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AN INVESTIGATION OF THE SPACE-TIME RELATIONS SKILL AT ELEMENTARY EDUCATION

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Abstract
The aim of this study is to investigate elementary school students' space and time relations skill. The data for this descriptive study were collected in the spring semester of 2013-14 academic years. The sample was consisted of 557 students attending the same primary and middle school in Nigde, Turkey. In order to determine students' use of space-time relations skills, a worksheet with two tasks was utilized. Students were asked to picture a hill covered with some trees (comprehension of three-dimensional space), and a transparent pitcher used to water a pot plant (comprehension of reference frame). Document analysis was used to classify student pictures into comprehension and incomprehension. According to the results, although the number of students who could comprehend both tasks was very low, the number of students who could comprehend either three-dimensional space or reference frame increased as the grade arose.

Key Words: Space-time relations, space concept, elementary education, Turkey.

INTRODUCTION

Students' developmental characteristics especially those in cognition give information to teachers on providing an effective teaching and learning environment.

Cognitive development is the advancement in thinking and comprehension systems. Piaget divides cognitive development into sensory-motor (0-2 years), preoperational (2-7 years), concrete operations (7-12 years), and abstract operations (12 years and more) stages. The features of concrete operations are important for science education since the students are in this stage at grade 4 and 5 where science is first taught.

Cognitive development is also important for acquisition of science process skills, which are the abilities, and thinking processes used when investigating the nature and natural phenomena and producing scientific information. In this way, a child who is in concrete operations can establish cause and effect relations and make classification. Similarly, a child who is in abstract operations can make inference, hypothesize, and, determine variables. In other words, the individual can reach the solution in a systematic way (Hazır & Türkmen, 2008).

Space and time relations are one of basic (simpler) skills. While numerical relationships are activities that require counting and arithmetic; the concept of space is related to how close or far the objects together in space, and form a basis of understanding of space.

Space-time relations skill forms a basis for understanding other basic process skills. Space-time relations skill, which is related to how children comprehend their physical world and how children mention the world, has directed the context of this study to itself.

Using space and time relations, which is to mention about the place and three-dimensional shape of objects, helps us to define our physical environment.

Comprehension of space-time relations:
"is a process to comprehend the relations between place and time of objects, facts, and events, and to determine them appropriately by using place and time adverbs, and to comprehend them in this kind of verbal and written statements." (Çilenti, as cited in Erbaş, Şimşek, & Çınar, 2005).

From a Piagetian viewpoint, these two processes appear in children. Science experiences are important in developing these processes. When these processes are improved, they help to understand other processes. When learning space related processes, students start to explain objects according to plane and three-dimensional shapes. Hardness and smoothness are helpful for comparative and definitive purposes (Turgut, Baker, Cunningham, & Piburn, 1997, p. 10.4).

Comprehending space and time relations is a requisite because with the skills developed with this process, to be able to explain physical world becomes possible. The questions that are related to this process include the following questions: In which shape, there are two symmetrical line or axis? How can you transform a two-dimensional shape into a three-dimensional one? How many edges a square have? How can you define the shape of a solid object by looking at its' shade? How many seed can you find in this fruit? What is the approximate height for all baby plants? (Turgut, et al., 1997, p. 10.4).

The aim of this study was determined as "the investigation of the use of space and time relations skills of primary school students' according to their grade levels".

Cognitive Development

Piaget and his colleaques studied cognitive development of child from birth to adolescense and deetermined that some concepts and perceptions are acquired starteing from birth.

Cognition is the mental activities that include learning and understanding about the world and covers perception, memory, reasoning, thinking, comprehension processes (Yavuzer, as cited in Çukur & Delice, 2011). Cognitive development according to Piaget is emerging in four consecutive periods:

1. Sensorimotor Stage (0-2 years old): Infant interact with the outside world through sensory and motor activities by interacting, and has various reflexes (the most important ones are to absorb and capture). When the baby is eight to 2 months, the understanding of object persistence begin to develop. Between 12 and 18 months, the baby shows effectively making the research and experimentation; between 18 to 24 months, the baby shows signs of simple thinking are observed (Yavuzer, as cited in Çukur & Delice, 2011). Imitation, memory, and using thinking is just beginning.

2. Preoperational stage (2-7 years old): At this stage, children are capable of language and symbolic thought. Completely self-centered mindset is dominant. Children believe that their opinion is the only one; are not able to understand about other perspectives. Logical thinking process has not yet developed. Therefore, children are under the influence of images of objects. Yet cognitive structures have not reached to comrehend conservation.

