Acquisition of Basic Geometric Concepts Among Students Who Have Completed Class VIII

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Abstract:

Geometry is a subject, the cognition of which is paramount in developing visual-spatial skills among children. Cognition of basic ideas of geometry is also required to explicate concepts in other subject areas such as physics, geography, art and craft etc. Faulty conceptualization of these basic ideas and lack of comprehension can lead to insufficient power among children to solve various problems in life and can also lead to frustration and negative attitude towards geometry.

This study has attempted to find out how far the basic ideas of geometry are really acquired by middle school children. A comprehensive study to this effect was carried out among the children coming from different environments. The sample group comprised of 486 children who included children who had just completed Class VIII and entered Class IX, both from rural and urban areas in and around Kolkata. Administration of Cattel and Cattel's Culture Fair Intelligence Scale ensured that the participants' scores were above the first quartile, thus ensuring their educability. A questionnaire for detailed assessment of the basic geometric ideas indicated for middle schools by the most popular boards of education was constructed and standardized and subsequently administered to the sample. The resultant scores were examined and analyzed by statistical techniques including descriptive statistics. The result yielded a significant improvement in acquisition of basic geometric ideas among children as they proceeded from class VIII to class IX, though many of the basic ideas of geometry were lacking among a large number of students.

Key words: *Visual-Spatial Skills and Basic Geometric Concepts.*

I. INTRODUCTION AND PROBLEM

Children are naturally attracted to illustrations rather than the written word. Illustrations help the reader to picture the happenings in a story they are reading, thus making the reading more intimate and imaginable. The happenings related in the story spring to life with illustrations by giving them visual spatial references. It is, as if illustrations are the bridge to realization of the world inhabited by the story. Geometry, seen from the above perspective, has the potential of enlivening mathematics. It can be set aside from the more 'mundane' activities of arithmetic and algebra. Yet Geometry is often seen to be one of the most intimidating areas of mathematics. This is probably because of theover dependence on textbooks by teachers and students, and by the stress on formal proof by the school curriculum. The prevalence of examples in the immediate environment of the child is more often than not overlooked. As Pierre Van Hiele (1952) noted "…… the student knows only what has been taught to him and what has been deduced from it. He has not learned to establish connections between the system and the sensory world."

As a mathematical domain, geometry is to a large extent concerned with specific mental entities, the geometrical figures. At a mathematical level, geometrical figures are mental entities, which exist only based on their definitions and their properties. But, a distance is identified between the geometrical-mathematical meaning of these specific concepts and students' personal meanings of geometrical figures, since in students' minds these figures are often related to real objects (Mesquita, 1998).

Different Mathematics curricula in schools presume that children will have acquired concrete ideas regarding shapes, directions, similarity and symmetry by the time they reach secondary school. The report of the committee set up by the Ministry Of Human Resource Development, Government Of India, (Minimum Levels Of Learning At Primary Stage) N.C.E.R.T (1991) regarding "the Understanding Of Geometrical Shapes And Spatial Relationships", suggests that at the end of class-V children should be familiar with basic and fundamental shapes and be able to draw them and identify some of their characteristics. By the time children finish elementary schooling in class VIII, they are expected to know the rudimentary facts of Euclidean Geometry. Much of the curriculum in the secondary and higher secondary stages presume that children have basic knowledge in geometry.

In the secondary schools many of the central ideas in physical sciences and earth sciences are built up.Thus it is advisable that a thorough knowledge of basic facts of geometry is acquired by students of class VIII. This includes comprehension and familiarization of basic geometric concepts.

The importance of studying and teaching geometry is well established in literature and is stressed in contemporary

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mathematics curricula not only as an autonomous mathematics field, but also as a means to develop other mathematical concepts (Gagatsis, Sriraman, Elia & Modestou, 2006; Kurina, 2003; Clements, Sarama & Wilson, 2001). Through the study of geometry, students are expected to learn more about geometric shapes and structures and how to analyze their characteristics and relationships (NCTM,2000), building understanding from informal to more formal thinking and passing from recognizing different geometric shapes to geometry reasoning and geometry problem solving (Daher & Jaber, 2010). The importance of the environment to teaching and learning geometry is emphasized in literature (Clements & Battista, 1992; Harrell & Fosnaugh, 1997).

