IDC School of Design अभिकल्प विद्यालय

IIT Bombay

P3 Report

Project Title:

Design in Schools:
Using Design Thinking Process to teach concepts of Mathematics in the Preparatory Stage of Schooling

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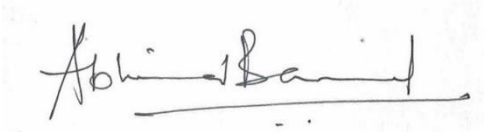
Declaration

I declare that this written document represents my ideas and interpretation of the data derived from literature, in my own words. I have tried (to the best of my capabilities) to adequately cite and reference the original sources wherever others' ideas or words have been included. Being a project with extensive work done in the field of creating unique activities, any resemblance to such activity is purely coincidental. I declare that the work is not plagiarized by any means and was the outcome of exploration with my mentor. I have not misrepresented or falsified any information in my submission, all such data has been referred from reliable sources. I understand any violation of the above can lead to disciplinary action by the Institute and evoke penal action.



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May 2023

Approval Sheet

The Interaction Design Project 3 titled “Design in Schools: Using Design Thinking Process to teach concepts of Mathematics in the Preparatory Stage of Schooling” by Abhinav Bansal, Roll Number 216330003 is approved in partial fulfilment of the Master in Design Degree in Interaction Design at the IDC School of Design, Indian Institute of Technology, Bombay.

Project Guide (Prof. Ravi Poovaiah)

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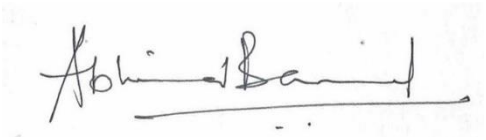

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Abstract

The project aims to curate a framework for teaching Mathematical Concepts to Elementary School students using the Design Thinking process. The project follows an iterative approach, where the engagement and learning outcomes of the process and designed activities are studied for subsequent development, culminating in a series of Lesson Plans for the identified topics. The activities are proposed as complementary teaching methods rather than substitutes for existing mechanisms of teaching. Through the field study we identified the current teaching methods and the conceptual difficulty the students face. We prepared a set of activities using the Design Thinking Methodology and conducted a Pilot Study. The results were evaluated by domain experts following which we designed our first draft of Lesson Plans and further tested it out using 3 different teaching methodologies. We found out that although traditional teaching mechanisms produced better overall results than purely Experience based Design Thinking Process, there were certain areas of application where the exploratory approach worked better. Based on the observations and another set of feedback, we designed the final Lesson Plan and Activity Workbook combining theory-based teaching with Experiential Learning. Overall, we aim to enhance the teaching of Mathematics by offering innovative activities and lesson plans, driven by research, testing and expert evaluation.

Contents

Introduction

As per the New Education Policy 2020 (5+3+3+4), the Preparatory Stage follows the Foundational Stage, and precedes the Middle Stage. This stage involves students from Classes 3 to 5 (Ages 8 to 11) and encourages a 'Discovery & Activity based learning' [1] to lay a solid groundwork in reading, writing, speaking, physical education, art, languages, science and mathematics.

Although comprehensive modules under Design Thinking and Innovation (DTI) are under implementation for classes 6 to 12, discussions in NCERT and other concerned authorities have raised the point of exploring using Design Thinking as a teaching methodology in Primary School Education.

The project attempts to curate a set of activities related to Concepts of Mathematics (For Class 3) that can complement or act as alternatives to existing set of activities that are being used to teach these concepts. The project will involve an iterative approach using a series of Pilot Tests to gauge the same. Lesson plans were designed, tested and updated after every session.

Aim and Objectives

The aim of the project would be to teach the concepts of Mathematics in the Preparatory Stage using Design Thinking Process (Collection, Observation & Analysis) as a baseline. We choose Class 3, since it's the transition from Foundational to Preparatory Stage in Schooling, as per NEP. The activities would be designed keeping the above in mind. The possibility of coming up with multiple outputs would encourage students to look at the same problem through different perspectives, and apply the concepts in different ways.

Scope

Scope of the project would be to curate a set of activities and test it with children. It will be an iterative process. The engagement and learning output would be studied, and accordingly the final set of activities (and subsequent lesson plan) would be designed.

We do not propose these activities as a substitute to the existing teaching mechanisms in Schools. We propose them as 'alternatives' that the teachers can use while teaching some concepts of Mathematics to the students. The role of the instructor would also be thought upon with every activity, after constant feedback and expert discussion.

Further, the decisions regarding testing were taken logistically. Given the time-frame, tested the designed activities in the schools located conveniently within our location, where permissions were granted without much difficulty. *At the end of the project, we aim to provide a template to design lesson plans in the most effective way – with or without using Design Thinking, using the results of our*

evaluation. We also try to identify the difficulty level of activities that should be kept in mind based on our observations.

Deliverables

For this project, a lesson plan for the instructors and task books for students are designed for the identified concepts/ topics. We also try to templatise a framework based on our research, observations and expert discussions to help the instructors design their own lesson plans using the Design Thinking Process.

Methodology

- Secondary Research into the topics in Mathematics covered in Classes 2,3 & 4 along with study of Mathematics Text Books (Topics, Activities, Group v/s Individual Activity)
- Primary Research: Interview and Discussions with School Teachers teaching in primary school to understand the learning capacity of students
- Identifying the Topics that can be conceptually taught using Design Thinking methodology
- Designing of Activities (Topics: Multiplication, Money) and Pilot Testing (Iterative Process)
- Expert Feedback (Before and After Pilot Testing)
- Designing of a new summarised Lesson Plan (Topics: Symmetry, Place Value and Numbers) based on learnings from Pilot Test
- Controlled User Testing for Evaluation
- Design of the Final Revised Lesson Plan (Detailed) and Activity Workbook for the students
- Expert Evaluation on Revised Lesson Plan

Motivation

In a classroom, although most of the students can gauge the concepts correctly through the traditional teaching methodologies adopting behaviourist approach, there is still a proportion of students that are not able to grasp them.

Further, there is a difference and a Learning Gap that is observed in the classrooms. This requires the teacher to give special attention to those who are slow-learners, or are conceptually weak. The textbooks in today's curriculum are designed primarily using two major techniques- Pictorial Activities, and Abstraction (application based) based problems.

Models based on theories of Cognitivism and Constructivism have been applied in the field of education, and also in mathematics. Design Thinking process is also a technique of problem solving used in design schools. [2]It is widely accepted to comprise of 5 stages: Observation, Understanding, Analysis, Ideation, Testing and Reflection. [3] Being a designer, I aim to see if the design pedagogy style helps in effective teaching of mathematical concepts. We try to focus more on the iterative aspect, where student would be able to

observe and explore the concepts. In cases where the concepts are more theoretical in nature, we would explore how ***'intangible concepts can be made tangible.'***

Positioning

In this project, we explore the possibility of using Design Thinking in Primary School to teach abstract and intangible concepts of Mathematics. It aims to see how the instructor can modify or design a set of activities given in the textbook (Here, NCERT text books) using Design Process as a framework to raise the understanding level of the class, specifically those of the late-bloomers.

The project will deliver a set of Lesson Plans for such concepts. It will also try to give a framework and suggestions for the teachers to adopt while making their own lesson plans. In case activities need to be designed, we will lay out our observations as observed from the iterations and subsequent testing. The findings of the project will lead to implementing the methodology in schools' curriculum, especially since there is a demand of teaching using DTI being introduced in the primary level of education.

Literature Review

Design Thinking in Pedagogy

Many researchers have taken their stance on what Design Thinking is. Many define it as both a process, and a mindset. It is agreed upon to be a creative problem-solving approach used by designers to provide a solution to an existing undesirable situation. [4].

Herbert Simon (1969) introduced seven stages of Design Thinking process which were later used by D-School to popularise their design process [4]

1) Define- essential to define the issue to be resolved and the audience for which it has to be done
2) Research- history, existing obstacles, example etc
3) Ideate- identifying needs and motivations of the users behind it, brainstorming
4) Prototype- making draft solutions
5) Choose- reviewing and selection of powerful ideas
6) Implement- execution
7) Learn- reflection and your learnings out of the whole thing

Tim Brown, the Chairman and President of IDEO suggests Design Thinking to be a cyclic process of inspiration, ideation and implementation. [2]

Ineta and Brown suggest that since a child is in its early stages of life at this moment, it is important to also inculcate behavioural traits, values, and some sensitivity towards the people and environment around. [4] This was also observed in the primary research conducted in schools of New Delhi as follows:

- 'May I get 2kg of Apples' while roleplaying

- Information about Indian Monetary System
- Addition and Subtraction of States and Union Territories of India
- Some go as far as including the Sustainability Development Goals (SDGs) into their monthly assessments

In 2010, the method of D-School (Institute of Design at Stanford) was popularised. However, it was similar to the processes as defined earlier by Simon, and later by Brown. Today D-School's method is revised as Empathise, Define, Ideate, Prototype and Test

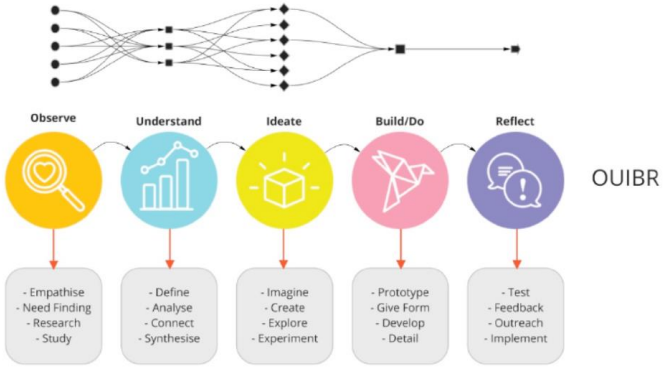
We see that Design Thinking has had several defining characteristics that are highlighted by the need of **problem-solving, observations, collaboration and discussions**. It has been seen as an opportunity where the students think, learn and innovate. [3] Based on these, the approach was taken by educators in India for the Design Thinking and Innovation Module, that is soon to be introduced in CBSE education system.

Adapting the Design Thinking in DTI Curriculum

In the DTI Curriculum, Design Thinking Process has been modified into OUIBR, namely Observe, Understand, Ideate, Build/Do, and Reflect. [3]. A student goes through these 5 steps to solve a problem:

1. Observe: This phase involves the need-finding and find the issues that need to be solved using observation
2. Understand: This helps create a pseudo-goal in the minds of the users, helping them understand the problem area
3. Ideate: Coming out with several innovative ideas to the problem
4. Build/Do: This phase helps in reaching out to the problem solution by building mock-ups and creating scenarios
5. Reflect: This is to get feedback through evaluation

We use the DTI model of Design Thinking as the design-based learning framework in our study since this model will soon be a part of the CBSE Education System.



Understanding the Learning Theories in Education:

We start by understanding the three major learning theories of behaviourism, cognitivism and constructivism, and further their use in the subject of mathematics. We also understand the role an instructor plays in each of them.

Behaviourism talks about learning through an objectivist philosophy, where knowledge is perceived to be independent of the learner. Here, the learner acquires the knowledge, and the instructor is the primary source of giving knowledge. [5] In mathematics, behaviourism can be used to reinforce some methods and behaviour through repetition and practice. An example is seen in learning tables where repetition enhances fluency. The instructor plays a more directive role providing clear instructions at every step.

Cognitivism focuses on the idea that the students process information they receive. A cognitive learning environment includes interesting and eye-catching behaviour, questions from the instructor which generate response by the student, and the need to recognise mistakes and learn from it. Pioneers like Vygotsky focus on environmental learning, where language, discussions, feedback and collaboration play important roles. [6] In Mathematics, cognitivism is reflected in understanding mathematics concepts and problem. It highlights the importance of students engaging in thinking, reasoning, and applying their learnings. Mental Math and pattern analysis is one such example. [6] Here, the instructor acts as a facilitator or a guide, providing opportunities for the students to engage in problem-solving activities, critical thinking, and discussions.

Constructivist theorists argue that learning results from an on-going process of understanding, self-learning and applying the acquired knowledge. Here, the teacher plays the role of information conductor, rather than information giver, as in the behaviourist approach. However, researchers like Klinger argue self-discovery of 'basic' processes, that is often applied to the everyday arithmetic of addition, subtraction, multiplication and division is not 'simple' or 'obvious.' It is not reasonable or sensible to expect students at any level to 'discover' the basic mathematical concepts through constructivism. They are rules that have been defined, and are not meant to be discovered, argues Klinger. [6] However, the rules and practical applications that can be derived from these basic operations are something that can be done in a constructivist way, since that involves a logical application.

By incorporating elements from behaviorism, cognitivism, and constructivism, we can create a balanced and effective mathematics learning environment. This can involve providing clear instructions and reinforcement (behaviorism), promoting active thinking and problem-solving (cognitivism), and creating hands-on learning experience (constructivism)

Understanding the Learning Models in Education:

Multiple Intelligences by Howard Gardner

This theory states that early student has a different learning curve and they adapt to different teaching environments in a different way. Some may adapt easily to reading and writing (linguistic environment), while others are better taught using logic-based learning. Some might benefit more from learning-by-doing. [7]

These multiple intelligences can be used in isolation, or in a combination to create different ways of learning. These might be done by using words, numbers, musical activities, self-reflection, discussion, experiments, and observations. [7] [3]

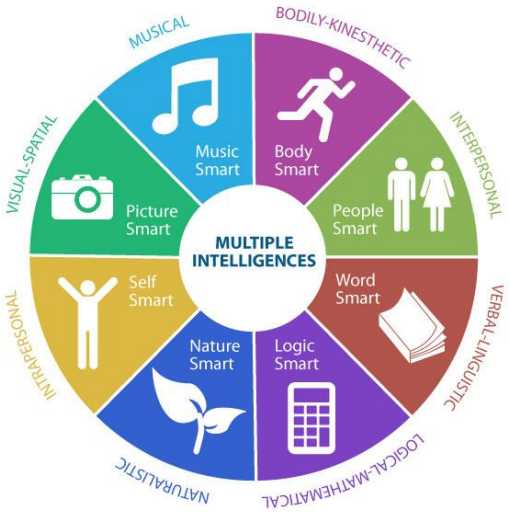


Figure 1: Gardner's multiple intelligences

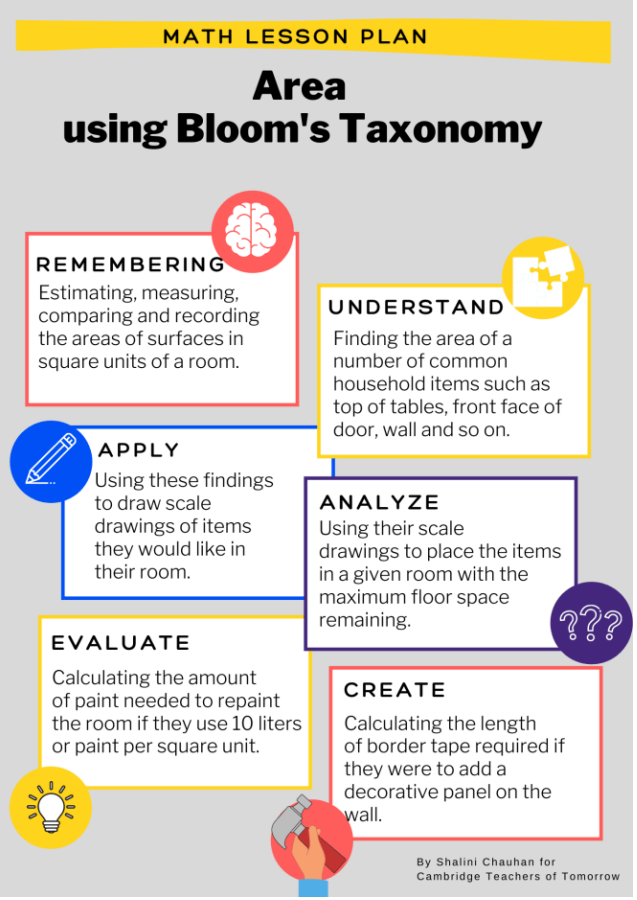
Bloom's Taxonomy

Benjamin Bloom broke down the cognitive learning (knowledge-based) learning into 6-levels of objectives. These are as follows: [3] This provides a base for the teachers for learning and assessment methods.

- Remember: Can the student recall or remember the information?
- Understand: Can the student explain ideas or concepts?
- Apply: Can the student use information in a new way?
- Analyze: Can the student distinguish between parts?
- Evaluate: Can the student justify their decision?
- Create: Can the student create a new point of view?

Many educators have tried to interpret Bloom's taxonomy in the mathematical domain. Some words for lesson plans that emerge out of it work as follows:

Following is a lesson plan made by Educator Shalini Chauhan, using Bloom's Taxonomy. This is made for the topic of 'Areas'.



Kolb's Cycle

David Kolb proposed that learning begins from the observation stage from where it proceeds to reflection, where learners transform their experiences into knowledge. [8] He defines it as a process where knowledge is created through a transformation of experience. (Kolb, 1984)

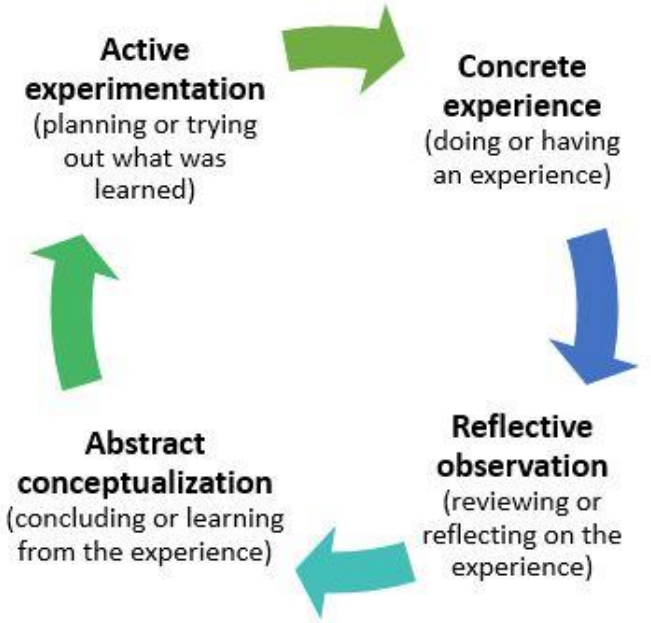


Figure 2: Kolb's Learning Cycle [8]

Prior to Kolb's theory, Jerome Bruner proposed the form CPA (Concrete, Pictorial, Abstract/Application) approach in Mathematics. [8] The theory further suggests that involvement is the key to learning, and recipients must actively engage in the tasks. This encourages them to reflect on the actions they have taken.

Communication is the other important aspect of this theory. It encourages active discussions from the learners.

Clubbed with Gardner's theory of multiple intelligences, one can conclude that this requires a wide range of activities that can cater to the multiple learning styles. [4] However, it is also to note that in mathematics, owing to the time limitation, one must design activities in such a manner that they do not overwhelm the practice time i.e. the abstract applications of the concepts. [2]

Summary in Implications for Pedagogy

We can summarize the use of Design Thinking in Pedagogy as follows – Design Thinking can be considered as design-based learning, something that can be extended to other subjects that involve problem solving. It can be perceived as a model for enhancing creativity, thinking and learning. **An ideal learning cycle must include the 'Experiential' component too, that helps a learner engage in real-life scenario. Discussions and Reflections, talked about in both Kolb's Model and George Polya's methodology are necessary since they reflect the understanding of abstract concepts which the child learns in the earlier mentioned stages.**

A few methods that have worked out include but are not limited to : working in groups, human-value addition, collaborative learning and enhanced participation. Although, they haven't been tested actively with primary school mathematics education. Testing for high schools have been done using the Constructivist Approach earlier.

Design Thinking further helps a learner to be mindful of the process and operations they apply while problem solving, something inherent in mathematics.