Conservation is the principle that quantity, weight and volume of an object will not change when its shape and position have changed (Erden and Akman, as cited in Çukur & Delice, 2011).

At this stage, a large portion of children perceive generally without considering the details and integrate unrelated objects and concepts (Yavuzer, as cited in Çukur & Delice, 2011).

Children can not consider the part with its whole at the same time and can not make mental comparison yet. They can classify matters with their unique and prominent features. And they can not comprehend abstract concepts. towards the end of the period, self-centered thinking Gradually decreases and begind to leave its place to logical thinking. Therefore, this step is the preparation phase for concrete operations (Yavuzer, as cited in Çukur & Delice, 2011).

3. Concrete operational stage) (7-12 years old): At this period, logical thinking and number, time, space, size, volume, distance concepts begin to establish; conservation is comprehended; the abilities of grouping, such as classification and of sorting, and of organizing and developing a system nurture (Yavuzer, as cited in Çukur & Delice, 2011).

Thus, the first and last childhood periods show great differences in terms of mind and language development. For example, for a five-year-old child, a ball is for play and she thinks about the ball only in a functional sense. Toward eight year, child defines the ball with its shape, size, material and color (Yavuzer, as cited in Çukur & Delice, 2011).

Accordingly, pre-school child perceives a complex shape especially as a whole. She does not pay attention to details. After six years, she pays attention to details. In later periods, child turns into a complementary perception In this case, child can start to perceive whole, parts, and relations of parts with each other and relationship of parts with whole at the same time (Mangır & Çağatay, as cited in Çukur & Delice, 2011).

Development of Space Concept

Since Piaget has tried to answer “what is knowledge?” with the question of “how knowledge is obtained?” (Akarsu, 1984), and the concept of time is similar to spatial concept and coincides with general principles (Akarsu, 1984), only development of space relations will be explained in this section.

Development according to Piaget is not an accumulation of acquisitions. Development is a gradual formation of behaviours: Instinct is used by newborn, schemas cause regular and formal actions, and these concrete and active actions over time leads to abstract actions in other words operational thinking (Akarsu, 1984).

Four main periods in the development of mind are named as sensorimotor (0-2 years), preoperational (2-6 years), concrete operations (6-12 years), and formal operations (12 + years). Senses, perception and intuition dominate the first two periods whereas the child, who interacts with situational stimuli, shows the ability to think by gaining a relative autonomy and independence in the last two periods. In other words, the child, who can think operational, can reveal her behaviours mentally without the requirement of concrete, sensory, emotional actions (Akarsu, 1984).

According to Piaget, to have knowledge of an object, if it means to reconstruct that object, this knowledge must have both formal (figurative) and operational (operative) aspects. Formal aspect is related to touching or seeing, perceive with the senses. Operational aspect is related to actions or processes taken on the object in order to recreate the object so as to allow for the necessary transformations. Here, whatever the mental level

is, there is a distinction between perception and intelligence. The same distinction is reflected on the issue of space as perceptual and mental space (Akarsu, 1984).

The concept of spatial perception as opposed to the concept of space always preserves its relative nature and because it lacks reverse - convertibility feature that not found in perceptual structures cannot be purified from certain systematic distortions. Mental space includes the steps of sensorimotor space and reanimated space in a way to coincide with pre and post operational thinking (Akarsu, 1984).

Understanding of sensorimotor space seen in the first two years of the child is one of the most important mental acquisitions of that period. In addition to the perception of space, this concept of space that experienced practically, organised, and balanced at the action or behaviour level has not reached the stage of revitalisation yet. Representational space concept begins approximately at two years and enters a competent manner as late as at twelve years of age when concrete operational phase where operational thinking takes a part. Re-enactment is not to remember the spatial action but is a symbolic and internalized action. In other words, visualisation is to create and reproduce. As it seen, to pass from sensorimotor space to operational space is a long, slow-moving and becoming abstract from action to operation (Akarsu, 1984).