It is also expected that a problem solving attitude should develop among the students, at the end of their secondary school stage. This kind of attitude can be developed through a particular kind of geometry teaching method which involves problem solving activities. An important technique in problem solving (Baturo,2002 and Battista,1998) in area determination, for example, is the division of a complex shape to simpler pieces that are recombined to create a new shape of equal area but of different form through the actions of 'cut', 'paste', 'rotate' etc. Such tasks designed for concept enhancement in practice become exercises in problem solving. The 'cut and paste' method is a common activity that is used for young children concerning area. In the example cited, the problem solving aspect is exactly what cutting and pasting must be done in order to obtain a given shape from another.

In spite of the elementary school curriculum including geometric ideas in its content area, it is common knowledge that students in high schools fear geometry. They often avoid visual spatial problems that curtail their creative prowess. One of the reasons for this could be that faulty conceptualization multiplies over years, progressively incapacitating the student in his or her ability to cope with the visual spatial demands of life. Moreover, failure to conceive the ideas in geometry can lead to a negative attitude towards the subject.

Blanco from the University Of Extremadura (2010) has shown how errors in acquisition of basic concepts of geometry happen because of the way geometric figures are placed before the students. Not only are unwarranted generalizations surmised but genuine errors of perception may also occur. As an illustration Blanco has shown how this can happen when teaching the altitude of a triangle.

As per the study conducted by Panaoura,(2009) and Panaoura, (2010) students' cognitive performance on any mathematical concept is related with their respective self-beliefs on understanding it, and on using strategies in order to overcome cognitive obstacles. Recent experiences and success or failure in solving geometrical tasks affect the development of self efficacy and self concept beliefs about the use of representations in geometry figures, diagrams etc. The significant interrelations of students' self-beliefs with their mathematical performance in geometry confirm that students with lower performance have negative self-beliefs about the use of representations because they are not able to use them fluently and flexibly as a tool to overcome cognitive obstacles on understanding a geometrical concept. A similar result was found at a previous study about the concept of fractions and decimals.

Cognitive development of any concept is related with affective development (Zan, Brown, Evans & Hannula, 2006). Affective domain in mathematics education is an area to which considerable research attention continues to be directed (Leder & Grootenboer, 2005). The literature suggests that there is an influential connection between affective mathematical views and performance in mathematics (Ai, 2002; Schreiber, 2002). The relationship between affective factors and learning in mathematics is not simple, linear and unidirectional; rather it is complex and convoluted (Grootenboer & Hemmings, 2007). Marsh and Craven (1997) mentioned that, "enhancing a child's academic self-concept is not only a desirable goal but is likely to result in improved academic achievement as well" (p. 155). The anticipated improvement of student's performance is based on the existence of a reciprocal relationship between self-concept and academic achievement (Marsh, Trautwein, Ludtke, Koller, & Baumert, 2005).

According to Pajares (2008) "self-efficacy should not be confused with self-concept, which is a broader evaluation of one's self, often accompanied by the judgments of worth or esteem that typically chaperone such self-views" (p. 114). Self-efficacy beliefs refer to matters related to one's capability and revolve around questions of "can", whereas self-concept beliefs refer to matters related to being and reflect questions of "feel". Academic self-concept is referred to as self-perceptions of ability, which affects students' effort, persistence, anxiety, and indirectly, their performance (Pajares, 1996). Self concept refers to individuals' knowledge and perceptions about themselves in achievement situations (Wigfield & Karpathian, 1991). Self-concept includes beliefs of self-worth associated with one's perceived competence (Pajares & Miller, 1994).

Besides individual impressions, students can develop their academic self-concept externally through a comparison with their classmates (Wang, 2007). Bong and Skaalvik (2003) state that academic self-concept primarily indicates one's self-perceived ability within a given academic area, while academic self-efficacy primarily indicates one's self-perceived confidence to successfully perform a particular academic task. According to Ferla, Valcke and Cai (2009) academic self-efficacy and academic self-concept, measured at their natural specificity level, represent conceptually and empirically different constructs, even when studied within the same domain. Their study further suggests that students' academic self-concept strongly influences their academic self-efficacy beliefs and not vice versa.