Teaching of Mathematics

One of the most significant change a child experiences from moving to Foundational to Preparatory stage of education is the gaining of skills to understand the world around them. [1] W.r.t mathematics, it includes the concepts of numeracy, making observations, collection and analysis of Data as well as understanding the use of mathematics in the surroundings. This is further supported by Vygotsky's theory that environment plays a coherent role in a child's learning capacity. [9]

Change in Learning Pedagogy

NCERT further asks for a need in change of Pedagogy and Assessment style. They emphasize on a need of abstraction, along with experiential learning. Although textbooks and workbooks can start to play a bigger role in organizational learning, content can be expanded and made localized to fulfil the child's experience. [1] This brings in an opportunity to curate (or modify) the content to create a more experience-based learning. James Bruner, in 1969 proposed a similar model of CPA Learning (Concrete, Pictorial and Abstract),

in his Theory of Representation. He states that in an "enactive stage, the child needs to indulge with real materials to understand object, which are transformed into a symbolic and later operational representation of the same." [10]

NCERT also notes some problems in Teaching and Learning of Mathematics:

- A sense of fear and failure
- Curriculum that is non-participatory in nature- excluding many
- Methods of Assessment that encourage perception of mathematics as mechanical computation and not application-based
- Lack of teacher preparation and support in the teaching of mathematics

Works of George Polya

George Polya suggests that the main learning objective in school mathematics relates to numeracy. [11] In his book How to Solve, Polya suggested a 4-step approach to mathematic problem solving that includes:

1. Understanding the problem
2. Devising a Plan
3. Carrying out the plan
4. Looking Back

We can find similarities in this method to the Design Thinking Process, where Understanding & Devising a Plan can be inferred to as Observation and Understanding; and Looking Back can be related to Reflection. However, this method does not take into consideration the 'Experiential Learning', that is proposed by Kolb, and touched upon by Vygotsky.

Works of Jean Piaget: Discovering Space, Time, and Numbers

Piaget's works harboured on the Constructivist theory. He claimed that a child learns by doing. He said that the child interprets the world around itself, which is not limited to only observation. This aligns with the Design Thinking model of DTI of 'observation, interpreting and analysing' the things around us. [3] Piaget says that the child must understand that the numerals have no value unless they understand the significance of a 'unit'. Unless the value of a 'unit' is understood, the children will not be able to apply operations on them. [12] This is the basic concept of numbers in mathematics.

Piaget's works focused more on a child's individual development. He says that a child begins performing mental operations based on the actions that were performed physically. A child at this age begins estimating objects based on their grouping (principle of conservation). He further states that a child at this stage develops thinking about shape (spatial relationship), arrangement, and classification (part-whole relationship).

Works of Jerome Bruner

Bruner, in his Theory of Representation states that a child goes through three stages of representation progressively from enactive, to iconic, to symbolic. [10] Bruner devised the Concrete, Pictorial and Abstract framework that is a highly sought-after method to teach mathematics. CPA method uses physical and visual aids to build a child's understanding of abstract topics. Once adept with concrete aids, they are given pictorial cues of the objects (or similar objects) that they were using, and finally they solve problems using only abstractions- i.e. numbers and symbols.

CPA Method has been well established in multiple classroom settings with five major steps:

- Let's get physical **(concretize eg.)**
- Turn children into teachers **(grouping)**
- Assess as you go **(reflect)**
- Make the word heard **(key terminology)**
- Questions are key **(explore)**

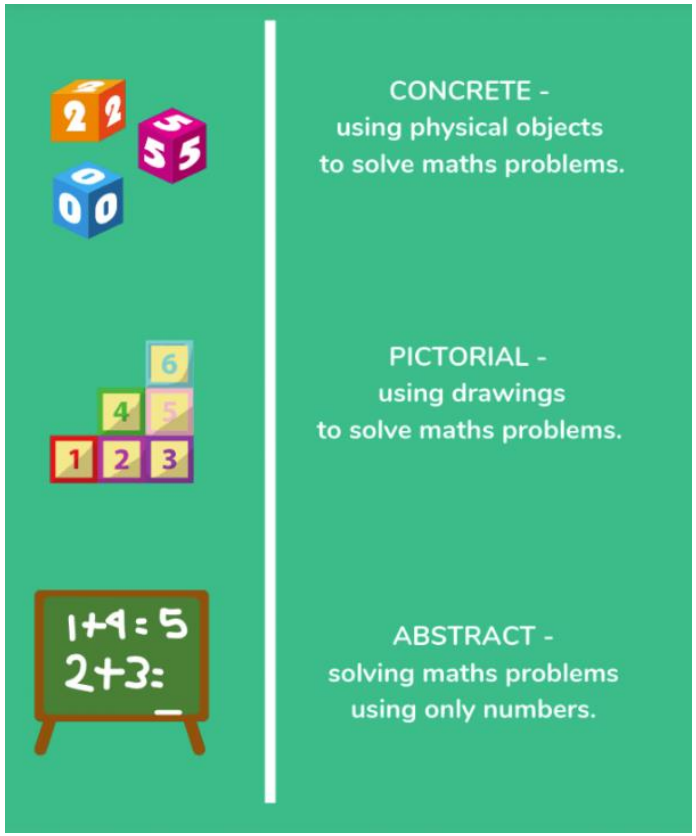


Figure 3: Bruner's CPA Approach [10]

Mathematics Games and Activities

John Gough, in 1999 defines a game as an entity that needs to have 2 or more players, taking turns to achieve a winning situation by making logical decisions, unlike in snakes and ladders, where winning relies on chance. [13]

However, Oldflied describes mathematical games as 'activities' that include the following:

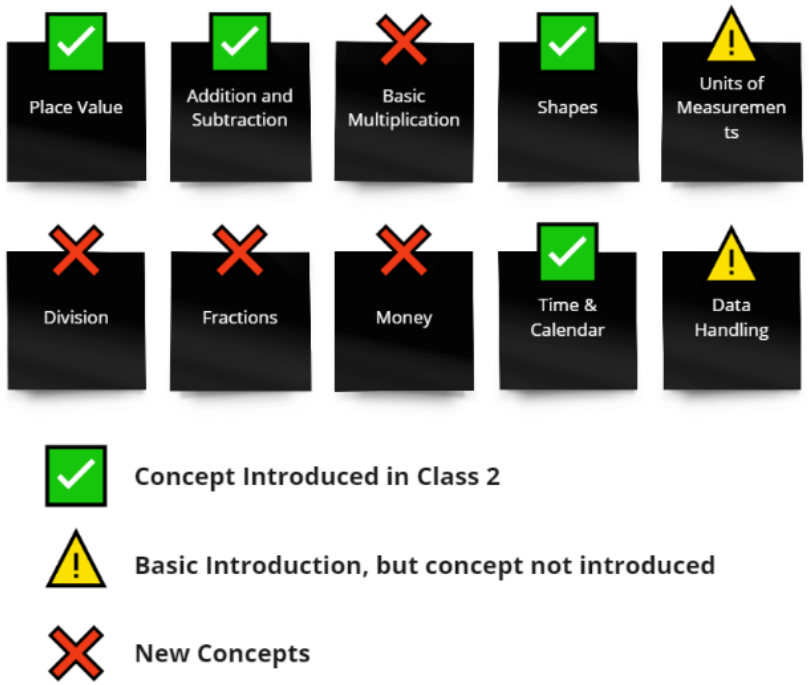
- Involve a challenge against one or more opponents
- Have a set of governing rules
- Have a distinct finishing point
- Have mathematical cognitive objectives

According to this, snakes and ladder can be described as a mathematical activity, if we replace snakes by equations resulting in forward or backward movement.

Aldridge and Badham, in 1993 present some tips that help in making successful classroom mathematical games. They argue that games should fulfil specific purposes along with an element of chance so that the weak students feel that have a chance of winning. [13] They further propose changing the mathematics, rather than changing the 'rules' in a game. They also propose that games act as a good means of making the child do homework and apply the concepts learnt during classroom activities. [13]

Existing Knowledge with Students

The chart shows the different core concepts of Class 3 Mathematics (as present in NCERT-III).



The following diagram maps the existing knowledge that a student has in Class-2 as per the NCERT Textbook, to the curriculum used in 2 private schools of New Delhi.

The broad topics covered in NCERT Class 2 are as follows:

- Identifying Objects, Counting in Groups
- Value Estimation
- Patterns
- Measurements (Only Estimation)

- Calendar
- Basic Addition & Subtraction
- Data Handling (Introduction)

A lot of repetition is seen in terms of the content that is taught. This is separated into different chapters, especially in the chapters involving measurements and time.

Further, a lot of concepts of Class 2 are already taken up in Class 1 in the Private Schools. Similarly, many topics covered in Class 2 of Private Schools exist in Class 3 of NCERT. This creates a learning gap in the students who study in schools that follow the NCERT curriculum w.r.t who study in schools that have self-curated syllabus.

Hence, it is important to understand that the lesson plans and activities that are designed need to have some degree flexibility. They should be designed in a manner such that the teacher is able to modify the difficulty based on the intelligence of the students, keeping the conceptual understanding the same.

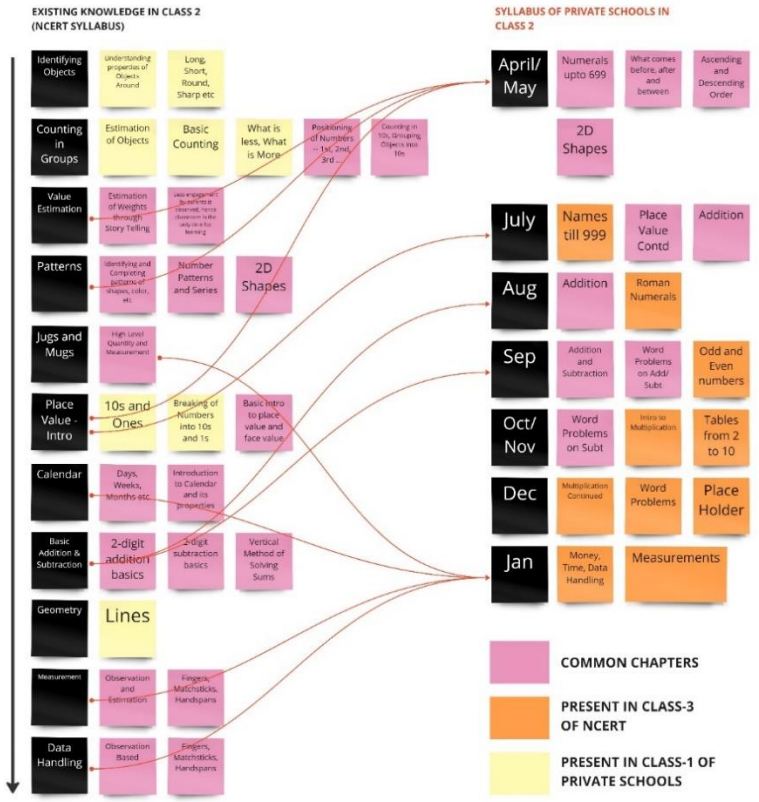


Figure 4: Overlaps between topics as seen in classes 2,3 and 4

Primary Research:

Primary research was done in 2 parts: The purpose of the first was to understand the current pedagogy of Mathematics in schools. For this study, 5 different schools of Delhi were visited, with the following aims in mind:

- Interact with Teachers to Understand the common areas of problems
- Understand the Teaching Methodology they use
- Understand the Behaviour of children towards learning Mathematics, and which approach suits them the most
- Understanding the Breakdown of a 40-45 min session (How much time can be given to an activity?)

The second part was a 8-day (7 session) study in the Kendriya Vidyalaya School (IIT Bombay Campus). This also served as a pilot test for the study, where it was observed how students interacted with the activities, and the responses were quantitatively recorded. The aim of the pilot study was to gauge the difficulty level of the designed activities, understanding the role of the instructor in them, and to check whether teaching via activities is sufficient for Practice Questions.

Part 1: Interactions with Teachers and Observing the Teaching Environment

For the purpose of knowing the current pedagogy of Mathematics in Indian Schools, I visited the following places: (1 govt school in Haryana, 2 MCD Schools in Delhi, 1 Private School in Delhi, 1 International School in Gurgaon). The following figure shows the teaching practices in the schools:

	WHO	HOW
MCD School	2-3 teachers teaching multiple Subjects	NCERT Book Exercises, Real-life objects
Delhi Govt. School	TFI Volunteers & Head Teacher	Concrete Exercise Lesson Plans, Group Activities, Use Book as a reference
Village School in Haryana	One teacher teaching all Subjects	NCERT Book, No Notebook
Private School (Non-International)	Different Teachers for diff. subjects from Class 2	Different Book, Mainly Sums, 3-4 activities per semester
Private School (International School)	Different Teachers for diff. subjects from Class 2	Proper Lesson Plans, Digital Media, SHIN, VUCA, Ph.E

Table 1: Table showing teaching methodology used in the schools visited

In this study, I observed 2-3 sessions of Maths classes being conducted in each school. Further, I also talked to the teachers and tried to understand the existing gaps, and the difficulty an instructor faces while teaching the new concepts to the students. Notebooks of some students was also checked to find a pattern in the mistakes, highlighting a conceptual failure.

Problems Identified and Observed:

- The text in activities is too much, often making it a grammar exercise
- Group Activities often lead to fights amongst the students. 2-student pair works well.
- Terminology such as 'More than', Less Than are problematic in some schools. (Mainly MCD and Public Schools).

However, language was not a problem in the International Schools.

- Language was seen as the major problem in the Haryana Govt School, where students could not even understand Hindi. However, this was not a problem in any other school.
- Activities should not consume more than 30 mins of the time, since an average class functions for 40 mins, out of which, 5-10 mins are wasted
- In activities that involved the entire class participation, a few students gave all the answers, despite being asked not to. This reduced the participation of many students**. Here the role of the instructor becomes important to ensure equal participation.**
- It happened that activities took too much time in a class, leaving no margin for doubt clearing**. One solution is to make group activities that involve intermediary discussions.**
- Only activity-oriented learning might leave very less scope for practice
- At times, there are too much activities, hence the teachers do not know what is beneficial for the students, and what is not. **Hence the goals of every activity is to be defined.**
- Less engagement by parents is observed, **hence classroom is the only time for learning for many students** (specially in MCD and Public Schools)

- **Some concepts that were universally difficult to understand are: Place Value, Fractions, Horizontal Addition, Conversion Scale in Measurements**
- Teachers often face difficulty to convert the syllabus into Concrete Activities (Real-Life based) in terms of Evaluation. Even though they try to create their own activities based on the syllabus, **they find it difficult to set up evaluation parameters for the same**

Different meaning of Concept

In 4 schools, the topic of 'Money' was being introduced. The teachers said that 25% of students do not understand the concept. However, it was interesting to note that the meaning of 'concept' differed in the schools.

School 1: Village School in Haryana	25% students do not understand 100p is 1 Rupee
School 2,3: MCD School in Delhi, Private School in Delhi	25% students can not write 12.50 as 12rs 50p, but they can operate if given individually; Students write 120p and not 1Rs 20p
School 4: International School	25% students can not add 33.75 and 134.45 using horizontal addition; They cannot identify Dollars and Cents

Table 2: Table showing the meaning of concept in different schools

This shows that on an average, there are 20-30% of the students, identified as 'late-bloomers' in the class. However, this term is relative and contextual. For example, all the students of School-1

might be considered late-bloomers in the setting of School-4. Hence, a fixed Lesson plan might not be the solution for everyone, we need to provide a degree of flexibility in it. Templatization with a set of guidelines seems an even better option now.

Part 2: Conducting Teaching Classes and Pilot Study

The second part was a 7-session study in the Kendriya Vidyalaya School (IIT Bombay Campus). It was conducted from 15th Feb 2023 to 23rd Feb 2023. Being a later stage of the academic year, most of the topics had already been covered in the schools. Hence, the pilot study involved more of 'Revision of Concepts' rather than teaching new concepts altogether. Here, we tested different activities for the same concept to see what works and what doesn't.

The goals of this study were:

- Find out the difficulty level of designed activities
- Understand the students engaging with activities
- Finding out how structuring of sessions can be done

Sessions Plan

Sessions	**Objective**	**Activities Done**
Session 1,2	To observe how the students participate in class. Identify the difficult concepts by engaging in the revision process and clearing doubts	Set of Revision questions modified from NCERT textbook
Session 3,4	Testing out Activities on the Topic of 'Multiplication & Division'. Quantitative assessment on the number of Questions we could give out for practice in 35 mins	Activity-2 was tested out with students. Active participation was noted quantitatively.
Session 5	Simplifying Activities, and testing it out again. Checking for Concept Clarity by Quantitative Assessment.	Activity-3 was performed. The results (number of students who could solve them) were noted.
Session 6	Revision of topic: Money	Roleplaying Activity with fake currency and Making Accounting Chart of a Shopkeeper's Day
Session 7	Understand if the activities worked	Quick Revision of Topic with special focus on some identified students

The framework for these activities was designed directly using the OUIBR Framework, where for every activity, there would be a part related to Observation, Understanding, Ideate, Build and Reflect based on the identified concepts.

The activities can be found here. (link to activities)

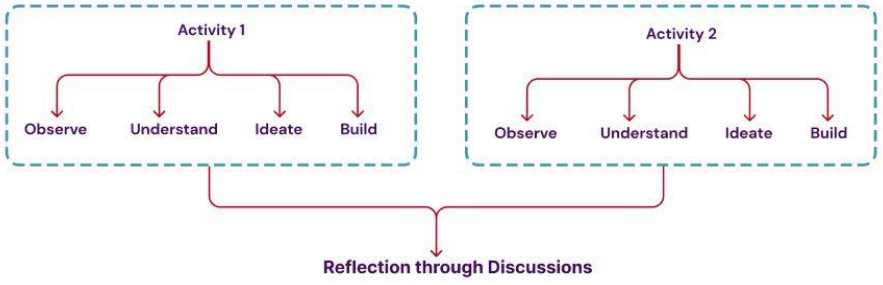


Figure 5: Basic Framework for this session. Each individual activity incorporates phases of Design Thinking

ACTIVITY-2 (Revised Version)

- This was more inclusive and required the students to reach a give number using a set of dice.
- 2 dices were made- one odd, and other even.
- Starting with 1, you select a dice, roll it, and then perform a necessary operation **(Addition, Subtraction, Multiplication or Division)** on the number to move forward or backward and try to reach the given number.
- Solve the Questions as they come in the notebook
- **Try to reach the target number in the least steps possible (Start with 10 points, deduct 1 for every dice rolled)**
- **Bonus points if you cross the BONUS NUMBER (Add this to the final score)**

Observe	Understand	Ideate/ Explore	Build	Reflect (Instructor's Role)	Concept Learning
Studens Observe the Number that they have to reach. Example 12.	Students roll a number and decide if thtey want to move forward by Addition or Multiplication.	They ideate different sets of routes they can take to reach 12. Example (1 x 4 x 3, or 1 x 2 x 6, or 1 x 4 x 3 etc)		Instructor should encourage the students to think out aloud their ideas/ routes before selecting the dice to roll	Understanding that a number has many factors
Studens Observe that some numbers can be reached through multiple ways	They understand that some numbers can come in multiple TABLES	Students attempt to reach the desired number in the lowest number of moves possible		Instructor should explain how the activity is similar to such questions	They realise it is the solution to __ x __ = N type of problem questions
Students observe the properties of Numbers while dividing	Odd / Odd = Odd Odd / Even = not possible Even / Odd = Even Even / Even = Odd				Basic Multiplication and Division Property of Odd and Even Numbers
Students observe the Grey Colored Numbers	They understand that they cannot reach these numbers throughout the game by multiplication			Instructor to Prompt about the grey numbers	The concept of PRIME numbers in explained by the instructor
Students observe that they have to move to a Large Number (Example 32)	They understand moving forward by Addition ONLY will take more turns than moving via multiplication			Instructor Observes the movement pattern and gives suitable hints as to why use multiplication.	Repeated Addition & Repeated Subtraction
Students observe if the bonus number is Before or After the Target number		They premediate the operation to be used. They also figure out if the target can be reached within 10 turns. Arer they willing to take a risk?		Instructor prompts to reach the bonus number in the smallest steps possible. (Multiply!)	Application of Multiplication Tables

Advanced Learning: Challenge Modes

- Reach a lower number with the Bonus being set at a higher number. (Example reach 12 after passing 48)
- Set the bonus number as a PRIME number --> Students will learn that they cannot multiply to reach it

Figure 6: Breakdown of an activity trying to teach the rules of Multiplication

Observations and Results:

Session 1, 2 (70 mins total): Revision on 'Weight Measurement' and Basic Multiplication was done over two sessions of 35 minutes each. 47 students were present. In total, 5 sets of questions were given as follows.

