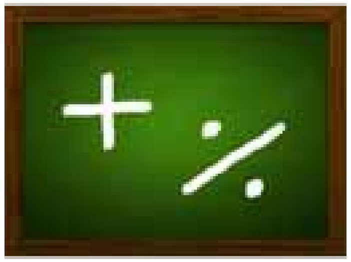

# Teaching mathematics to deaf children using built spaces

A Special Project Report by:

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My dad, Dr. G. Purushothama
My Family and friends who kept me going all the way.

-Anantha

# Mathematics is omnipresent

We are inseperable from the facets of impact mathematics has on our lives.

# CONTENTS

# 1.0 INTRODUCTION

Children look at and play with everything they own at the same time. Giving young children a safe space to explore and allowing their eye and hand coordination to improve if interesting things can be given to be looked at and touched, is a shortcut to enhancing their organisational and academic skills. Using their environment to teach them mathematics would be an ideal outlook along with what is present and would bridge as such the experiential learning into their essential development.

“We have been modifying/changing our space but at the same time we have been modified/changed by the space”

This has been quoted in the course titled ‘Mathematics in Architecture’ for third year students of Department of Architecture of Middle East Technical University, . So true is the above statement which leaves us conscious beings inseparable from our environment.

Architecture is immensely affective in our lives. The third most need of man, being shelter–not just keeps him/her alive, but also greatly enters into our experiences.

Architecture approaches nearer than any other art to being irrevocable, because it is so difficult to get rid of. You can tear a poem to pieces; it is only in moments of very sincere emotion that you tear a town-hall to pieces. (G. K. Chesterton from Tremendous Trifles, 1909)

# 2.0 LITERATURE STUDY

# What is Experiential Learning?

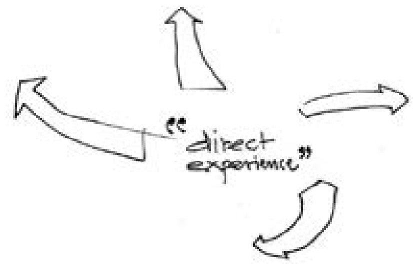
Experiential Learning is the term coined for learning through direct interaction with the topic and consciously experiencing the process. When children are exposed to concrete experience of operations on the environment, they will develop concepts that will give meaning to the words they hear and read.

It is not a transmitional process where a person acquires the knowledge dissipted while interacting with another. And nor can it be absorbed from books. It is about going to the place of the activity, engaging upon the world and experiencing direct feedback in all available modes. Experiential learning deals with the following.

• studying own actions/experiences
• personal/cognitive skills
• social learning eperience
• reflection of doing
• collaboration for common goal
• learning by doing

**Talking about Conventional Opinions**

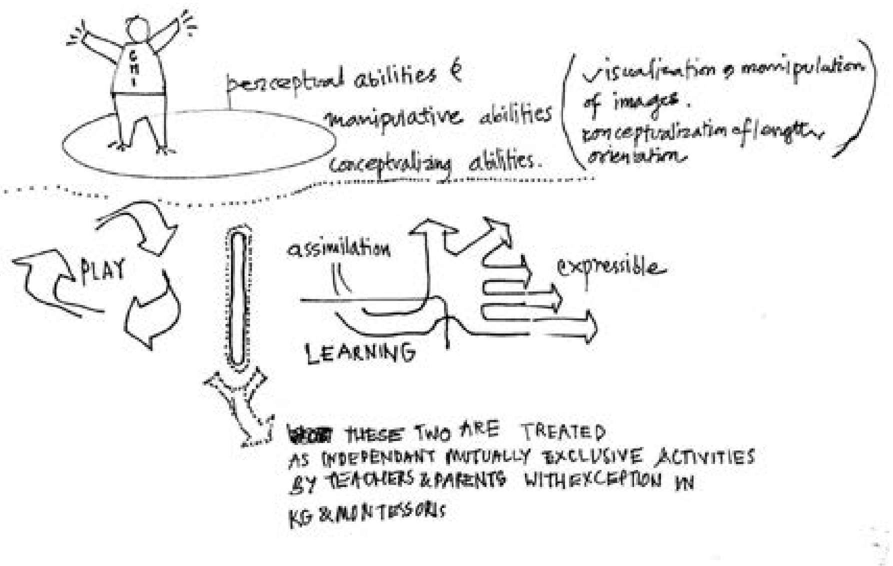
David Wood [45] talks about keeping ‘less abstraction’ in the class, avoiding learning in class/‘not classroom-based’ and providing as much of ‘concrete experience’ as possible to children.

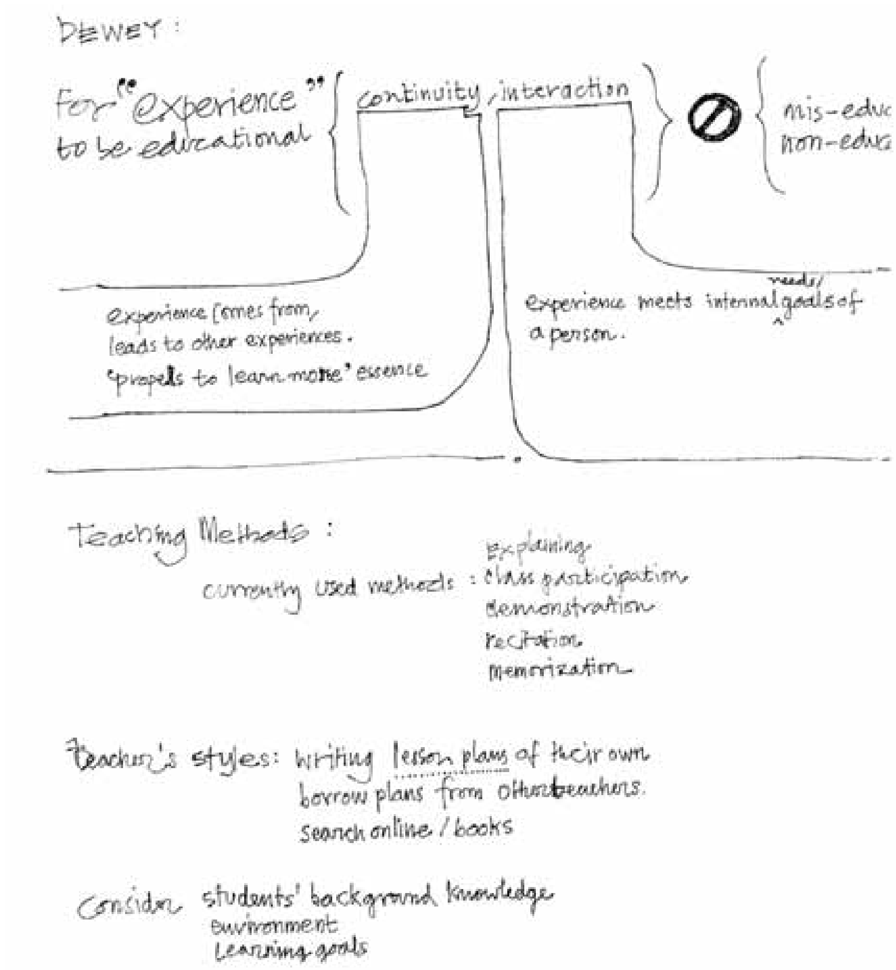



= Learning by doing
= learning through reflection on doing
[opposite = rote learning / didactic learning]

≠ experiential education
≠ action learning
≠ adventure learning
≠ free choice learning
≠ cooperative learning
≠ service learning

In this context, **John Dewey**, in his book, Experience & Education (1938), put "EXPERIENCE" at the centre of educational process. While describing his ideas about curriculum theory in context of school organization, he has widely critiqued the modern traditional education.



# Spatial Learning Experience

While talking about spatial learning experience contemporary ideas defines spacial thinking as powerful and pervasive, underpinning everyday life, work, and science. It plays a role in activities ranging from understanding metaphors, becoming good at way-finding, and interpreting works of art, to engaging in molecular modelling, generating geometry proofs, and interpreting astronomical data. Spatial thinking comes in many guises. It can rely on any of the senses; it can take place entirely in the mind or it can be supported by tools that are simple—a pencil and paper—or complex—a graphic information system. Spatial thinking can be a basis for sophisticated expertise—as in the calculations of a world-class orienteer—or for everyday judgments—as in the rough-and-ready estimates of the amount of paint needed to cover the walls of a room.[10]

Although everyone can and does think spatially, people do so in different ways and with varying degrees of confidence and success in different situations. Some people are good at spatial reasoning, and others struggle; the results of giving travel directions exemplify the difference in levels of success. In giving directions, strategies vary: directions can be given as turns, as landmarks, or as a sketch map. Some people are good at spatial thinking only in a limited domain of knowledge and literally cannot find their way out of the proverbial paper bag, whereas others seem able to tackle a wide range of spatial problems[10]

Spatial abilities in children have been shown to be related to activity in the environment, particularly to walking and other forms of active locomotion.[9]

The abilities of children in terms of spatial categorisation and reaching to their goal can be very easily studied by observing different kinds of outdoor games and sports. (sense of spatial grouping, making strategies, underlying patterns)

# Learning Styles

There are different schools of though that exist in learning styles and intelligence. Learning Styles theorists believe there are several different types of intelligence or ability. Under these theories, every person is believed to have strengths and weaknesses in one of nine different skill areas. Learning styles theory is sometimes also called multiple intelligences theory.

Visual Spatial Learning Styles is one of eight types of learning styles defined in Howard Gardner's theory of Multiple Intelligences. Visual Spatial learning styles, or intelligence, refer to a person's ability to perceive, analyze, and understand visual information in the world around them.

**There are eight styles:**
• Verbal Linguistic;
• Mathematical Logical;
• Musical;
• Visual Spatial;
• Bodily Kinesthetic;
• Interpersonal;
• Naturistic; and
• Existential.

**Learning Modes:**
- Auditory
- Visual
- Kinesthetic

(Incorporating all three is effective)

**Visual-Spatial Learners**

Learning, for visual-spatial learners, takes place all at once, with large chunks of information grasped in intuitive leaps, rather than in the gradual accretion of isolated facts, small steps or habit patterns gained through practice.[7]

# Teaching Styles

**Lesson Plans:**
- Questioning
- Explaining
- Modelling
- Collaborating
- Demonstrating

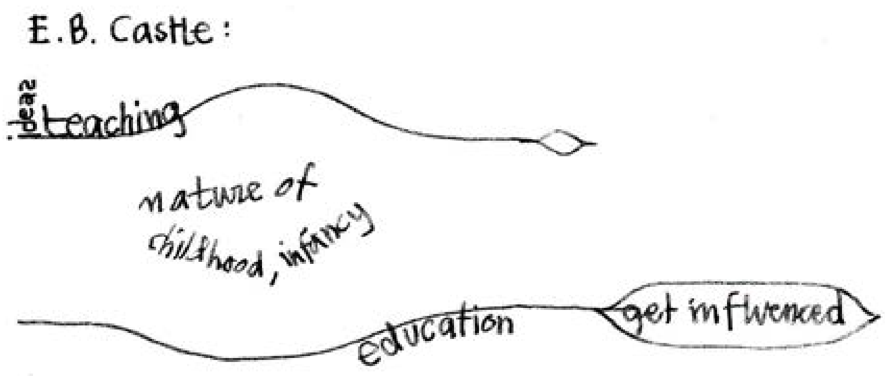
**Explaining:**
It is similar to lecturing
Similar to modelling (visualizing and using reasoning & hypothesizing to determine answers.)

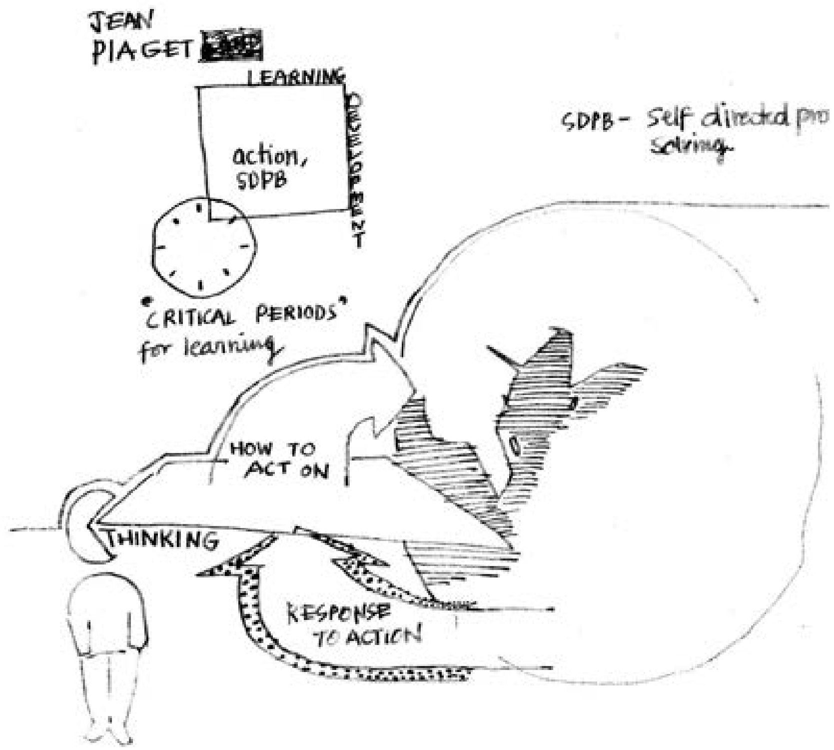
**Demonstration:**
Proving a conclusive fact by reasoning or showing evidence.

**Modelling**
The acquisition of a new skill by observing and imitating that behavior being performed by another individual.

**Collaborating**
To work together, especially in a joint intellectual effort (on a piece of work).

**Demonstrating**
to explain or illustrate by experiment, example, etc. To display, operate, and explain the workings of (a machine, product, etc.)




E. B. Castle tells us that ideas on teaching ought to be centered around the nature of childhood or infancy itself and the education should incorporate the same.

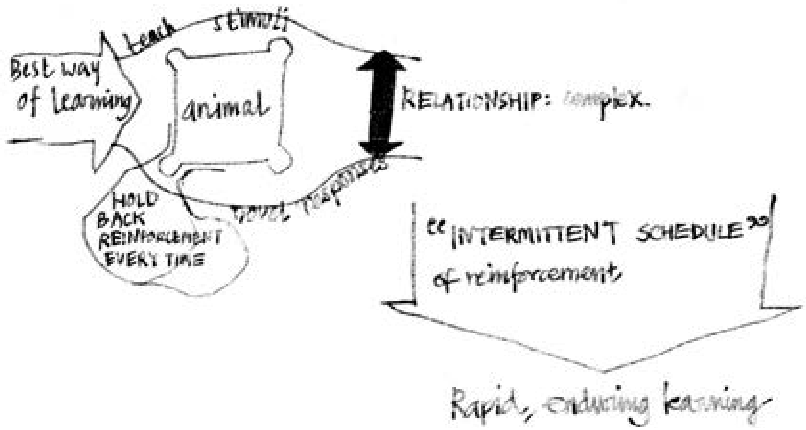
Ivan Pavlov in 1927 showed us that any animal can be taught to give novel responses by recieving stimuli. He conceptualised the first ‘learning theory’, also called the ‘S-R theory’.

Piaget showed us from his studies that children have critical periods in their development when learning can be facilitated and thus response to stimuli is dependent on such a factor.

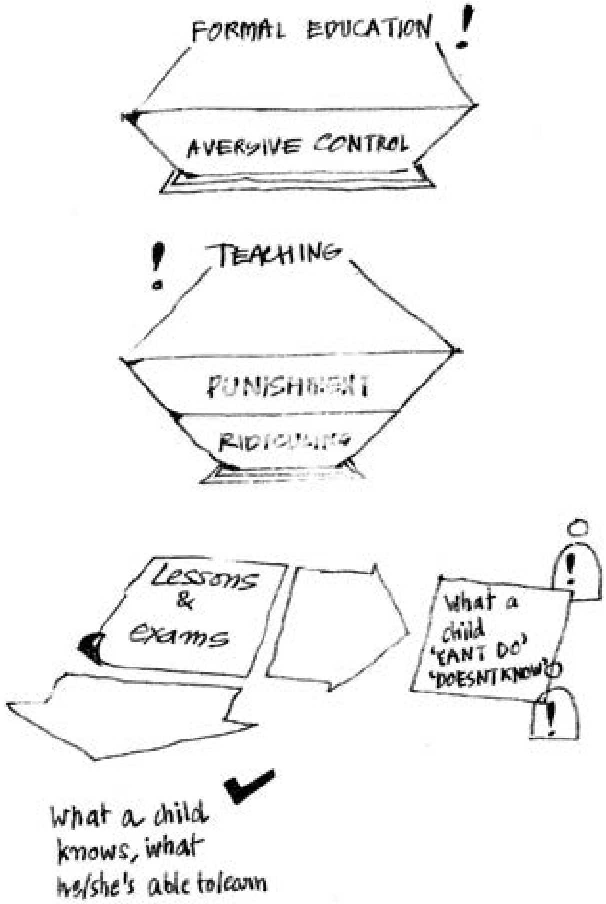
Ivan Pavlov; Russian Psychologist, 1927


"S-R"
"Learning theory"
– OBSERVABLE, MANIPULABLE PHENOMENA

B.F. skinner, American Psychologist, 1938:




B.F. SKINNER "WHY TEACHERS FAIL", 1968.




B.F. Skinner, showed us from his experiments he built on the model of Ivan Pavlov that any animal will give novel resposnes if there is reinforcement included/held back and the relationship between the stimuli and response is a complex one.

He also applied these to the then existing system of education and critisized the formal education that it is based on aversive control, giving punishment and ridiculing children. He suggested that lessons & exams point to what children can't do and doesn't know rather than looking at what a child is able to learn or knows.

He came up with the first 'Learning Programs' that were used in the domain of teaching machines to assist in human tasks.

# Math concepts and skills by age

Ann bowers, an educationist, [5] lists down the math skills that start to be developed at a very early age and goes on till 18 years of a child. This is an international perspective, curriculum being used in California (United States). We can use this a counter point to verify what we're introducing in out geometry and asses the global with our scenario.

Ages 1-3

- Count to 5.
- Put objects in order by size.
- Sort objects by shape and color.
- Learn the meaning of math vocabulary words, such as: big, small, large, tiny, round, etc.
- Learn to respond to math vocabulary commands such as: "Give me some pennies." "Give me more pennies." "Give me fewer pennies." "Put the penny (in, above, below, beside, inside, outside, underneath, over) the glass." "Put the penny between the glasses."
- Learn concepts about volume by playing with rice or sand and various kinds of containers.
- Learn concepts about volume by playing with water and various kinds of containers.

Ages 3-5

- Count to 10, then 25.
- Learn to match objects one to one (one to one correspondence).
- Learn the names of a circle, square, triangle, and rectangle.
- Sort objects by shape and color.
- Put objects in order by height.
- Learn to recognize a penny and a dime.
- Learn to recognize numbers from 1 to 10, then up to 25 (use flashcards).
- Learn to write numbers 1-12 starting at age 5. (Some children have trouble with 2, 3, 8, and 9 and may reverse them for a while. This is normal.)
- Learn to match the correct number of objects to numbers up to 12.
- Learn to respond to math commands, such as: "Put the penny (in front of, behind) the cup." "Put some water in this bowl. Put less water in this bowl." "Put more water in this bowl." "Put the string around the cup." "Put the penny first in line. Put the dime second in line." "Put the pennies first and second in line. Put the dime third." Put the pennies first, second, and third. Now put the dime fourth." "Point to the second (or sixth, or eighth, or tenth) penny (in a line)."
- Learn concepts about volume by playing with rice or sand and various kinds of containers.
- Learn concepts about volume by playing with water and various kinds of containers.
- Pick a shape that is different out from a group of other shapes.
- Pick all the shapes that are the same out from a group of shapes.
- Pick a number that is different out from a group of other numbers.
- Pick all the numbers that are the same out from a group of numbers.
- Find "hidden pictures" in a background picture.
- Find your way through a maze (on paper).
- Create a simple pattern using two or more colors.
- Create a pattern using two colors and one or two shapes.

Ages 5-7

- Learn to count to 100, then 500.
- Learn to count backwards from 10 to 1, then 20 to 1.
- Learn to "count on," i.e.; Give the child a number and he or she must count on from that number. For example: Give "33." The child should say, 34, 35, 36, 37, etc.
- Learn the concept, name, and symbol for 0.
- Learn to write numbers 0-100.
- Learn to recognize number names (printed) 0 to ten.
- Learn the signs: plus (add) minus (take away, subtract), and equals (equal to, equal).
- Learn to add numbers to 10, then 20 using manipulatives. Later, memorize the facts.
- Learn to subtract numbers from 10, then 20 using manipulatives. Later, memorize the facts.
- Learn to skip count by 10s and 5s. (5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, etc.)
- Learn to solve simple word problems up to 20.
- Learn the sign X (i.e.; times).
- Learn to multiply numbers: 2s, 1s, 10s, 5s, 0s (in that order) using manipulatives.

• Learn place value for ones and tens.
• Learn to recognize the nickel, quarter, half dollar, dollar bill. (international perspective)
• Learn the worth of each coin and bill.
• Learn to add money.
• Learn the names of the hour, minute, and second hands on a clock.
• Learn how many minutes in an hour, half, and quarter hour.
• Learn to tell time on a manual (not digital) clock.
• Learn to solve simple word problems about money.
• Learn to solve simple word problems about time.
• Learn fractions: one-half.