Students experience a wide range of representations from their early childhood years onward (Elia & Gagatsis, 2003). Representations can differ with respect to their informational content and their usability. Given that a representation cannot describe a mathematical content fully, and that each representation has different advantages, using multiple representations for the same mathematical situation is at the core of mathematical understanding (Duval, 2002). Ergo, mathematics textbooks should use a variety of representations in order to enable students to understand the mathematical concepts (Panaoura et al., 2010). In geometry, the understanding of mathematics requires that there is no confusion between mathematical objects and the respective representation (Duval, 1999).

Thus the affinity towards Geometry or repugnance towards it is affected by students' self concept and self efficacy regarding the subject. These traits hamper conceptualization or have the power to make learning Geometry a pleasant meaningful experience.

Unfortunately, high school students balk at the very name of Geometry. Neither do they find it interesting nor do they perceive any relevance of it in their lives. The reason may depend on the way geometry is taught and the lack of concrete illustrations in the teaching process. Lack of connection to the environment of students may breed negative attitudes towards Geometry among students. Aktas, Meral Cansiz ; Aktas, Devrim Yasar(2012) conducted a survey to determine high school students' attitude towards geometry with respect to various variables. A 'Geometry Attitude Scale' developed by the researchers was used. At the end of the study it was determined that there was a significant difference in attitude towards Geometry according to the kind of school attended by the student and the student's stream of study. On the other hand there was no significant difference in attitude between the genders and between the different grades. This shows that differences in the environment in teaching with methods of teaching in different schools had an effect on students' attitude towards geometry.

Teaching of geometry should not only follow a proper method. The concepts placed before the students should be related to their life experiences as well. In this respect the Van Hiele model (1957) of teaching Geometry is pertinent. This model eschews rote learning and recommends building up familiarity with Geometric ideas with numerous examples from the early stages of schooling. The model stresses the need for establishing the relationships between Geometric ideas among students. The levels of cognition of Geometric ideas proposed by Van Hiele are visualization, analysis, abstraction deduction and rigor. The methods of teaching Geometry in most Indian schools do not always answer to those specifications. Elementary school Geometry rarely connects to illustrations from the environment and rarely evokes independent thought. The stress in Indian schools is more on textbook learning. Consequently, whether children imbibe Geometric concepts correctly and in their entirety is a query that may occur to educationists. Any lacunae in this respect bear the danger of multiplying manifold over the high school stage leaving countless students visually and spatially disabled.

While teaching geometry, very often educators fail to give the essential attention to the precise structure of the figure on the board, for various reasons such as access to old materials and time pressure to complete the syllabus (Gagatsis et al., 2010). In such cases, educators often take for granted that students will rely on the processing of the verbal statements of the problem in order to understand it. The results of Xistouri, Nicolaou, Koukoufis and Gagatsis (2005) indicated that many students do not rely on the verbal statements of the task as much as the educators expect, and quite often their performance can be affected negatively by a figure.

The above discussion shows that there is a need to examine how well students acquire Geometric concepts, particularly in the secondary schools in our country so that any lacunae in this regard may be rectified. The investigator therefore intended to find out how far the concepts of points, lines, familiar shapes and angles are acquired by students when they are about to enter secondary school. In other words, the investigator intended to assess the extent of acquisition of these concepts by students in the secondary school.

Objective

The objective of the study was thus to investigate how far the students who have completed class VIII and have just entered High School have acquired basic concepts related to Geometry. Here 'Basic geometric concepts' refers to ideas about

- Points and Lines.
- Familiar two dimensional and three dimensional shapes.
- Angles and directions.

Hypotheses for objective:

Ho -There is no significant improvement in acquisition of basic geometric ideas among children as they proceeded from class VIII to class IX.

II. METHOD OF THE STUDY

Procedural Framework

The following steps were taken in conducting the study.

- A thorough literature review was done to get an overview of the recent developments in the field of cognition.
- Problem and title of the study were selected on the basis of a strong rationale.
- Objective of the study was framed.
- Population and location of the study was determined from which the prerequisite representative sample was selected.
- Requisite hypothesis of the study was framed against the objective for systematic investigation.
- A personal data sheet and the geometry scale "How Much Geometry Do You Really Know" was constructed by the researcher.
- The personal data sheet and the geometry scale, both were applied on the sample group and the results /raw scores were tabulated for statistical analysis.
- Statistical analysis was conducted by using SPSS 16 software and the results were analyzed.
- The findings were then interpreted and supported by various literatures.
- The investigation was based on data taken in West Bengal and the results were generalized to arrive at conclusions regarding the acquisition of basic ideas related to Geometry by the upper primary and secondary school going children of both urban and rural Indian families.