1. Which is More? (Estimation of Weight of 2 objects)
2. Fill in the weights of the given 5 objects. (Selection out of the given options)
3. Multiplication = Repeated addition (4 sets)
    a. 3 x 8 = 3 times 8 = 8 + 8 + 8 = 24
4. Breaking numbers into its various factors (4 sets of 4 Qs each)
    a. 48 = 12 x _____, 48 = 1 x _____, 48 = 6 x _____
5. Basics of Multiplication (From easy to tough)
    a. 4 x 9 = _____
    b. 316 x 1 = _____
    c. 7 x _____ = 42
    d. _____ x _____ = 18

A total of 26 Questions were done in 70 minutes. 11 out of 47 students successfully managed to complete all the 5 sets. (Counting was done using raised hand-counts). Most of the students (24) were on the 2nd & 3rd set of Q4. (Effectively completing 14-18 questions).

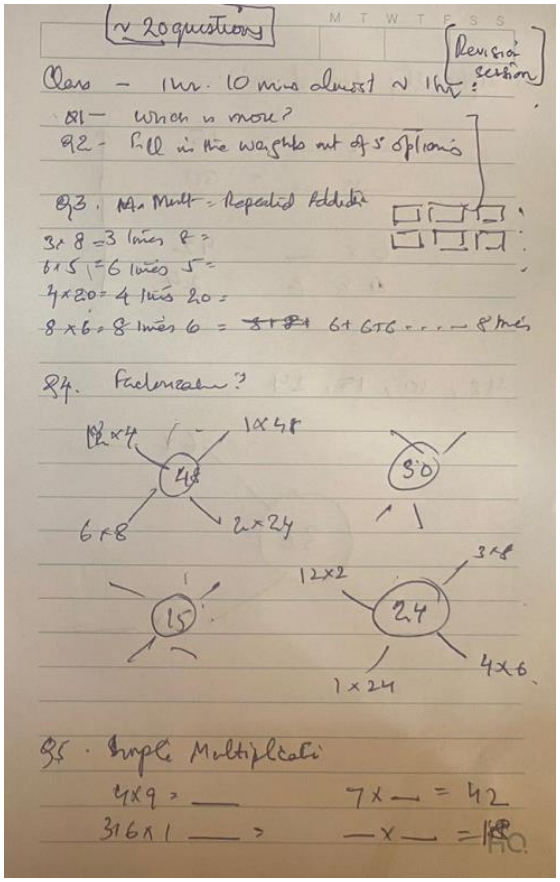


Figure 7: Sketched notes of Session 1,2

Session 3,4: Activity Testing (80 mins total): In these two sessions, 2 different activities were used to teach the concept of multiplication and division. Activity 2 was more inclusive and showed greater participation. Activity-1 seemed like a forced application of multiplication on a board game. The basic idea was to help students identify the multiples of a number quickly. (Essentially revising the multiplication tables).

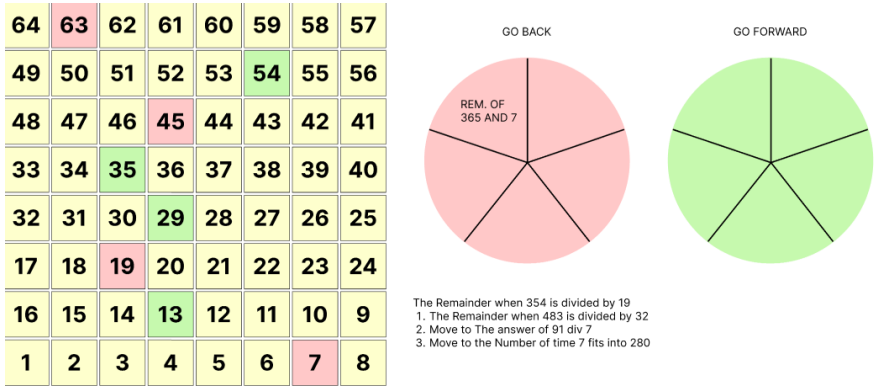


Figure 8: Activity 1 designed to teach Multiplication & Division

Activity 1: Students were asked to roll a dice and move forward. They would move additional steps by moving onto the green blocks and backward by moving onto the red blocks. However, since this required them to complete the questions first, the activity was not engaging. However, it was observed that the questions were found to be difficult for their understanding and this activity was scrapped mid-way.

Activity 2: This was more inclusive and required the students to reach a give number using a set of dice. 2 dices were made- one odd, and other even. Starting with 1, you select a dice, roll it, and then perform a necessary operation (Multiplication or Division) on the

number to move forward or backward and try to reach the given number.

100	99	98	97	96	95	94	93	92	91
81	82	83	84	85	86	87	88	89	90
80	79	78	77	76	75	74	73	72	71
61	62	63	64	65	66	67	68	69	70
60	59	58	57	56	55	54	53	52	51
41	42	43	44	45	46	47	48	49	50
40	39	38	37	36	35	34	33	32	31
21	22	23	24	25	26	27	28	29	30
20	19	18	17	16	15	14	13	12	11
1	2	3	4	5	6	7	8	9	10

Figure 9: Activity 2- The initial board and the dice

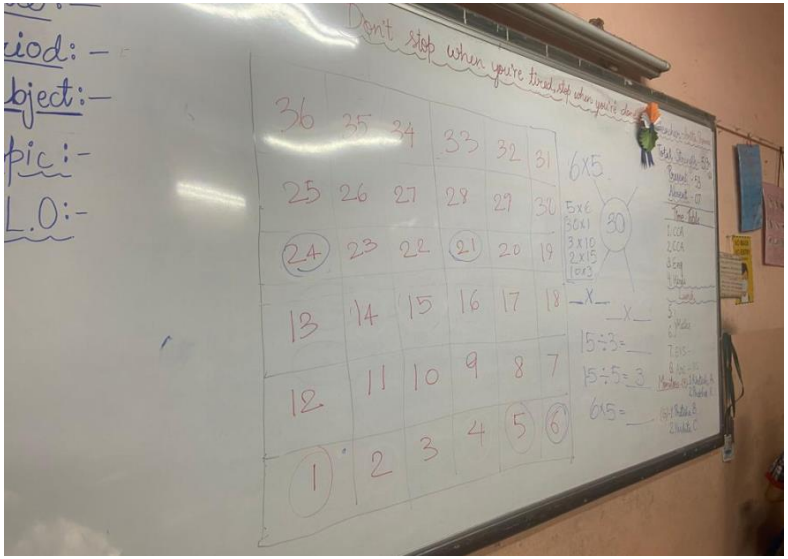


Figure 10: 6x6 grid till 36 drawn on the board to conduct the activity

For the purpose of the game, since only the concept was to be taught, the activity was simplified into a 6x6 grid up to 36.

The rounds went as follows:

Round 1: Reach 12

- Started from 1 (Selected Odd Dice)
- Rolled 3: 1 x 3 = 3
- Asked to decide which dice to take, odd or even, leading to initial confusion
- Answer comes- even, because 3 x 4 = 12
- Next Student rolled, got 4 (lucky!), we reached 12
- Students were asked to write these questions in the notebook

Round 2: Reach 15

- This time they picked up the odd dice
- Told me that 3 x 5 is 15, so we need to reach 3 first
- First Roll: 1 x 7 = 7
- Now, confusion arises, how to reach 15 from 7?
- Here, the students could not understand they need to reach a number beyond 15, and get back to the smaller number. However, the logic of progressing towards 15 was seen

Round 4: Reach 4

- Started with even dice
- Rolled 6: 1 x 6 = 6

- Since working with even numbers is easier (more multiples), they understood they can reach a larger number and divide it
- However, they were still confused whether to pick an odd dice, or even dice (6 x 3 = 12, 6 x 4 = 24....) and you can reach 4 with both
  But, now they realised that there are MULTIPLE ways to reach the same target number 4

We further conducted this activity with a few numbers. In total, 6 rounds could be completed in 40 minutes, for a total of 17 questions (Excluding the starting step in each).

Positives:

- In the first round, only 4 hands were raised to select the dice to roll
- By the 5th round, 27 students were interested in coming on the black board to roll the dice
- An opportunity was seen to include the late-bloomers by making them come up front, roll the dice and solve a question.
- By the end of the session, the students could solve the (____ x _____ = N) question comfortably with proper logic

Problems Identified:

- Since this method required a lot of back and forth between multiplication and division, it needed some quick solving.
- Students were not VERY quick at Division; hence it took them time to understand the concept of coming to a lower number.

Session 6: Revising concept of Money (70 mins)

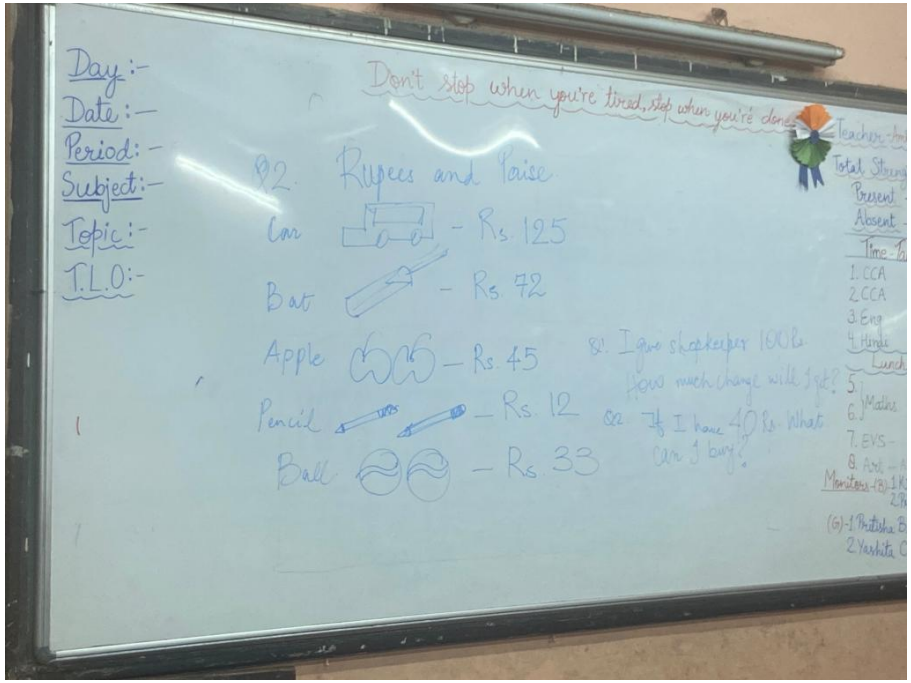
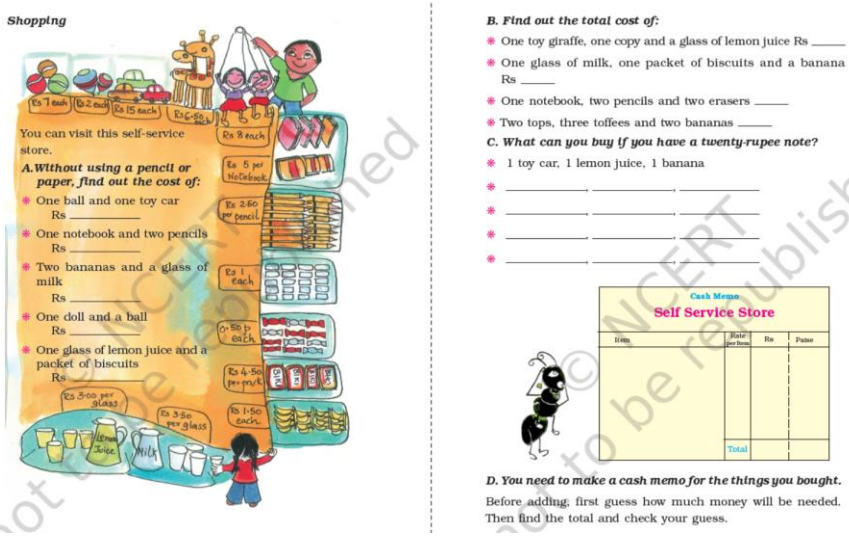


Figure 11: Testing Activity Designed for teaching the concept of Money

To teach the concept of money through addition and subtraction, we started by conducting a Roleplay session where students were asked to put 5 items on display in their shop with their prices. 5-6 examples were performed where the students were given some

money, and they were asked to buy the listed items. This activity was designed by slightly modifying the existing activities in NCERT textbook.



Shopping

You can visit this self-service store.

A. Without using a pencil or paper, find out the cost of:

- One ball and one toy car Rs _____
- One notebook and two pencils Rs _____
- Two bananas and a glass of milk Rs _____
- One doll and a ball Rs _____
- One glass of lemon juice and a packet of biscuits Rs _____

B. Find out the total cost of:

- One toy giraffe, one copy and a glass of lemon juice Rs _____
- One glass of milk, one packet of biscuits and a banana Rs _____
- One notebook, two pencils and two erasers _____
- Two tops, three toffees and two bananas _____

C. What can you buy if you have a twenty-rupee note?

- 1 toy car, 1 lemon juice, 1 banana
- _____, _____, _____
- _____, _____, _____
- _____, _____, _____
- _____, _____, _____

Cash Memo

Self Service Store

Item	Rate per Item	Rs	Paise
	Total		

D. You need to make a cash memo for the things you bought.

Before adding, first guess how much money will be needed. Then find the total and check your guess.

Figure 12: NCERT textbook exercise involving money

Here, we conducted similar exercises but in an experiential way, using a constructivist approach. They proceeded as follows:

1. Students were called and given Random fake cash. They were asked to identify what all objects they can buy from the prepared list. They were encouraged to engage in a conversation "I want 2 pencils"
2. Students were given less cash and asked to buy a costlier commodity. Then they went to the parents to get some extra money to buy their favourite item. They were encouraged to ask "I want 22 more rupees to buy a cricket bat". Essentially, we applied word-problems in the form of a roleplay.
3. One student was asked to become a shopkeeper, and 4 sets of students acted as customers. They were given different money and were asked to buy and collect cash back from the shopkeeper. A memo was created in the end, that the students had to solve.

Customer	Objects Bought	Cost	Money Given	Change
Cust 1	Pencil	Rs. 12	50 Rs	Rs. 38
Cust 2	Pencil	Rs. 12	20 Rs	Rs. 8
Cust 3	Bat, Apple	Rs. 117	150 Rs	Rs. 33
Cust 4	Apple	Rs. 45	50 Rs	Rs. 5
Total		Rs. 186	Rs 270	Rs. 84

Figure 13: The account memo created at the end

In total, we were able to solve 21 questions in 45 minutes, including the time spent in roleplaying.

Figure 14: High engagement observed during the sessions

At the end of the session, the students were asked about their approach in solving the questions. Almost all the students added the individual cost of the items to find the total earnings of the shopkeeper. None of the students Subtracted the Total Money and Change (270 – 84) to come up with the answer, possibly because of the way they had already been taught these concepts.

This further highlights the role of the instructor in teaching the concepts, where the students should realise that there are multiple ways of coming up to a solution. This is possible by the process we use in Design Thinking, where we actively engage the students in problem-solving by creating an experiential environment.

Concept Errors identified:

- Some calculated the earnings as Rs. 270. They did not account for the returned change to be deducted. Hence, this comes up as a problem of language (meaning of return) instead of addition.

Session 7: Revision of the Concepts (~ 20 mins) : The final session involved a verbal discussion with the students. This did not include any question solving, but was an attempt to see if they understood the concepts that were applied in the previous sessions. They had to justify their reasoning. The following observations came out:

Question/ Observation	**Reason/ Recall**
We cannot divide an odd number with an even number	We selected the odd dice when we had to reach 5 from 15
___ x ___ = N can be written in multiple ways	We could reach 12 in multiple ways in the game
Do all numbers give a whole number on division?	No, we had to re-roll the dice on several instances
Why can't I buy a bat (Rs. 72) if I have 2 notes of Rs. 20?	Because 40 is less than 72, we need to borrow more money

It was also important to note that more doubts also emerged after these sessions during the discussion. The best way to solve these

doubts, however, was seen using the behaviourist approach of teaching them the necessary rules.

Learnings and Limitations identified from Pilot Study:

Learnings:

- The role of the instructor is immense. It was observed that the methods the teacher used to teach were the ones the students finally adopted, even when asked to think out of the box.
- In the Pilot, we had to test out 3 different activities to teach a concept. It was not easy to design these, as our learning scale is beyond the proximal zone of the students which resulted in a lot of time wasting.
- It is a good idea to modify the existing activities of NCERT itself into a more experiential activity, that helps in 'recall' and effectively greater understanding.
- Instead of designing a completely new activity (or a game), modifying same activity resulted in More Practice questions per session.
- Students actively asked more doubts

Limitations:

- The pilot study was conducted in February. This was the time when the curriculum was completed, and learning was going on. Hence, it cannot be concluded whether the students would have engaged in the similar way had they not known the basics beforehand.
- More quantitative evaluation is necessary, this session was more of a qualitative nature.
- Owing to the examination schedule of the classes, a detailed study involving practice questions at the end of the study could not be conducted

The limitations, however, were taken into consideration when we conducted the Second round of Study with a revised Lesson Plan.

Feedback and moving forward in the project:

In the pilot, activities were taken and moulded into the OUIBR framework. Although the activities served their purpose, at times, their design and implementation seemed forced. When these activities were designed, every step of OUIBR was attempted to be incorporated in them. The feedback from jury also pointed out the following:

- Not all concepts need all Design Thinking Steps
- Some steps of Design Process seem forced into the activity
- Instead of keeping all the Design Thinking steps in a single activity it would be better to design activities that focus only on certain steps of design thinking
- Are the students understanding the activity rules, or the concepts?

- It was also noted that Reflection is something that the instructor would need to facilitate, and would be needed after every stage of Design Process

Redesigning the Sessions

Not all activities and teaching methods could have all the steps of OUIBR Framework. Certain concepts required more of Observation and Understanding, than the ideations. Hence, moving forward, it was decided that the sessions would be designed in such a way that over a period, students first Observe and Understand the concepts, and then apply them in the form of a related activity instead of trying to force all the steps in one activity. Reflection through either Discussions or Exercises would follow every session. We also adopted Kolb's Experiential Design Framework in it.

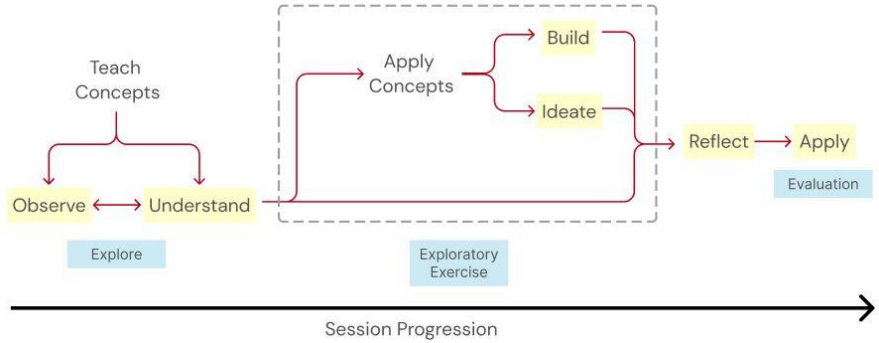


Figure 15: Revised structuring of the Framework after Feedback

To test the effectiveness of this approach, we designed a summarised lesson plan with more structured activities.

Structuring of Classes

The lesson plan would be designed to be completed in a week (6-7 sessions). Based on the Pilot Study, feedback and research, the activities for the identified concepts were designed. They tended to provide a concrete experience. We kept the textbook exercises for Home-Activities and provided a doubt clearing session for them. The activities provide a concrete experience after which some time was kept for discussions.

Topics and Concept Selection

We already identified the 10 major concepts in the beginning. However, it was important for us to test the design of the session before defining a framework. We got the permission to conduct Evaluation in Kendriya Vidyalaya, IIT Powai in the month of April. Chapters 1,2 and partly 3 of NCERT Class 3 were enlisted in the school's curriculum. Hence, we focused on designing activities on these topics.