The first of these is metric (or Euclidian) space relations, which are basically based on the notion of distance, and in which the equivalence figures are related to mathematical equality. In contrast, straight line forms the basis of projective space relations in the second type. Perspective view or the conversions (probability) provides the similarity of shapes. Topologic space in the third type is based on qualitative relationships (neighbourhood, disconnection, circumscription, etc.) that exist entirely within a particular form (Akarsu, 1984). When it comes to topological space, the initial perceptions and the real, concrete actions of child on objects, ie, to play with items and objects, form a springboard used in revitalization of the intuitive space in a structured, systematic and regular way. These topological perceptions include the relations of proximity, discontinuity, sequence-order (or spatial adjacency), circumscription, and continuity (Holloway, as cited in Akarsu, 1984). Codification of this type of perceptions and revitalizations determine the size of intuitive perception until the age of seven. However, after this period a new system is being entered with the possibility to turn into internalized and reversible processes. This system includes disassembly (partition), pick up the pieces (partitive addition), linear or cyclical alignment, reciprocity of neighbourhood areas, symmetrical relationships, and all members or relations (Akarsu, 1984).

In addition to the topological characteristics of the space, place of the objects or elements of objects in projective objects should be determined in the context of relationships with others and in a certain perspective. Development of projective space concept, too, can be summarized in the three general stages just as topological space concept: Perceptual activities that initially completely sensorimotor with revitalizations despite the distortions caused by variability of perspective and distance with acquisitions of invariance of shape and size ultimately achieve competency in coordination of perspectives and reversibility of viewpoint (Akarsu, 1984).

Already existing topological operations enriches by the addition of perspective transactions and install new meanings. For example, the introduction of perspective causes linear sequencing to turn into the concept of arrangement comprised of segments (straight line like projections). A similar conversion can also be observed in the transition from the reciprocity of neighbour areas to reciprocity of neighbour perspectives (Akarsu, 1984).

Euclidean space stems from a topological space and develops in parallel to projective space. Projective space is limited with the integration of different perspectives belong to an object. In Euclid place, the places of objects or the coordinates of relations between objects must be determined in a general frame of reference, which need the positions of surface area and distance, or according to a constant Cartesian (X-Y) reference system (Akarsu, 1984).

Conservation means surface area or distance do not change even if the viewpoint or relationships with other shapes changes, and quantity dimension is retained against perceptual distortions (Akarsu, 1984).

Conservation, which is one of the skills in the stage of concrete operations, is an indication of the operational thinking at the same time. Acquisition of conservation that related to surface areas and length is possible only when the perspectives are symmetric or reciprocity can be seen (Akarsu, 1984).

For these reasons, projective and Euclidean spaces show a parallel conceptual development. Relationships belonging to Euclidean spaces that intuitively started to be internalized and coordinated in pre-operational stage reaches only in real terms to a metric and quantifiable (i.e. measurable) space concept in the stage of concrete where first conservations (surface , distance , etc.) emerge (Akarsu, 1984).

To summarize, three important additives in connection with the development of spatial concepts brought by Piaget (Flavell, as cited in Akarsu, 1984) are: (1) as can be seen in achieving other concepts, child's actions by interacting with the environment, turned into first kinaesthetic movements, and later internalized actions and eventually procedural actions. There is action on the basis of the concepts. (2) contrary to common belief, spatial concepts do not only occur at the level of perception, though space is seen as data already exists in life concept is gained by mental evolution. (3) Piaget's main hypothesis about space can be summarized as: concept of space in child in contrast to historical development follows a logical development. First topological relations, than correspondingly relationships that projective and regarding Euclidean space emerge (Akarsu, 1984).

METHODOLOGY

Research Design

The research is a descriptive study and survey model was used in this study.

Population and Sample

Children, who are five to 13 years-old and are attending to a primary and middle school from grade one to six, in Niğde city constitute the population of this study. There are 20 primary schools and 14 middle schools in the city. Due to recent schooling reform only four schools from each category have students at all grade levels. The accessible population therefore was limited to only one of these four schools. This school was also preferred for having the biggest student population. When selecting the sample, the criteria was to get at least half of the branches. This sampling method was broken only for the sixth grade when the students were taking an elective course out of their classroom (There are some elective courses offered to the sixth graders. And as the teachers told us many students do not attend these courses).

This study was conducted in 23 Nisan Havacılar Primary and Middle School on the spring semester of 2013-14 academic year. Table 1 shows the population and sample of the study.