Ages 8-11

• Learn to count to 1,000.
• Learn to skip count by 2s, 3s, 100s, and 1,000s.
• Learn place value for tens, hundreds, thousands, ten-thousands, etc.
• Learn to add numbers in two, then three, four, and five places (i.e.; 25, 693, 3,089), without carrying over (regrouping) and then with carrying over (regrouping).
• Learn to subtract numbers in two, then three, four, and five places (i.e.; 42, 978, 1576), without borrowing (regrouping) and then with borrowing (regrouping).
• Learn the multiplication tables 0-12 using manipulatives.
• Memorize the multiplication tables.
• Learn to divide using manipulatives.
• Learn the signs for division.
• Learn to divide using the multiplication tables. For example: 6 X 8 = 48. 48 / 8 = 6 and 48 / 6 = 8
• Learn to subtract money.
• Learn to make change.
• Learn to solve word problems about money.
• Learn to solve word problems about time, including days, months, and years.
• Learn measurement (English/American and metric): linear.
• Learn fractions: all types, adding, subtracting, multiplying, and dividing.
• Learn decimals.
• Learn simple percentages: 10%, 50%, 25%.

Ages 12-13

• Continue learning fractions.
• Continue learning decimals.
• Learn percentages.
• Learn measurement (English/American and metric): volume.
• Begin simple algebra.
• Begin simple geometry.
• Learn to solve word problems with two or three steps.

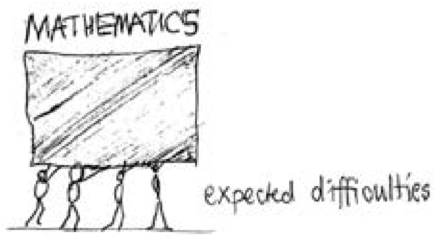
Ages 14-18

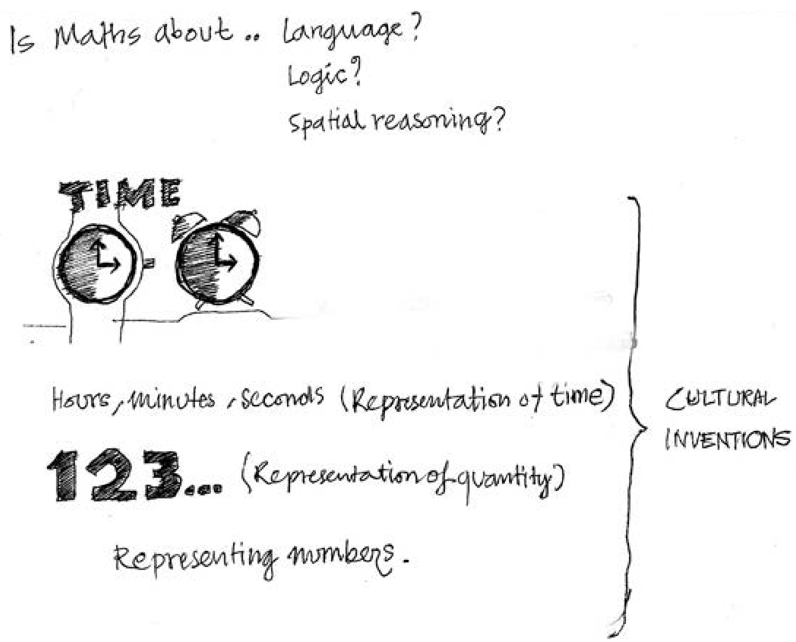
• Algebra

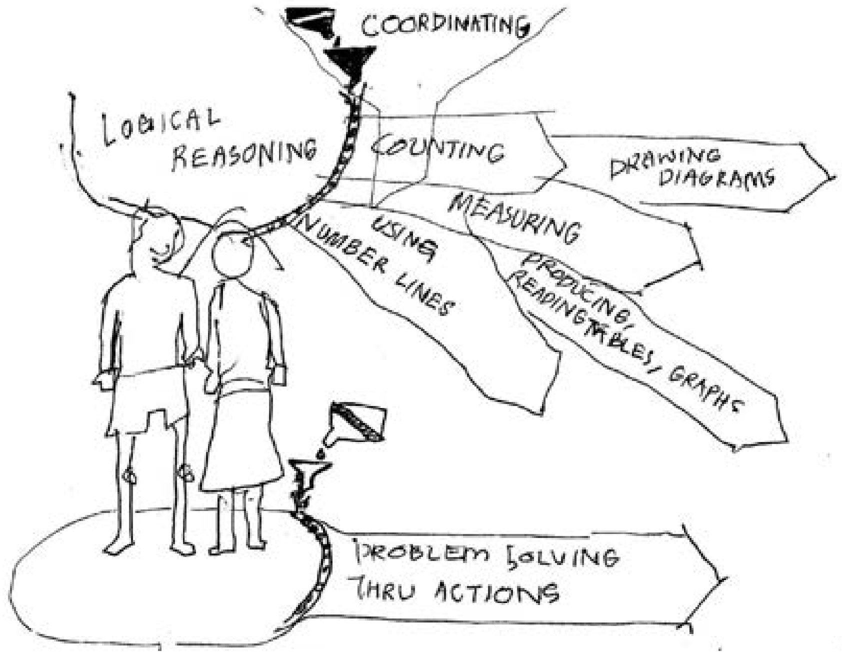
# Teaching maths to deaf children.

In a 1980s and 1990s study, Mathematical skill of deaf & hard of hearing children was seen equivalent to the weakest hearing pupils present. They form 15% of any standard maths classroom and were comparable to hearing pupils couple of years younger to them.

We solve problems by thought operations, and our thinking works with mental representations. To solve a problem, even practical ones, like a shopkeeper counting the total purchase in his mind, we need to construct a mental representation of the situation.



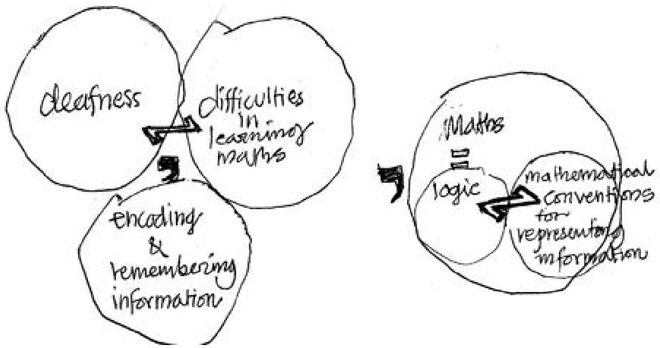



# MATH

LOGIC

SPATIAL REASONING

TIME SPENT ON LANGUAGE TEACHING, LITERACY > TIME SPENT ON MATHS




PROBLEM IN MATHEMATICS LEARNING ∞ DEAFNESS

LEVEL OF HEARING LOSS - - - - - - - ACHIEVEMENT IN MATHEMATICS

Almost NO

weak correlation

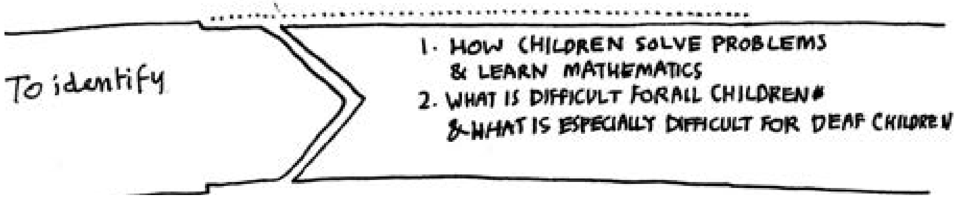
Not compatible with many observations

AVERAGE PERFORMANCE IN NON VERBAL INTELLIGENCE TESTS:

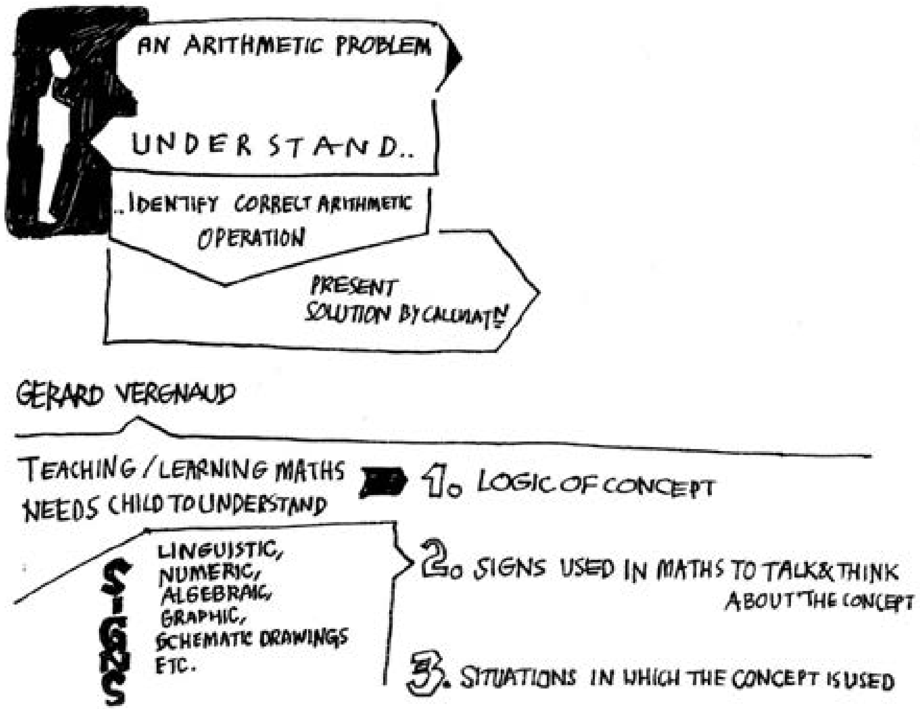
DEAF CHILDREN ⟺ ON PAR ⟺ SO-CALLED NORMAL CHILDREN

HIGHLY CORRELATED WITH MATHEMATICS LEARNING

To identify

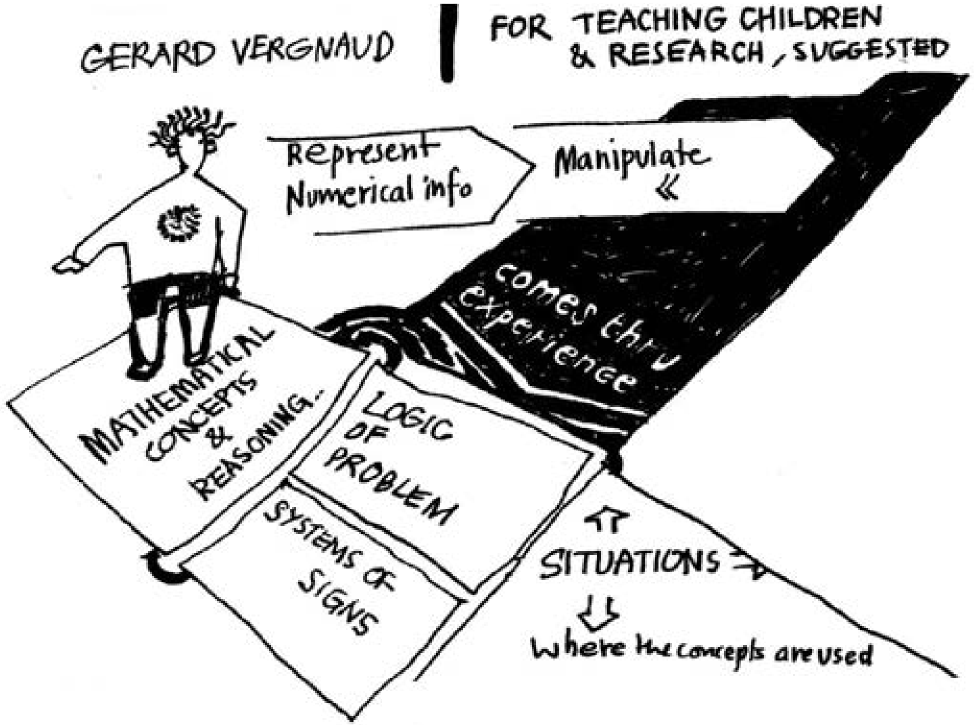


1. HOW CHILDREN SOLVE PROBLEMS & LEARN MATHEMATICS
2. WHAT IS DIFFICULT FOR ALL CHILDREN & WHAT IS ESPECIALLY DIFFICULT FOR DEAF CHILDREN

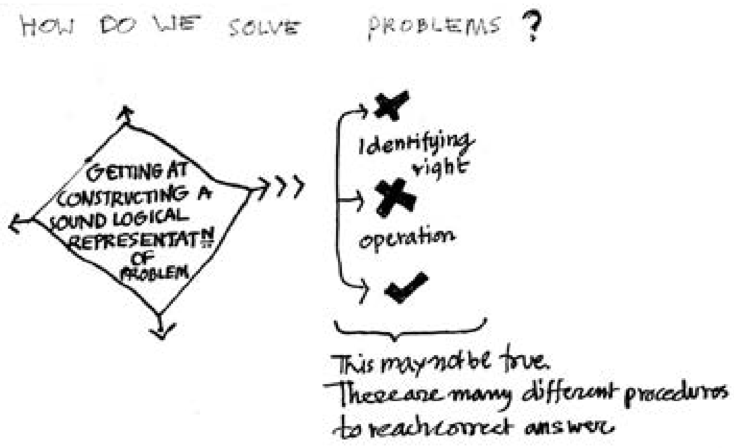


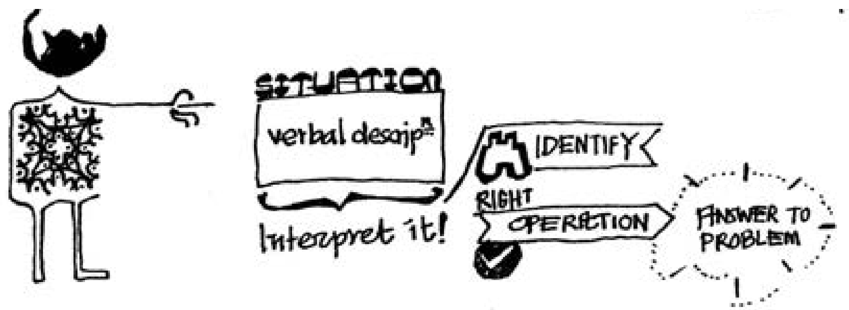

There are two parts which comprise the whole process of carrying out a mathematical operation. The first part consists of understanding the logic and the second one involves application of that logic in daily life examples.

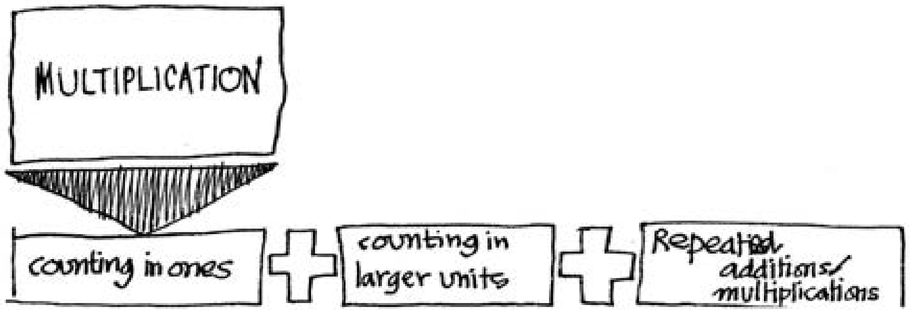
Children from age 3-5 did better at understanding it (logic) and pointing out when someone else was doing the procedure than doing/applying the procedure themselves.




There is no need to count in order to understand the logic of numbers. [20]




For an example, in the case of TRANSITIVE REASONING [20]

If A>B and B>C, then it is to be understood that A>C

Example: 'longer than' relation is transitive.
'father of' relation is not transitive.
'equal to' is transitive.
'different from' is not transitive.

Logical principles are innate and programmed in brain. [21]
Experience with situations allowed children to understand the logic of the situation. [20] For example, causal relationship once understood through a real life experience can be successfully applied in such a situation for other real life as well abstract situations.

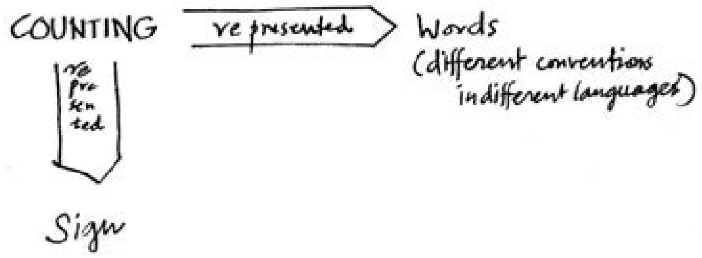
Deaf children suffer a lack of experience in different situation primarily because of their physiological limitations. [22]

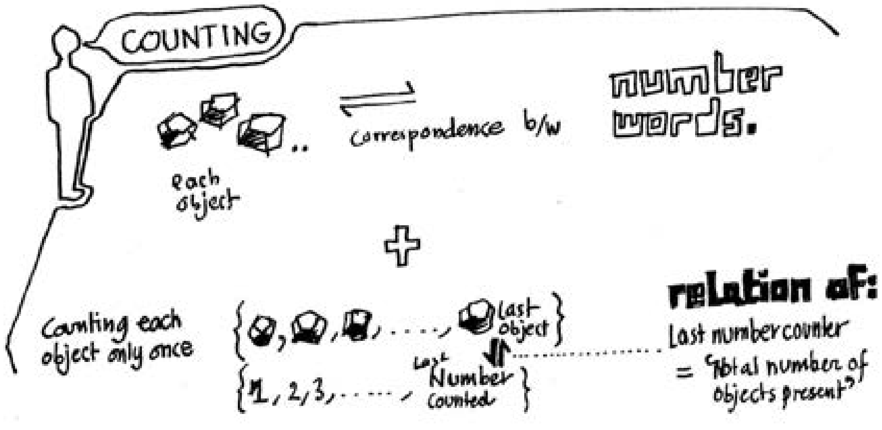
As they are missing learning opportunities in daily experiences, certain normal skill development becomes critical for deaf children. For example, they have a delay in development of money concept. Deaf children are perhaps are less likely to go out to shop & buy things own their own because of the difficulty the might face when trying to communicate with the shop assistants. [23]

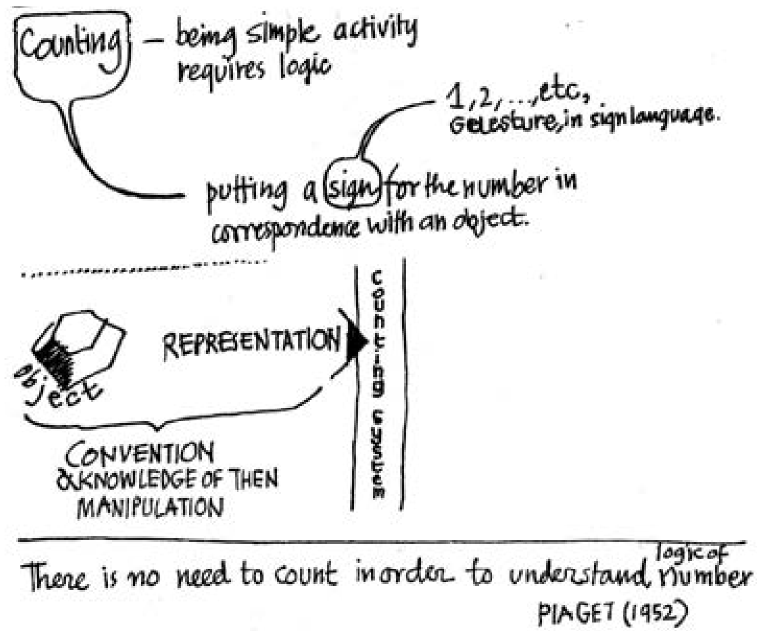
Deaf Children may face problem in picking up
- logical reasoning ability
- ability to mentally represent and recollect numbers
- ability to count use counting to solve problems.[27]

If they fall back on...before joining school, the curriculum and discourse could be redesigned for otherwise. Deaf children may be just as capable as hearing in counting

Young Children have a pre-verbal sense of numerosity( recognising small numerosity, upto three/four rapidly accurately). [24, 25]



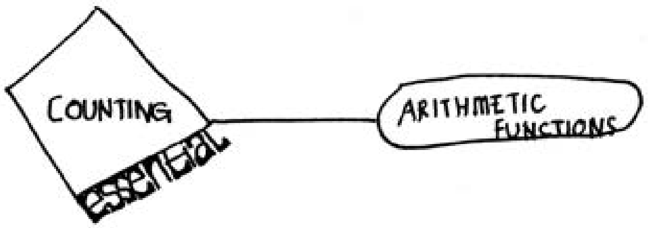



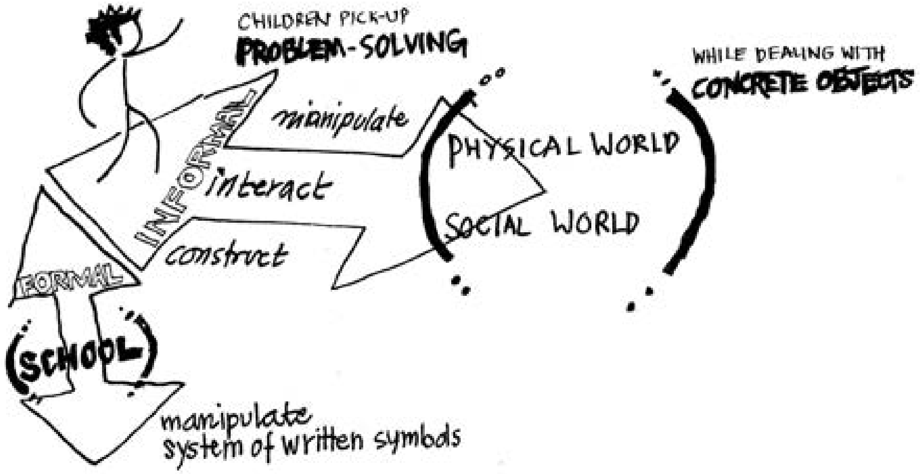




**Number copying task** designed by Piaget(1952) [20, 26]

includes activities like Recalling and Reproducing mentally without the presence of a model.

a) Reconizing that it is necessary to count in order to reproduce the number
b) Counting the objects in the model
c) Counting the objects in the reproduction




## COUNTING:

Considering deaf and hearing pre-school children's ability to represent numbers and to count, children can have much mathematical knowledge without having been exposed to formal school teaching. [28]

Informal knowledge is necessary for children to be successful in learning the formal knowledge transmitted in schools. Ex: problem solving situations with concrete objects; children interacting with the physical and social world.