Chapter	Title	Concepts
1	Where to Look From	Symmetry & Axis, Mirror Images
2	Fun with Numbers	Place Value, Grouping of Numbers, Number Series
3	Give and Take	Basic Addition & Subtraction

Features of Lesson Plans

While designing the Lesson plan, we kept in mind the following aspects with respect to Activity-Design and Learning Objectives:

Activity Design:

- **Adequate Complexity:** The activities can be moulded to match the necessary complexity as per the learning capacity of the class. They should be complex enough for a Class-3 student to understand. These were discussed with the teachers of Class-3 before testing out.

- **Class Activity:**
    - **Observation Based**: These are experiential activities designed in a manner that students observe certain concepts, like seeing a fold on a shape to understand the concept of Axis. The teacher conducts these activities, however prompts the students to share their findings in group discussions. Further, these would not be given as Homework.

    - **Ideation Based**: These served as application of the observed concept. Here the instructor acts more as a facilitator of knowledge and merely helps the students get started. Although these are open-ended, to successfully complete them the students must apply the concepts learned. These can be continued as Home Work if not completed in class.

Specifying Learning Objectives:

- Understanding the concepts being taught, first in an experiential manner, and then in an abstract way

- Applying the concept that was taught in a real-life scenario, or an activity/ application that requires cognitive thinking

- The learning objects also help the instructor to prompt the questions that would facilitate discussions

- Broadly, the concepts taught would make the students adept at the following, wherever applicable:
    - Mental Maths
    - Word Problems
    - Abstraction of Numeric Operations

Content of the Lesson Plan

For the purpose of evaluation, at this stage only a summarised lesson plan was designed. However, in the end we designed a detailed Lesson Plan including:

- Information manual
- Defining the Instructor's Role
- Session Plans

- Activity Work Book
- Framework/ Template to design own Sessions

We did not make the theoretical content since that is already available in NCERT text book. The content of the activities designed was referred from the text book.

Lesson Plan: Patterns & Mirror Symmetry

Time: 1 Week (7 sessions, including 1 double period)

Placement in Curriculum: While ending chapter 1, or at the beginning of Chapter 5 (NCERT 2023)

Overview: In this, the students will be made aware of basic shapes and patterns. They will be introduced to the concept of mirror symmetry.

Link to Summarised Lesson Plan

Concretising the Abstract: Before the start of every lesson plan, we tried to identify how we can make an abstract concept experiential for the students.

Abstract	Concretising
Symmetry	Observe that symmetry is formed only on COMPLETE overlap of the given cut outs
Axis	The creases we observe on folding papers are similar to axis. The crease that gives a complete overlap on fold is the axis of symmetry
Mirror Image	Using a hand-mirror to experience shapes directly in mirror and observe its properties by making changes

Session	Topic/ Concept	Task Summary
Session 1 (40 Mins)	Underestand Basics of pattern: Dots connect to form Lines, Lines Connect to Form patterns and Shapes To understand the meaning of words such as: Top, Bottom, Side, North, South, East, West	• Students join dots to form lines, and lines to form pattern as drawn by the instructor on the board • Using NCERT book and using objects in the classroom, the instructor draws on the board and asks students to identify the viewpoint of the objects **Instructor's Role:** Encourage students to use the target words while saying their answers
Session 2 (40 Mins)	Understanding symmetry in basic shapes: Traingle, Square, Rectangle, Circle, Hexagon, Heart, Star, Trapezium **Observe:** Some shapes can be made into equal halves in multiple ways, while others cannot. **Understand:** Symmetry means when the two halves can be FOLDED exactly on top of one-another	**Requirement:** The students ask their parents to cut the given shapes: Traingle, Square, Rectangle, Circle, Hexagon, Heart, Star, Trapezium • Instructor makes 2 groups on the board: single symmetry, multiple symmetry. At the end of the session, the students identify which shapes come under what category • Students asked to observe the Shapes and Fold them to make equal halves. They observe the crease(s) formed • Students asked to come on board and draw their shapes with the dotted line (example square can have vertical and horizontal dotted line)

Figure 16: Part of the Summarised Lesson Plan for Symmetry

Activities Designed: Below is a brief of the activities designed, the details can be found here. (Link to activities can be found here) It is to be noted that they were modified after the feedback for the final lesson plan.

1. **Fold and Observe:** Folding the given shapes and observing its creases to identify the axis in a symmetric shape.
2. **Drawing Mirror Halves:** Students draw a pattern on a square-grid pad, place a mirror and observe the pattern formed in the mirror
3. **Symmetry in complex figures:** Learning Axis and symmetry in alphabets and other shapes
4. **Weaving:** Exploring symmetric patterns through weaving

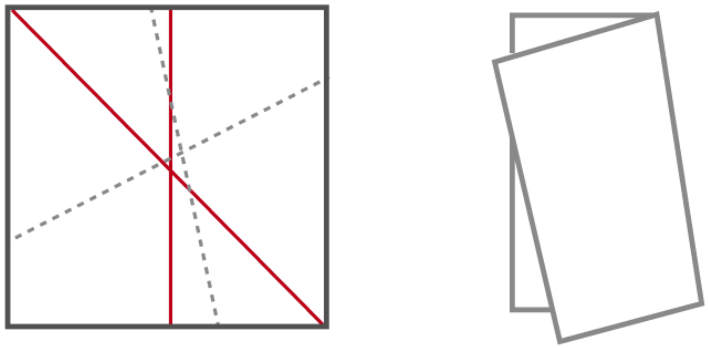


Figure 17: Activity 1- Fold and Observe

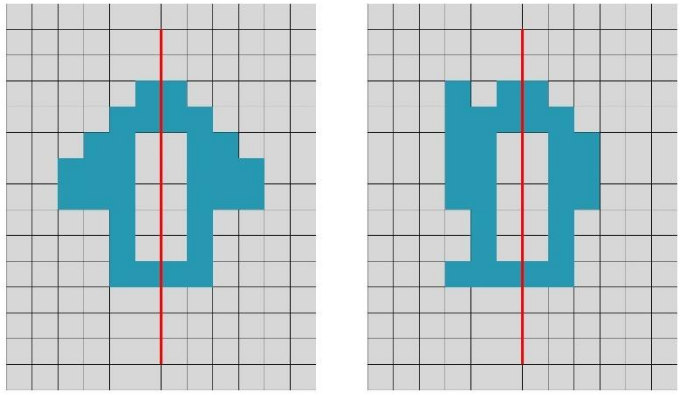


Figure 18: Activity 2- Drawing Mirror Halves

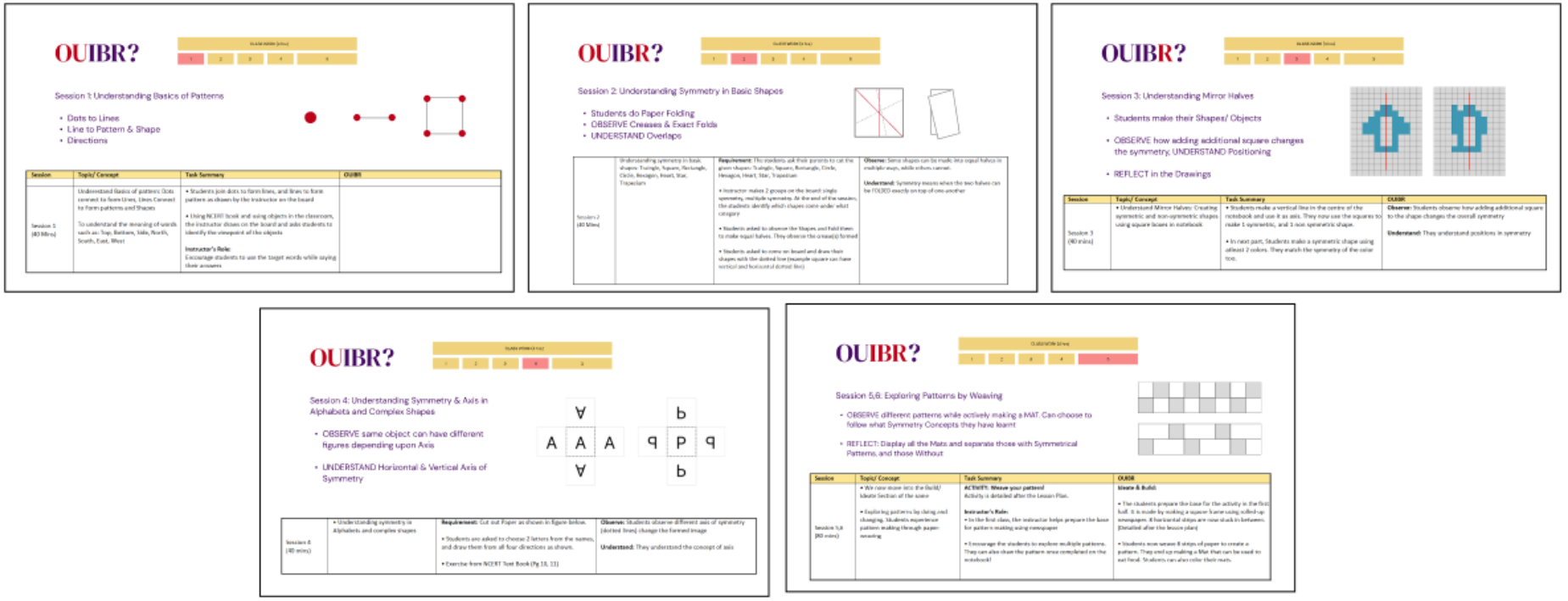


Figure 19: Activities as designed in this Lesson Plan for Symmetry (before revision)

Lesson Plan: Fun with Numbers

Time: 1 Week

Placement in Curriculum: While Teaching Chapter 2 (Fun with Numbers) and before Chapter 3 (Give & Take)

Overview: In this, the students will be made aware of Place Values. Further, they will understand how grouping of numbers leads to addition.

Link to Summarised Lesson Plan

Concretising the Abstract:

Abstract	Concretising
Place Value	Students hold digits and move from one place to another physically to understand 'Places of Digits'
Grouping of Numbers	Already much explored concept in literature, the best way is to make bundles on 10, 20, 30 and so on to move from one Place Value to Another
Number Series	Make students stand and sit on their seats to replicate a number series

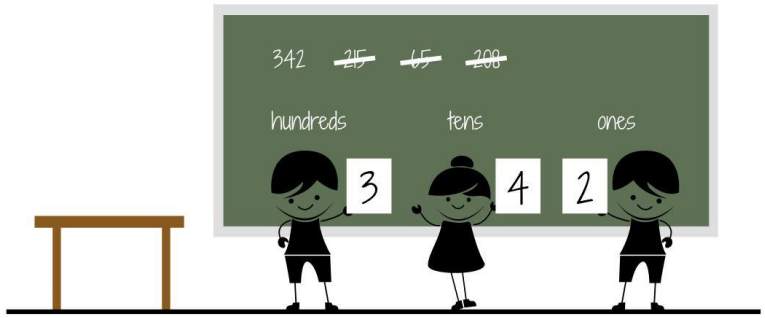


Figure 20: Image showing use of Number cards to learn the Numeric System

Activities Designed: Below is a brief of the activities designed, the details can be found here. (Link to activities can be found here) It is to be noted that they were modified after the feedback for the final lesson plan.

1. **Move Around:** Students are given digit cards and place values are written on the board. They move around to form the number as instructed

2. **Group Them:** This is a group exercise where the students learn conversion of ones to tens by grouping sticky notes into groups of 10.

3. **Quick Addition:** Students make a shape using blocks given as points. As they add blocks together, they are adding the respective points to get a total sum.

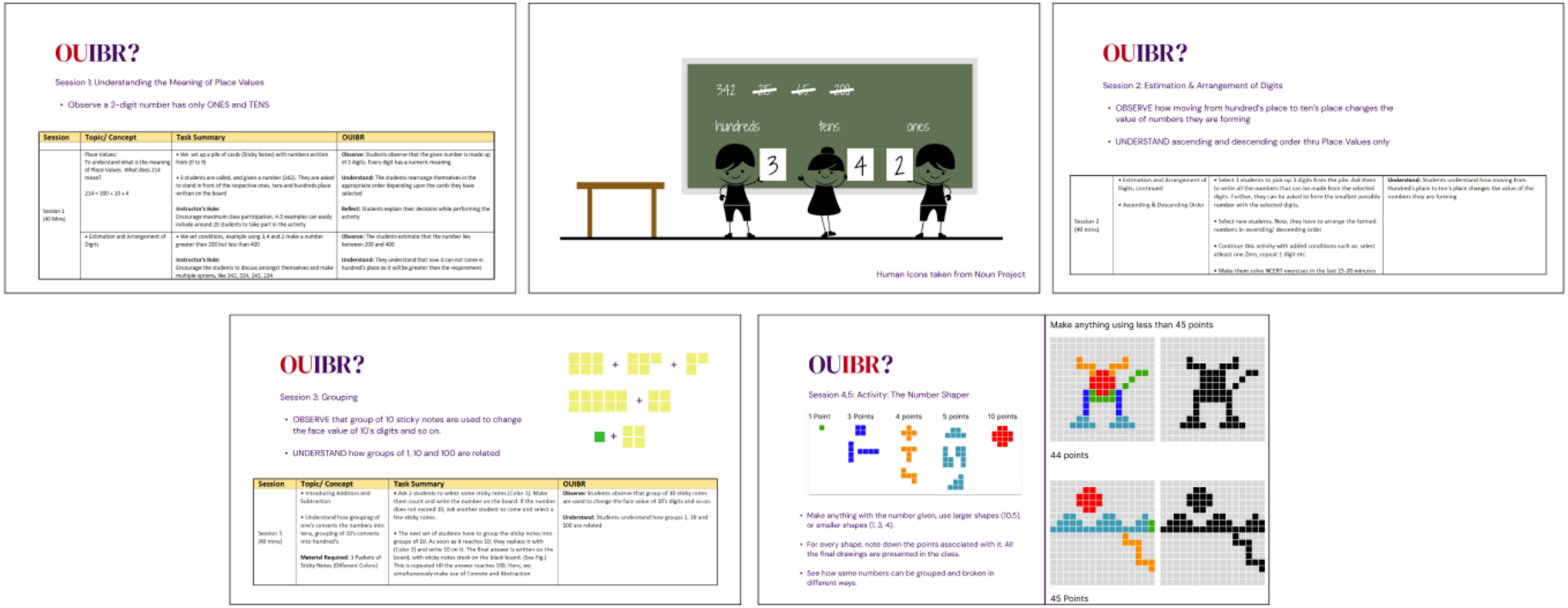


Figure 21: Activities as designed in the lesson plan for Place Value and Numbers (before revision)

Evaluation Plan

Before Evaluation, we also discussed the Lesson Plan with domain experts and removed/ modified certain activities (Link to Revised Summarised Lesson Plan). We also kept in mind the following while evaluating:

1. Overall Engagement shown by students in the class
2. Response to Activities (Difficulty and ease of understanding) and whether they helped in teaching the concepts
3. Overall Evaluation Results through an Exercise

Expert Evaluation

Before testing the lesson plan with students, it was discussed with the domain experts. (Maths teachers from 2 private schools in Delhi NCR, and Interaction Design Faculties) The discussions were as follows:

- **Activity Design:** Some schools might not be able to complete all the activities in the given time, hence you may reduce some in the final lesson plan. The content seems adequate for Place Values, but it seems too much in the Symmetry Lesson

- **Content**: You can limit the activities to only 2. Keep activities less, and give more time to do them. Keep it such that the instructor does not have to think about multiple activities while making the lesson plan in the future.

- **Make the session plans easy to understand and offer some flexibility** in them specially while doing activity sessions. Eg- 10 mins for briefing might not work everytime, instead give a 40 minute complete session with a defined flow.

- **Observe and define the role of the instructor:** The purpose of every activity should be clear in the instruction manual. The instructor should also know when to stop an activity/ session if it is not going as per the desired goal.

- **Ideal Teaching Methods:** To get a better understanding of whether the lesson plan is working or not, do teach the same concepts using the existing teaching methodology also, and compare the results.

- **Cannot get rid of Theory:** Teachers also pointed out that in will not be possible to get rid of theory to explain certain concepts. **Hence, we added another method of testing, where Experience was theoretically guided.**

While designing the lesson plan inclusion of the following was suggested:

- Add instructions and visuals in you lesson plan showing how activities will be done

- Activity book for the students where the pre-requisites of these activities are given. (If parents want, they can also do the same at home while teaching the students. Plus, there will be consistency throughout)

- Include backup for Theory if desired lesson plan does not function as intended. Some also emphasised on the fact that we need to have theory while making the students explore the activities itself.

Evaluation of Lesson Plan by teaching Students

Conducting the Pre-Test

Once we had prepared an outline of the evaluation, we conducted a Pre-Test of about 40 minutes in which we tried to understand the current knowledge with the students.

Topics	Observations
Directions	Students were aware of the directions N,E,S,W. Although they could identify the objects from these directions, it was tough for them to draw it.
Mirror Half	Majority of the students were unaware of the meaning of Mirror Half. They knew that Mirror replicates anything kept in front of it. However, they did not know that images are reversed.
Symmetry & Overlap	Completely new concepts to them. They knew what 'Fold' means, but were unable to relate it with overlap.
Shapes	Students were aware of basic shapes- circle, square, rectangle, oval, triangle

Pre-Test Observations for Place Value and Numbers

Topics	Observations
Place Value and Face Value	Students were unaware of the term Place Value or Face Value. However, they know the meaning of Ones, Tens, Hundreds, Thousands etc. Conceptually, they were unaware that 2 in Hundreds means 200 and 2 in Tens means 20.
Basic Addition and Subtraction	Students could add 2-digit and 3-digit numbers. However, one surprising observation was that they were having trouble calculating simple sums such as 2 + 5 when asked to do mentally. We played a game called boom, in which we start with 1 and the next person adds 2 to it, the subsequent person adds 2 and so on. A lot of difficulty was observed in it, specially when the numbers went from ones to tens.
Number Series	Students could not identify number series. It was challenging for them to complete a series of 21, 24, 27, 30, 33

Word Problems	Most of the students could not solve the questions that involved 'more than', 'less than' etc. The problem of 'What is 10 more than 25' was assumed to be a comparison of 10 and 25. (Students answered with 'NO' thinking that 10 is less than 25 instead of answering 35.)

Teaching Methodology

We taught the students in 3 methods. We took 3 different sections. To see whether the process that involves Design Thinking makes an impact, we also taught one section using traditional theory method that was practised in the school. The concepts taught however were the same for all three sections.

Class A: This approach was done using the traditional behaviourist methods. The concepts were taught, and evaluation were to be done on the following: (5 sessions)

Theory → Exercises → Practice → Test

Class B: In this approach, we used the Design Thinking Process based purely on Exploration, Experience and Discussions as part of reflection. (7 sessions)

Exploratory Exercise → Discussions → Test

Class C: In this, we first started with an exploratory exercise, but before giving them exercises, we taught them the theory, with reference to the exploration they had done. After this, we had further exploratory activities followed by recall sessions. (7 exact sessions)

Exploration → Theory → Exploration → Discussion → Test

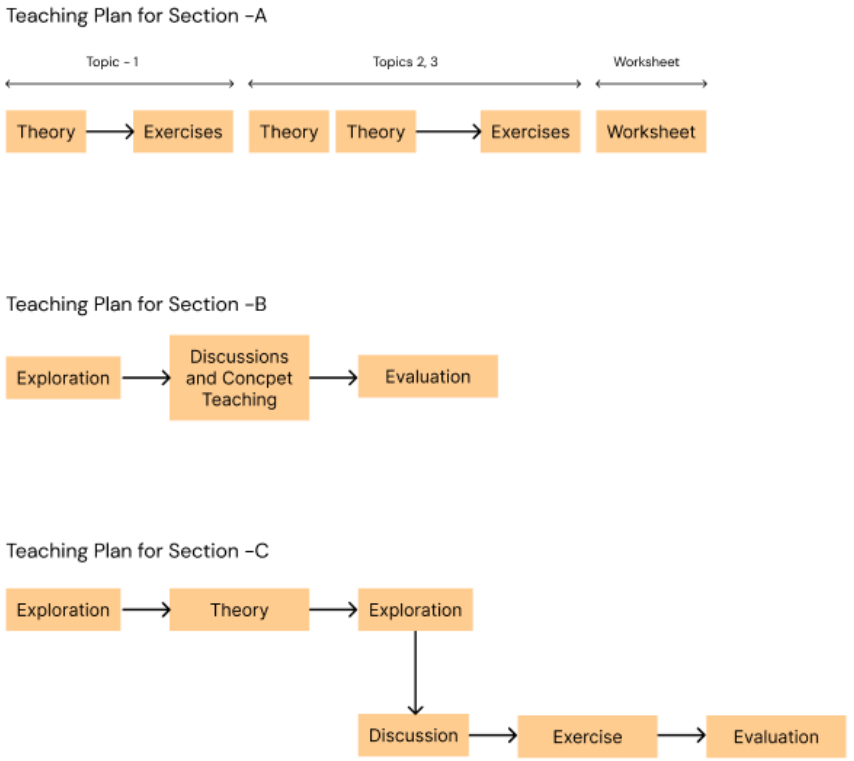


Figure 22: Teaching Methodologies Adopted for the same learning goals

Detailed evaluation notes are attached in the appendix.