Sample

The sample was chosen from a population which consisted of those students who had completed Class VIII (i.e. elementary school) and entered class IX (i.e. secondary school) in

Kolkata and districts surrounding Kolkata. The secondary schools in Kolkata and surrounding districts were approached and chosen, until the requisite sample size was obtained.

The sample was as follows:-

	BOYS	GIRLS	TOTAL
URBAN	109	98	207
RURAL	111	168	279
TOTAL	220	266	486

Tools of the Study

A test entitled 'How Much Geometry Do You Really Know?' was constructed by the investigator to evaluate the acquisition of basic concepts in Geometry. The concepts were identified by consulting with prescribed mathematics text books of the W.B.S.E, C.B.S.E AND C.I.S.C.E boards. The content of basic geometric ideas was divided into five main conceptual areas, viz.

- 0 Dimensional figures -----Point
- 1 Dimensional figures------Line
- 2 Dimensional figures------a. Plane
  b. Polygon
  c. Types of Polygon
  d. Circle
  e. Triangle
  f. Quadrilateral
- 3 Dimensional figures ----- a. Cuboid/Cylinder/ Net/Cube
  b. Cone
  c. Sphere
- Angles and directions.

Content analysis of each conceptual area was carried out by identifying the properties pertaining to each area. The test was framed by constructing items to evaluate each property. Each item was dichotomous in nature.

The test was then validated by experts in the field, and was then administered to a representative sample and the item facility and discrimination index of each item were calculated. The items were of medium difficulty, but discriminated between those tested, ability wise. The inter item correlations were calculated and largely found to be significant. The item total correlations were also found to be significant, thus ensuring the consistency of the test. Finally, the reliability of the test was calculated by Cronbach's (alpha) and found to be .87.

III. ANALYSIS OF DATA

The test was administered to the sample and the responses were scored. The scores were then analyzed according to the concepts within each of the five main conceptual areas through appropriate statistical techniques.

0 DIMENSION

Point

Properties of Point	***% of correct responses***	***% of incorrect responses***
1. Only position & no dimension.	86%	14%
2. Two lines intersect to make a point.	73.2%	26.8%

Noticeable observations:

1. The basic idea of point was cognized by most students.
2. A quarter of the sample was not aware of a point as the intersection of two lines.

1 DIMENSION

Line

Properties of Line	***% of correct responses***	***% of incorrect responses***
1. Length only and no breadth.	53.1%	46.9%
2. Line extends indefinitely in both directions.	31.7%	68.3%
3. Infinite number of points can lie on a line.	38.4%	61./6%
4. Infinite number of lines can pass through a point.	76.3%	23.7%
5. A line does not change direction.	60.8%	39.2%
6. Intersecting lines are never parallel.	28.7%	71.3%
7. Points lying on one line are called Collinear points.	53.9%	46.1%
8. Lines are formed by intersection of two planes.	30.3%	69.7%
9. Two different lines intersects at only one point.	68.8 %	31.3 %
10. Line segment, ray are parts of a line.	38.8%	61.2%

Noticeable Observations:

1. Many properties of a line were not cognized by a large percentage of students.
2. There was a lack of physical identification of lines outside the realm of textbooks.

2 DIMENSION

Plane

Properties of Plane	***% of correct responses***	***% of incorrect responses***
1. A flat surface with no edge.	51.7%	48.3%.
2. A plane has no thickness.	57%	43%

Noticeable Observations:

1. Plane as a 2-dimemsional concept was not cognized by nearly half the students.
2. More than half the students are aware that a plane has no thickness.

Polygon

Properties of Polygon	% of correct responses	% of incorrect responses
1. A closed plane figure.	29%	71%
2. It should have boundary of at least three or more than three lines and named by the number of lines.	43%	57 %
3. Interior and exterior angles of a polygon.	58.5%	41.5%
4. Concave and convex polygons.	56.3%	43.8%
5. Line of symmetry.	56.3%	43.8%
6. Regular and Irregular polygons.	33.5%	66.5%.