**School maths** comprises of the manipulation of system of written symbols. [29]

For children to reproduce an array of numbers, they need to recognize that they should count the existing model for the number, create a mental representation of that number for reproducing the same.

Deaf children code information like numbers for short term memory tasks.

Hearing children code the information using language (phonological coding). [30]

Phonological coding helps in identifying **order** of items.
Visual coding helps in identifying the **location** of items.

Deaf children are not inherently poor in number representation, regardless of whether the presentation of the items is spatial or sequential for a 'reproduction of numbers' task. [27]

Visual processing seems to be a strength in deaf children's cognitive abilities. [31] Educators should design instruction keeping the above direction. Remembering large number of items in a sequence to be recalled sequentially is difficult for deaf children compared to their hearing counterparts..

In number system, number labels have rules. In English it exists as zero to nineteen, further using decades with units, further on hundreds with decades and units, so on.

**COUNTING STRING**

1. Oral counting string - serial recall task (more difficult for deaf).
2. Counting in sign - visual recall.

Young deaf children are as good as their hearing counterparts in learning rules. They use rules to remember the numbers. better at answering 'what comes after number x?' and counting backwards compared to their hearing counterparts (when matched for their counting range). [43, 32]

Quantities represented by numbers require the knowledge of counting string. Deaf children show a delay in learning the counting string.

**COUNTING OBJECTS**
Coordinating the counting string with the logic of one-to-one correspondence and indicating the number of objects present.

Hearing children of 4-5 years are able to share discrete quantities equally. They count one of the division set and associate the same quantity to other set having realized 'one-for-you' and 'one-for-one' procedure results in equal size quotas. [33, 34, 44, 35]

Learning rules requires verbal processes that allow for rehearsing the rule internally. [36]

Deaf children need more time and practice for **counting**. Counting system employs use of Reconstructive Memory not reproductive memory.

**Reconstructive memory process**
We remember by generating facts on the basis of rules and not by reproduction from long term memory. [37]

**Logical priciple of commutativity**
The order of numbers in the addition procedure does not affect the result.

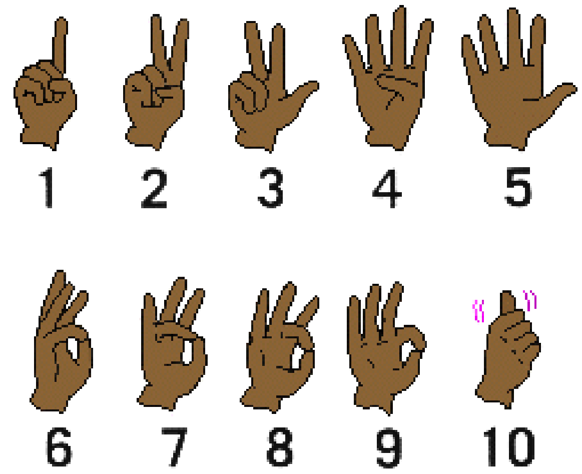



*Image credits <http://www.iidc.indiana.edu/cedir/kidsweb/amachart.html>*

**Opportunity to practice a skill often allows people to develop more efficient ways of getting to the solution.**

With experience young children do invent new ways of using counting to solve problems. [38]

AN ANALOGUE REPRESENTATION OF NUMBERS, Brissiaud, 1992. [45]
When hearing children use their fingers to solve a problem sum, their fingers represent the units to be counted and any three fingers for example can represent the number 3. The fingers can be counted in any order because they are representing each unit and thus the order in which the fingers are added or taken away doesn't matter.

Each finger=1 number, could be any finger.

**Signed Algorithm**
This method is better than verbal recall. 'pad' variable to operate on left hand, the passive hand.

**Activity** (ex: tapping on experience)
Use real scenario that they've heard, seen or come across. Application of knowledge to lead to investigation of rule and then assimilate rule.

**Game** - Means of giving way to assimilate the rule. Games have the ability to tap on motivation. Interesting games like Bingo, board games like monopoly, etc., with number operation tasks.

**Compare current actions and associate rule with context.** For ex. taking away with subtraction.

Creating new **actions based on association**
Example: If Red = 3
5-2 = Which colour?
7-4 = Which colour?

**Failure to carry** example: 18 + 26 = 34
**Taking the smaller from the bigger** example: 23 - 15

Errors for example; counting from 18 to 44 wont manifest orally. they happen in writing tasks. These are reffered to as **Bugs** in research

**Commutativity of addition:**
Needs sufficient training, indication and stressing.
Only most skilful children tend to pick up by themselves.

Young hearing children find it easier to understand the commutativity of addition in combine problems than in change problems.

**Representing number arrays:**
preschool deaf children have more internal knowledge of tasks compared to informal math knowledge tasks of hearing preschool children.
Arrays need to be presented spatially to deaf children

**Reading And Writing Numbers**

Digits 1,2,3 represent quantity/value (do not represent sounds, meaningful as they represent quantity)
Alphabets A, B for words
represents sounds: difficult to learn by deaf children and very difficult for severely / profoundly deaf children as they cant get direct experience of sound.
Reading and writing numbers is difficult for all children, Needs understanding of logic and learning conventions(number labels)

**Additive Composition**
Any number can be formed from addition of two numbers.
Upto number twenty, additive composition in English is not evident.

**SHOP TASK**

Deaf children enter school with less informal knowledge of concept of units than hearing children. They will be at disadvantage when learning about number system in school. Concept of units of different sizes seem to be developed by hearing children informally, often before school.

If the children can code visually that a double unit is made of two singles, they understand it better than telling them these double units correspond to two single units. [39]

Practice in solving problems in situations where the visual coding is facilitated improves the performance of hearing 4 years old. In later task where visual coding is no longer facilitated, this improvement transfers there.

Deaf Children are very good at using visual codes & are likely to learn about units of different sizes if given right type of problem solving experience.

Both hearing and deaf children should have the oppurtunity to learn about units of different sizes before they are given instruction on additive composition. Beacause the ones that understood concept of units performed significantly better on additive composition task.

There is no linguistic facilitation in the children's understanding of additive compostion when seen in the British Sign Language or English oral/total communication. By using a particular gesture while counting, changes the symbolic representation it has to offer into an analogue representation created by the child. Analogue representation helps children understand additive composition.

It might be necessary for teachers to simulate the pupils to use analogue representations when they show difficulty with symbolic representation more than once in the context of additive composition (for ex: 20+1 = twenty one)

For ex. using fingers to represent objects for doing a task involving dealing with a number of objects to be dealt with.

**Micro Genetic Analysis**
A method used by pyschologists in which children are given hints and then observing how they are using those hints in order to complete the task which they have failed earlier. It tests the possible causes or origin (the genesis) of success. If the children use a hint and succeed on the task then it is possible that this hint plays a role in helping the children to understand the concept.

**Hearing children have better knowledge of counting string in comparison with non-hearing peers.**

**Moreno's Experiment (2000)**
Deaf children find it difficult to cope with the demands of a serial recall task where they need to simultaneously make inferences about how the events change the quantity in the problem. [40]

Followed can be noted:
1) knowledge of counting string is not causing difficulty in recalling serial events for deaf children.
2) Design for instruction procedures for deaf children that will support in keeping in mind information in order of events and simultaneously make inferences about how quantities change, may be useful.

Change problems (quantity) comprise of recalling sequence of events. The sequence is specially coded to become easy for deaf children to solve Arithmetic problems on change of quantities.

**Different teaching approaches to solve story problems for deaf**:

Moreno's research results suggest that it is important to focus more, not less, on the structure of mathematical problems when teaching deaf children.

Children should be given opportunity to develop their understanding of problem structure, linguistic competence can then be developed. [41]

## REPRESENTING SEQUENCE OF EVENTS

Deaf children have and refer for working with information by **Spatial Coding Ability**. Supporting Introducing spatial coding techniques to deaf children for solving story problem of following formats:

1) Direct problems
2) Inverse problems
3) Change-Unknown-problems

For this purpose a board game consisting of pictorial sequential frames was introduced for teaching number line. Upon this thought, drawing cartoons along with number line can be helpful. [48]

As analogous representations like drawing help them explore part-whole relations, connections between different forms of numerical representation.
This facilitates discussion amongst themselves, comparing solutions and would significantly affect on their problem solving skills (positive effect).

There is no difference between performance of hearing/deaf children on change problems that do not require inferences(non-computation ones). Deaf children's performance is lower when change problems with increased task demands and the need to make inferences comes into picture.

Deaf children, even at beginning of their school have informal strategies for solving problems and can use them to solve combine problems. Because combine problems do not require sequential recall, as change problems do, the deaf children's good performance is a demonstration that they have sufficient number understanding to succeed when they can cope with the task demands.

While talking about inverse problems for deaf children, the difficulty of combine problems with one set of unknown is similar to that of inverse problems for both hearing and deaf children. Compare problems are tough for hearing children and tougher for for deaf children. Strategies developed for supporting hearing children's need understanding of compare problems can also be effective for deaf children.

### Manipulate materials and Number Line task

Supporting children's learning and mastering of additive composition by means of manipulative materials cut out figures, bricks etc, number lines task.

The task helps to support children learning and mastering of additive composition. Educational fraternity across the world has the assumption that 5-6 year old don't have any knowledge of multiplication and division. But in reality, 5-6 year olds do have some informal knowledge of multiplication and division that could be used as a basis for further learning in school. Educational practice treats multiplication as repeated addition.

**Additive Reasoning** includes children's action of joining, seperating, addition and subtraction are inverse actions. They can cancel each othere's effect out.

**Regression Analysis**
Moreno (2000) [40], found from the results of research that it is important to ensure that deaf children who may start school without having acquired this informal knowledge, have the oppurtunity to learn about additive composition quite early in their school life.

**Transitive Inference**
A = 2B
C = 2B
Than A=C
Piaget [20] showed with an experiment that 5-6 years old showed transitive inference and did the task as designed satisfying the goal of the experiment. The gap between hearing and deaf children doesnt seem to be wide in the age group of 6-7 years in solving problems with commutativity by correspondence (having had no instruction of multiplication).

Children without having instruction on reading and writing numbers tend to use digits in the numbers they write. They exhibit additive composition when they write 10005008 for "1508". 1508 contains five words hence one to one correspondence between words and digits doesnt get pulled into the scenario. Children use a logical system to support their number writing.

Lexical errors like the following can be seen (using wrong digit in Reading/Writing)
For ex: 6 in place of 7

Syntactic error– representing the place value inappropriately
For ex: writing 148 as 1048
signing 108 as 1,0,0,8

**Multiplicative Reasoning**

Multiplicative Reasoning includes children actions of **placing in one to many** correspondence. It is based on the fact that there is a fixed ratio between two quantities (or variables).

Multiplication problems have atleast two variables.
For ex: Number of boxes, number of eggs per box.

Piaget 1952 [20], suggested that the origin of children's understanding of multiplicative reasoning is their understanding of correspondences.

The connection between the ideas of ratio and correspondence is quite easy to see. The ratio 1 to 6 can be expanded as each box corresponds to 6 eggs. Ratio is an abstract idea. Corresponding process can be acted out, hence can be learnt by children informally.

Division Problems have three variables/quantities
- The number of objects to be shared
- The number of recipients
- The number of objects received by each one.

**Division and multiplication**
Work on the idea of fixed ratio between two variables.

Youngs children of 5 years can divide sets int equal parts by sharing, using a one for you and one for me distribution.

If divisor is kept constant and divident increases, factor increases( Direct Relation).
If dividend remains same divisor is increased, lesser becomes the quotient.

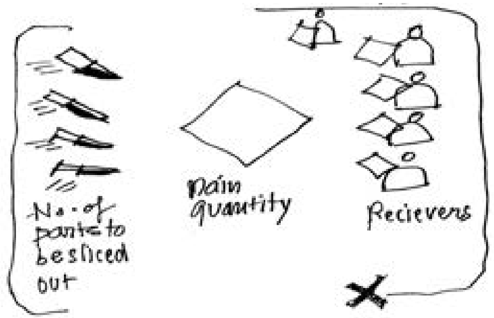
Although children have informal knowledge of multiplication and division, they find it easier to think about relations between variables in multiplication than in division.

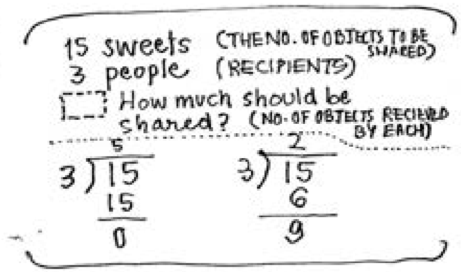
**Partitive Division**: Identifying (dividents, divisor given)
**Quotitive Division**: Identifying divisor( quotient, divident given)

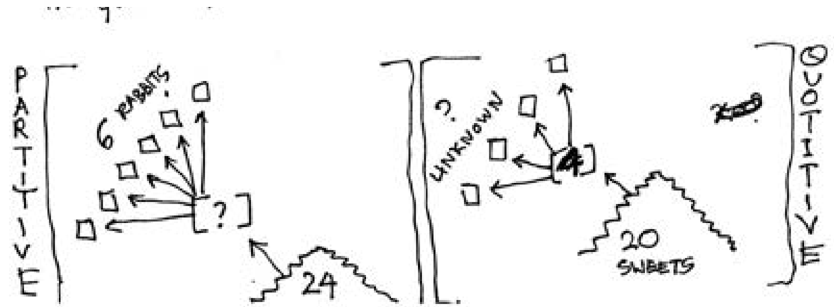
Childrens level of success seen more with problems of direct relation compared to increase for both hearing and deaf children.

Quotitive Division Tested with deaf [42]

Deaf childrens informal reasoning about division situations particularly identifying how many people will the sweets be shared when number of sweets present and share of sweets to each person is fixed, is very weak compared to hearing childrn in quotitive problems



**Scope of Design Intervention:**

1. Providing help/intervention by spatial design for supporting additive composition assimilation by deaf children in earlier years of school life.

Currently in schools, Unifix Blocks/Bricks are used to help children understand additive compostion. But children continue to perform poorly in money/shop task. As money is symbolic representation and Unifix bricks do the job of analogous represntation, the transfer of learning doesn't cross over.

2. **Creating opportunity for deaf children to explore concept of units, additive composition in the domain of money in situations like the shop task, in an effort to bring in a positive impact on their later learning.**

(Austin 1975, studied and showed that deaf children are behind hearing children in their understanding of money concepts).

**3. Attempt to use Architecture to promote a genuine understanding of underlying mathematical concept and enable to truly grasp the reason employed in a school for the deaf children.**

Problems childrens have in learning geometrical ideas is rooted in their conceptualizations of the spatial world. [13]

“External factor” cause most of conceptual difficulties- Clements 1984

**Geometry:**

is the study of space, a set of points with lines and planes as important subsets.
Also can be called the "Mathematics of space"

Language becomes a hurdle if teacher employs language of higher level (Van Heili's model) than is understood by student.

# Van Heili's Levels of Geometric Reasoning

A husband-and-wife team of Dutch educators, Pierre van Hiele and Dina van Hiele-Geldof, noticed the difficulties that their students had in learning geometry. These observations led them to develop a theory involving levels of thinking in geometry that students pass through as they progress from merely recognizing a figure to bei ng able to write a formal geometric proof. Their theory explains why many students encounter difficulties in their geometry course, especially with formal proofs. The van Hieles believed that writing proofs requires thinking at a comparatively high level, and that many students need to have more experiences in thinking at lower levels before learning formal geometric concepts.

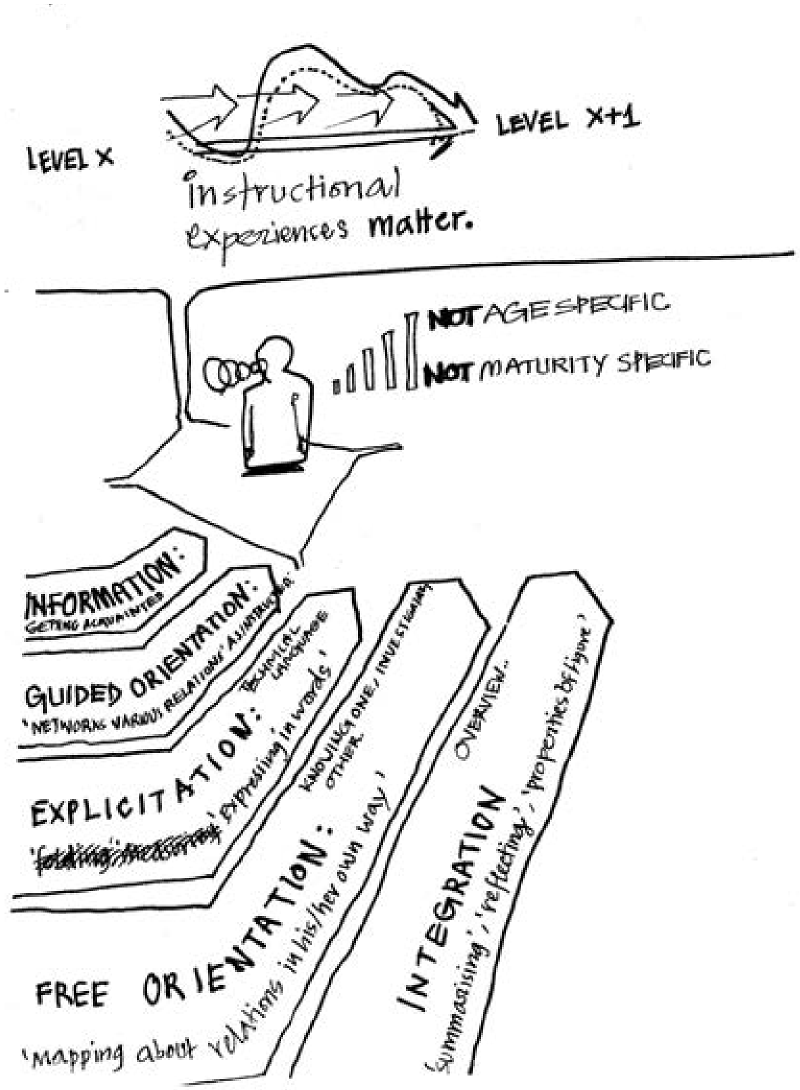
He describes that Geometry taught in elementary school has to be informal and is not age dependent. The levels he describes are of Sequential Processing; dependent on educational experiences; "Geometric experiences" to influence advancement of a child through the various levels of geometric reasoning.

**Van Heili's phases of learning**

a) **Information:** Orienting new topic to student by identification of what's known already.

b) **Guided orientation:** Exploring of subject by carefully structured task (ex. folding, measuring, constructing)

c) **Explicitation:** Students describing what they have learnt about the topic



d) **Free orientation tasks:** Student apply the relationships they are learning to solve problems, investigate open ended tasks

e) **Integration:** summarising and integrating what they have learnt.

## LEVELS OF GEOMETRIC REASONING

**Level 1- Visualisation**
Recognising figures by appearences, comparing to a known prototype. (No reasoning and properties perceived)

- **"Recognising shape by appearance"**
- Sorting, Identifying and description
- Manipulating physical models
- Same Shape; Seeing different sizes, different Orientations of same shape
- Distinguish Characteristics
- Building, drawing, making, putting together taking apart shapes.

**Level 2 - Analysis**
Collection of properties are perceived in figures recognitions, naming , may not discern which properties are sufficient to describe the object.

- **"Working with concrete or virtual models"**
- Define , measure, observe, change properties
- Using models to dfine properties, making property lists, discussing sufficient conditions to define a shape.
- Classfying using properties of shape.

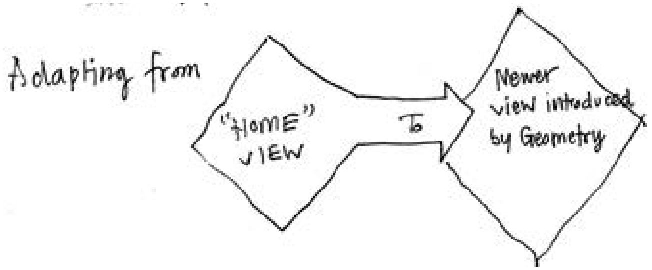
**Level 3 - Informal Deduction**
- **" Recognising relationships between and among properties of shapes/classes of shapes"**

- "Following logical arguments using such properties"
- Problem solving of properties of shapes
- Discussing which properties of shapes are important constituents for a specific one
- Informal deductive language
- {If, then, all, some, none, what if...}
- Generalising from models , drawings & counter examples.
- Making & Testing hypothesis

Perception of relationships between properties, meaningful definitions, informals arguments to justify their reasoning. By end of 8th grade, level 3 should be achived. ex: square=rectangle (logical implications, class inclusion)

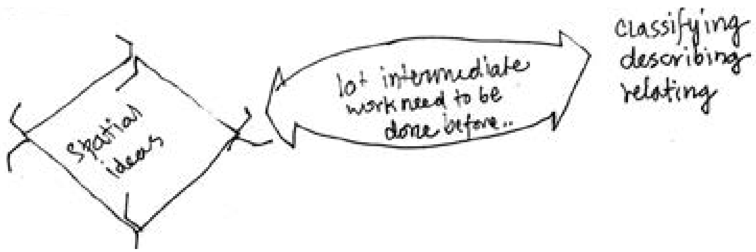
**Level 4 - Dedcution** (High School Geometry Level)
Going beyond identifying characteristics of shapes and constructing proofs using postulates/axioms and definition. Construction of proofs, understanding of role of axioms, definitions and knowledge of sufficient/necessary conditions.