Link to detailed evaluation in the report is here.

Qualitative Observations:
Qualitative observations were tabulated below. Observations from the teachers helping me conducting the sessions were also noted.

	Class A	Class B	Class C
Method of Teaching	Existing teaching Methodology followed by school. First ONLY Theory, then NCERT exercises based on it.	Teaching using only Experience based Activities as shown in the process above, followed by subsequent discussions	Teaching using some Theory as part of the Observation and Understanding of concepts, along with Experience based learning
Reflection Technique	• NCERT Exercises only	• Discussions over Experience based activities only	• Few NCERT Exercise (HW) • Experience based discussions in class
Engagement shown in class	• Medium level engagement • Students readily asked if they were unable to solve any question • Time wastage observed in the last 10-15 minutes	• High Level of engagement shown while conducting the activity. Less engagement shown in discussion sessions. • High Interaction while observing with mirror. • Students started talking to one another instead of participating in the discussions	• It was evident that once theory was added in the mix, the subsequent discussions were better. Highest level of engagement seen • High Interaction while observing with mirror. Requested to try it many times with different patterns.
Response to Exercises/ Activities	• Majority of the class was able to complete the exercises • Heavy doubts observed in application parts	• A lot of confusion seems to arise while beginning the exercises • Took more time to understand what needs to be done than Class-C	• Since they understood the theory, they had less difficulty in understanding the activities • Some could start them without even an explanation on the board
Observation in Discussion Sessions	• Fast learning methodology • Problems observed in understanding the concept of 'Reversed Images'	• Majority of the class had doubts in understanding the 'Positioning' property • Least participative discussions • Face Value not understood	• Relatively fast learning methodology • Highly engaging discussions since students were able to give reasons to their observations based on theory • Best understanding of application of Place Values while playing around with number cards

	Class A	Class B	Class C
Method of Teaching	Existing teaching Methodology followed by school. First ONLY Theory, then NCERT exercises based on it.	Teaching using only Experience based Activities as shown in the process above, followed by subsequent discussions	Teaching using some Theory as part of the Observation and Understanding of concepts, along with Experience based learning
Overall Time Taken	• The desired objectives could be completed in 5 sessions	• Took lot more than expected time. Some sessions had to be repeated • 8 sessions in total (9 including Assessment)	• Took expected time to complete (6 sessions) although one activity was given to be completed as homework
Worksheet Evaluation Results	• Best overall results	• Worst overall Results • Even the application-based results were worse than traditional in case of Symmetry and Mirror Lesson	• Results comparable to Class A (Traditional teaching methods) • Best results observed in Application based questions

Student Reflection for Symmetry & Mirror Images:

- If the moon was to the left of the house in the paper, it was to the right in the mirror *(Agar woh paper pe left mein tha, toh mirror mein right mein chala gaya)*
- Shapes got reversed *(Jo maine triangle banaya tha, woh ulta ho gaya)*
- Oh, this is incorrect *(Maine toh galat banaya hai)*
- This got reversed from L-R, but why didn't it reverse from Up-Down *(Ye upar neeche ulta kyun nahi hua)*

Some other observations for Place Value and Numbers

Since this was a more abstract concept, more observations were seen while teaching using the Design Thinking Process.

- The concept was difficult to explain in all the three ways -- even the behaviourist approach of teaching was difficult. However, it was easier for the students to recall when they had experienced the change in positioning themselves.
- The class that had more practice in this regard fared better (Method A since they had more practice about the term place Value and Face Value)

- The type of questions in which 'greatest', 'largest', 'least' were to be formed were performed better by the classes that had Experiential Learning.
- It is not possible to adopt this method for grouping of larger number in a short span of time
- Rearranging themselves on giving the digits was the most successful activity, both in terms of class excitement and the subsequent evaluation results
- Visibly, the students were able to arrange each other as per the place values more effectively than writing the answer in the notebooks
- In the activity of using blocks to form an image, students were not able to make a 'whole'. Example- it was tough for them to use different blocks to form a combined image, but they were able to form multiple different things using the blocks individually, as seen in the Evaluation (Appendix-1).
- It was difficult for them to form 4 numbers using 3,4,5 when asked on paper, but when given the cards to rearrange they could do it instantly.

Feedback given by the teachers who assisted me while teaching

- We saw a lot of interest shown by students who are otherwise not involved in the class sessions
- Students completed more Homework when they were incentivised with the activity to be done the following day
- Students were confused when being taught using only Experience based learning
- It might be difficult for us to prepare such lesson plans from scratch since they are time consuming
- Students are able to explain themselves once they are aware of the theoretical terms. It was difficult for them otherwise.
- One downside is that students who are otherwise capable of solving everything, they pretend to not understand the concepts in order to come upfront during the group discussions (since weaker students were called upfront to express their observations first)
- For concepts like Place Value, exploratory exercises may be helpful in the shorter run, but a theoretical knowledge builds a framework over a long time. Hence, you should include theory with every exploratory exercise.
- What about the students who miss out on these sessions due to unforeseen reasons? How will you include their teachings?

Quantitative Results:

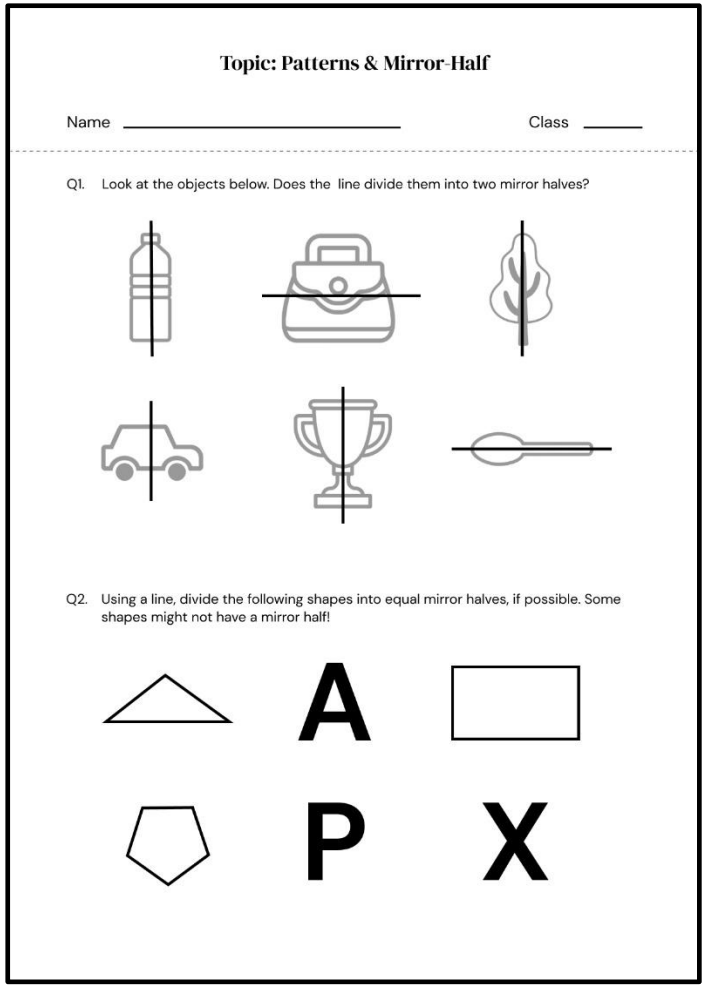
The final evaluation was assessed quantitatively. We measured how many correct and incorrect answers each of the class gave. Since the number of students who took the assignment were different, we measured the error rate as 'Error per 100 students.' We also calculated the total score achieved by students in all the three methods. The assignments for evaluation were as follows:

For Symmetry & Mirror Halves:

Objective	**Type of Questions**
Identification	Identifying whether the given shapes can form a mirror image or not
Understanding	If they can identify, can they form a mirror image on their own?
Recall	Applying the Concepts learned
Conceptual Understanding	Theory-based True or False Questions

For Place Value & Numbers:

Objective	**Concept**	**Type of Questions**
Identification	Identifying Ones, Tens, and Hundreds	Is 214 the same as 241?
Understanding	Understanding that the value of 'digits' change according to their place value	Greater than and Less than Exercises; Number Formation
Recall	Applying the Concepts learned in an abstract way	Number Series
Conceptual Understanding		Able to solve word problems having 'More than' and 'Less Than' questions



Topic: Patterns & Mirror-Half

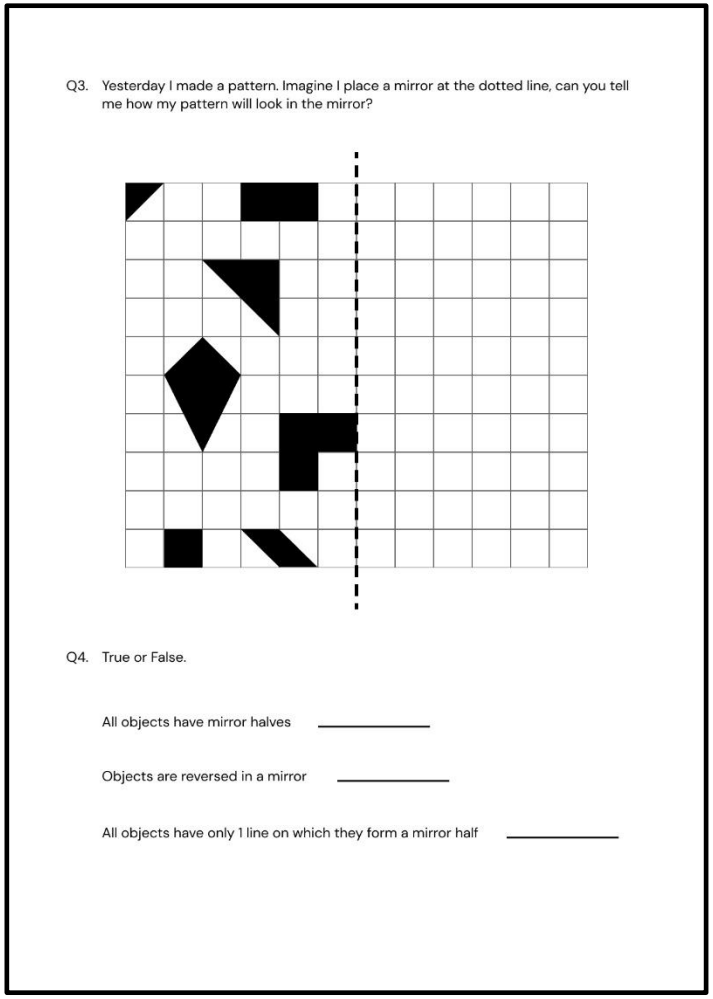
Name _____ Class _____

Q1. Look at the objects below. Does the line divide them into two mirror halves?

Q2. Using a line, divide the following shapes into equal mirror halves, if possible. Some shapes might not have a mirror half!

A P X

Figure 23: Assignment for Lesson of Symmetry (Side 1)



Q3. Yesterday I made a pattern. Imagine I place a mirror at the dotted line, can you tell me how my pattern will look in the mirror?

Q4. True or False.

All objects have mirror halves _____

Objects are reversed in a mirror _____

All objects have only 1 line on which they form a mirror half _____

Figure 24: Assignment for Symmetry (Side 2)

Place Value & Numbers

Name _____ Class _____

Q1. Solve the Following:

Place Value of 4 in 342 _____

Place Value of 2 in 299 _____

Face Value of Hundreds in 214 _____

Face Value of Ones in 299 _____

Any number larger than 400 using 2, 3 and 5 _____

Write any number larger than 200 but Less than 400 _____

Write any number smaller than 100 but larger than 90 _____

Smallest Number formed using 3, 1 and 7 _____

Greatest Number formed using digits 2,8 and 4 _____

Greatest Number formed using the digits 4, 7 and 4 _____

Q2. Complete the Following Series

24, 28, 32, 36 _____ _____ _____

125, 131, 137, 143, 149 _____ _____ _____

93, 90, 87, 84, 81 _____ _____ _____

Q3. Answer the Following:

What is 17 more than 82 _____ What is 38 more than 275 _____

What is 4 Less than 86 _____ What is 8 Less than 324 _____

Figure 25: Assignment for Place Values and Numbers

Reading the Results: Each row is the answer given by the student. Green is correct, red is incorrect or did not attempt. The columns show the question number. Every Stack is a different question set.

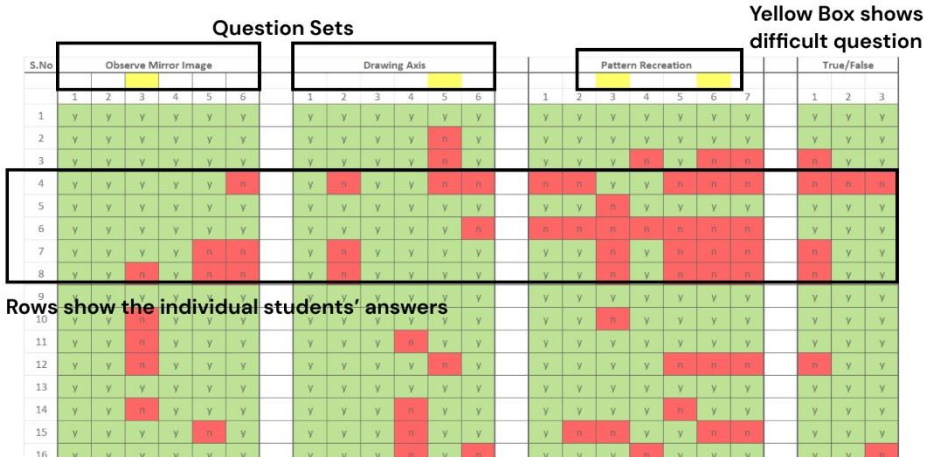


Figure 26: Reading the Evaluation Data

The results showed that in both the Lessons, the traditional method of teaching yielded overall most successful results. Teaching using Experiential Way followed by discussions (Class B) showed the worst results. The results from Class C however, (Guided Experiential Learning) were similar to the traditional way of teaching. However, due to the short nature of the study it cannot be concluded if the learning was based on experience or the little theory that was taught.

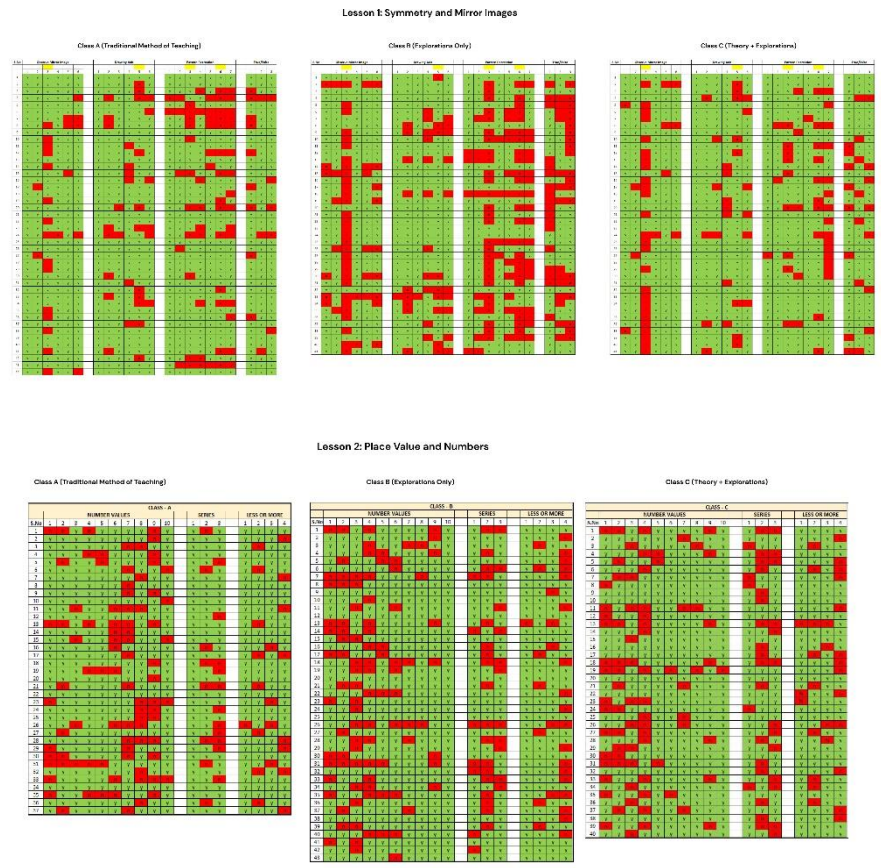


Figure 27: Combined Evaluation Results

The full-size images of data can be seen here.

Early results show that application of concepts are best done by students taught using Method 3 (Combination of Theory and Explorations). However, there is another possibility that this is driven by the fact that evaluation assessments were somewhat related to the type of exploratory activities that were performed.

	METHOD A			METHOD B			METHOD C		
	Correct	Incorrect	Inc. Per 100 Students	Correct	Incorrect	Inc. Per 100 Students	Correct	Incorrect	Inc. Per 100 Students
Observing Mirror Images	39.67	4.3	9.7	31.2	9.8	23.9	34.8	6.2	15.04
Drawing Axis to make Mirror Halves	38.5	5.5	12.5	34.2	6.8	16.5	36.3	4.7	11.38
Pattern Recreation	36	8	18.2	27	14	44.3	36.3	4.7	11.38
True/False	38.3	5.67	12.8	24	17	31.2	33.7	7.3	17.8
Overall			13.3			28.975			13.9
Place Value and Forming Numbers	29.4	7.6	29.4	31	12	28	32.1	7.9	18.3
Number Series	30.67	6.33	17	28.33	14.67	34	28.33	11.67	27.2
Word Problems	31.75	5.25	14	31.25	11.75	27.3	32.75	7.25	17
Overall			20.1333			29.7667			20.8333

Figure 28: Incorrect Answers per 100 students in all the three methods

We observe that although traditional teaching method results in the best overall results (13.3 & 20.13 incorrect answers on average 100 students), the application-based questions were most successfully answered by the students taught by Method C (Combination of Design Thinking with basic Theory).

	Max Marks	METHOD A	METHOD B	METHOD C
Observing Mirror Images	6	5.41	4.56	5.1
Drawing Axis to make Mirror Halves	6	5.25	5	5.32
Pattern Recreation	7	5.57	4.58	5.95
True/False	3	2.61	1.73	2.46
Overall	22	18.84	15.87	18.83
Place Value and Forming Numbers	10	7.94	7.2	8
Number Series	3	2.48	1.9	2.12
Word Problems	4	3.43	2.9	3.27
Overall	17	13.85	12	13.39

Figure 29: Marks obtained by the students in all the 3 methods

Similar results were also seen for the marks obtained. Highest marks in application based questions were obtained using Method C.

Development of Detailed Lesson Plan

The final revised lesson plan incorporated the observations from both the field studies and the suggestions given by the experts. Link to the lesson plan can be found here.