Table 1: The distribution of the students according to grade levels

Grades	Branches	Branches in Sample	Number of students in sample
Grade 1	A, B, C, D, E	A, C, D	102
Grade 2	A, B, C, D, E, F, G, H	A, D, E, F	113
Grade 3	A, B, C, D	C, D	63
Grade 4	A, B, C, D	A, B	75
Grade 5	A, B, C, D, E, F, G	B, C, D	91
Grade 6	A, B, C, D, E, F, G, H	A, B, C, D, E, F, G	113

Instrument

In order to determine students' use of space-time relations skills, a worksheet, where there were two tasks, was utilized. Students were asked to picture a hill covered with some trees (comprehension of three dimensional space), and a transparent pitcher used to water a pot plant (comprehension of reference frame).
The tasks were selected from the activities suggested by Kaptan (1999, p. 78-88). There were 19 activities related to children's developmental characteristics: Four activities are on ordering; four activities are on classification; three activities are on conservation of length, volume and mass; one activity is on comprehension of two dimensional space; one activity is on three dimensional space, one activity is on comprehension of reference frame; one activity is on comprehension of the location of three-dimensional objects, one activity is on repetition of unit element; one activity is on equivalence of two forces; one activity is on balancing gravity; and one activity is on floating rule.

From these activities, two activities related to comprehension of three-dimensional space and reference frame were selected because Erbaş, Şimşek, & Çınar (2005) thought that they measure space-time relations.

After getting the permissions of school authorities (administrators and teachers) the data were gathered from the students when they were at the class. When collecting the data from a class, the class or course teachers were also present.

Pilot Study

The worksheet was piloted in the fall semester of 2011-12 academic years. The pilot sample was consisted of 88 students from second grade to fourth grade attending the afternoon session in one of the four schools explained earlier.

Students were asked to picture a hill covered with some trees (comprehension of three dimensional space), and a transparent pitcher used to water a pot plant (comprehension of reference frame).

Document analysis was used to classify student pictures into comprehension and incomprehension. According to the results, although the number of the students who could comprehend both tasks was very low (only one at second and third grades and four in fourth grade), the number of students who could comprehend either three dimensional space (three at second grade, one at third grade, and five at fourth grade) or reference frame (three at second grade, six at third grade, and eight at fourth grade) increased as the grade arose. The distribution of the students in the sample according to grade levels is given the Table 2.

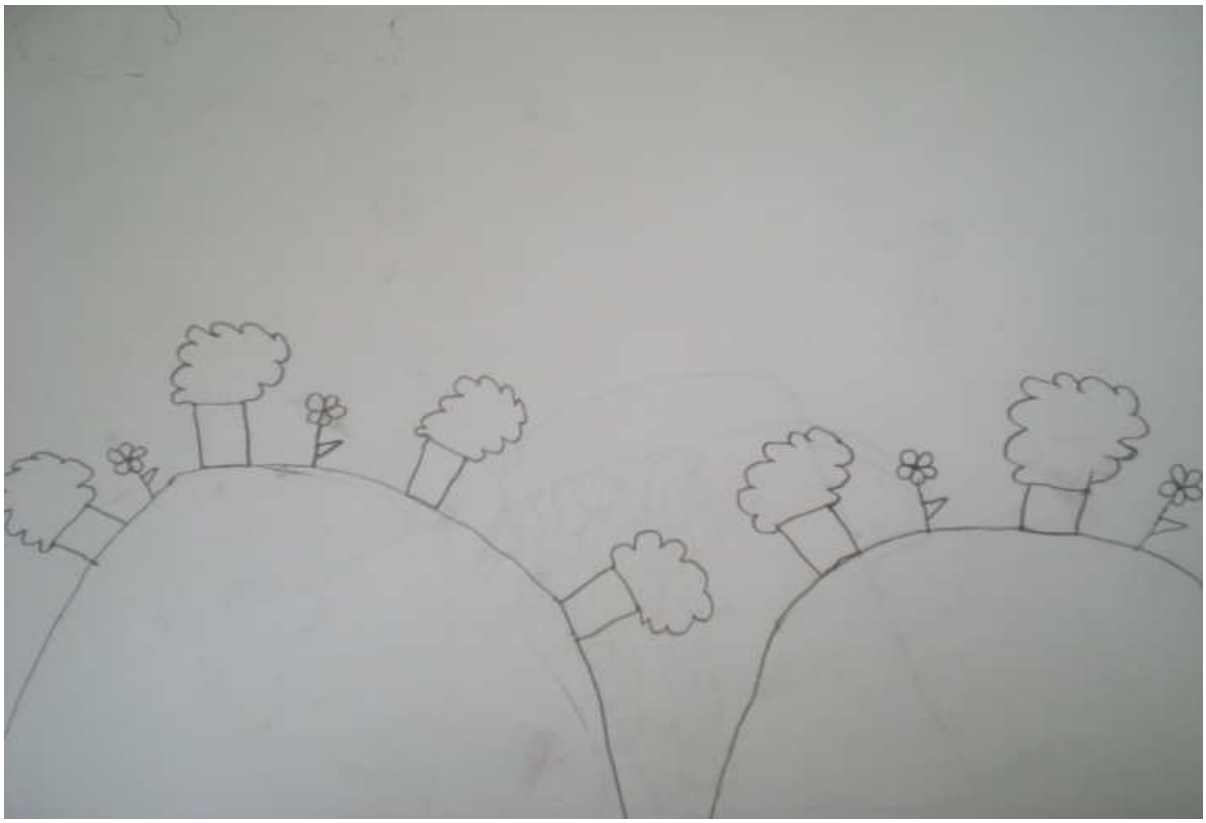
Table 2: The distribution of the students according to grade levels during pilot phase

