Changes in Children's Conceptual Models of a Natural Phenomenon Using a Pictorial Computer Simulation as a Tool

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Abstract

This paper describes an investigation examining the constructing of a conceptual model of a selected natural phenomenon by children when using a pictorial computer simulation of that phenomenon. The paper concentrates on describing changes in children's conceptual models which appeared after an independent and spontaneous exploration process. The selected natural phenomenon was the variations of sunlight and heat of the sun as experienced on the earth related to the positions of the earth and the sun in space. Before the exploration of the natural phenomenon with the pictorial computer simulation children's conceptual models were at very different levels. Some children's conceptual models of the phenomenon were quite unidentified, and some others' very developed. Only some children's conceptual models contained misconceptions. The most significant change in children's conceptual models was that the interconnections of different things and phenomena began to be constructed and the construction seems to be in the direction of the currently accepted scientific knowledge. According to these findings it seems to be possible that an independent exploration by means of a pictorial computer simulation of a given natural phenomenon at a very early stage, when children are spontaneously interested in those things, could help children in the formation of a correctly directed conceptual model of that phenomenon.

Introduction

In several studies it has been suggested that children in everyday situations form conceptions in physics and astronomy which differ from the conceptions of scientific theories in question and seem to be robust and difficult to reconcile with currently accepted scientific knowledge (See Vosniadou, 1989, 1991a; Vosniadou and Brewer 1987, 1990, 1991). In current research there have been attempts to find the ways by which children could be guided in the formation of conceptions and the change of misconceptions (See diSessa, 1988; Vosniadou 1991a, 1991 b).

This paper describes changes in children's conceptual models when children have explored independently a given natural phenomenon by means of a pictorial computer simulation of that phenomenon. A pictorial computer simulation shows the effects of the variations of sunlight and the heat of the sun on the earth in nature, and the origin of those variations caused by the interrelations of the earth and the sun as a part of the solar system. The children taking part were seven-year old Finnish first-graders. They had at school no formal instruction before or during their exploration process of this natural phenomenon.

This paper first describes briefly the children's conceptual development in astronomy based on the findings of Vosniadou (1991b). After it the research strategy is described and finally changes in children's conceptual models of a given natural phenomenon are examined.

Conceptual development in astronomy

Vosniadou (1991b, p. 169) has concluded, on the basis of her findings, that children start their knowledge acquisition in astronomy by constructing an intuitive cosmological model

of a flat, stationary earth in a geocentric solar system in which the sun and moon move in an up/down direction and cause the day/night cycle. Eventually this intuitive model changes to that of a spherical earth, which rotates around its axis and revolves around the sun in a heliocentric solar system in which the day/night cycle is caused by the axial rotation of the earth and not by the movement of the sun and the moon.

In her findings Vosniadou (1991b, p. 149) has observed that the process of conceptual change from these intuitive models based on children's everyday experience to scientific models is a slow and gradual one and is characterized by the emergence of various misconceptions of scientific explanations. Misconceptions are caused when students try to reconcile the scientific concepts with their experiential beliefs.

Vosniadou (1991b) argues that focusing on students' misconceptions alone may not always provide a solution to the problem of restructuring. Students must learn to question their intuitive beliefs and to replace them with a new explanatory framework.

Research strategy

Aim

The aim was to investigate to what extent the independent use of a pictorial computer simulation of a selected natural phenomenon could be of help in the organizing of the phenomenon and the forming of an integrated picture of that phenomenon. Attention was paid to the constructing of a conceptual model of the phenomenon by children and children's exploring strategies during the use of the computer simulation. This paper concentrates on the first question examining the resultant changes in children's conceptual models after the use of the computer simulation.

Pictorial computer simulation

The pictorial computer simulation concentrates on the variations of sunlight and heat of the sun as experienced on the earth related to the positions of the earth and the sun in space. In the simulation it is possible to explore the variations of sunlight and heat of the sun and their effects on the earth in a natural environment. It is also possible to examine the origin of these phenomena from the basis of the interconnections and positions of the earth and the sun in space. The simulation concentrates on phenomena which are close to the everyday experiences of children, such as day and night, seasons, changes in the life of plants and birds etc. The simulation program has been implemented in such a way that the knowledge structure and theory of the phenomenon are based on events appearing together with the phenomenon in question, and these events are illustrated. In the simulation all events and necessary elements are represented as pictures and familiar symbols. At the earth level the pictorial simulation represents the surrounding world, its phenomena and objects in a very natural and realistic way. In exploring the phenomenon at the space level the interrelations of the earth and the sun are represented with the help of an analogue model. The selected place on the earth from where the phenomenon has been modeled and simulated for a computer is the suburb of Lentävänniemi in Tampere, in Finland. The children who participated in this research live in this area. Therefore the exploration of the phenomenon with the pictorial simulation takes place in an environment familiar to the children.