The following components were designed:

- Information manual & Session Plans
- Defining the Instructor's Role
- Activity Work Book
- Framework/ Template to design own Sessions

Defining the Session Planning & Guidelines

Sessions (1-2): Observe, Understand & Reflect

The initial sessions include the Theory of the concept along with an exploratory group activity that the students would perform. These are based on 'Observation' and 'Understanding' of Design Thinking Process. The students would understand the theory by observing the things they do in the exploratory activities. At this stage, the students would want to relate the theory with some experience they have encountered.

Sessions (3-6): Ideate, Build & Reflect

Doing the activities: These are the sessions where the students build upon their learnings by applying the concept that they have learnt previously. This is in the form of individual exploratory activities. Given the structuring of the sessions, it is advised the activities to be limited to 2 at maximum. The main objective is that the students build upon their previous knowledge through active experimentation and discussions.

Discussions through Reflection: Discussions should happen following every activity and preceed the beginning of the new activity. This would help the students to recall the application of the concepts they have learned. Throughout the session, while the students perform the activities, the instructor should prompt them the students to think about the concept.

Homework: Repetition and exercised forming a core part of Mathematics Education, it is advised to give small text book exercises (NCERT or any other book the school uses to teach) related to the concepts taught in the exercises. They should be discussed before the next session begins.

Sessions 7: Evaluation (Apply)

Assessment: Evaluation can be done in 2 methods - Assessment Worksheets, or NCERT Exercises followed by Viva Session, with the latter taking more time and would require at least 2-3 sessions.

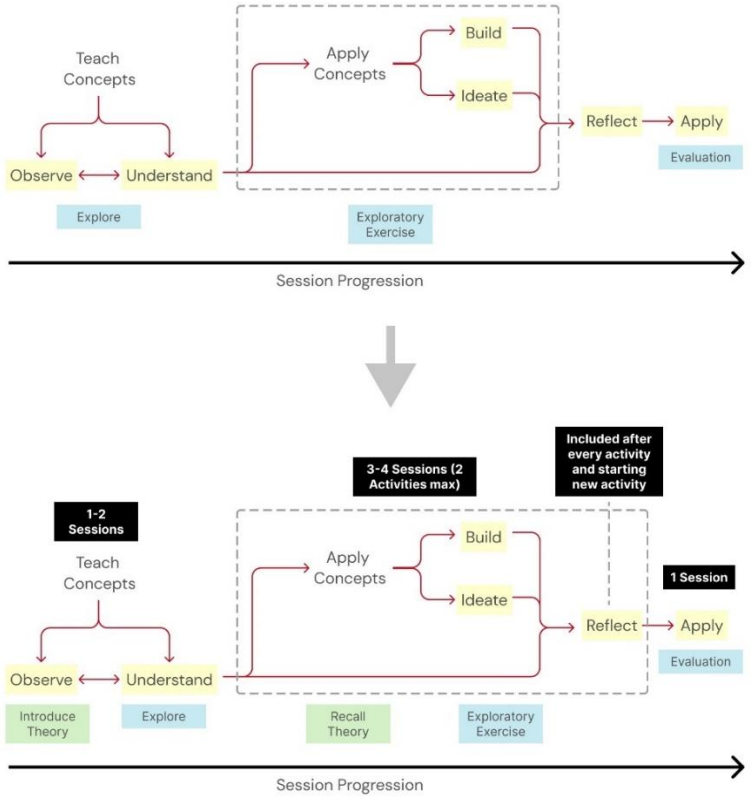


Figure 30: Revising the Framework based on Evaluation

Features of the Lesson Plan

The lesson plans begin with a summary of session-wise plans, with the learnings and evaluation associated with them

Lesson Plan

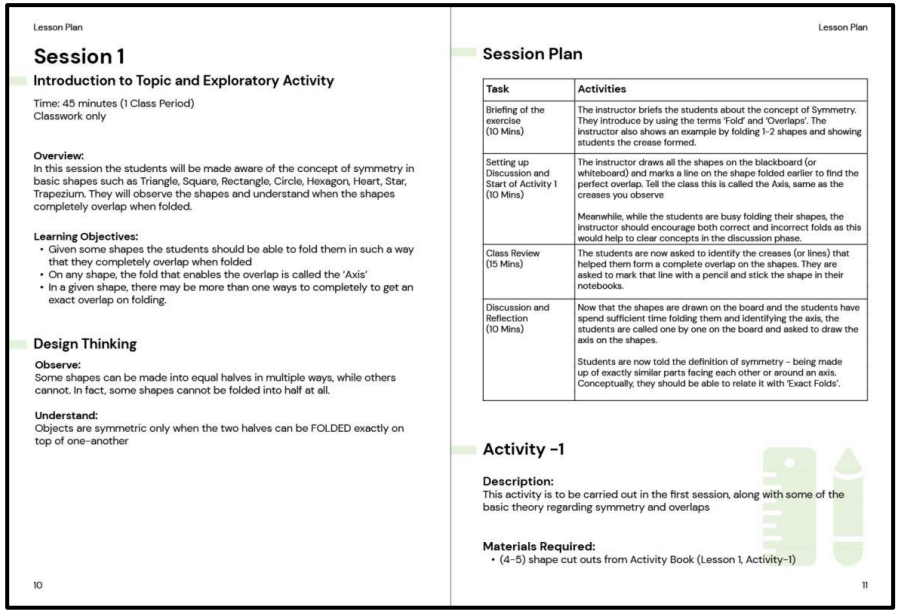
Summary

A summary of the 1-week Lesson Plan that would be carried out. It includes the necessary teaching directions and activity details. However, the detailed Day-wise lesson plans are to be referred to while conducting sessions.

Day	Summary	Learning & Evaluation
Day 1 (45 Mins)	• Students introduced to concept of Symmetry through an exploratory exercise	• Students to learn the meaning of Overlap and concept of exact folds • Students to identify 'tangible' axis be observing creases
Day 2 (45 Mins)	• Students are taught the basic theory behind symmetry by recalling the observations • Students are briefed about Activity-2 in class	• Students identify symmetric or non-symmetric objects as drawn on the board. • Students identify symmetry in objects around them
Day 3 (45 Mins)	• Students complete Activity-2 (pattern making) • Students draw pattern on the notebook and using a mirror observe the mirror images • Students discuss their observations in class	• Learn about how the position of things change when put in front of a mirror
Day 4 (45 Mins)	• Students are paired up. Now that they have been introduced to the concept of mirror images, they try and make complex mirror symmetric drawings • Each pair make 2 sets of drawings, where the partner has to make the mirror symmetric version (Activity detailed in session plan)	• Students observe that mirror images are reversed even in the orientation by directly seeing them in a mirror • Relationship between reverse images and the axis is observed

Figure 31: Part of Summarised Session Plans with their learning objectives

Every Session Plan contains an **overview and the learning objectives associated** with that session. Further, it also highlights the **Design Thinking objectives** of that session.



Lesson Plan

Session 1

Introduction to Topic and Exploratory Activity

Time: 45 minutes (1 Class Period)
Classwork only

Overview:
In this session the students will be made aware of the concept of symmetry in basic shapes such as Triangle, Square, Rectangle, Circle, Hexagon, Heart, Star, Trapezium. They will observe the shapes and understand when the shapes completely overlap when folded.

Learning Objectives:
- Given some shapes the students should be able to fold them in such a way that they completely overlap when folded
- On any shape, the fold that enables the overlap is called the 'Axis'
- In a given shape, there may be more than one ways to completely to get an exact overlap on folding.

Design Thinking

Observe:
Some shapes can be made into equal halves in multiple ways, while others cannot. In fact, some shapes cannot be folded into half at all.

Understand:
Objects are symmetric only when the two halves can be FOLDED exactly on top of one-another

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Lesson Plan

Session Plan

Task	Activities
Briefing of the exercise (10 Mins)	The instructor briefs the students about the concept of Symmetry. They introduce by using the terms 'Fold' and 'Overlaps'. The instructor also shows an example by folding 1-2 shapes and showing students the crease formed.
Setting up Discussion and Start of Activity 1 (10 Mins)	The instructor draws all the shapes on the blackboard (or whiteboard) and marks a line on the shape folded earlier to find the perfect overlap. Tell the class this is called the Axis, same as the creases you observe Meanwhile, while the students are busy folding their shapes, the instructor should encourage both correct and incorrect folds as this would help to clear concepts in the discussion phase.
Class Review (15 Mins)	The students are now asked to identify the creases (or lines) that helped them form a complete overlap on the shapes. They are asked to mark that line with a pencil and stick the shape in their notebooks.
Discussion and Reflection (10 Mins)	Now that the shapes are drawn on the board and the students have spend sufficient time folding them and identifying the axis, the students are called one by one on the board and asked to draw the axis on the shapes. Students are now told the definition of symmetry – being made up of exactly similar parts facing each other or around an axis. Conceptually, they should be able to relate it with 'Exact Folds'.

Activity -1

Description:
This activity is to be carried out in the first session, along with some of the basic theory regarding symmetry and overlaps

Materials Required:
- (4-5) shape cut outs from Activity Book (Lesson 1, Activity-1)

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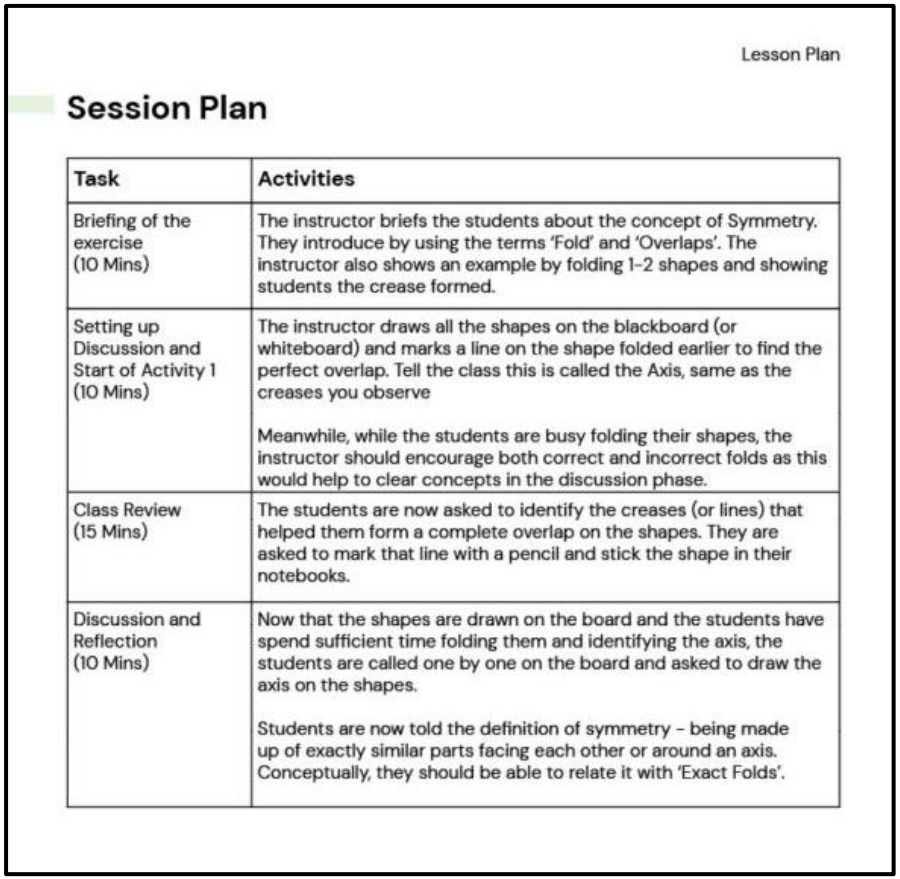
Figure 32: Beginning of the session plan

Session plan is detailed out as per Task and Instructions about how to conduct the session. Further, an approximate time is also given, that may vary as per how the session progresses.



Lesson Plan

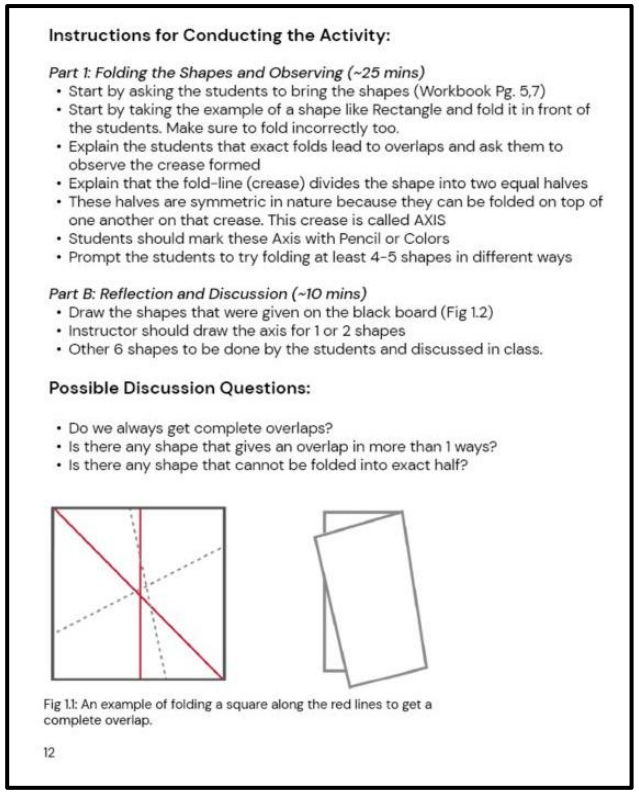
Session Plan

Task	Activities
Briefing of the exercise (10 Mins)	The instructor briefs the students about the concept of Symmetry. They introduce by using the terms 'Fold' and 'Overlaps'. The instructor also shows an example by folding 1-2 shapes and showing students the crease formed.
Setting up Discussion and Start of Activity 1 (10 Mins)	The instructor draws all the shapes on the blackboard (or whiteboard) and marks a line on the shape folded earlier to find the perfect overlap. Tell the class this is called the Axis, same as the creases you observe Meanwhile, while the students are busy folding their shapes, the instructor should encourage both correct and incorrect folds as this would help to clear concepts in the discussion phase.
Class Review (15 Mins)	The students are now asked to identify the creases (or lines) that helped them form a complete overlap on the shapes. They are asked to mark that line with a pencil and stick the shape in their notebooks.
Discussion and Reflection (10 Mins)	Now that the shapes are drawn on the board and the students have spend sufficient time folding them and identifying the axis, the students are called one by one on the board and asked to draw the axis on the shapes. Students are now told the definition of symmetry - being made up of exactly similar parts facing each other or around an axis. Conceptually, they should be able to relate it with 'Exact Folds'.

Figure 33: Detailed Session Plan

Detail of Activities: Every Activity that has to be performed by the students is detailed out. It has the following:

- Description
- Materials Required
- Learning Objectives
- Instructions for Conducting Activity
- Possible Discussion Questions



Instructions for Conducting the Activity:

Part 1: Folding the Shapes and Observing (~25 mins)

- Start by asking the students to bring the shapes (Workbook Pg. 5,7)
- Start by taking the example of a shape like Rectangle and fold it in front of the students. Make sure to fold incorrectly too.
- Explain the students that exact folds lead to overlaps and ask them to observe the crease formed
- Explain that the fold-line (crease) divides the shape into two equal halves
- These halves are symmetric in nature because they can be folded on top of one another on that crease. This crease is called AXIS
- Students should mark these Axis with Pencil or Colors
- Prompt the students to try folding at least 4-5 shapes in different ways

Part B: Reflection and Discussion (~10 mins)

- Draw the shapes that were given on the black board (Fig 1.2)
- Instructor should draw the axis for 1 or 2 shapes
- Other 6 shapes to be done by the students and discussed in class.

Possible Discussion Questions:

- Do we always get complete overlaps?
- Is there any shape that gives an overlap in more than 1 ways?
- Is there any shape that cannot be folded into exact half?

Fig 1.1: An example of folding a square along the red lines to get a complete overlap.

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Figure 34: Part of Activity Details

Further, every activity also has the references that are to be used from the workbook and illustrations showing how to approach them

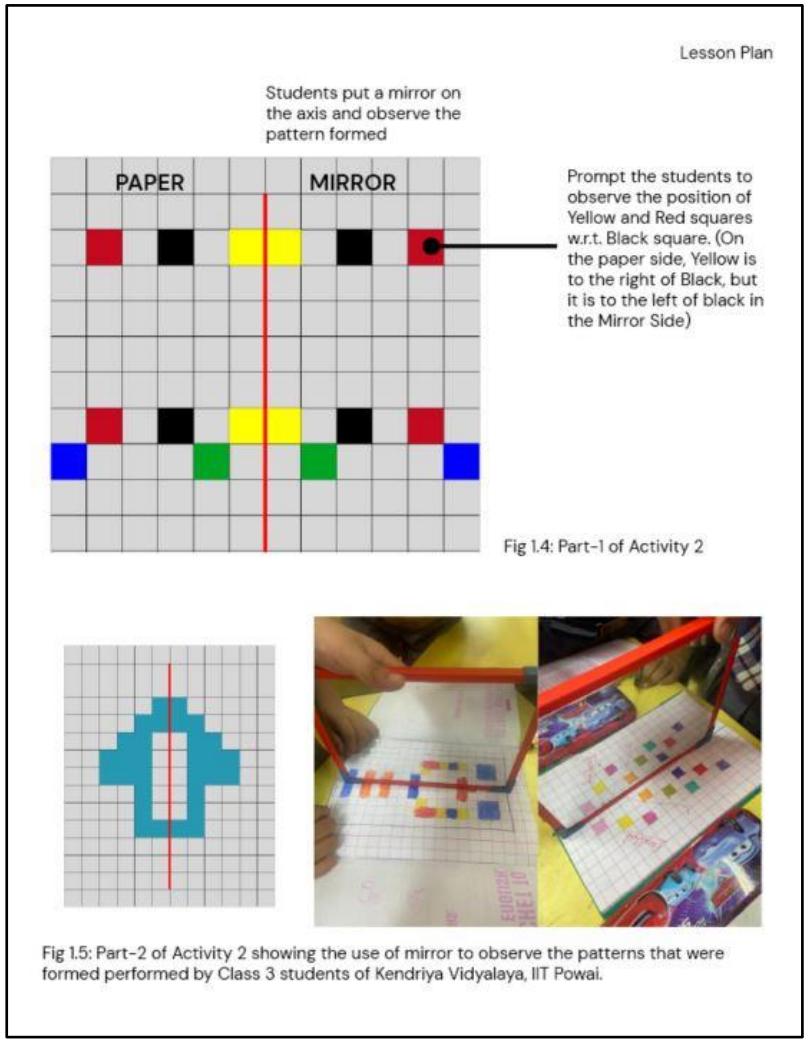

Figure 35: Illustrations showing how activity can be conducted

Lastly, at the end of each lesson plan, evaluation exercises are given. Evaluation criteria, however is left to the instructors as it varies as per the school's grading system.

Template: The activities can be detailed in the form of a template, simplifying for the teachers to design them. It includes: summary, time, and Observe, Understand, Discussion points. Further, it also has a section to note down the relevant NCERT Exercises related to the activity.

Type: Group Activity		
Name: Folding Shape Cut-Outs		35 Mins
Summary In this session the students will be made aware of the concept of symmetry in basic shapes such as Triangle, Square, Rectangle, Circle, Hexagon, Heart, Star, Trapezium.		
Observe	Understand	Discussion
Observe that sometimes the shapes completely overlap eachother	If the shapes can be folded exactly on top of one another, they are symmetric in nature	Is it possible to fold all the shapes to get a complete overlap?
Observe the creases formed when folding the shapes	The crease that gives an exact overlap is called Axis of Symmetry	Is there any shape that be folded to get complete overlap in more than one way?
NCERT EXERCISES		
• Page 9 and 10 of NCERT Textbook		

Figure 36: Template for Group Activity

Type: Individual Activity		
Name: Pattern Making		45 Mins
Summary Students first observe images in a mirror. Then, they draw pattern on the notebook and using a mirror observe it. Then, they replicate pattern they observed.		
Observe	Understand	Discussion
Observe the box colored in paper is equidistant.	Objects seen in the mirror are at the same distance from the axis.	Which is the closest box from the center line on paper? Is it the same in mirror?
Images facing left are facing right in the mirror.	Images are reversed in a mirror.	Is there any shape that be folded to get complete overlap in more than one way?
Output		
The students should make a pattern and recreate it as it is seen in the mirror. Instead of a pattern, it can also be a shape.		
NCERT Exercises		

Figure 37: Template for Individual Activity

Features of the Activity Workbook

The activity workbook contains the description and learning objectives of the activities. It also has the list of materials required along with adequate space to perform the activities. It also contains any material, if needed, as a cut-out.