**Level 5 - Rigor** (College Level Course In Geometry)
Knowledge of formal aspects of deductions, use of indirect proofs, proof by contrapositive, non euclidean systems.




Internalising and capturing intellctually a child's spatial experiences

While talking about spatial experiences or representating spatial phenomena, growing up in an environment where he/she was encouraged in painting, making models, drawing, imagining, visualising and reflecting on spatial experiences can be really helpful.




**Removing Obstacles**

1) Working on to improve understanding of spatial world.

- **Form** (how spatial ideas are represented)
- **Content** (what is being representated)

which typically include Static, dynamic, look of a shape, similarity, concept of shape and represenatation of shape is essential for removing obstacles in geometry learning.

Concept of general shape, distinction, circular, flat, oblongness, regularness, roundness, sharpness, standard shape, feel of a shape, curvature, turning, short, long, circularity, rolling, size, scale, larger, smaller. transformation should be looked at being introduced first before naming a shape/form.

For example, by use of cutout shapes, labelling them tends to leave only one reprentation attached to the label . It creates restricted notion of what is important in a geometric form, a narrow view of represntation and brings into picture the confusion of form with content. Children ought to be made to represent and not only identify/interpret.

Introducing language like nouns (squares,circle,triangle) sooner than introduction of geometrical adjectives like circular,flat rectangular can be avoided in too early stage.

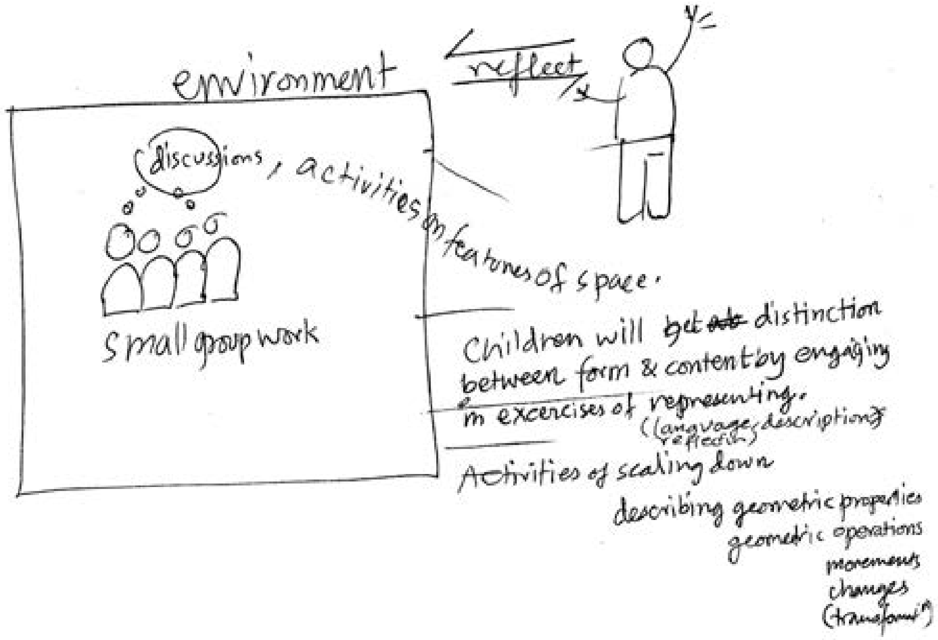
Use of **language** by teacher like:
- North is up
- We drop a perpendicular
- Board is vertical
- Geometric shapes have bases and heights
- Y axis is vertical can be avoided

For children who are just getting introduced to spatial phenomena the geometric learning can be full of activities with containers of different shapes, tiling patterns, tessellations, paper folding, model building, sketching and mapping.

**The proposed activities should emphasize on Geometric features so that the geometry learning can take an objective form.**

**Bridging disconnectedness**

We should develop ideas from the children geometric and spatial roots to avoid problems caused in higher classes of study and application.
For ex: ratio and proportion




**Examples of initial geometric learning**

Making objects itself from drawings in plastics and clay

Constructing figures using pencil, ruler, curves from verbal descriptions

Describe and ask some who's not seeing the object to pickout from a collection

Proving is a mathematically refined ways of arguing- Bell 1979

Children face difficulty in transformational geometry, rotation , mirroring ( actual representations are used)

Emphasis on ration and proportion in geometrical figures(similar ones) can be given a solid base with both visually and in imagination the ideas of enlargement and similarity.

Teaching Vectors and coordinate geometry need not be taught using algebraic terms. In place, Map , city grids layout of chairs in classroom, etc. can be made use

Fitting of 3D space in a 2D form can be tricky situation in teaching. Models, experiments, animation can be made use to compensate and bridge the two scenarios.

# 3.0 STATE BOARD OF EDUCATION GEOMETRY SYLLABUS

Topics covered under for Geometry Curriculum of Maharashtra State Board Schools include books provided by Maharashtra State Bureau of Textbook Production & Curriculum Research, Pune have been collated.

**FIRST STANDARD**

They are able to identify shapes - square, rectangle, triangle and circle.

**SECOND STANDARD**

Introducing the line, vertical line, horizontal line and slanting line.
Introducing triangle, rectangle, square, circle.
Introducing geometric shapes – cylinder, cuboid, sphere, cone
Introducing surface top bottom
Measuring length of objects by hands, feet, pencil, ruler, stick (palm hand span)
Measuring capacity of objects using pitchers of water, bottles of water glasses of water, pots of water.

**THIRD STANDARD**

Objective:
Identifying figures – triangle, square, rectangle, circle giving example from common objects.
Living conversion relationships between different units of a quantity:
Length
Mass
Capacity

GEOMETRIC SHAPES & FIGURES
Rectangle, square, triangle, making figures with objects, naming a figure, introducing the measure scale
Introducing the metre scale

**FOURTH STANDARD**

Objective:
To name the parts of some geometric figures
To find perimeter of triangle, square, rectangle
To identify symmetrical and asymmetrical figures
To give the proper units for measuring length, mass and capacity

GEOMETRIC FIGURES AND SHAPES
Sides and vertices of rectangle, square, triangle

SYMMETRICAL AND ASYMMETRICAL FIGURES

MEASUREMENT: Length, mess, capacity
Units of length – km, hectometre, mm, dm. Conversion between mm – cm, m – cm, m – km
Mass – kg, hg, dg, cg, mg. Conversion between g – kg
Capacity – kl, hl, dl, l, etc. Conversion between l – ml
THE CIRCLE
Centre, radius, diameter, chord, circumference

**FIFTH STANDARD**

GEOMETRY BASIC CONCEPTS
Point, line, line segment, ray, intersecting and non-intersecting lines

ANGLE AND TRIANGLE
Elements of an angle, angles in various geometrical figures

SEGMENT: MEASUREMENT AND CONSTRUCTION:
Ruler to measure the length of a given segments, use of divider to draw a segment of a given length.

PROPERTIES OF RECTANGLES AND SQUARES:
Elements of a rectangle
Properties of a rectangle
Elements of a square
Properties of a square

CIRCLE
To draw a circle of given radius using compass. The relation between radius and diameter of the circle. To verify the relationship between radius and diameter by paper folding method.

PERIMETER
Perimeter of a rectangle formula, perimeter of a square formula

AREA
Region and area of a geometrical figure, unit of area, graph paper. Area of an irregular figure, area of rectangle, area of a square.

**SIXTH STANDARD**

POINT LINE PLANE
Point, line, line segment, ray, length of segment, lines throw a point, two points, collinear points, non collinear points
Plane, parallel lines, intersection, concurrent lines

ANGLE
Measure of an angle, interior of an angle, exterior of an angle
Complementary angles (adding to 90 degree)
Supplementary angles (adding to 180 degree)
Adjacent angles, angles in a linear pair (suppl)
Vertically opposite angles, transversal (cutting at two different points, makes 8 angles)
Corresponding angles, alternate angles
Interior angles, corresponding angles

TRIANGLES, TYPES of TRIANGLES
Elements of triangle, interior and exterior of a triangle

Triangular area, exterior angle of a triangle, types of triangles acute angled, right handed, obtuse, equilateral, isosceles, scalene properties of triangle, properties of exterior angle of triangle

GEOMETRIC CONSTRUCTIONS:
Perpendicular lines, bisector, perpendicular bisector
Bisecting an angle, equal angles, parallel lines

AREA
VOLUME

Standard unit of volume, formula of volume, volume of cuboid

CIRCLE:
Arc of a circle, chord of a circle, interior, exterior of circle

**SEVENTH STANDARD**

PROPERTIES OF TRIANGLE:
Altitude or height of a triangle, congrvency of altitudes, perpendicular bisector of sides of a triangle, median, angle bisectors

CONSTRUCTION OF TRIANGLES:
Construction

QUADRLATERALS
Opposite vertices, sides, angles of a quadrilateral
Adjacent vertices, sides, angles of quadrilateral, diagonals
Interior and exterior of a quadrilateral, sum of angles
Addition of two triangles

What will be tested in examination in the topic?
Equations involving triangles, quadrilaterals. Solve using properties.

Congruence:
Congruence of line segments, angles, angles, triangles, quadrilaterals, circles.
Types of quadrilaterals
Square, properties, diagonals
Rectangle, properties, diagonals
Rhombus, properties, diagonals
Parallelogram, properties, diagonals
Trapezium, properties, diagonals

AREA
Area of rectangle

VOLUME AND SURFACE AREA
Volume of cube, total surface area, volume of a cuboid
Volume of log of wooden plank

CIRCLE
Segment of a circle, semicircle, regions
Angles in same segment, angles in semicircular region
Angles in major and minor segment

CONSTRUCTION OF QAUDRILATERALS:
Construction of square, rectangle

OBJECTIVES:
To understand meaning of congruence with respect to line segment angle and triangle
To express and read statements of congruence
Explain Pythagoras theorem. Use explanation to identify a right angled triangle
Identify altitude, perpendicular bisector of sides, mean, angle bisector of a triangle
Identify types of quadrilaterals
Arc of a circle, an angle in semicircle angles in segment, properties of angles in segments

Identify cubes, cuboids, tell differences between them
Use formula to find volume of them when their sides are given
Expressing volume in proper units
Identifying differences between flat and curved surfaces
Explain meaning of surface area, use formula and calculate for cubes and cuboid

## PROBLEMS NOTICED IN SSE GEOMETRY TEXT BOOK/ CURRICULUM

logic and math are very practical tools that simply extend our common sense for the most part to make life easier and more successful.

Our school curricula goes in a direction of providing disconnected "recipes" of logical techniques. Language used in book is difficult for children. The information intended for communication is not appropriately captured/ represented in the sentences used. The information needs to be conveyed as pictorially as possible. the intention of teaching a topic (say maths) through a set paragraphs of text accompanied by a picture or two is not an ideal way of communicating to the children because the language used in the books mentioned above contain sentences with supporting words which may not be familiar to Indian students and can be done a way with by paraphrasing most of them.

An example:
In mathematics text book part 2 of Maharashtra state bureau of textbook production and curriculum research, Pune (MSB of TP & CR)

Chapter – measurement: length, mass, capacity
An excerpt
"When length is measured using devices like tape measure or scale, we get the same figure no matter who measures it"

Can be paraphrased as:-

"No matter who measures it, the measurement will be same when using a measuring tape or scale"
Rest of above used words in the excerpt and not in the suggestion need not appear. They are adding to the abstractness of a sentences and don't play a positive part in communication

In geometry class of 2nd standard, MSB of TP and CR, Pune:
For teaching concept of measuring scales

Give them an edge of paper printed with mm markings. Ask them to peel it off. Similarly give them another strip with markings of cm (not giving mixed scale in the beginning, letting them figure out that they are inter-convertible).

Ask them to measure objects with these two scales:
1. Millimetre
2. Centimetre

A third scale of a meter (has mixed markings) is distributed by teacher to all the children.
First exercise is with 1 and 2 once they are comfortable. Ask them to compare each of them. Once at least a few of the children stumble upon and let out the answer, encourage and show to all of them that millimetre scale and centimetre scale is inter-convertible.

| 1 cm | = | 10 mm |
|---|---|---|
| marking distance | | marking distance |

Then introduce the metre scale and create/ let them discover the connection between cm, mm and m
Teach / show them labelling of centimetre, millimetre, meter and their symbols show or scales present these symbols
Tell them anyone can make a scale. Scale allows you to measure your world. Any object in the world including your house, car, vehicles, road, etc.

Maths, standard five – chapter 12
Topic: angles indifferent geometrical figures

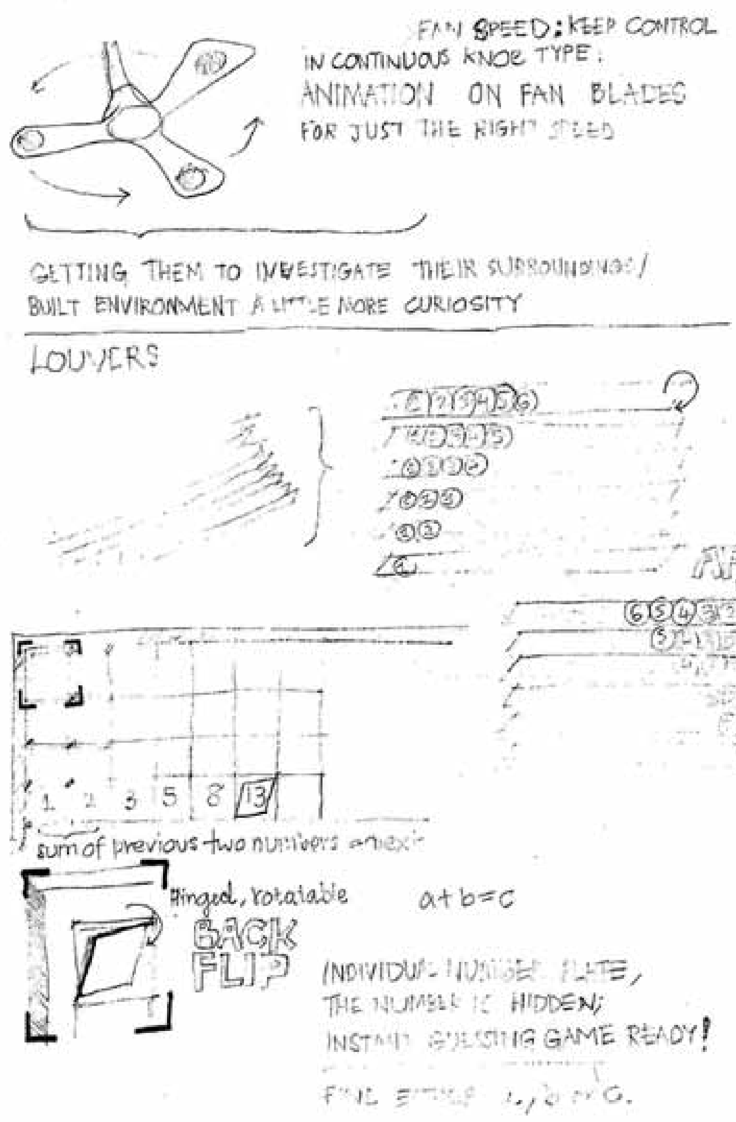
The above word different does fit well into the context. In  place of it the word various could be employed or the word itself could be dropped. It is not semantically valuable in the context.

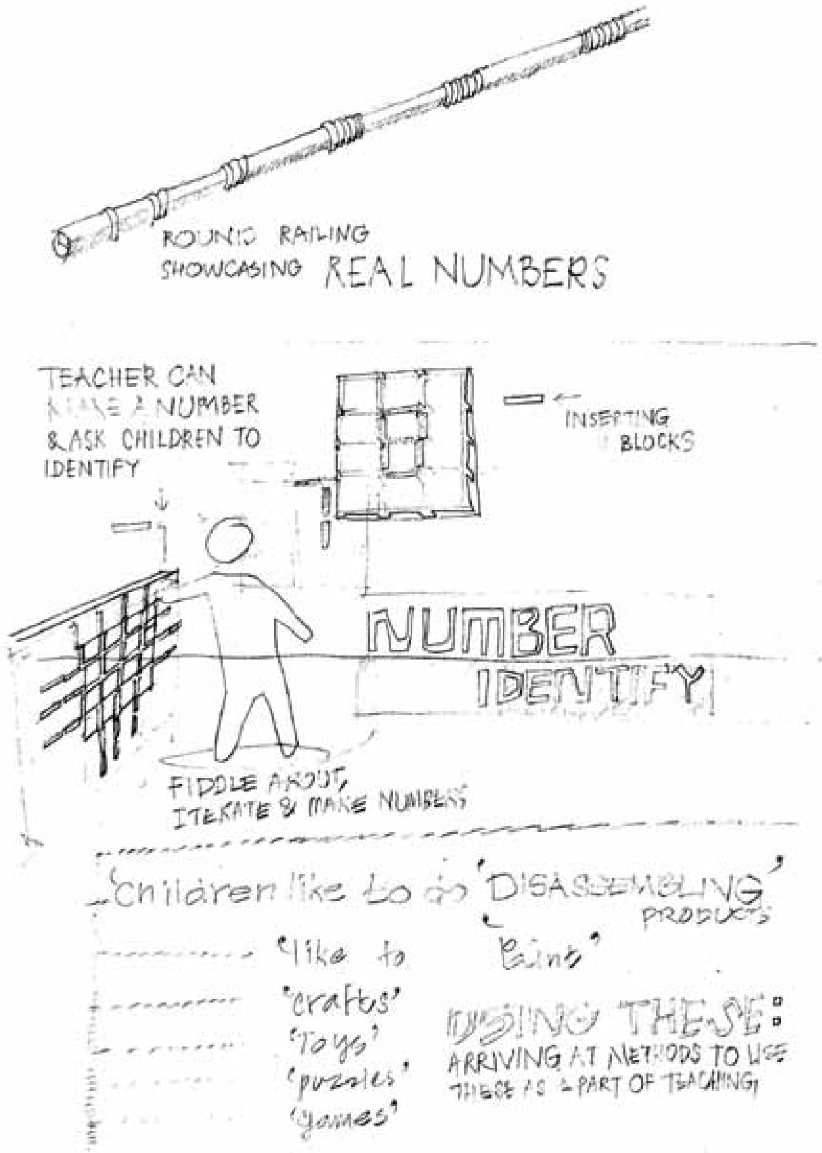
Maths, standard 5 – chapter 21:
Topic area of an irregular figure
Under activity, third bullet

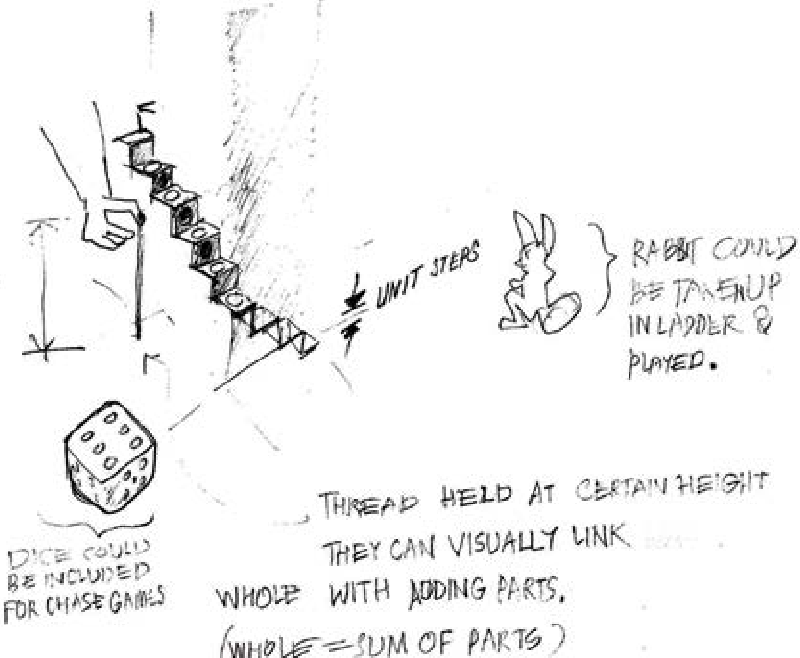
They are of given figure is equal to the sum of the number of complete squares and half the number of incomplete squares.
This is a serious misunderstood concept by book writers, editors of MSB of TP & CR

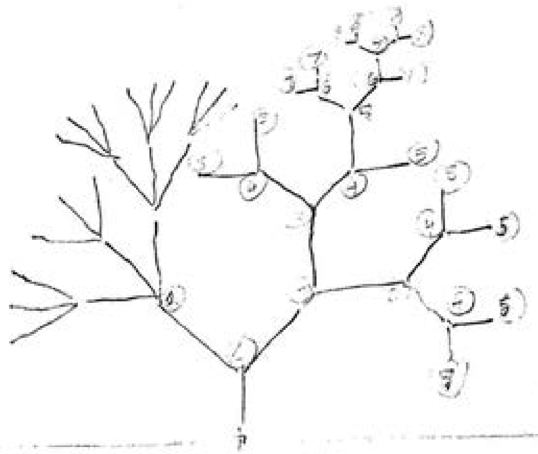
Even for adults this is a perturbing concept!
Nothing close to truth should be taught in text books to the children. All facts have to be true and no approximation can be considered when me are introducing topic in subject that are funded on logic and science like mathematics, more specifically geometry.