Noticeable Observation

1. Most of the properties of polygon have not been cognized by a large percentage of the sample.
2. More than half the sample groups have acquired the basic ideas about interior and exterior angles of a polygon, concave and convex polygons and lines of symmetry.

Types of Polygons

Properties of Polygon	% of correct responses	% of incorrect responses
1. A pentagon has five sides.	72.6%	27.4%
2. A hexagon has six sides.	59.4%	40.6%
3. A heptagon has seven sides.	58.8%	41.2%
4. An octagon has eight sides.	71.1%	28.9%
5. A nonagon has nine sides.	71.9%	28.1%
6. A decagon has ten sides.	75.2%	24.8%

Noticeable observation

1. More than half the sample have cognized the ideas about different types of polygons.
2. About 1/3rd of the sample have no idea about different types of polygons.

Circles (2-dimension)

Properties of Circle	% of correct responses	% of incorrect responses
1. A circle is a closed figure consisting of all those points which are at a constant distance from a fixed point	75%	25%
2. A fixed point inside the circle which is the centre.	55.3%	44.7%
3. The distance from the centre to boundary Is called radius.	36%	64%
4. A chord passing through the centre of the circle is called the diameter of the circle.	50.6%	49.4%
5. A line segment joining any two points on the circle is called the chord of the circle.	46.5%	53.5%
6. A diameter is the biggest chord of the circle.	51.3%	48.7%
7. The boundary of the circle is called circumference of the circle.	45%	55%
8. A diameter divides the circle into two equal halves, which are semicircles.	70%	30%
9. Two or more circles with a common centre are called concentric circles.	45%	55%

Noticeable Observation

1. The properties of circles have been cognized by half the sample.
2. Some concepts like Radius, Circumference and Concentric Circles have not been acquired by more than half the sample.

Triangles (2-dimension)

Properties of Triangles	% of correct responses	% of incorrect responses
1. A triangle is a plane closed figure enclosed by three line segments.	100%	0%
2. A triangle has 3 vertices, 3 interior angles and 2 sets of exterior angles.	100%	0%
3. Sum of 3 interior angles of a triangle is 180˚	100%	0%
4. Sum of any two sides of a triangle is greater than the third side.	100%	0%
5. Right angle to its correspondence side.		
6. Similar triangles.	100%	0%
7. Congruent triangles.	100%	0%
8. Acute, obtuse, and right angled triangles.	100%	0%
9. Equilateral triangles.	100%	0%

Noticeable Observation

All students have cognized the basic ideas related to triangles.

Quadrilateral

Properties of Quadrilateral	% of correct	% of incorrect
1. A closed figure with four sides.	45%	55%
2. It has four interior angles.	40%	60%
3. Diagonals of a quadrilateral intersects each other.	40%	60%

4. sum of the interior angles of a quadrilateral is 360˚	30%	70 %
5. Rectangle	30%	70%
6. Parallelogram.	35%	65%
7. Square.	30%	70%
8. Rhombus	30%	70%
9. Trapezium	40%	60%

Noticeable observation:

More than half the students have not cognized the concepts of quadrilaterals completely.

3 DIMENSIONS (SOLID FIGURES)

Cube,Cuboid,Cylinder and Net

Properties of Cube, Cuboid, Cylinder and Net	% of correct responses	% of incorrect responses
1. Circle based cylinder	40%	60%
2. Rectangle based cylinder.	30%	70%
3. A cuboid has12 edges.	30%	70%
4. A cuboid has 6 faces.	35%	65%
5. A cuboid has 8 vertices.	30%	70%
6. Volume of cuboid	35%	65%
7. Net of cuboid	70%	30%
8 . A cube is a square based	45%	55%
9. A cube has 12 edges, 8 vertices & 6 faces.	70%	30%

Noticeable Observation

The result shows that nearly 70% of the sample had not cognized fully the ideas of cylinder and cuboids. However nearly 70% of the samples had cognized about the ideas of Net and Cube.

Cone

Properties of Cone	% of correct responses	% of incorrect responses
Right circular cone.	35%	65%

Noticeable Observation

The result shows that nearly 70% of the sample have not well cognized about the ideas of a right circular cone.

Sphere

Properties of Sphere	% of correct responses	% of incorrect responses
1. Sphere	30%	70%
2. Hemisphere	22%	78%

Noticeable Observation

The result shows that nearly 70% of the samples have not well cognized about the ideas of a sphere and nearly 80% of the sample have not well cognized about the ideas of a hemisphere.