Link to the Activity Workbook can be found here.

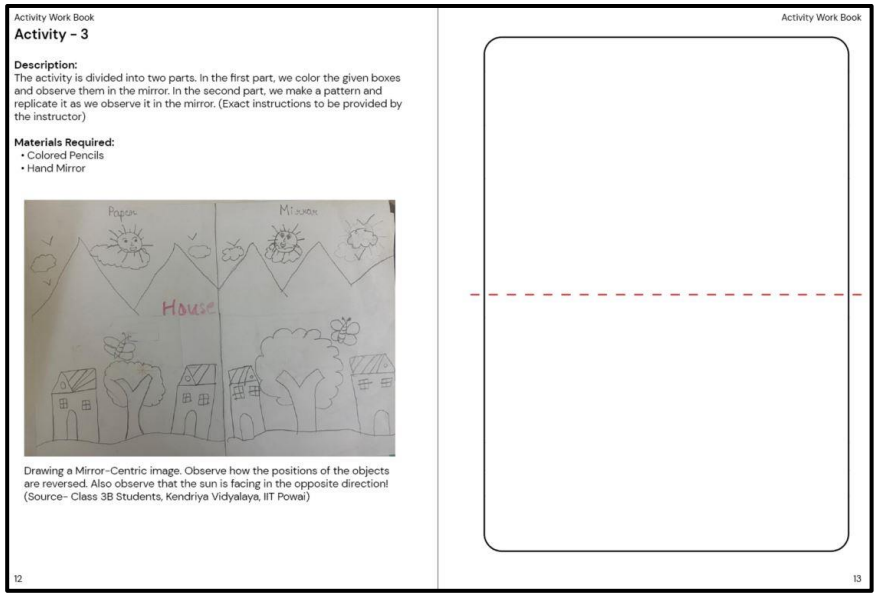

Figure 38: Activity Workbook showing Description, Materials Required, Examples and Workspace

Evaluation on Final Lesson Plan

Being the time when students were on vacations, an Expert Evaluation with Domain Experts was conducted. The following limitations and positives were discussed.

Limitations:

- Content seems Cramped in Lesson Plan 2. Why not make it in two weeks?
- How do you cater to the fact that students will be absent? Is it possible to follow the same process for them?
- Do not add Learnings at two places - either keep them in Overview, or Activity Design. Otherwise, it is confusing.
- Exploratory Exercises were effective, but do you think students will recall them over large periods of time? Think if you need more Theory Sessions here.
- Can add a feedback form for the students. Also, make the evaluation suggestive.
- Too elaborate and instructive at times

Positives:

- Overall Structuring was praised, especially in the Lesson of Symmetry & Mirror Images
- Liked the simple Activity Template. Liked how 'Understanding' and 'Observing' can be used to make concrete examples.
- Place Value is taught in a Unique Way. For grouping, you might want to make a separate 1-week session since we spend almost 1 month on these chapters.
- Reflection Strategy were praised, although suggested to merge it with Theory Session.

Project Limitations

- Testing was done in only 1 school. It would be better to test it out in a few more schools
- It cannot be concluded that Class-C (Exploration & Theory Combined) explained the concepts correctly due to experiential learning, or theoretical learning.

- It would be interesting to design evaluation assessments not based on the Exploratory Activities and then conduct the evaluation by 2 methods- Traditional Behaviourist approach, and Design Thinking Approach.

- Application based exercises were based on the Experiential Activities done in class. It would be interesting to note the results when they are different in nature

- Longer Study in different schools would be ideal, ideally for ALL 10 concepts identified

- Individual Brilliance of students might have impacted the results

- 1:1 mapping of students' learning could not be done (Did the weak students perform better?)

Future Steps

- Applying the Framework in other topics and concepts

- **Letting Teachers design their own lesson plans:** Although the framework is designed, it would be important to see if other teachers, new to this mode of teaching can use it to create their own lesson plans & session plans

- **Finding the correct time allocated:** In the study, 1 week (or 7 sessions) were allocated for the concepts. It would be important to see if this time frame is maintainable throughout the year for every concept.

- **Designing an evaluation criteria:** Proper time could not be spent in designing an evaluation criteria for the learning

- **Checking if template works** - Letting the teachers design their own session plans based on the Framework, on concepts other than Place Value and Symmetry

Conclusion

The project started off with the mindset of using 'Design Thinking Process' to teach concepts of Mathematics to students of class-3. It was observed that for students of this age (7-9 years), experiential and unguided learning failed. However, when the experience was guided, using some theoretical background, the results were comparable to the those found in the traditional teaching methods. In fact, in certain type of questions that involved application of concepts, the Design Thinking process worked better.

We cannot conclude that it is the better way of teaching, however some positive results were observed. Much more active participation

was seen in this method. Further, the teachers also observed that some students, who otherwise never pay attention in class were excited to participate in the sessions. Hence, currently we designed a framework where we combined Experiential Learning with Traditional teaching approach to create lesson plans and teach students.

Addressing the limitations and by working on the future steps, one may find the process to develop into a mechanism for teaching **'Intangible Concepts in a Tangible Way'**

Reflection

The project was a unique experience for me. I conducted almost 6 weeks of field study, that helped me evolve as a designer. This was my first experience of working with children. I realised that what seems to be obvious for us, is not so apparent for the children. While designing for them, we often try to make complex products that are appealing to us. However, we often fail to realise that this complexity might be problematic for the children. This happened multiple times during my evaluation, where I ceased to get a response from the children. I had to go back to the basics.

Secondly, I realised the importance of regular testing and feedback in an iterative design process like this. Being fond of Mathematics from an early age, I was under the impression that it is easy for me to teach Mathematics and work under the domain. I could not have been more wrong. However, during the project, with help of the teachers I soon found confidence in teaching students. I was able to look at the activities I designed from the lens of an instructor and the learner both, and not only as a designer. The challenge was to make the activities simple enough for the students to engage, yet conceptually sound and intriguing. I thoroughly enjoyed the project.

What we perceive to be easy and 'obvious' is not so obvious for children of this age. In case of complex activities, I failed to get a response from children many times. I had to keep a back-up in mind (Theoretical or Simplified Activity) for every activity designed. Simpler the Activities, more engaging they were for the students. Complexity led to confusion, that led to them ignoring my instructions.

Although it came with many limitations, I could see myself evolve as a designer. The words of encouragement and excitement shown by all the teachers involved and the happiness observed on the children's faces was really inspiring for me.

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Appendix 1 (Detailed Evaluation Results)

(Go back to Report)

The appendix contains the note making from the evaluation sessions, along with the observations from the activities conducted.

For Lesson plan 1: Symmetry & Mirror Images

Method A (Using Traditional Behaviourist Approach):

Session 1: Teaching theory based on Symmetry, Mirror Image and Overlaps. Students were taught by drawing shapes on the board and marking the symmetry lines on them

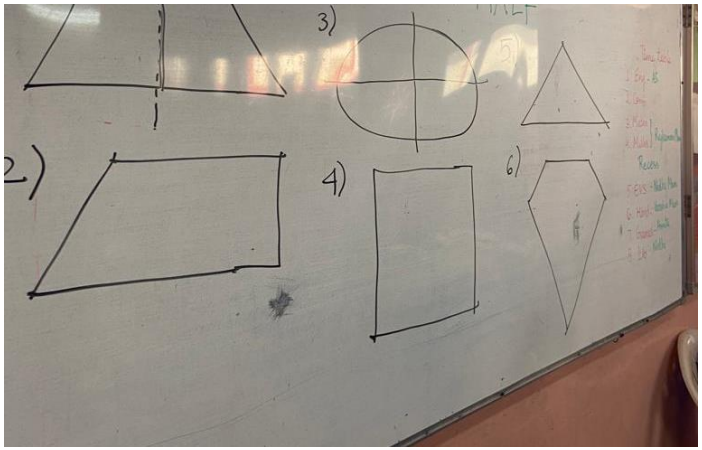


Figure 39: Drawing shapes on board and marking symmetry axis on them

Session 2: Taught the theory and concept behind mirror halves and asked them to complete the NCERT Exercises.

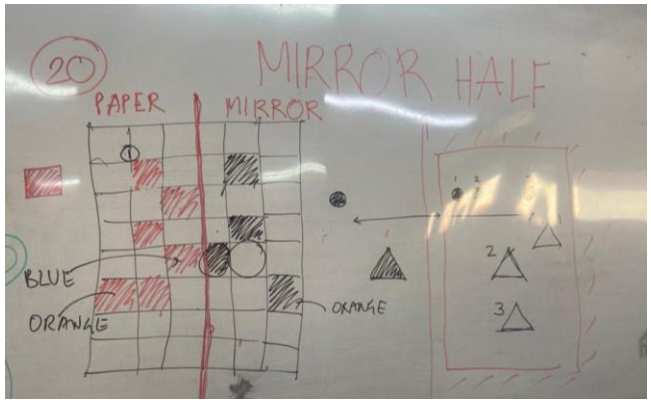


Figure 40: Teaching the concept of Mirror Halves

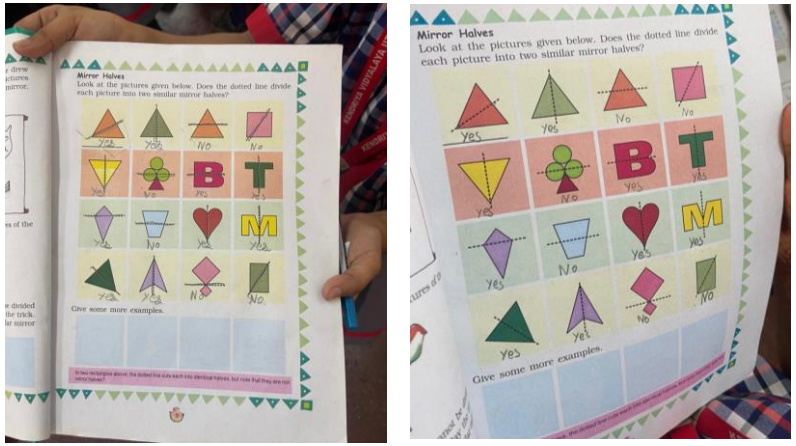


Figure 41: NCERT Exercise based on Mirror Halves

Session 3: Students are taught about multiple axis in complex shapes theoretically. They are told about the Reverse Images when formed in the mirror.

Session 4: Practice Exercises and Revision of Theory

Session 5: Evaluation (44 students)

Evaluation Results:

First Set of Observing Mirror Images had 6 questions. This result shows that on an average, a single question from this set was solved by 39.67 students, incorrect by 4.3 students. Since the number of students who took the assessment varied in classes, we averaged it out for 100 students.

Type of Question	Average Correct	Average Incorrect	Incorrect per 100 Students
Observing Mirror Images	39.67	4.3	9.7
Drawing Axis to make Mirror Halves	38.5	5.5	12.5
Pattern Recreation	36	8	18.2
True/False	38.3	5.67	12.8

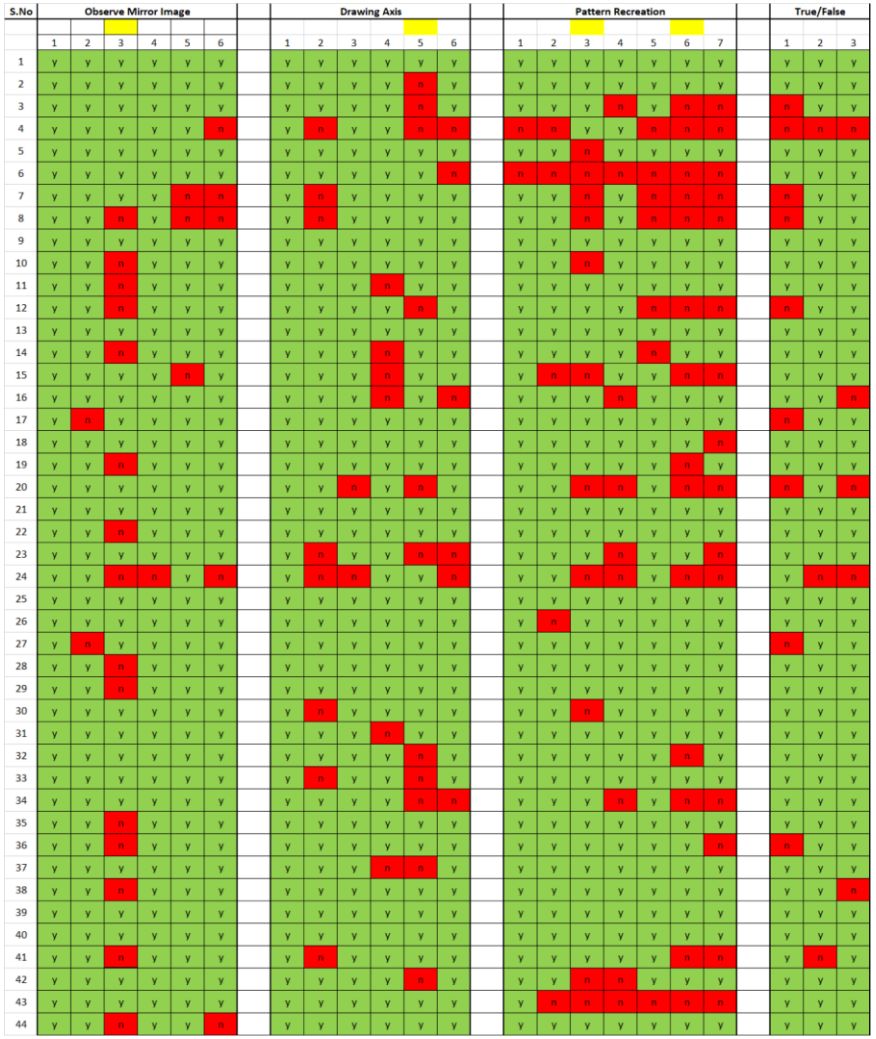


Figure 42: Evaluation Results of Class A for concept of Symmetry and Mirror Images

Method B (Using only Experiential Learning):

Session 1,2: Giving Students Paper cut outs of shapes and asking them to fold them until no overlap is observed. Observations discussed in the class and students were asked to mark the overlapping lines.

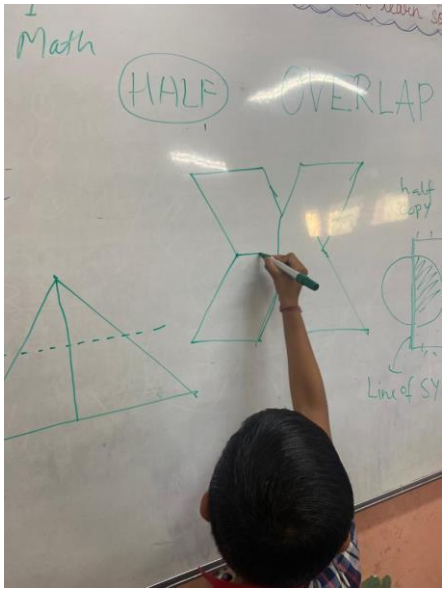


Figure 43: Students making lines on the shapes based on their explorations

Session 3,4 : The students were asked to observe a small pattern they make on their square grid note books and observe its mirror half by placing a mirror at the centre line. They were asked to make a vertical dividing line. The left side was the paper, right side had to be considered as the mirrored image.

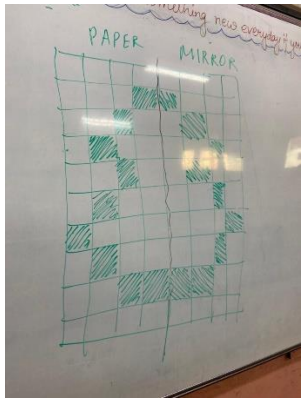


Figure 44: Explaining how Paper-Mirror exercise needs to be done

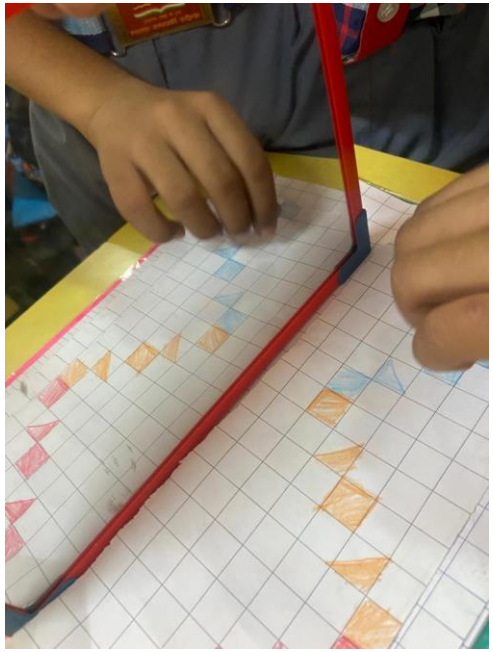


Figure 45: Students observing the Patterns they make in the mirror

It took a fair amount of time for the students to replicate the pattern on the mirror side. At the end of the first session, only 14 students could make the pattern. By the end of the second session, 27 correct patterns, and 15 incorrect patterns were made.

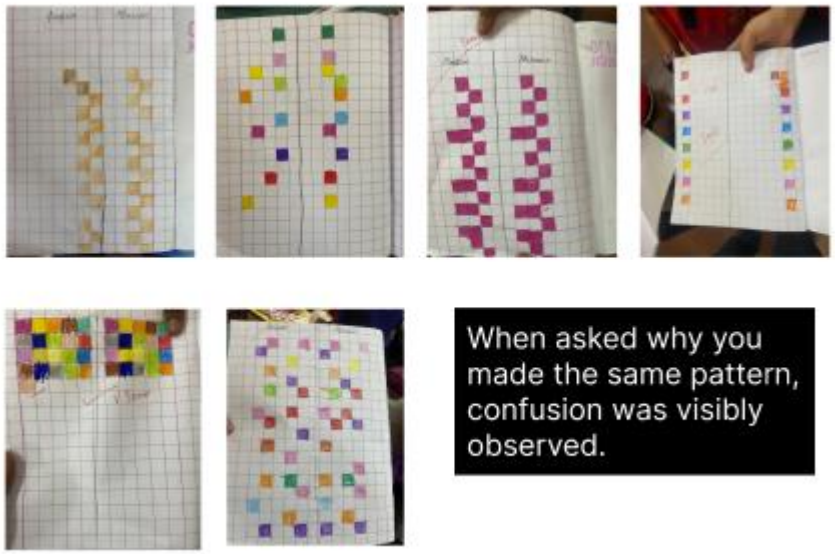


Figure 46: Some incorrect patterns made at the end of 1st session

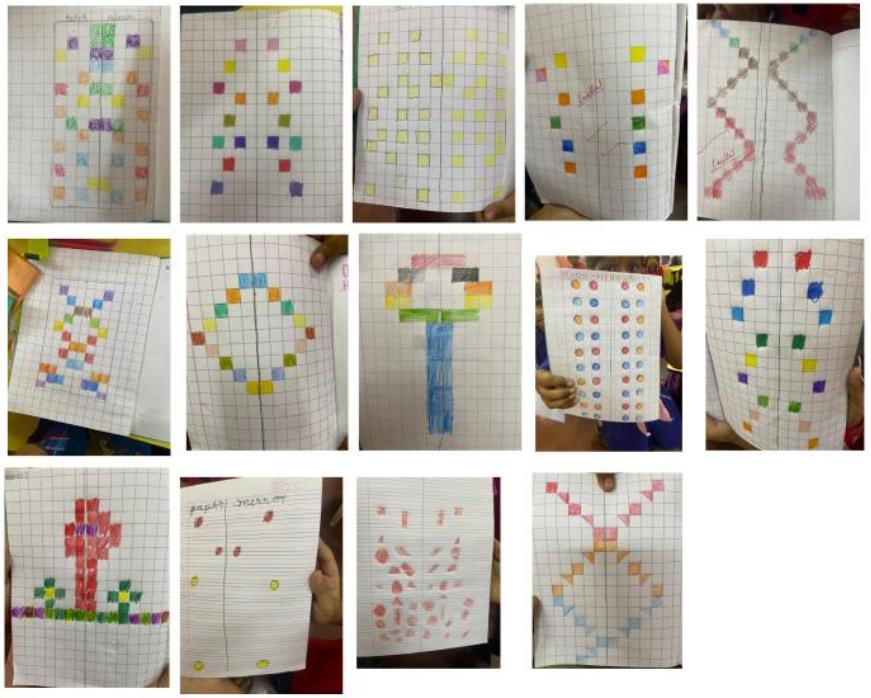


Figure 47: Some Correct Sessions made at the end of both the sessions.