The exploration of the phenomenon starts in Lentävänniemi on the 1st January at midnight. On a big screen is seen at that moment a dark, snowy, winter landscape in a direction of the south. The exploring can be continued by using icon pictures under the picture of the landscape, for example, a clock, a pictorial calendar, a picture map with different points of the compass and a space shuttle. The exploring of the phenomenon can be continued in many ways hour by hour, day by day, month by month, at different points of the compass and so on. At any moment it is possible to take a space shuttle and to look at the interrelations and positions of the earth and the sun at the space level. At the space level it is also possible to explore the interrelations and positions of the earth and the sun by using icon pictures which show the time in the same way as at the earth level. At

every moment it is possible to choose how to continue exploring. Exploring can proceed at every moment using the existing alternatives.

When exploring at the space level the earth rotating around its axis and revolving around the sun on its elliptic orbit appears on the screen. The plane of the earth's orbit is shown as viewed from directly above this plane. When exploring the phenomenon at the earth level the following may appear on the screen: the changes of darkness and lightness daily with an accuracy of one hour, the sun's positions in the sky every hour, the place and time for the sunrise and the sunset every day round a year, typical plants, birds and animals according to seasons and so on. With the help of the icon pictures, binoculars, magnifying glass and microscope it is possible to explore flowers, trees, leaves, insects, birds, spores, animals and so on in more detail. On the screen a selected object is seen as bigger. At the space level with the help of a telescope it is possible to look at the earth at a larger size so that, for example, Finland is seen more clearly. From this picture of the earth it is possible to continue further and to see the map of Finland, and finally an air photo of Tampere. In the simulation it is also possible to explore the mutual size of the earth and the sun and to get an image of the distance between them. Also the position of the earth in the whole solar system can be seen on the screen. The pictorial computer simulation is constructed so that it is very easy to use and it does not presuppose an ability to read or write. A pictorial computer simulation is described in details in the article by Kangassalo (1992).

Conceptual model

A conceptual model is a mental construct. Its origin is in the ability of the brain, at a very early stage, to analyze information of the external world in a three-dimensional layout. The units of this three-dimensional layout can be perceived to be spatially connected and separately movable. (See Spelke, 1988.) The developing of a conceptual model of a certain phenomenon is based on the forming of the brain's neural networks and their connections. Information about objects, their properties and relations is stored in the synapse connections of interconnected neural networks. The recall of information is based on the associative activation of interconnected neural networks. Activation can be caused by external or internal incitement which is connected with stored information. The activation of neural networks is experienced as recollections and images. The constructing and connecting of neural networks takes place in everyday situations during life. The more demanding and the more complicated the activities and things in question are, the more important a person's own attention and action in the constructing of organized neural networks and selected and strengthened connections. The neural basis of a conceptual model is based mainly on the model of memory mechanism of Kohonen (1984, 1988).

A conceptual model of a natural phenomenon develops over time through perceptions, experiences and as a result of mental activity. Visual perceptions have a central part in the forming of a conceptual model of a natural phenomenon and its use although experiences with the senses of touch, smell, taste and hearing concerning the phenomenon also have a great significance in this process. A conceptual model corresponds to a given natural phenomenon, its events, phenomena, objects and qualities both in their temporal and spatial relations. It consists of the regularities of those interrelations and interdependences which are characteristic of a given natural phenomenon. By means of a conceptual model through visual images it is possible to examine a phenomenon, its objects and their qualities and spatial and temporal relations, both the events of a phenomenon and also to follow the sequences of events (See Denis, 1991; Nickerson, Perkins and Smith, 1985). The origin, development, function and elicitation of a conceptual model are examined in detail in Kangassalo's (1993a, 1993b) articles.

Elicitation of a conceptual model

The elicitation of a conceptual model was achieved using procedures whose aim was to cause recall of the natural phenomenon in question. The activation of information stored in neural networks was caused by external incitements which were connected with the

phenomenon. As activating incitements and attention directors snow, pictures and verbal expressions were used. A child modeled the natural phenomenon from the basis of recollections and images through action, pictorially and verbally using different tasks. The modeling took place by showing, drawing, modeling and explaining. Pictures and modeling clay were used in the tasks.