Angles

Properties of Angles	% of correct responses	% of incorrect responses
1. Naming of an angle accordingly.	36.4%	63.6%
2. When two lines meet at a point they form an angle.	30%	70%
3. Types of angles- Acute angle, Obtuse angle, Right angle and Reflex angle.	22%	78%
4. Corresponding angles, Alternate angles and vertically opposite angles.	30%	70%

Noticeable Observation

1. More than two third of the students have not cognized about the basic concepts of an angle.
2. Nearly 80% of the sample cannot distinguish between various types of angles.

Directions

Properties of Directions	% of correct responses	% of incorrect responses
1. Knowledge about North, South, East and West direction.	33.8%	66.2%
2. Knowledge about clockwise turning from one direction to another direction.	28.5%	71.5%
3. Knowledge about anticlockwise turning from one direction to another direction.	22.2%	77.8%

Noticeable Observation:

1. Two thirds of the students do not have clear ideas about north, south, east and west directions.
2. More than two thirds of the students do not have ideas about clockwise turning and even more have no clear ideas about anticlockwise turning.

IV. CONCLUSION

This study frames the picture of the state of conceptualization of basic geometric ideas in elementary schools. Student responses seem to indicate that many of the ideas expected to be acquired by them had not been adequately related to their concrete manifestations. Rather, reinforcement of textbook knowledge may be seen in the responses. This is why all the students in the sample were aware of the properties of the triangle but did not fully cognize the properties of lines. Awareness of three dimensional visual –spatial schemas seem to be particularly lacking as may be seen from the responses regarding directions.

Nearly all the ideas encompassed by elementary school geometry are about familiar shapes and configurations in the immediate environment of the child. Yet a large percentage of students failed to identify these from their surroundings. This showed that they are prone to regard geometry as a conglomeration of discrete facts acquired through rote learning. That is, they have not been able to realize the ideas in their entirety.

A possible reason for the lack of complete conceptualization may be inadequate knowledge of geometric concepts among teachers as can be seen in the study of Sara Talley Lenhert (2000). This study investigated the relationship between middle school mathematics teachers' pedagogical content knowledge and students' learning scores. The result showed a positive relationship between teachers' pedagogical knowledge assessment scores and students' scores, indicating that student attainment can be a consequence of the teacher's depth of knowledge.

The National Curriculum Framework, 2005 , has stressed on active construction of knowledge by learners, ie, a constructivist outlook on learning. Unfortunately, this dictum is hardly followed in our schools. Yet the nature of the development of visual spatial skill acquisition, of which geometry is the main representative in the curriculum, is such that without hands on acquaintance of concrete referents it cannot be attained. This is also a reason for the lack of matching between textbook and constructive conceptualization among children.

Generally speaking, popular perceptions of mathematics often inhibit students from approaching the subject with positive attitudes. Pajares and Schunk (2002) found that many students suffered from lack of "self belief" regarding their ability to cope with the subject. Thus students tend to shy off mathematical ideas, leave alone connecting them to the real world.

The present study shows that many students are unable to fully understand the geometry concepts that they are meant to at the end of the elementary school years. Unfortunately, it is wrongly assumed that they do, indeed, imbibe the ideas by the time they leave class VIII and proceed through to the secondary school years. They are then expected to learn more geometric concepts based on the early concepts. This is not the reality. Wrong conceptualization of basic concepts does nothing but build up more wrong concepts, and finally, failure. Thus we have the beginning of "Geometry is difficult" and "Geometry is frightening". Thus the stumbling blocks of fear and antipathy towards geometry in particular, and mathematics in general, takes centre stage.

Quite obviously this state of affairs has to be rectified. Instead of covering large areas of content, care must be taken to instill geometric ideas among students through concrete and practical meaning so that they hold relevance for students and motivate them to know more.

This study can also be regarded as a reality lesson to teachers and curriculum makers. Further awareness can be generated about developmental attributes of elementary school children. Neo Piagetian ideas in this regard may be beneficial. (Pascual-Leon.J.1970 andCase,R.1985). Consequently, curricula regarding Geometry need to be in step with developmental characteristics and interests of the child and incorporate sufficient illustrations and practical applications of the concepts to be imparted.

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