# 4.0 EXPLORATIONS


FAN SPEED: KEEP CONTROL
IN CONTINUOUS KNOB TYPE:
ANIMATION ON FAN BLADES
FOR JUST THE RIGHT SPEED
GETTING THEM TO INVESTIGATE THEIR SURROUNDINGS/
BUILT ENVIRONMENT A LITTLE MORE CURIOSITY
LOUVERS
AFTER FLIP
1 2 3 5 8 13
sum of previous two numbers
Hinged, rotatable
a+b=c
BACK FLIP
INDIVIDUAL NUMBER PLATE,
THE NUMBER IS HIDDEN;
INSTANT GUESSING GAME READY!


ROUND RAILING
SHOWCASING REAL NUMBERS
TEACHER CAN
MAKE A NUMBER
& ASK CHILDREN TO
IDENTIFY
INSERTING
BLOCKS
NUMBER
IDENTIFY
FIDDLE ABOUT,
ITERATE & MAKE NUMBERS
Children like to do 'DISASSEMBLING'
PRODUCTS
'like to
'crafts'
'Toys'
'puzzles'
'games'
USING THESE:
ARRIVING AT METHODS TO USE
THESE AS A PART OF TEACHING

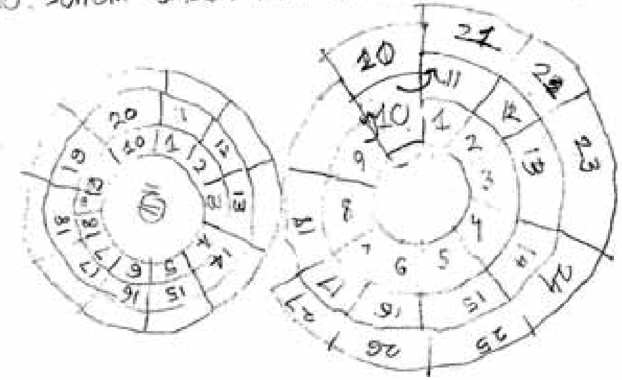


EXISTING TEACHING METHODS ARE DIFFICULT FOR TEACHERS TO USE ON CHILDREN WITH HEARING PROBLEM.

PHYSICAL ELEMENTS : / GAME / PLAY ACTIVITY

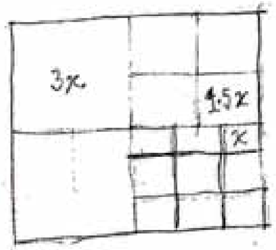
TO : SUPPORT CHILD'S MATHEMATICS ACQUISITION.



| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 18 | 20 |

$$(a-1)+(a+1)=2a$$

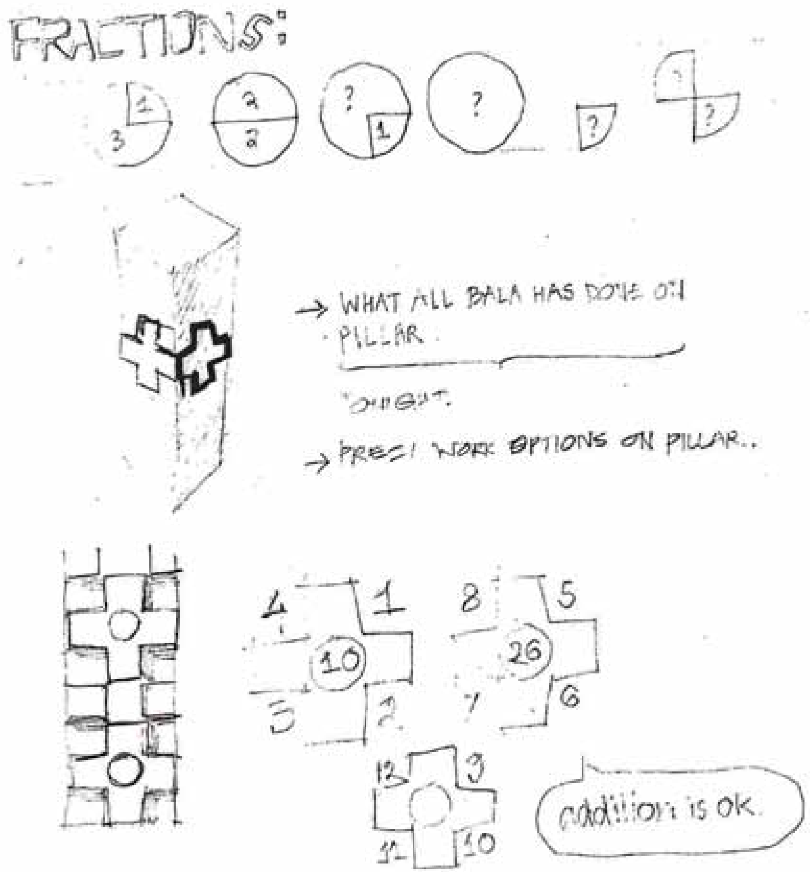
VALUE OF ZERO

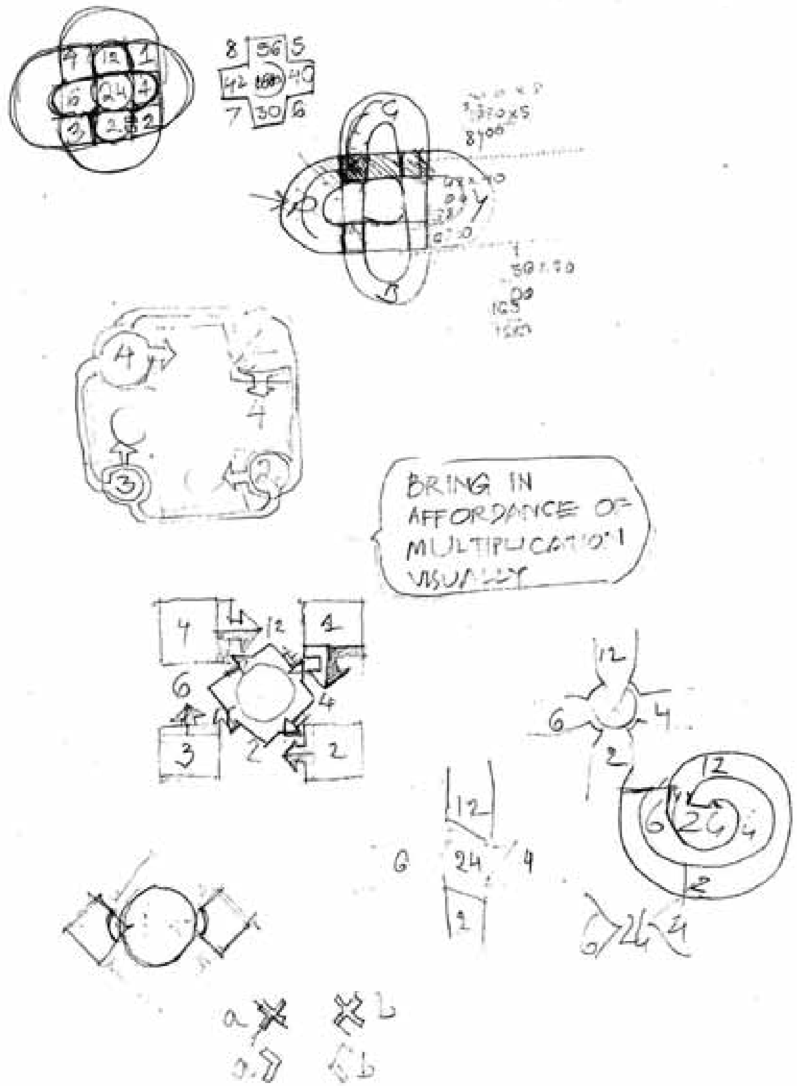


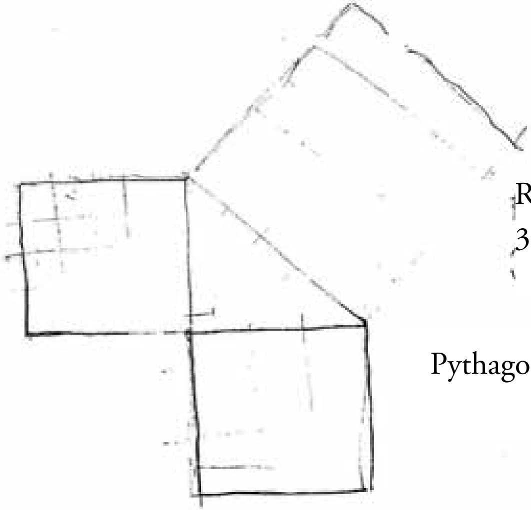

$3x = 2y$

$y = \frac{3x}{2}$

$(3x)^2 = 9x^2$

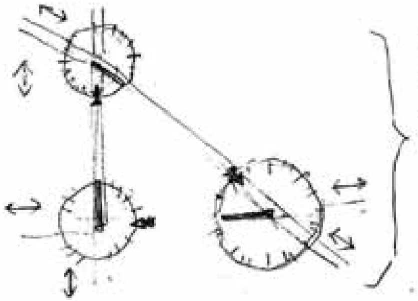

FRACTIONS:
WHAT ALL BALA HAS DONE ON PILLAR
PRESENT WORK OPTIONS ON PILLAR..
addition is ok.


BRING IN AFFORDANCE OF MULTIPLICATION VISUALLY



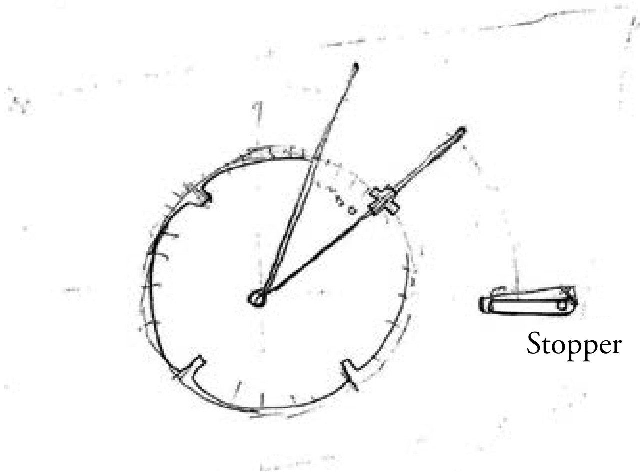
Right-angled triangled
$3^2+4^2=5^2$

Pythagoras theorem



A device to measure angles of triangle

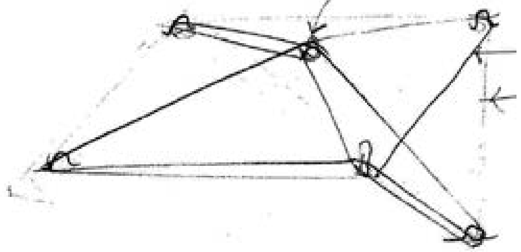
Shows reading



Stopper

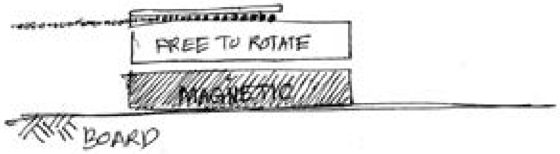
Angle Watch

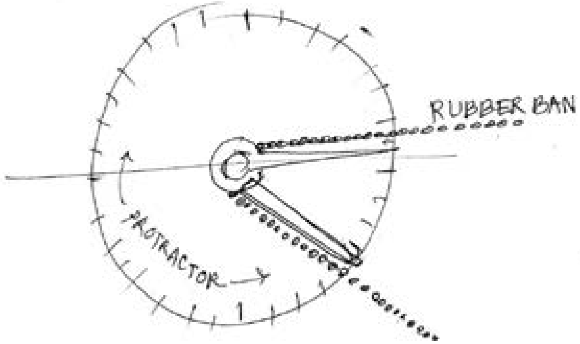
Metallic Pawn

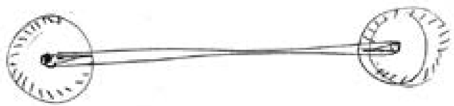


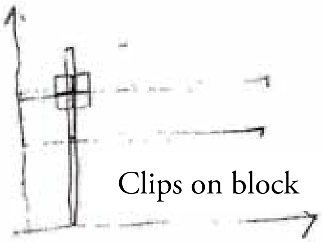
Coloured thick thread
Magnetic base

Show different geometric shapes by a board with pins/knob by tying thread appropriately. Possibility of adding vertices.



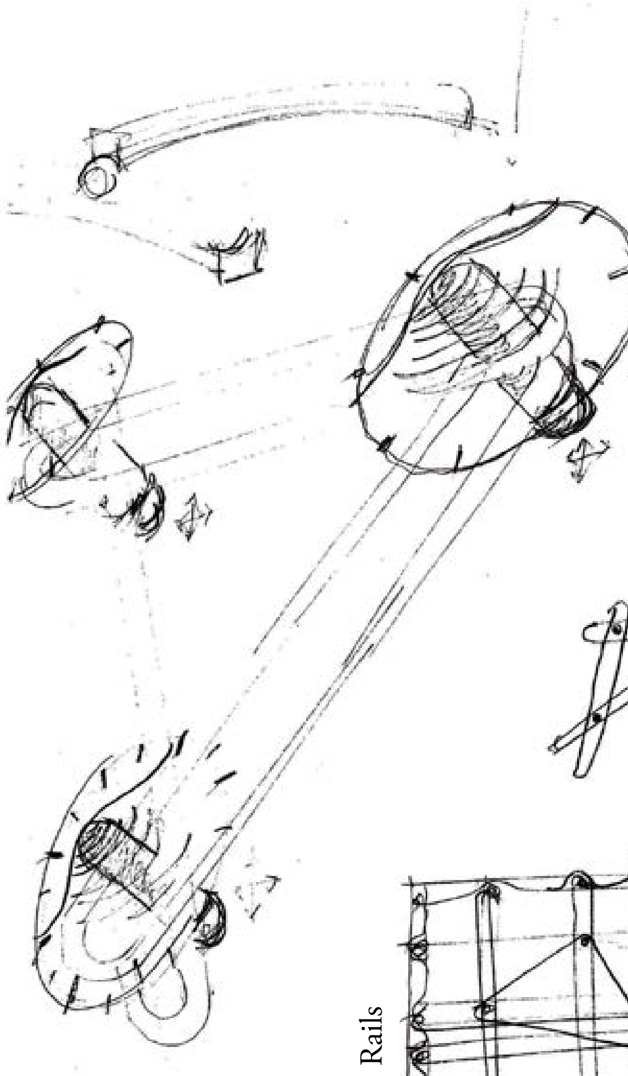



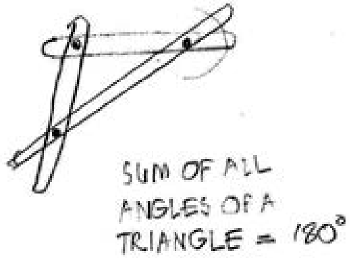


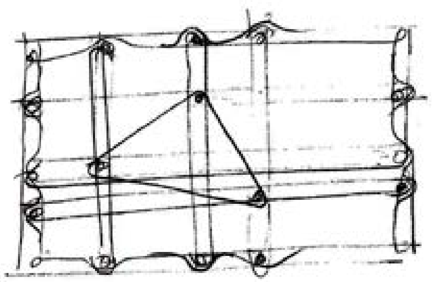
Clips on block

Number balance



Protractor pivoted



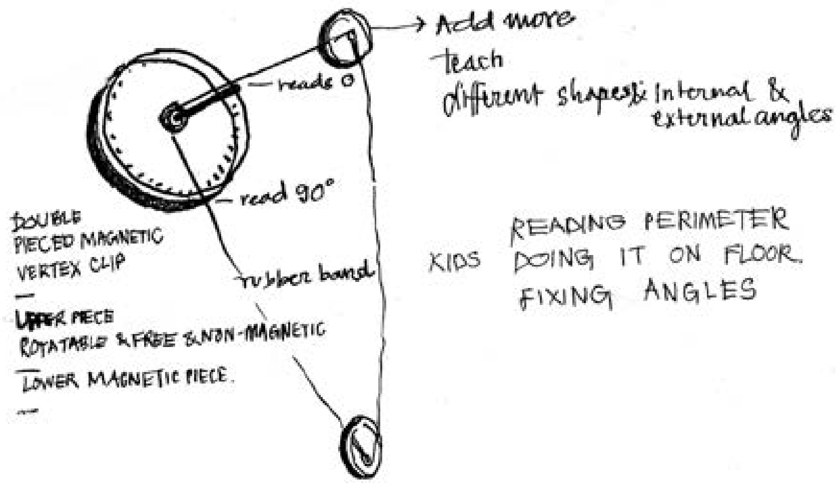
Rails

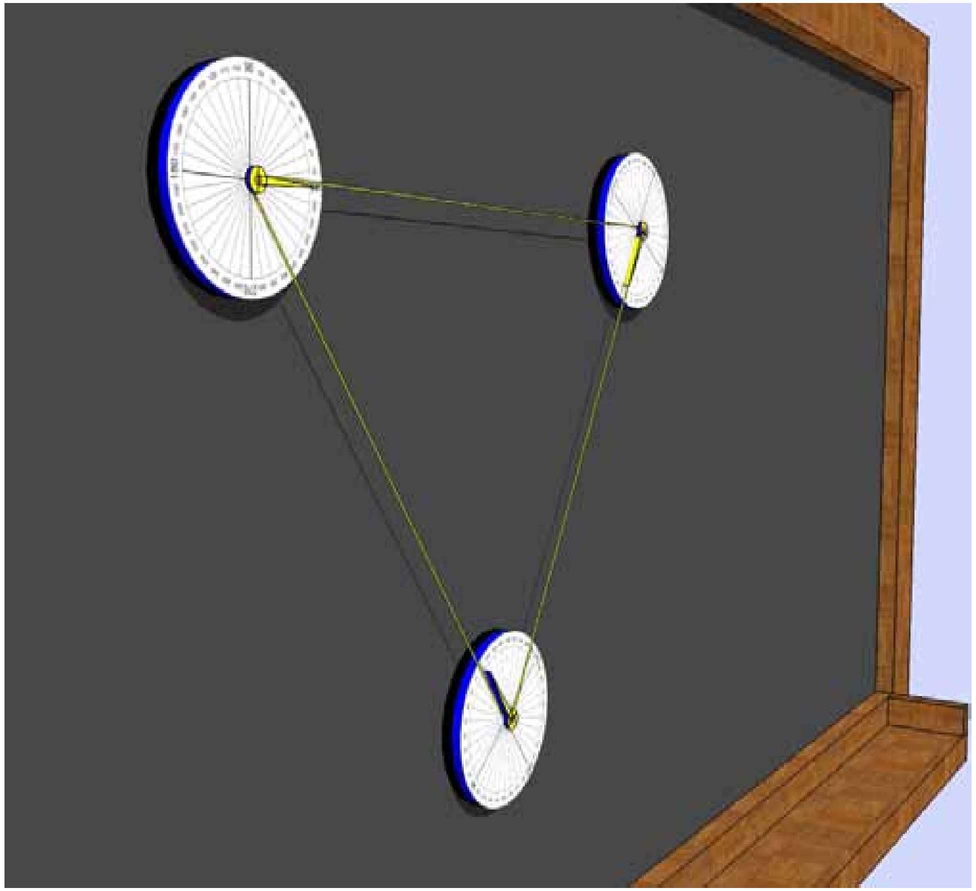
Flexible triangle

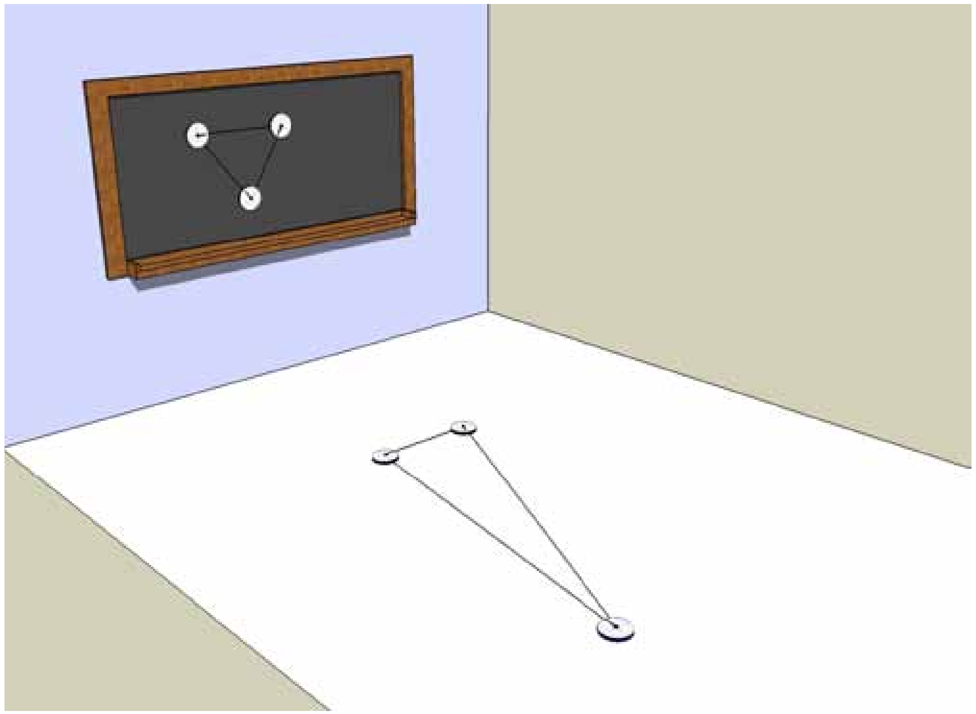
# Angle Study

A dynamic protractor fitted with a magnet can multiply itself to become an angles teaching tool. Such protractors modules acting as vertices could be linked together by a relatively big and tough rubber band which would serve as the sides of the figure.