Grade	Number of students
Second grade	31
Third grade	29
Fourth grade	28

Data Analysis

Document analysis was used to classify student pictures into comprehension (Picture 1) and incomprehension (Picture 2). If the task was not understood or not classified easily the picture was categorized as ambiguous (Picture 3).

Picture 1. One Student's Drawing of Reference Frame Task Classified in Comprehension Category



Picture 2: One Student's Drawing of Three-Dimensional Space Task Classified in Incomprehension Category

Picture 3: One Student's Drawing of Three-Dimensional Space Task Classified in Ambiguous Category

During data analysis, first the researchers were classified the pictures according to their perceptions. Then all of them were started to rate the pictures together. Consensus was sought for task categories. By this way, evidence for the validity of the data analysis was supported.

FINDINGS

Students' Performances on Three Dimensional Space Task

The result of the first space-time relations task is given in this section. When students' drawings of trees on the hills were analysed as in Table 3, it was found that while some of the students (19 %) correctly drew the trees on a hill (and were classified in comprehension category), most of the students (68 %) could not draw correctly and were grouped in incomprehension class. There were also some ambiguous drawings (13 %).

Table 3: Students' performances on three-dimensional space task

Grade	Comprehension	Incomprehension	Ambiguous	Total
First	10 (10)	76 (74)	16 (16)	102
Second	12 (11)	100 (88)	1 (1)	113
Third	13 (21)	49 (78)	1 (1)	63
Fourth	10 (13)	53 (71)	12 (16)	75
Fifth	22 (24)	43 (47)	26 (29)	91
Sixth	39 (34)	55 (49)	19 (17)	113
Total	106 (19)	376 (68)	75 (13)	557

Table 4 shows the number and percentages of the students who understood the task. According to this table, students' comprehension level raised as the grade level increased: If we consider school level, students in primary school had lower comprehension (from 11 % to 21 %) than those in secondary school (from 34 % to 41 %). On the contrary, students' incomprehension level decreased as the grade level increased. In terms of school level, incomprehension was higher in primary school (from 79 % to 89 %) than that in secondary school (from 59 % to 66 %).

Table 4: Students' comprehension of three-dimensional space

Grade	Comprehension	Incomprehension	Total
First	10 (12)	76 (88)	86
Second	12 (11)	100 (89)	112
Third	13 (21)	49 (79)	62
Fourth	10 (16)	53 (84)	63
Fifth	22 (34)	43 (66)	65
Sixth	39 (41)	55 (59)	94
Total	106 (22)	376 (77)	482

Students' Performances on Reference Frame Task

The result of the second space-time relations task is given in this section. When students' drawings of water in a pitcher (reference frame) were analysed as in Table 5, it was found that while some of the students (33 %) correctly drew the position of water in a pitcher (and were classified in comprehension group), some (12 %) did not have a comprehension (incomprehension) but more than half of the students (55 %) could not draw accordingly to this task.

When compared to the first task, we can say that students could not understand and draw according to this task (ambiguous rate was 13 % in the first task and 55 % in this task).

