Because one cup plus another makes two!
R: Correct! So let's pour one more cup of corn into the jar.

The researcher empties the tube and asks the pupils to devise ways in which to fill the tube and feed one, two, three, etc. chickens, without using the cup each time. Here we observed the successful transportation of the socially acquired knowledge to the communication framework of our activity.

R: If we don't use the cup, what else can we do? Because it's tiring with the cup. We can find a way to fill the tube at once, without the cup.
[…]
Maria: My mother has something she uses for flour; it's got numbers on it so she knows how much to use to make a cake!
R: Can we do what your mother does?
Maria: Yes, we can put numbers on the tube.
R: I think that's a very good idea! And how will we do that?
Maria: (thinking) We can pour one cup into the tube (empties a cup into the tube) and then we can put numbers (draws the "1" mark).

With another group, the researcher intervenes and helps the children out by marking the level of one cup's worth of corn in the container and writing the number "1" next to it. Then, through the appropriate questions, he leads the children's practices. In both cases, the children are asked to repeat the procedure up until the "7" mark. To check whether the pupils are capable of using this tool, they are asked questions concerning its use.

R: If the farmer wants to fill the container with as much corn as needed to feed exactly three chickens, how much corn should we put in the container? Would someone like to help me?
Nikolitsa: Yes, me!
The pupil starts to pour the corn into the container until it's full.
R: So then, in order to feed three chickens we should fill the container to the rim? Do you all agree?
Eva: No, further down!
R: So, Eva, what do you suggest? Can you help us?
Eva: We should take a little out.
The pupil empties the container up to the correct mark.
Eva: There! That's how much we need!

Discussion

In the study, part of which is presented here, our intention was to introduce the children to a difficult to comprehend geometrical characteristic of the three-dimensional objects, volume. We considered didactically advisable to approach this concept, through the concept of capacity.

The measurement process can take on different forms of varying difficulty. In the current study we examined two forms of measurement: the first requires direct comparisons of the dimensions to be measured, while the second is more complex and demands the use of transitive reasoning (Nunes et al., 1993; Nunes & Bryant, 1996). In the second case, the measurement processes are indirect and require the mediation of suitable units or measurement tools.

Generally speaking, the introduction of the unit of measurement adds huge possibilities to the ability to measure (Nunes & Bryant, 1996), since we do not limit ourselves simply to transitive reasoning and qualitative definitions, although we can have a quantitative depiction of the dimension being measured. The development of measurement processes in early childhood education can be achieved through the use of arbitrary units of measurement. Children are encouraged to use their own units of measurement, such as use of their body parts to measure length, the use of cards, paper rectangles or squares, etc. to measure area, and cups, containers et al. to measure capacity.

Especially in early childhood education, the already mentioned distinction between the magnitudes of 'volume' and 'capacity' suggests that the most suitable didactic approach of the concept of volume is to address it within a teaching framework in which the central role is played by the practices of 'filling' and 'emptying' containers. The process of 'filling' involves the use of materials that display 'fluidity', such as water, sand, rice or lentils, and are able to fill the interior of typical containers or three-dimensional objects that look like geometric shapes (rectangular or cubical boxes).

In the study presented here, we attempted additionally to emphasise the pedagogic role of activities which familiarize five- to six-year-old children with the process of measuring container capacity, and also develop the ability of young pupils to construct and use tools that measure capacity.

In conclusion, by adopting the view that the learning of every scientific subject, and therefore of mathematics, must be purposeful and systematic (Vygotsky, 1978), at the same time, in terms of the communicative framework of the activity, the educator is not the exclusive center of the students' expectations and interest is transferred to the experimental atmosphere created by the teaching situation, by expanding the students' degree of autonomy.

References

Clements, D. H. & Stephan, M. (2004). Measurement in Pre-K to Grade 2 Mathematics. In D. H. Clements & J. Samara (Eds.) *Engaging Young Children in Mathematics. Standards for Early Childhood Mathematics Education* (pp. 299-317). Lawrence Erlbaum Associates, Publishers, Mahwah, New Jersey, London.

Davydov, V. (1999). The content and unsolved problems of activity theory. In Y., Engeström, R. Miettinem, R.-L. Punamäki (eds.) *Perspectives on activity theory* (pp. 39-52). Cambridge University Press.

Dickson, L., Brown, M., & Gibson, O. (1984). *Children Learning Mathematics. A Teacher's Guide to Recent Research.* Cassell Educational Ltd.

Donaldson, M. (1991). *Children's minds.* Fontana Paperbacks, London.

Freudenthal, H. (1983). *Didactical Phenomenology of Mathematical Structures.* D. Reidel Publishing Company, Dordrecht, Boston, Lancaster.

Hughes, M. (1986). *Children and number difficulties in learning mathematics*. Basil Blackwell, Oxford.

Leontiev, A. N. (1978). *Activity, Consciousness and Personality*. Englewood Cliffs, Prentice Hall.

Nunes, T. & Bryant, P. (1996). *Children doing Mathematics*. Blackwell publishers.

Nunes, T., Light, P., & Mason, J. (1993). Tools for thought: the measurement of length and area. *Learning and Instruction*, 3, 39-54.

Oers, B. van (1996). Are you sure? Stimulating Mathematical Thinking During Young Children's Play. *European Early Childhood Research Journal*, 4(1), 71-87.

Piaget, J., Inhelder, B., & Szeminska, A. (1960). The child's conception of geometry. Routledge and Kegan Paul, London.

Stephan, M., Cobb, P., Gravemeijer, K. & Estes, B. (2001). The role of tools in supporting student's development of measuring conceptions. In A. A. Cuoco & F. R. Curcio (Eds.) The roles of representation in school mathematics (pp. 63-76). National Council of Teachers of Mathematics, 2001 Yearbook, Reston, Virginia.

Vygotsky, L. (1978). Mind in Society. The Development of Higher Psychological Processes. Harvard University Press.

Zacharos, K., Ravanis, K. (2000). The Transformation of Natural to Geometrical Concepts, Concerning Children 5-7 Years Old. The Case of Measuring Surfaces. *European Early Childhood Education Research Association*, 8(2), 63-72.

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