Figures like line segments, triangles, quadrilaterals and other polygons could be constructed. The set up holds for us angle readings at vertex pieces created by the rubber band. Children can use such a set up on the floor, engage in learning by doing.



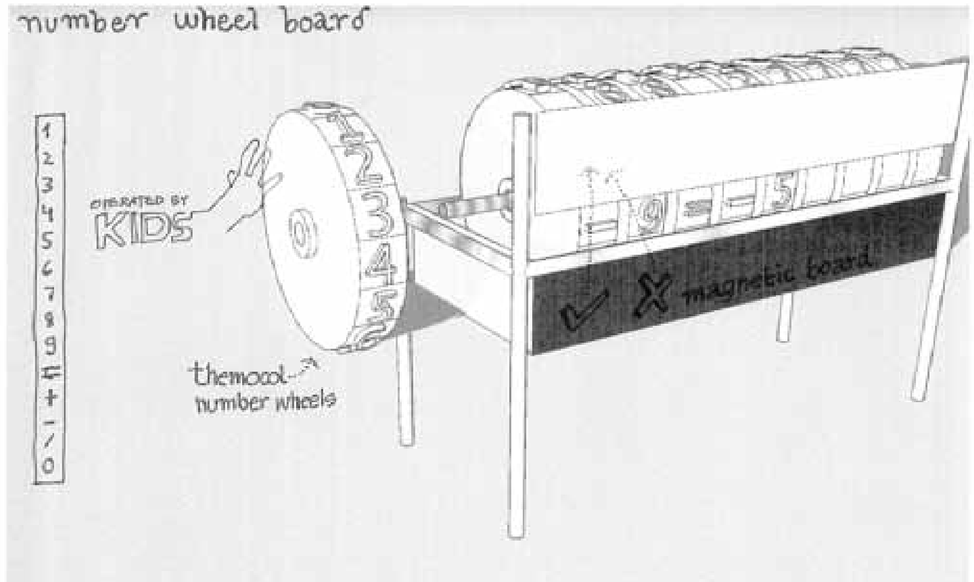



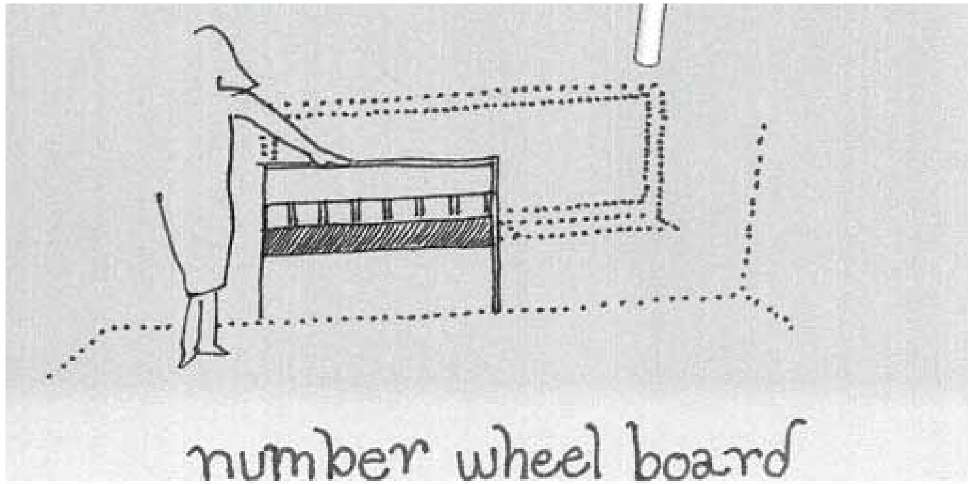


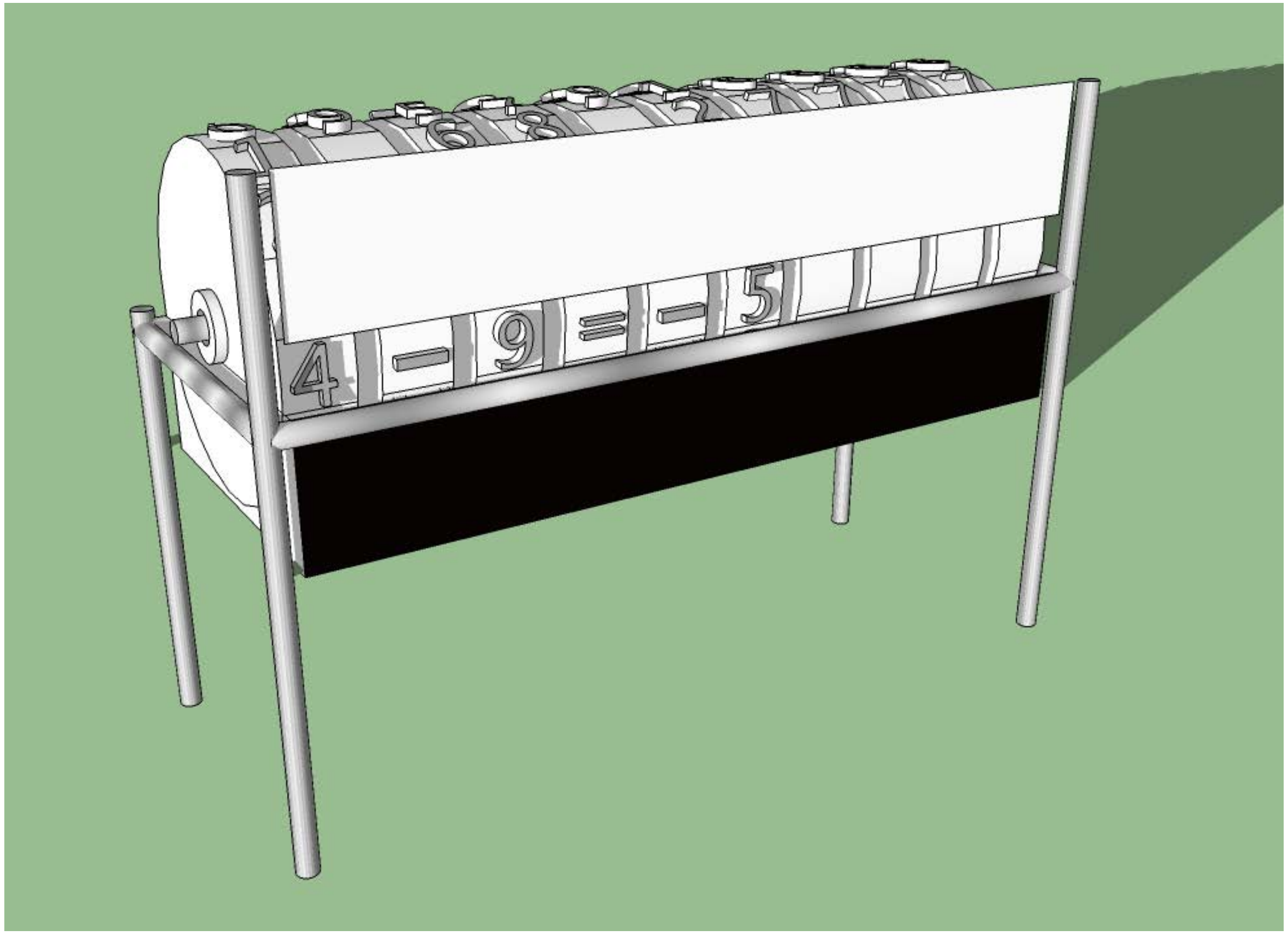
# Number Wheel Board:

Working with quantities on a platform based on movement rather than being static like a blackboard or books is explored in the number board. Our brains are more tuned to moving than static media. The number board is a dynamic manipulable set-up made for the teacher and children for maths classroom. It tries to capture the essence of "holding, turning, building recognition, recalling , finding" and being big enough, allows display of problems & solutions.

- Number board brings context of number line (starts with zero, move on to 10).
- Can teach a variety of first and second standard math exercises.
- Let children do (eg. move numbers and figure out by themselves how many times 3 is 27?)
- Showcase place values. A simple hook in each of the wheels can rotate the adjacent upon moving beyond 9.
- As per lesson requirement, number wheel set can be changed. (e.g. in beginning only 1-9 wheels can be used.)
- Wheel could be changed and side view could be used to teach time.
- It is still symbolic, pointing back to textbooks; why not use dots, colours? Could be played like jackpot, rotate all and leave. Whatever arrives, carry out set of operations.
- Asking questions like "What comes before?", " What comes after?"
- 1+1, 1+2, 1+3
- Using magnetic carry over numbers, magnetic right & wrong symbols
- Teacher writes problem on board. She goes to NUMBER BOARD and expresses the two quantities by counting each down from zero.
- Teacher lets children participate in finding answer by inviting them to the number board to turn the wheels to the right answer.
- A kit given to schools get thermocol cut in designated shape, get plastic cut in shape, fasten nuts & bolts, print doc file and cut and paste stickers, arrange for a rod of that size. Each wheel has 16 display slots
- Negative numbers can be introduced.






## Conclusion

These explorations were seen evolving more towards teaching aids than of architectural installations. They did not fit into the context of making permanent learning material available at all times to children in the school environment. Hence, they have been put on the hold and more relevant solutions have been given a look.

# 5.0 THE PROPOSAL

**Design Intervention**

Identifying building parts that could be considered for creating learning material present at all times for children.

# KDN Shruthi School for the deaf, Juhu

Shruthi school has been studied and solutions for learning material to be incorporate in the building and environment are suggested for teaching geometrical concepts. The solutions range from modification in building structure, additions to building elements like windows, flooring, paintings on pillars, etc to installations on building portions that can be employed to draw attention of anyone passing by.

Upon talking with teachers of Shruthi School regarding the topics that they find their students find difficult to assimilate, the following were mentioned:

- Addition and subtraction in the first hundred numbers
- Fractions
- Algebra: x means what?
- Borrowing in 16 - 9, 26 - 4
- Geometry: Understanding Area, Perimeter
- Mensuration: mm to cm conversion
- Splitting and adding or use of direct formula in multiplication of squares.
- Prime Numbers
- 60 degree, 120 degree (Identification)

These gave a starting point for my earlier explorations for including in the premises.

Having opportunity of sitting in one of the Mathematics classes for Fifth grade, I was exposed to the topic/class of "MIXED SUBTRACTION"

They were given a problem and were asked to do it upfront on the board in place of their book for the class. The problem is shown in the following along with the solution a child (who was invited) provided;

$$\begin{array}{r} 43 \\ -\ 26 \\ \hline 23 \\ \hline \end{array}$$

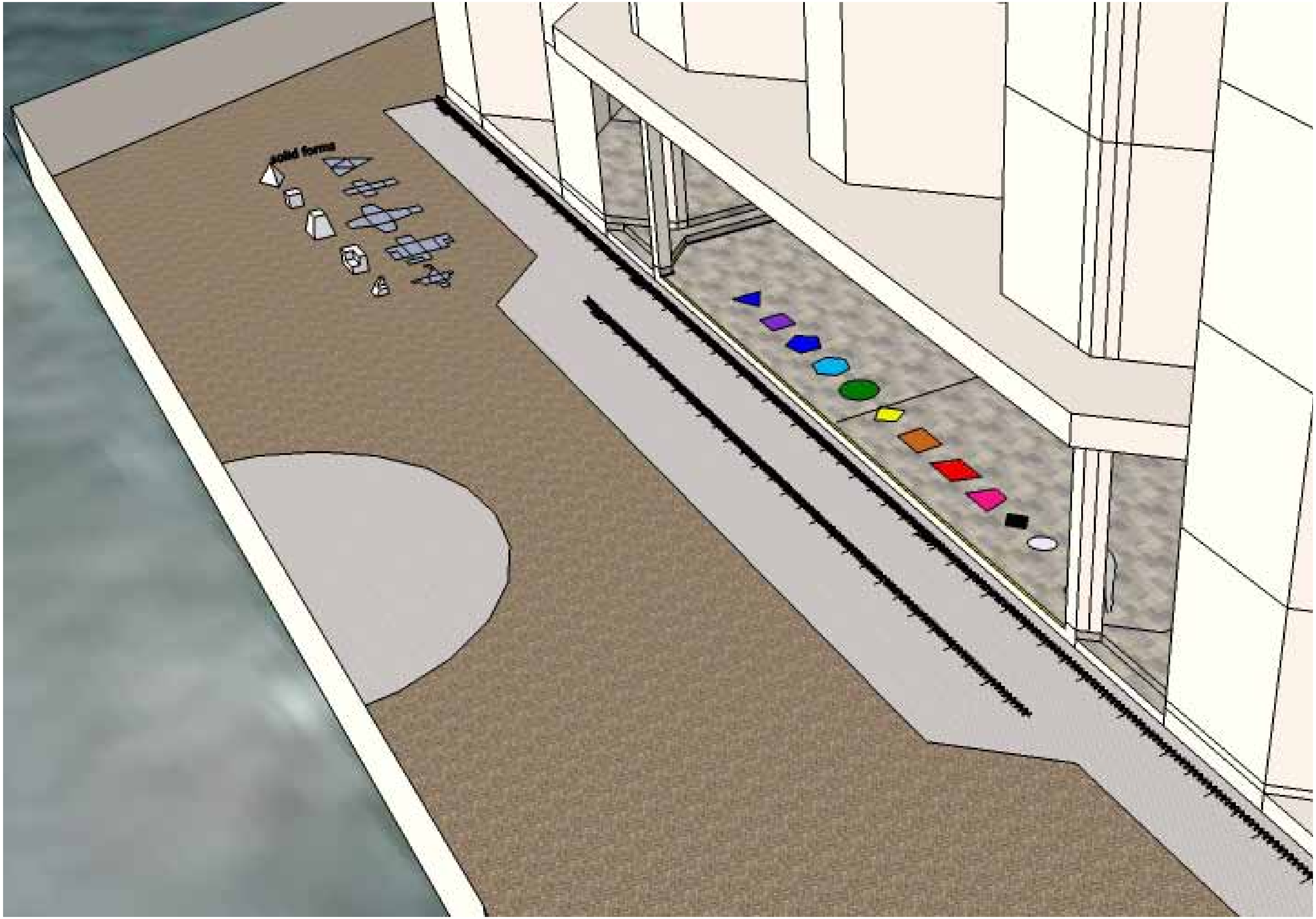
This clearly shows us that they have not got the opportunity to understand Subtraction as process of reduction. For them, the representation of '43' doesnt translate as a quantity of 43 units but can be seen to be a half baked notion in their minds. *(Refer to **actions based on association** on page 23)*

The teacher also stressed back on an example she's shared with them earlier to make them bridge this concept and continue back solving the problem correctly. The teacher brought up the fact that if you have five pens and I ask you to give me five of it, it is not going to be possible for you. And then it was linked to the above

As John Holt [47] tells us in his book *Why Children Fail*, the children here were only doing what was immediately being brought to their attention. I also noticed that they could make out from the intonation of teachers question whether she wants them to agree with her query or discard and choose the opposite stance in the query. As John puts it, they were dodging the situation with their strategies that they'd built over their time in the school. They had learnt to give the answer the teacher wants to hear and were not in the domain of understanding the problem at a level of overviewing the whole situation and using logic to arrive at the right operation to be carried out on the problem being posed to them.

What we can take from the above is that the direction in which this project looks to take is reinforced by the above scenario that children need to be brought to respond to the actual logic behing an exercise carried out in the class. This dissipated of logic in the understanding of pupils is more important to having the exercise itself. Without the teacher or the school going its distance in ensuring the above, we can see that the objectives of the mathematics curriculum for the State Board of Maharastra is not met.

Frontal portion of the school site showing existing infrastructure.


solid forms

# The additions

A **metre scale** can be added in front face on side abutting the building. It can run along the main pathway/entry to the building. Thereby sitting at the most accessed place in the school, it will be a sight for children everyday. It could be painted. They might even hop across line segments, expose to scale consciously/subconsciously.

In third grade, concept of measurement is introduced. Concepts of length, measure scales & metro scale are brought to children's attention. Till now, they are exposed to measuring dimensions of everyday objects with hands (hand-span), feet, pencil, ruler, stick, palm and similarly capacity of objects by utensils carrying water in the second grade.

Along with the metre scale, a feet scale runs parallel to the first metre scale. It does not steal the show, meaning it stays alongside in a fairly smaller size for just being compared with. This accustoms the children to both the scales of measurement that exists. Unlike what we see on a hand scale, at the level of building, we need not have both the measurement shown on the same line, which may add to overloading of new information to first time learners.

The children are believed to be at level 2 of Van Heili's model of geometric reasoning [12] as they have surpassed level 1 activities like sorting, identifying, describing, manipulation, seeing different sizes of same shape, different orientations, building, drawing, making, putting together, taking apart shapes. In a gist, level 1 is best described by "Recognition of shapes by appearance"

In second grade, by being exposed to it everyday, like what Alan Bishop [13] shares with us in his paper on geometric teaching, they experience an unblocked view of straightness of a scale. Later in their class, standard 3, when they are taught the chapter of Geometric Shapes and Figure, activities like introduction to rectangle, square, triangle, making figures with objects, naming a figure, flat surfaces, curved surfaces will be reinforced.

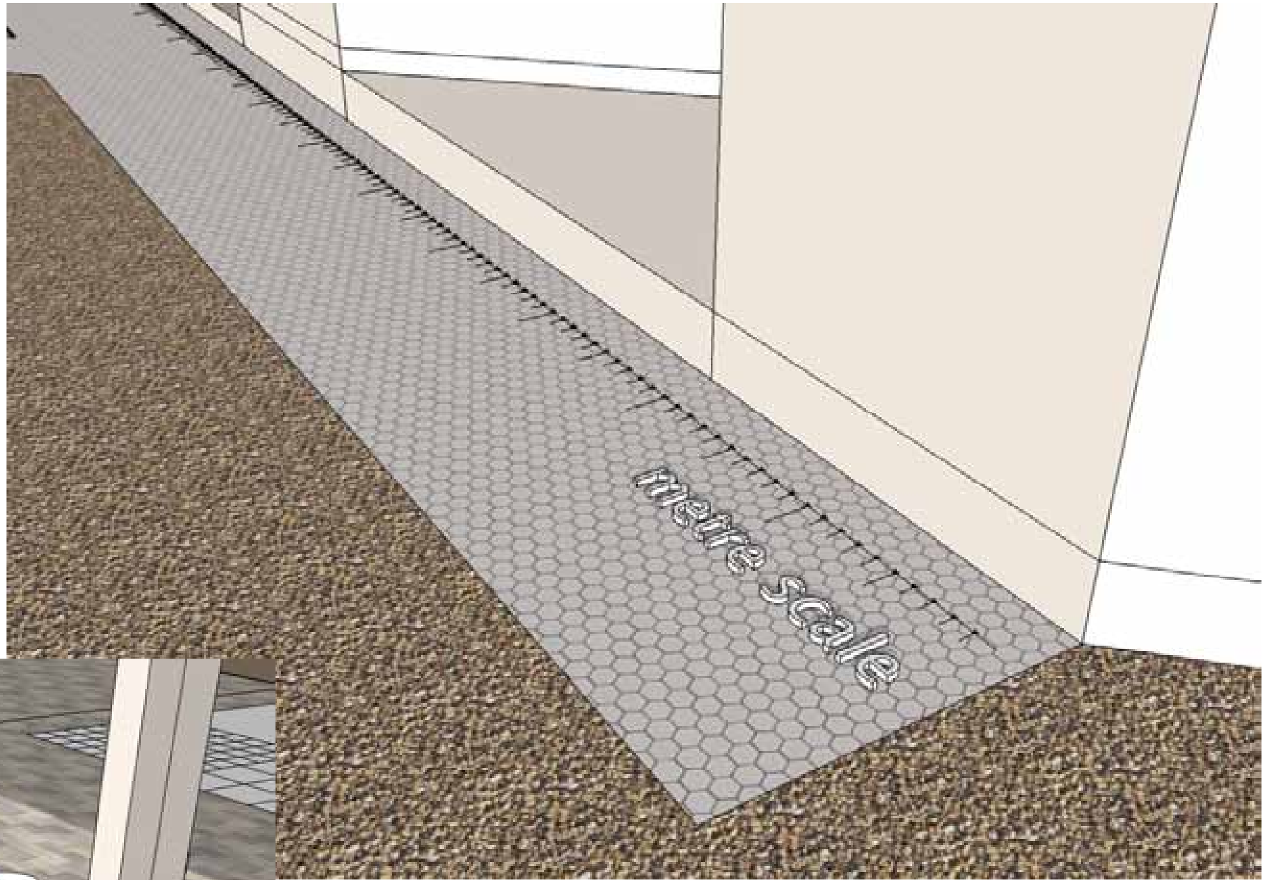
They are taught the concept of symmetry in standard 4 in the chapter symmetrical and asymmetrical figures and objects. The activity listed in the book is identification. Earlier in standard 4 and 5 they're introduced and expected to identify shapes and forms like triangle, rectangle, square, circle, cylinder, cuboid, sphere, cone, etc. Most of these are showcased or showed to them in class in textbooks, teaching aids, toys, may be shown in cartoons. But a degree of reinforcement by constantly exposing them on a daily basis by means of incorporating such learning material in their surroundings in school can help them move quicker from level 2 of Van Heili's model to level 3. Here they would get exposed to such shapes as proposed in the foyer of Shruthi school. The **solid forms sculpture** in the entrance area, **symmetrical display** at the first spot of building facade, **window grill pivoted shapes** in classroom, all these also play a similar role in supporting learning outside the class.