Table 5: Students' performances on reference frame task

Grade	Comprehension	Incomprehension	Ambiguous	Total
First	7 (7)	2 (2)	93 (91)	102
Second	41 (36)	10 (9)	62 (55)	113
Third	14 (22)	12 (19)	37 (59)	63
Fourth	8 (11)	11 (15)	56 (74)	75
Fifth	44 (48)	23 (25)	24 (27)	91
Sixth	71 (63)	11 (10)	31 (27)	113
Total	185 (33)	69 (12)	303 (55)	557

Table 6 shows the number and percentages of the students who understood the task. According to this table, students' comprehension decreases from first grade (78 %) to fourth grade (42 %) but then it raised from fifth (66 %) grade to sixth grade (87 %).

On the other hand, if we consider this situation at school level, students in primary school had lower comprehension (from 42 % to 80 %) than those in secondary school (from 66 % to 87 %).

Students' incomprehension level decreased as the grade level lowered. In terms of school level, incomprehension was higher in primary school (from 20 % to 58 %) than that in secondary school (from 13 % to 34 %).

Table 6: Students' comprehension of reference frame

Grade	Comprehension	Incomprehension	Total
First	7 (78)	2 (22)	9
Second	41 (80)	10 (20)	51
Third	14 (54)	12 (46)	26
Fourth	8 (42)	11 (58)	19
Fifth	44 (66)	23 (34)	67
Sixth	71 (87)	11 (13)	82
Total	185 (73)	69 (27)	254

Students' Performances on Both Tasks

The result of students' performances on both tasks is given in this section. When students' drawings of both tasks were analysed as in Table 7, it was found that at middle school level the percentages of the students who are successful in both tasks are considerably high (31 % at fifth grade and 43 % at sixth grade) when compared to primary school level (0 % at first grade, 18 % at second grade, 23 % at third grade, and 7 % at fourth grade).

Table 7: Students' performances on both tasks

Grade	Comprehension	Total
First	0 (0)	8
Second	9 (18)	50
Third	6 (23)	26
Fourth	1 (7)	14
Fifth	15 (31)	49
Sixth	30 (43)	69
Total	61 (28)	216

DISCUSSION AND RESULT

Primary and secondary school students' performances of space-time relations were investigated in this study. Students were found to be more successful at the second task (comprehension of reference frame) when compared to the first task (comprehension of three-dimensional space).

Although the frequency of ambiguous answers were high in the reference frame task (27-91 %) compared to three-dimensional space task (1-29 %), the students, who could understand the instructions, did draw more correct pictures on reference frame (42-87 %).

Though the frequency of ambiguous answers (1-29 %) was lower in three-dimensional space task, the students, who could follow the instructions, were incorrect in their drawings (47-88 %).

The difference between the frequencies of ambiguous answers on each task can be a result of perceived difficulty. Students might find the reference frame task more difficult than three-dimensional space task and drew pictures inconsistent with the instructions.

When students' grade (and their age) level is considered, comprehension of three-dimensional space and reference frame tasks increases with grade. This may be a result of cognitive development that allows these students to acquire space concepts.

Students' performances on both tasks show an improvement with grade too. Especially in middle school grades, students were more successful (31-43 %) in comparison to primary school level (0-23 %).

When students' performances on both tasks were considered, the second and third graders are more successful than their counterparts at primary school. This could be a result of the curriculum given in these levels. Although there are no science courses at these grades, the school curriculum might have related objectives that are facilitating students' comprehension of space concepts. As we know there specific objectives in primary mathematics (solid objects). To describe space is one of the objectives of geometry learning area (MEB, 2009b).

Moreover life sciences courses for grade one to three also assist self-management skills of student (one of these skills is correct perception of time and space). Life sciences program also aims the ability of identifying basic concepts of science (change and conservation are among these skills). Time is a concept in Past, Today, and Tomorrow theme in life sciences course (MEB, 2009b).

Children when experiencing the nature through their curiosity can acquire many concepts and learn their cognitive skills (Taştepe & Temel, 2013). From this point, acquisition of space concepts develops in direct proportion to cognitive development.

As in early childhood education (Taştepe & Temel, 2013), elementary education should provide children with acquisition of concepts by offering natural, informal and structured learning experiences.

Educational programs should have some standards appropriate to child's learning and readiness. And the content should be developed in line with these standards so that child's cognition is supported (Taştepe & Temel, 2013).

The objectives of an educational course program should be in congruent within itself (internal congruency) and with the other course programs (external congruency). Thus students' readiness on space concepts at for example at second or third grade where there is no science course can be supported at the later grades.

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