In the natural phenomenon attention was paid to the variations of sunlight and heat of the sun on the earth, the interconnections of the earth and the sun in space, and interrelations of phenomena on the earth and in space. In addition attention was paid to the size, form and distance between the earth and the sun.

The elicitation of a child's conceptual model took place before and after the exploration of the natural phenomenon with the simulation. In both situations attention was paid to the same things although separate tasks differed from each other to a certain extent. Children had possibilities to use the simulation program for four weeks in a day care centre after school. In the research group there were eleven children of about seven years old. The children did not discuss the things in the pictorial simulation at home or at school. This came out in the interviews with parents and teachers.

Results

In this chapter the main features of children's conceptual models of the natural phenomenon in question before the exploration of the phenomenon with the computer simulation and the most significant changes after the use of the simulation has been described.

Individual differences in children's conceptual models were very large. Some children's (3/11) conceptual models were quite vague and undeveloped. In their conceptual models the alternation of day and night on the earth was organized but the sequences of seasons were expressed according to the children's own preferences. One child organized the phenomenon only at the earth level. In two children's conceptual models the earth and the sun were modeled as spherical, but no connections were expressed between phenomena on the earth and the positions of the earth and the sun in space. After the use of the simulation a significant change in their models was that the earth began to revolve around the sun.

A little more developed were conceptual models by four children (4/11). The variations of sunlight and heat of the sun on the earth, the alternation of darkness and lightness and the succession of seasons, were organized quite well. The variation of day and night on the earth had been expressed to have resulted from the interrelations of the spherical earth and the spherical sun in space. In three cases the earth moved or swayed at the same point of the earth's orbit so that the pointing of the earth towards the sun changed. This was indicated by turning the earth towards the sun. In one child's model the earth revolves around the sun and daytime is caused when the earth is on the other side of the sun and darkness when it is on the opposite side of the sun. The succession of seasons was not yet connected with the positions of the earth and the sun in space. In these children's models, after the exploration process, the earth is revolving around the sun and the succession of seasons on the earth was perceived to be connected with the positions of the earth and the sun in space. The reconciliation of the alternation of lightness and darkness and the succession of seasons in the positions of the earth and the sun in space model proved to be problematic. In children's conceptual models these things are shown as either quite separate or the alternation of lightness and darkness is totally absent.

One child's (1/11) conceptual model of the phenomenon was very well developed. The only undeveloped thing in his conceptual model was the reconciliation of the alternation of lightness and darkness and the succession of seasons with the positions of the earth and the sun at the space level. The succession of seasons on the earth were quite correctly connected with the positions of the earth and the sun in space. The alternation of day and night on the earth was expressed to have resulted from the rotation of the earth around its axis once during the earth's circuit around the sun. On the earth it was daytime when the earth was on the other side of the sun and night when it was on the opposite side of the sun. During the exploration process the reconciliation was made. In the child's

conceptual model after the use of the computer simulation the earth rotates around its axis once every 24 hours when the earth is revolving around the sun, a circuit around the sun taking place once a year.

Three children's (3/11) conceptual models contained a clear misconception. In their models the sun is revolving around the earth causing the alternation of day and night and the succession of summer and winter on the earth. In these children's conceptual models on the earth the alternation of day and night and the succession of seasons were organized quiet correctly. These children were a little unwilling compared to other children to explore the phenomenon with the computer simulation. After the use of the simulation, two children's conceptual models were disintegrated. The sun's revolving around the earth was absent and interrelations of phenomena on the earth and in space became weaker. One child's model remained nearly unchanged.

The most essential change in children's conceptual models was that the interconnections of different things and phenomena began to be constructed and the construction seems to be in the direction of the currently accepted scientific knowledge. The extent of constructing varied in children's conceptual models. This seemed to be in connection with the time for which a child explored the phenomenon with the computer simulation. Children used the computer simulation for an average of 65 minutes. The shortest operating time was 33 minutes and the longest 112 minutes over a period of four weeks. The expression of children's conceptual models took place mainly by showing, modeling and pictures. With a few exceptions verbal expression was used on average very little or not at all.

Conclusions

According to these findings it seems possible that an independent exploration by means of a pictorial computer simulation of a given natural phenomenon at a very early stage, when children are spontaneously interested in those things, could help children in the formation of a correctly directed conceptual model of that phenomenon.

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