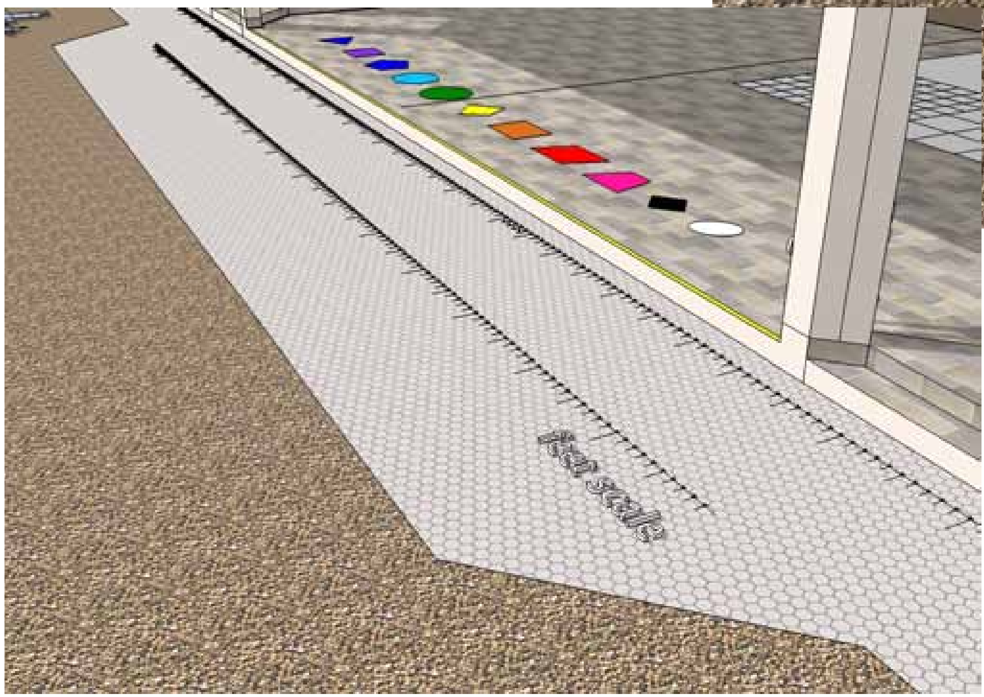
**Angles below door:**
They are introduced the concept of angles in 5 standard. Topics covered include elements of an angle, angle in various geometrical figures.

Having the display of angle markings below the door of the class can become an instant physical model for manipulation and distinguishing of characteristics is possible. This is at level 1 of Van Heili's model. They are also taken to level 2 in the same standard later in the course where they are expected to measure angles with protractor - identifying and describing properties of various types of angles.

In standard six, they are introduced the concepts of their earlier learnings of angles. Hence, they are expected to operate at level 3 and as Van Heili postulates it, they should attain level 3 by standard 8. Level 3 ought to have been achieved as they will be exposed to relevant topics of higher levels then onwards.

Other additions could be **Rulers** embedded in class desks of third grade.



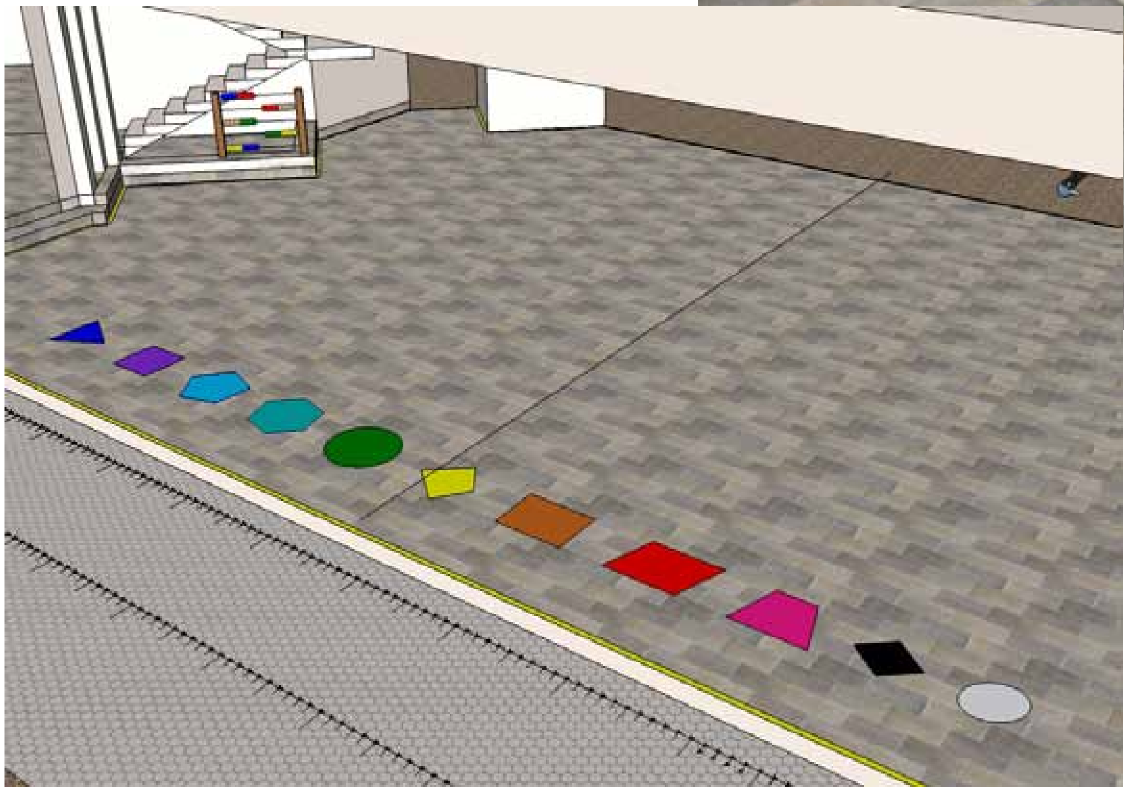

The Metre and Feet Scale in the main pathway

# Height scale

In the main foyer, the most visible point which sits at the first column a person entering bumps into, is marked with measurements in feet and metre scale subsets. This can engage children in checking their measurements and could become a comparing activity also brought to notice by the teacher.

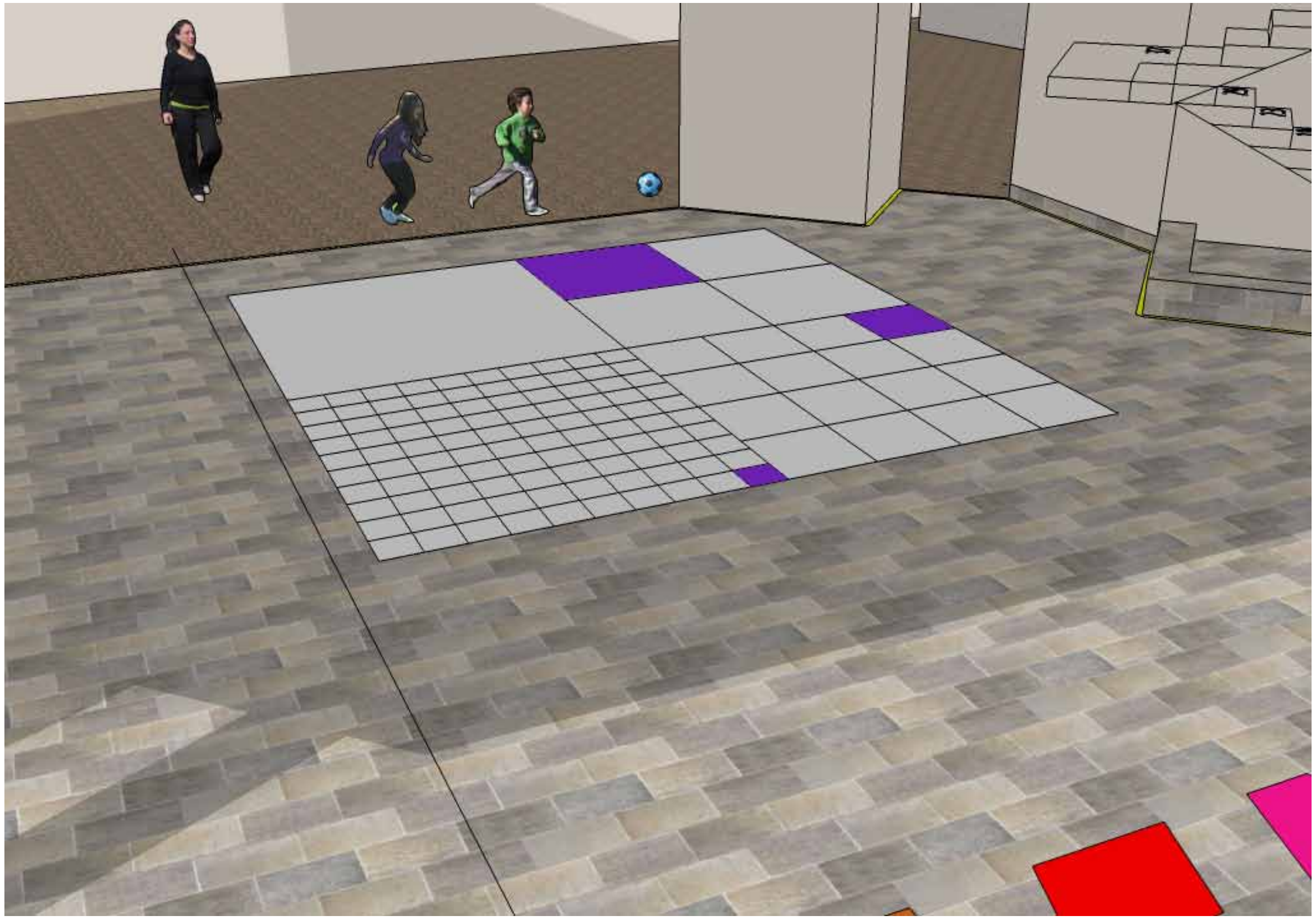

# Perimeter installation

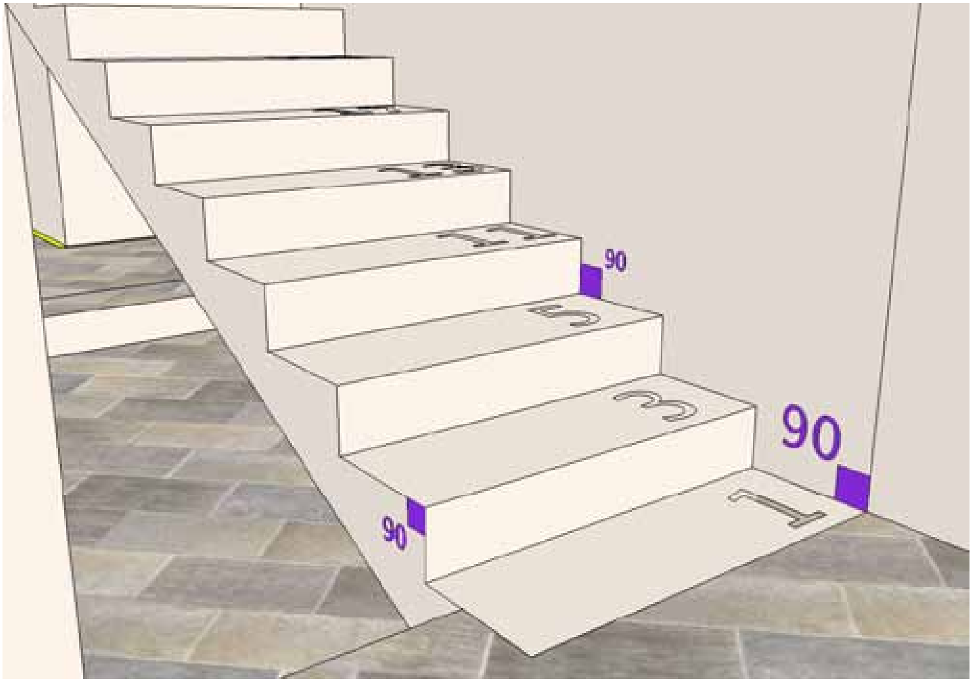
In the main foyer, the features of the structure around becomes a contextually ideal place for a marking, like the one shown in the figure to be employed for teaching or exposing children to the idea of perimeter of  shapes. When teaching perimeter, the teacher can bring the children down from the classrooms and use both the yellow line and the shapes laid out on the flooring to make them point out, ponder over, measure and arrive at similar such activities.

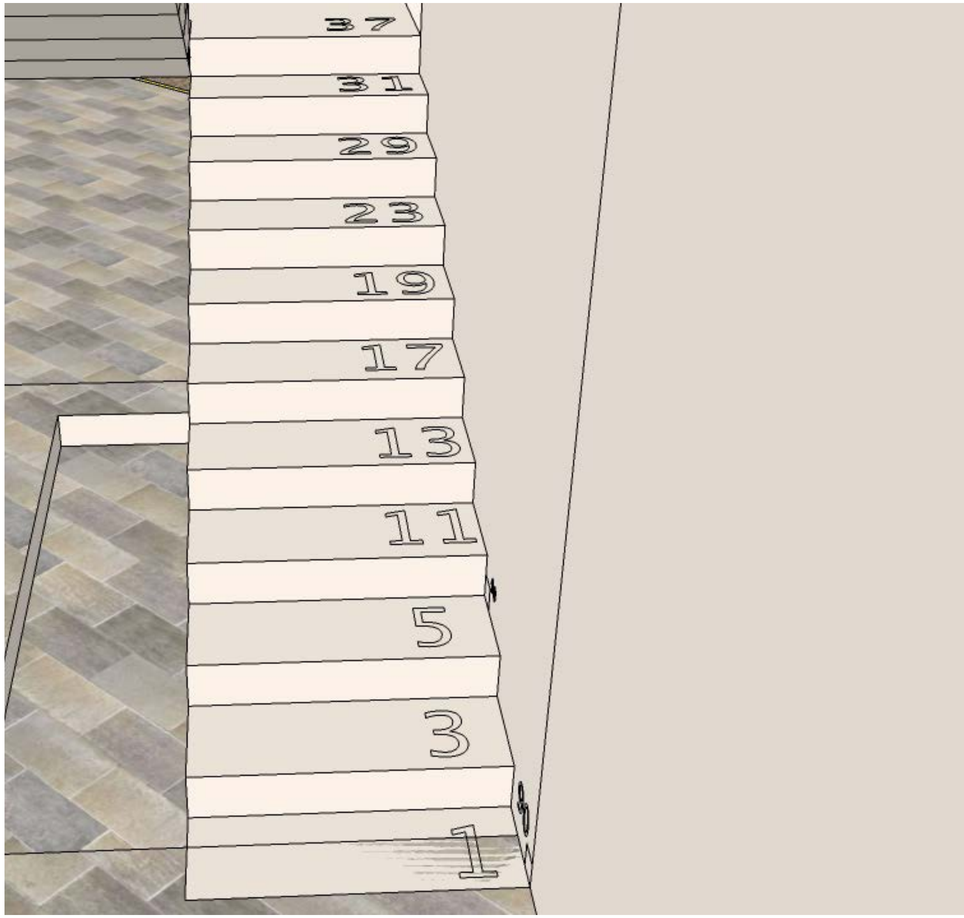


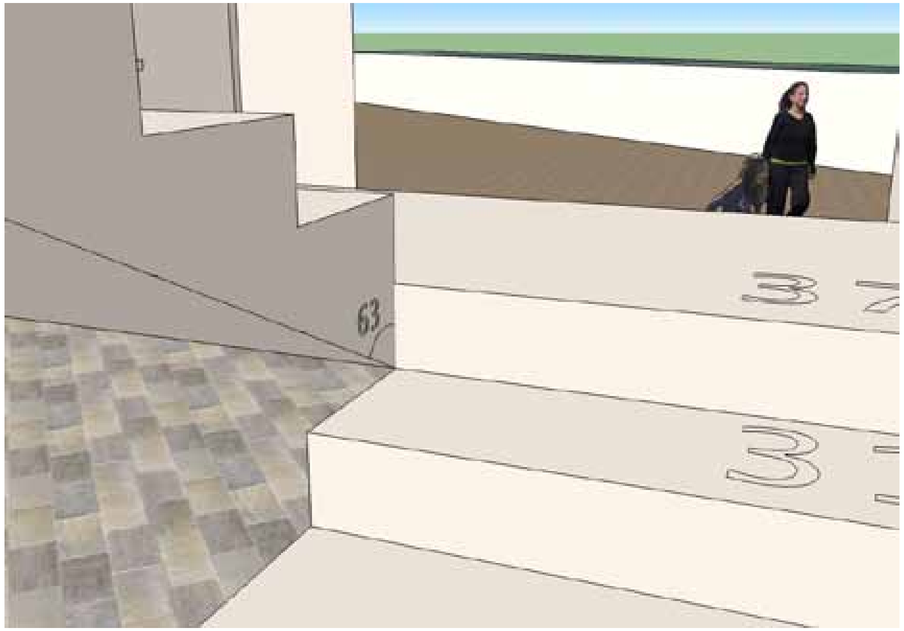
# Squares installation

In the main foyer, a super-sized graph can be painted. This gives a place to stand on and observe how quantities increase and so do their representations. This could be linked back to what they learn if the teachers could bring the children down to the foyer from the classes and exploit this platform for showcasing squares of numbers, area of squares, etc. Again these squares are visually coded for bringing in redundancy and reinforcing recognition.



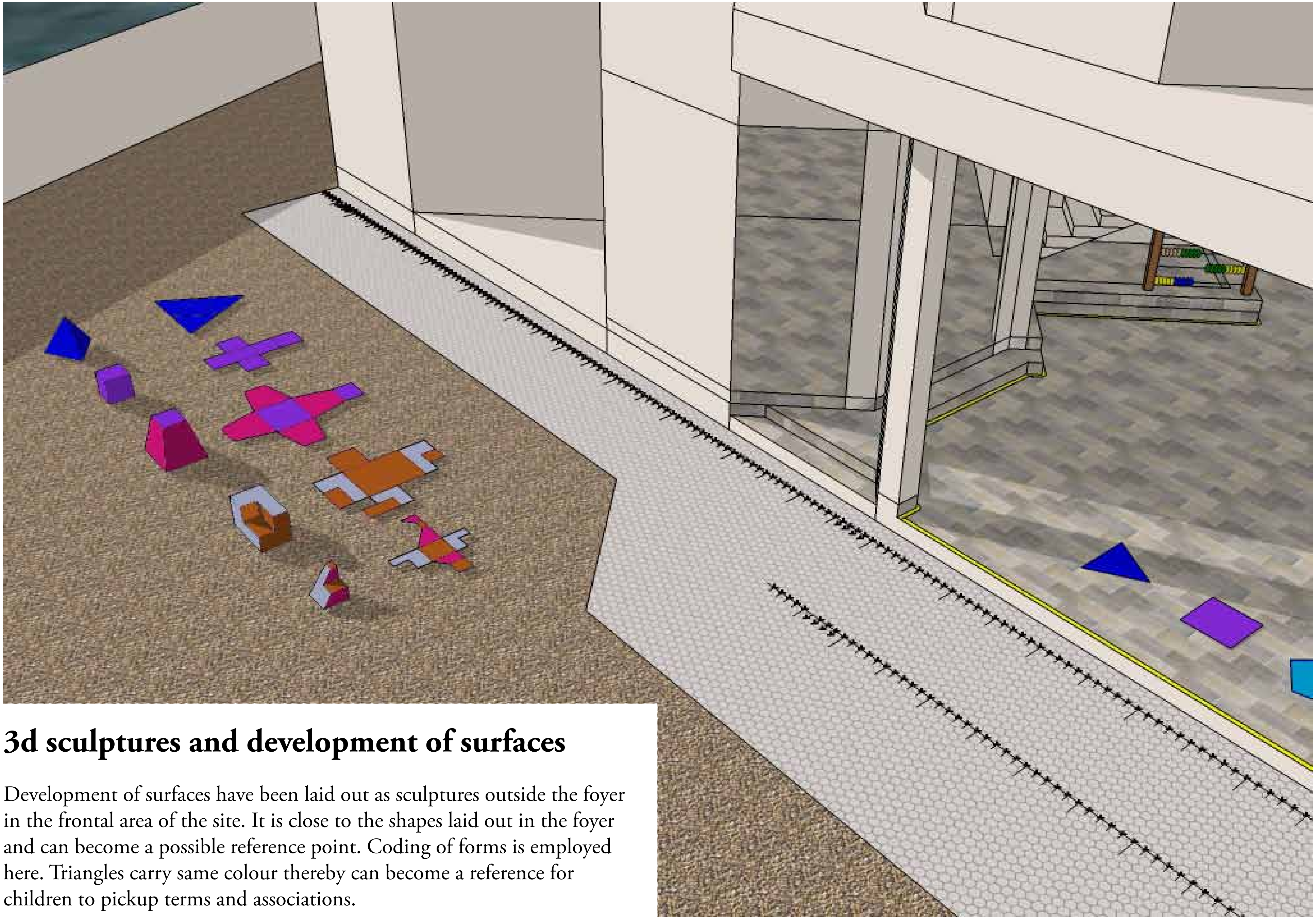



## Stairs installation

As seen in the school, the deaf children can manage numbers in the counting string, What could be explored for additional learning material on the environment could be prime numbers being in their access way so that seeing it everyday may help imbibe in them the series. And at a point later in their classroom sessions, they are able to rationalise how the prime numbers exist in the counting string.

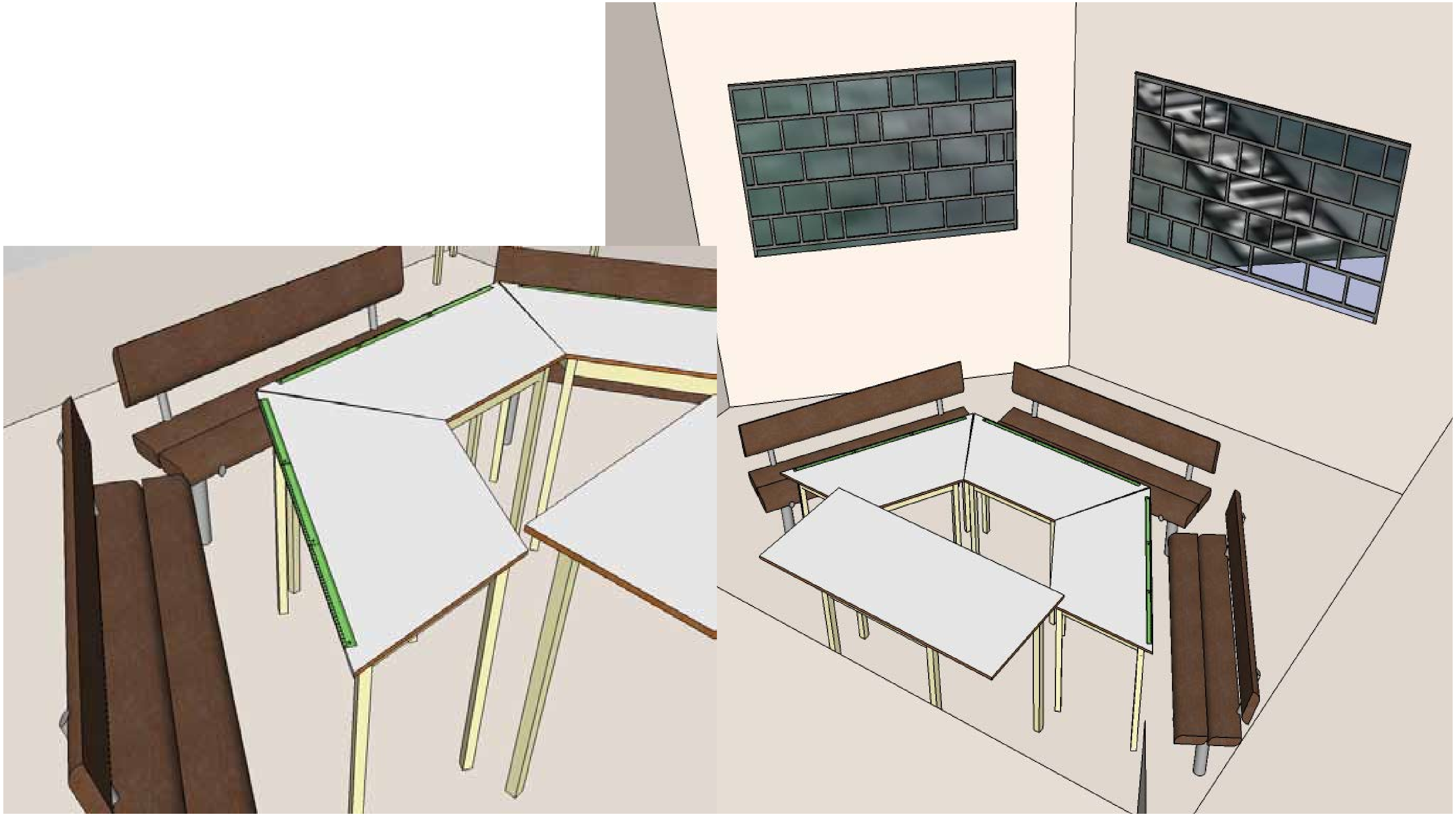


## 3d sculptures and development of surfaces

Development of surfaces have been laid out as sculptures outside the foyer in the frontal area of the site. It is close to the shapes laid out in the foyer and can become a possible reference point. Coding of forms is employed here. Triangles carry same colour thereby can become a reference for children to pickup terms and associations.

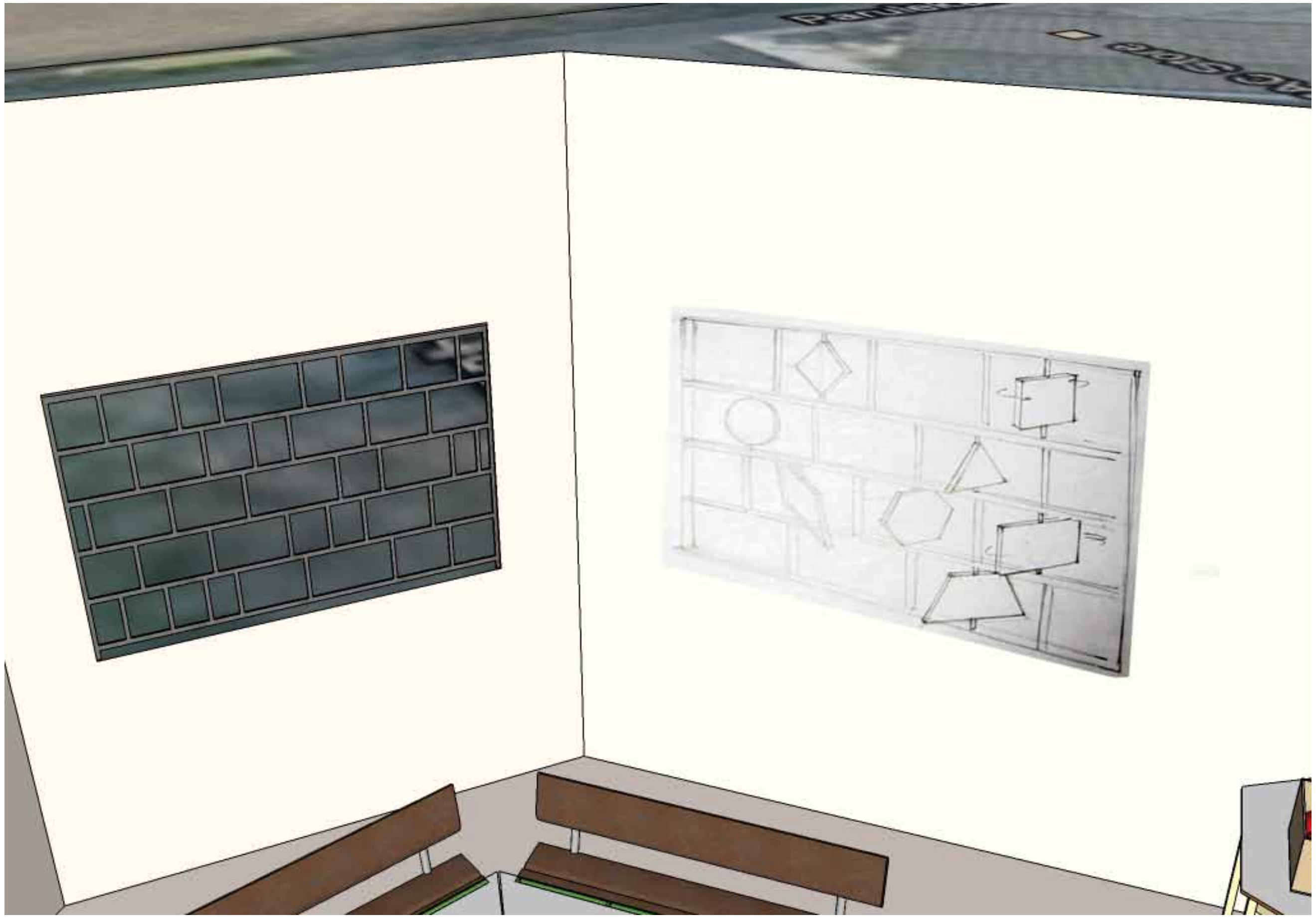
# Rulers in desks

Rulers can be embedded in desks of children. It gives them a chance to be noticed umpteen times and may tend to ponder over when introduced about it. It is also a platform/manipulative space to keep objects and measure.



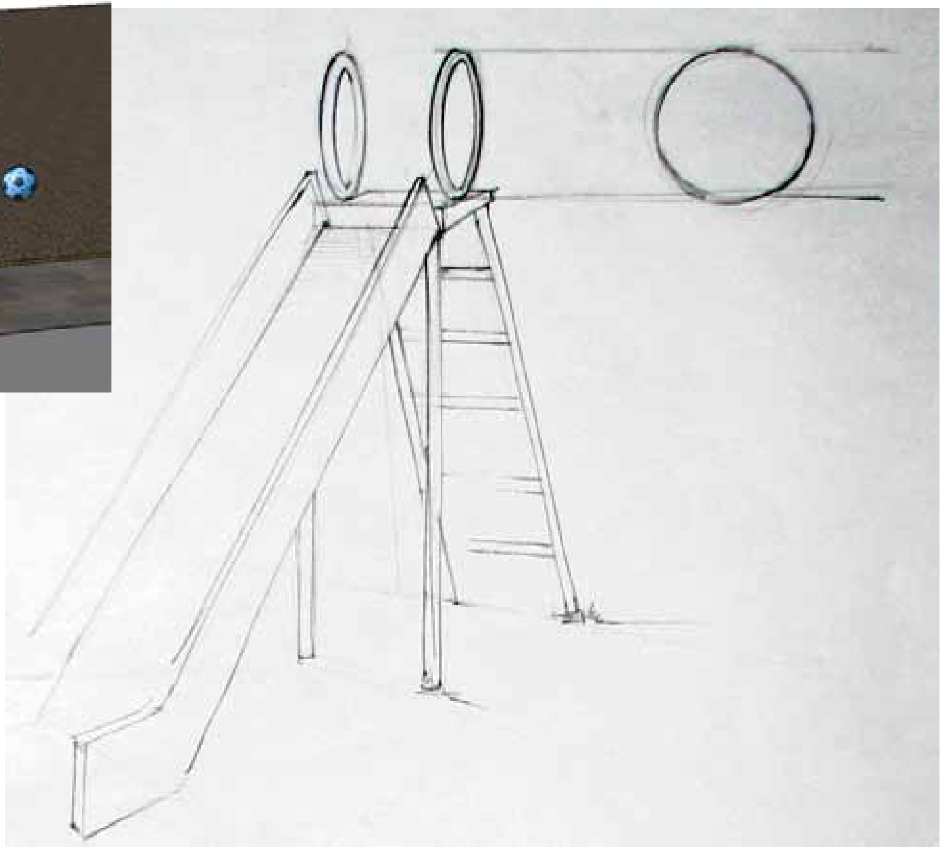
# Various rotatable shapes in Windows

The window grill can be given an addition. We can add small plastic/rounded metal plates which are of various shapes pivoted to the grill bars. These can be pivoted so that they become manipulable. Being dynamic, they attract the attention of children and can become a valuable learning aid when they are being taught shapes and angles. They can measure angles with a protracted on these as well.



# Slides installation

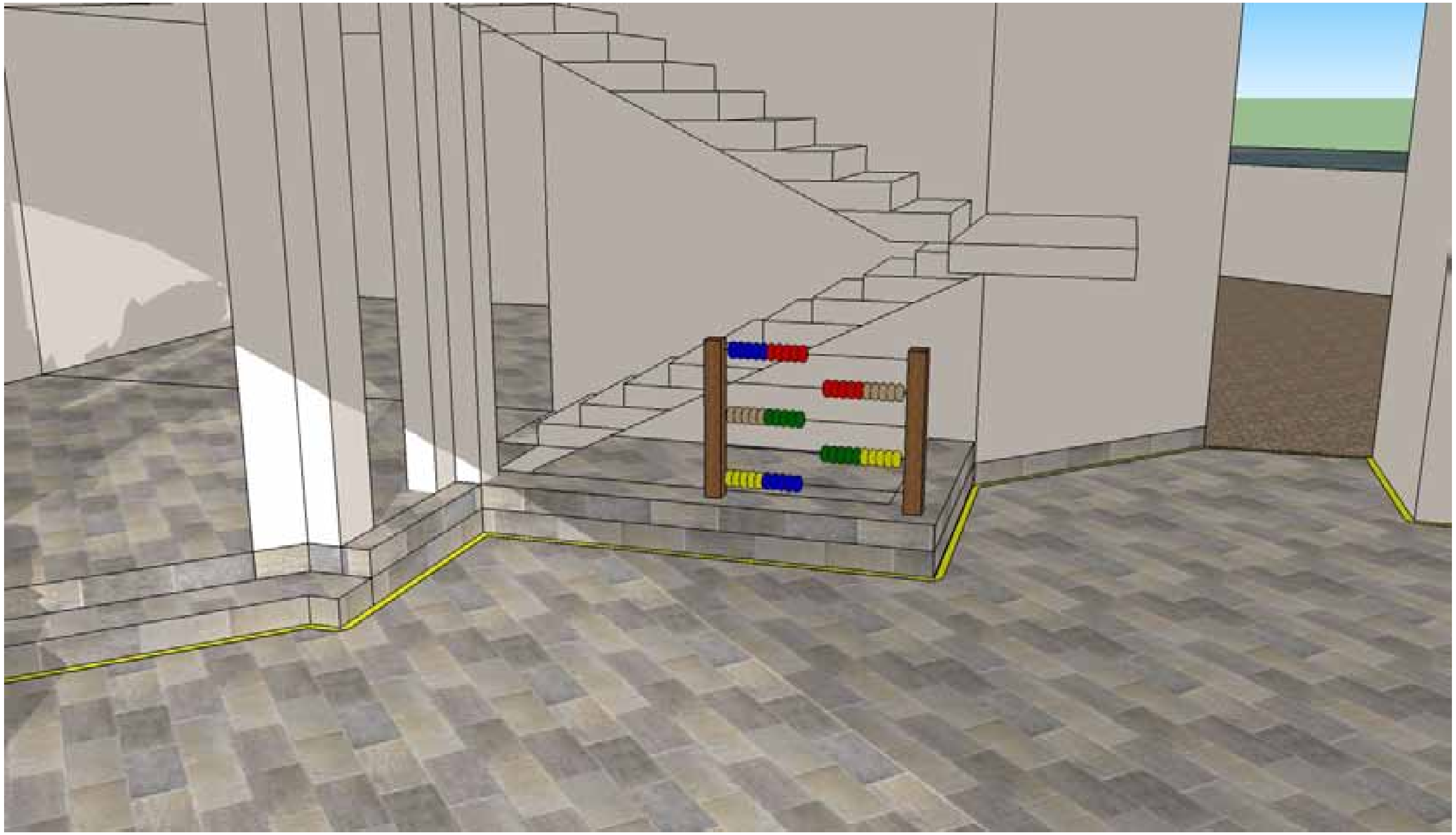
The circular disc in the slide can be used for pinpointing area, perimeter.



## Abacus installation

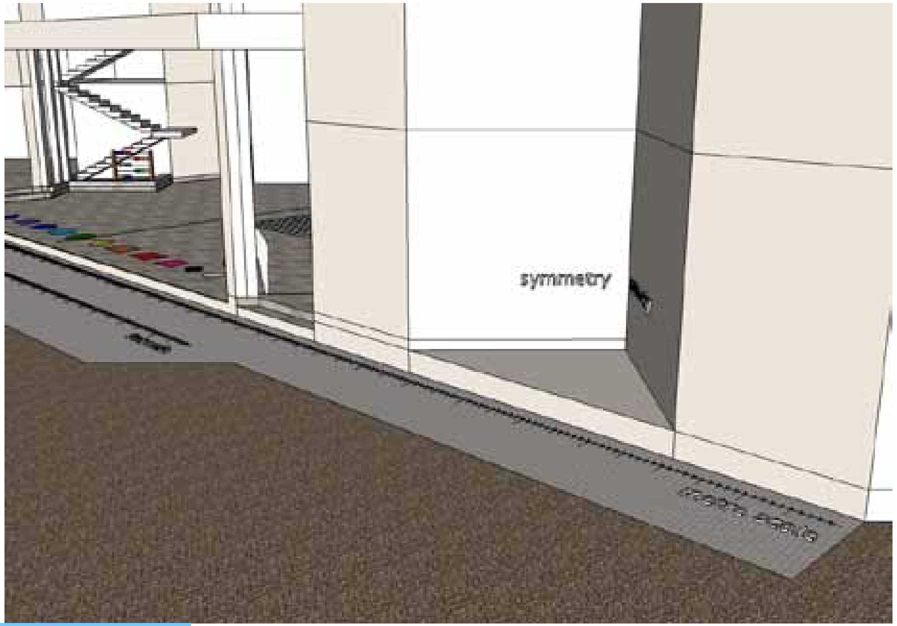
In the anterior part of the foyer, the principals office, the school office and store take seat in the ground floor. As they have sitting/waiting space out, a lot of children who come with their parents/family members were seen loitering around the area where an a bigger sized abacus has been proposed to be installed. It becomes an ideal place for any bystander to play with the abacus and also learn a thing or two upon pondering well enough.

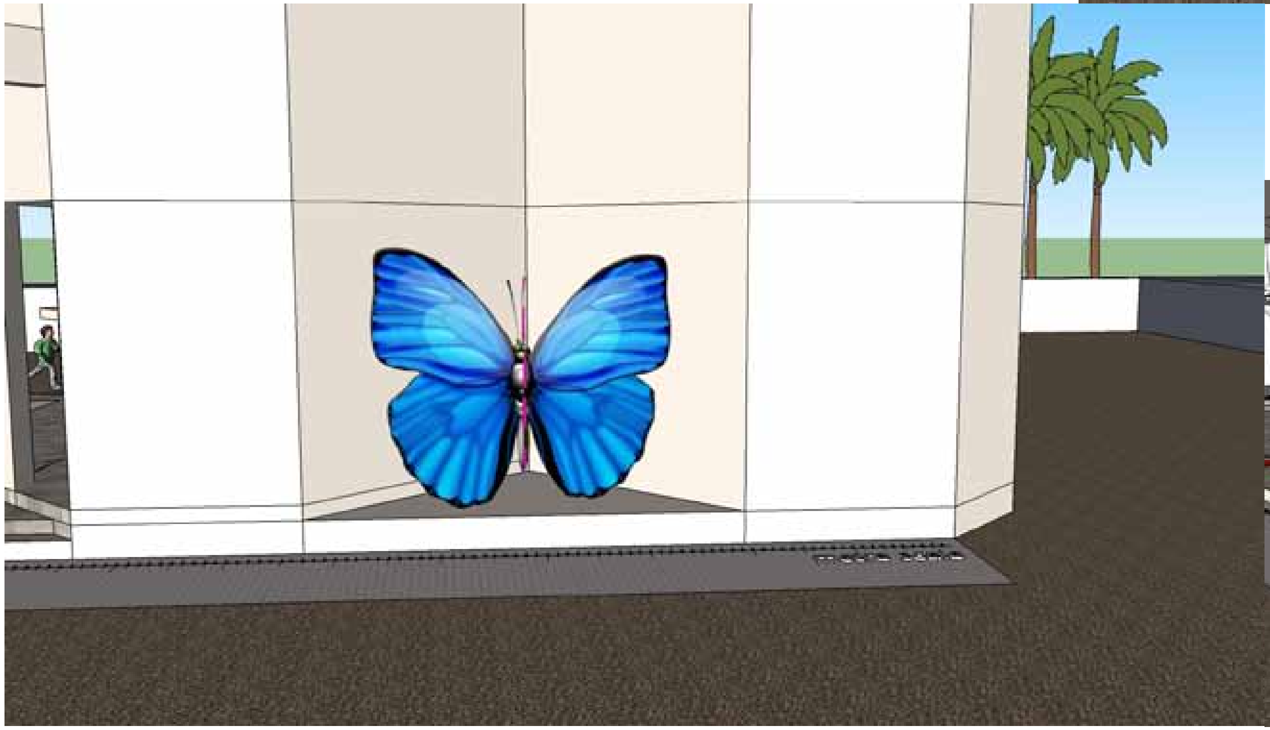
What can be continued in this project's next set of proposals for the same premises is to have the abcus shown below include teaching of negative numbers along with the existing scope of suggested abacus. Today, abaci are often constructed with bamboo frame with beads sliding on wires, but originally they were beans or stones moved in grooves in sand or on tablets of wood, stone, or metal.

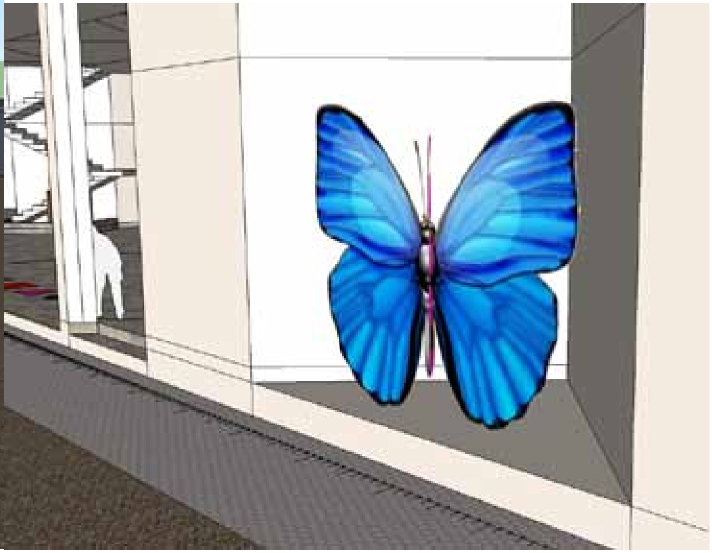


# Symmetry installation

The building flexes inwards in the first visible stretch of the facade. It becomes an ideal place to showcase a concept. The butterfly or symmetrical icon is seen as an ideal showcasing element. The teacher can bring the children down from the class while introducing the concept of symmetry, start from the butterfly sculpture and create an activity for them by asking them to go around the school and identify more such figures or examples-man made or natural.





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