Session 5,6,7 : The session started with a discussion about the observations and learning from the previous activity. It was observed that although all the students participated in the activity, the response rate was not high until prompted about the properties. It seems although students observed certain things, they were unable to put across their thoughts.

Next, students were paired. A4 size sheet was given to them with a line at the centre. In this activity, the student on the left had to make

any drawing that had to be replicated as observed in the mirror by student on the right. The partners were reversed in Drawing 2.

Figure 48: Completed Drawings by the end of the first session

22 (11 pairs) students were able to complete the drawing after the first session. However, one observation was that the mirrored imaged were all drawn correctly with respect to the positioning of the objects. All completed by the end of the last session.

Session 8, 9 : Discussions and Evaluation (41 students)

Type of Question	**Average Correct**	**Average Incorrect**	**Incorrect per 100 Students**
Observing Mirror Images	31.2	9.8	23.9
Drawing Axis to make Mirror Halves	34.2	6.8	16.5
Pattern Recreation	27	14	44.3
True/False	24	17	31.2

It was surprising to see that even the application based questions had the maximum error using this method.

Method C (Using Theory with Experiential Learning):

Session 1: Giving Students Paper cut outs of shapes and asking them to fold them until no overlap is observed. Observations discussed in the class and students were asked to mark the overlapping lines. However, this time theory was being taught parallelly.

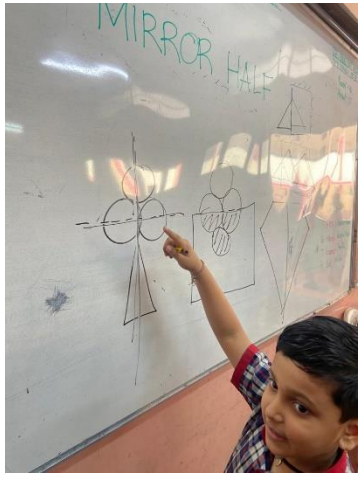


Figure 49: Theory of Symmetry being taught

Session 2,3 : The students were introduced with the Theory of Mirror Halves asked to observe a small pattern they make on their square grid note books and observe its mirror half by placing a mirror at the centre line. They were asked to make a vertical dividing line. The left side was the paper, right side had to be considered as the mirrored image.

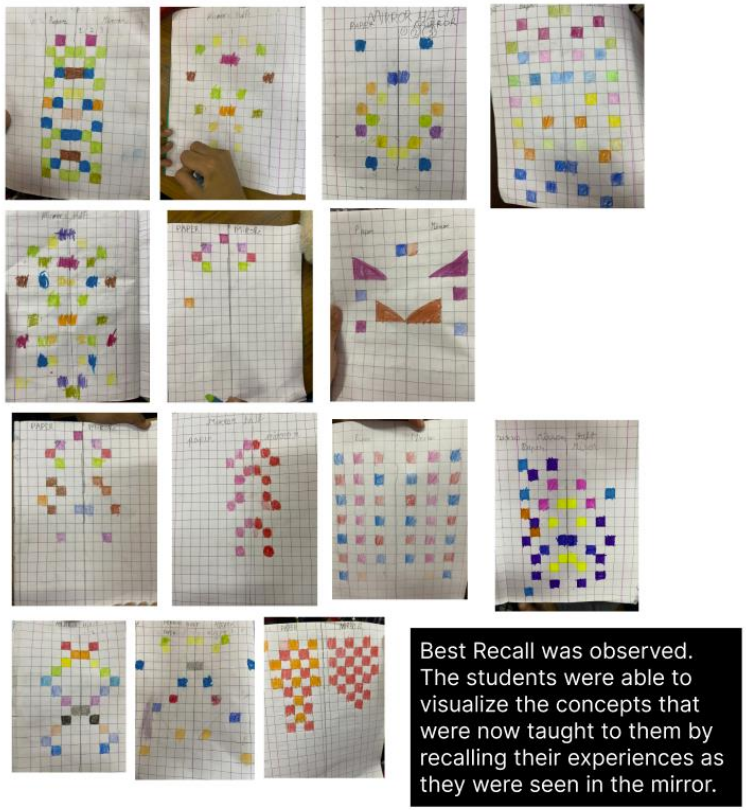


Figure 50: Activity as done by the students

In the subsequent discussions, excellent recall was observed. They were able to put their thoughts into words, using the terms taught in the theory sessions.

Figure 51: Matching their pattern with the pattern seen in mirror

Session 4,5 : Next, students were paired. A4 size sheet was given to them with a line at the centre. In this activity, the student on the left had to make any drawing that had to be replicated as observed in the mirror by student on the right. The partners were reversed in Drawing 2.

38 (19 pairs) students were able to complete the drawing after the first session. The activity did not need to be extended in the next session at all. Recall was evident.

Figure 52: Work done by students in only 1 activity session

We had around 25 minutes left for recall and discussion by the time everyone had completed the two sets of drawings.

Session 6 : Evaluation (41 students)

Type of Question	Average Correct	Average Incorrect	Incorrect per 100 Students
Observing Mirror Images	34.8	6.2	15.04
Drawing Axis to make Mirror Halves	36.3	4.7	11.38
Pattern Recreation	36.3	4.7	11.38
True/False	33.7	7.3	17.8

The results obtained were comparable to the ones as observed in the method of teaching the class using the Traditional Behaviourist Approach. However, the sets of Drawing Axis to make Mirror Halves and Pattern Recreation saw the least error.

For Lesson plan 2: Place Value and Numbers

Method A (Using Traditional Behaviourist Approach):

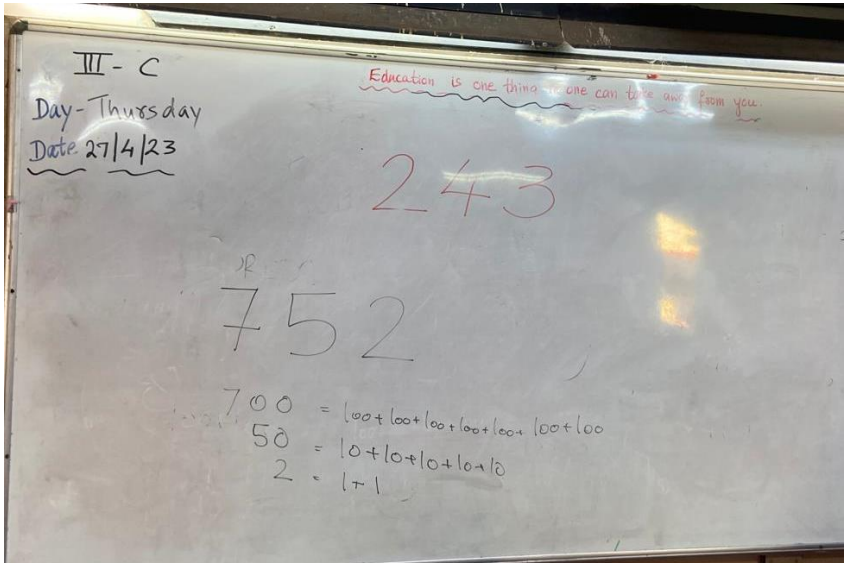
Session 1: Teaching theory on Place Value and Face Value. Recalling the terms 'Ones', 'Tens', 'Hundreds'. Explaining that while reading a number we always start reading from extreme right and move towards the left.

- Numbers were written on the boards and students were asked identify their Ones, Tens, and Hundreds.

Session 2: Digits were written on the board and students had to arrange them form the possible numbers. Then they identified the largest and smallest numbers from it.

Session 3: Teaching grouping of numbers and converting from ones to tens to hundreds. Then they were asked to break down the numbers to into their Hundreds, Tens and Ones. (Example 275 = 200 + 70 + 5 = 2 hundreds, 7 tens and 5 ones)

This session was easiest to teach using the traditional theoretical way, as it took a lot of time to teach it using concrete examples.



Session 4: This session consisted of practice questions based on the previous three classes. Exercises on Pg 23, 25, and 27 were solved and discussed in class. The next topic of Word Problems was introduced.

Session 5: Small Word problems were solved. The students were told the meaning of 'more', 'less', 'greater' and 'lesser'. Some questions discussed in class were:

- What is 7 more than 11?
- What is 8 less than 24?
- What is 23 more than 45?

Session 6: Evaluation Assessment given to be solved. (37 students)

Type of Question	Average Correct	Average Incorrect	Incorrect per 100 Students
Place Value and Forming Numbers	29.4	7.6	29.4
Number Series	30.67	6.33	17
Word Problems	31.75	5.25	14

Method B (Using Only Experiential Learning):

Session 1,2: Here we introduced the topic of Place Value and started by a recall session of whether the students were aware of the terms hundreds, tens, and ones.

We wrote the place values on 3 sections of the blackboard and then some numbers board. We placed some digit cards on the table, asked

the students to pick them and rearrange themselves (holding the digit cards) as per the given number. During the session, we discussed why the students arranged themselves. The class was asked to tell if the position formed was correct or incorrect. In case of incorrect positioning, the class was asked to correct the sequence.

Figure 53: Forming Greatest Number

When the students were asked to rearrange themselves in ascending/ descending order, there was visible confusion initially. However, after an example or two, they began justifying. It was noted that in the beginning only a few students who could grasp the concept were answering. However, by the end most of the students raised their hands to answer/ identify mistakes (if any)

Without Theory, this topic took 2 sessions to complete, instead of the anticipated single session.

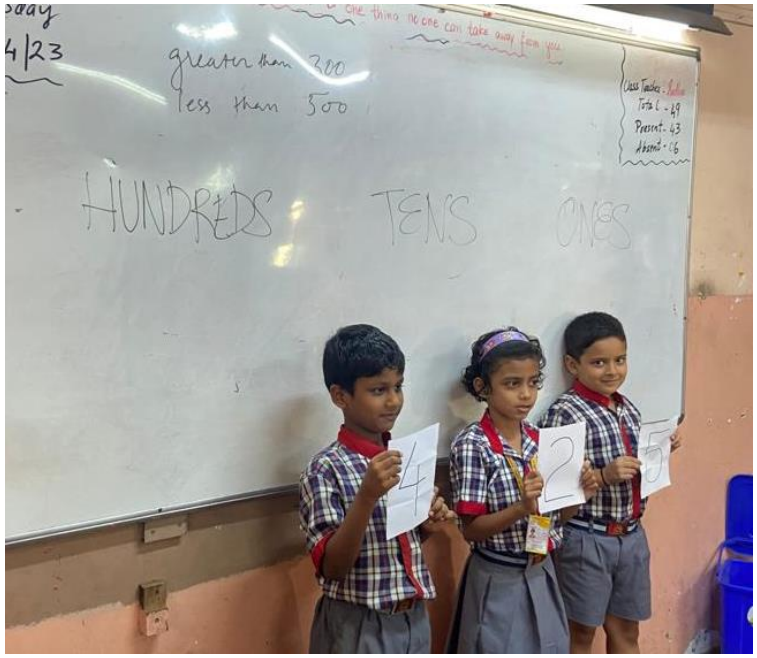


Figure 54: Forming number given the condition 300 < X > 500

Session 3: Students brought the numbers as asked (0-9 written on square chits). We conducted Activity-1. (writing some set of digits on the board, and students had to use the chits to form as many numbers possible.)

Throughout the session, it was difficult for the students to get all the possible numbers. In case of 2 digit numbers, most of the students could get both the numbers. However, in case of 3-digit numbers (expected 6 numbers), 3-4 was the average numbers they could form. From the numbers formed, almost half the class could not identify the largest/ smallest number formed.

Session 4: Grouping of Numbers – converting from Ones to tens, and breaking down of large numbers

Visibly, this was the most confusing session for the students. Even though they could calculate (100 + 20 + 7 = 127), they could not break down 127 into 100, 20 and 7 (H, T and O). We could not conduct the exercise that was intended for the session, as it took way longer than expected to explain this concept in an experiential way. **This understanding was observed way better in the Theoretical Session. It was understood that it is not possible to force every identified concept to be taught in an experiential way.**

While sticking notes one-by-one it was seen that many students were losing interest entirely. Hence, the activities should be designed in such a way that all the students are somehow engaged in it, either actively or passively (by observing).

Session 5: Quick Addition while drawing (Activity 2)

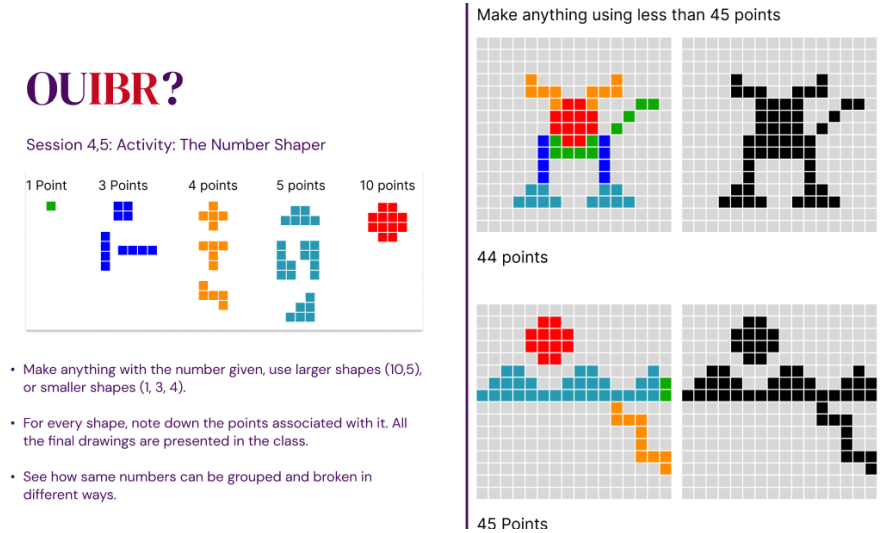
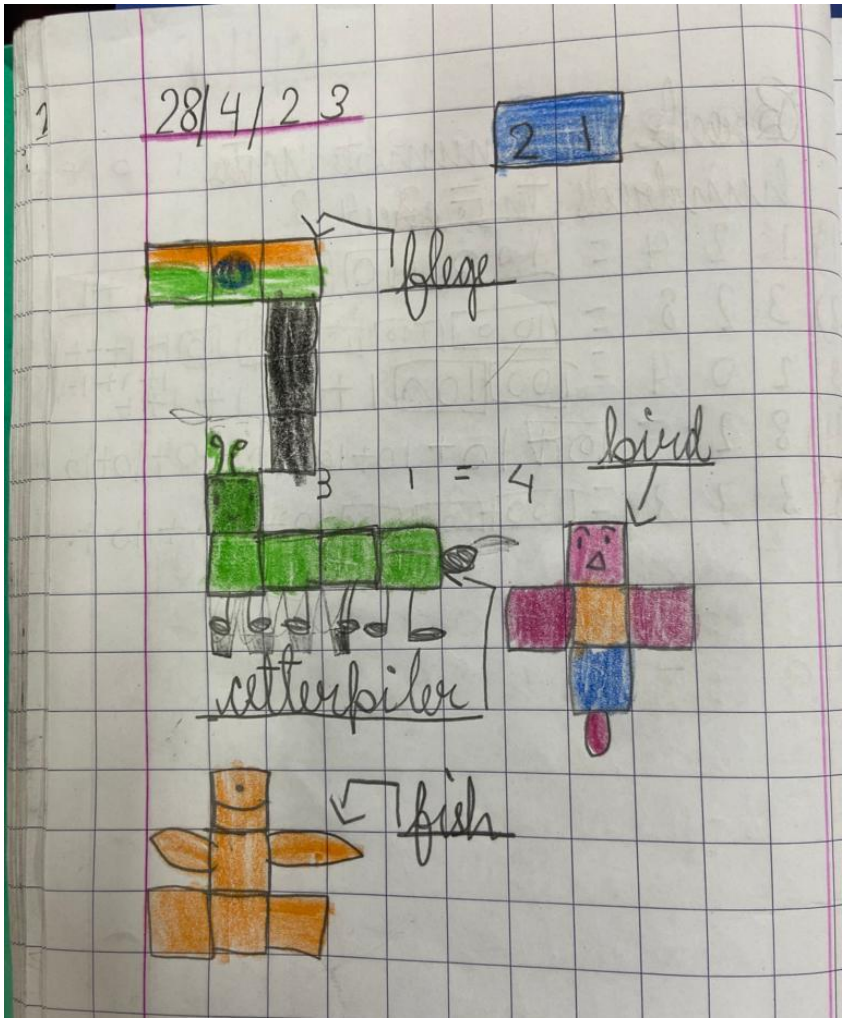


Figure 55: Activity 3

This was a session that required some on the spot changes. While explaining them how to perform the activity, it was observed that no one seemed to be clear upon what to do. The students found it very tough to make a 'whole' image. Instead, they started drawing these individual blocks out.

Hence, I changed the activity midway. They were now asked to color any number of squares and make images out of it. Then they were asked to count the total number of squares used. If the total number exceeded 40, they were to remove any image and make a new one so that they remain under 40 blocks used.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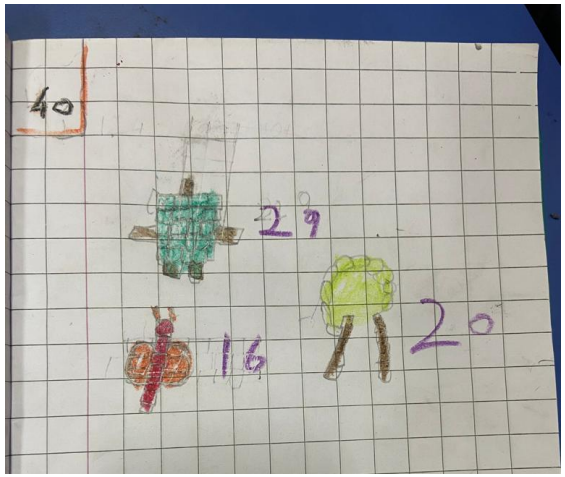
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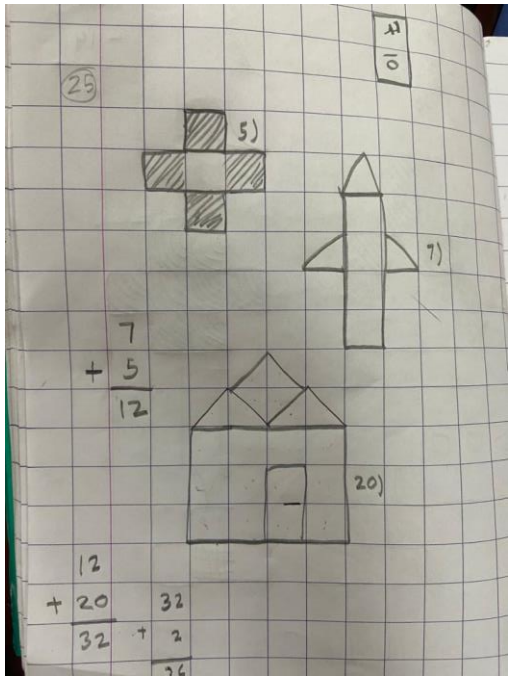
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Session 6: Evaluation Assessment given to be solved. (43 students)

Type of Question	Average Correct	Average Incorrect	Incorrect per 100 Students
Place Value and Forming Numbers	31	12	28
Number Series	28.33	14.67	34
Word Problems	31.25	11.75	27.3

Method C (Using Theory with Experiential Learning):

The teaching methodology was same as that of Method-B with the exception being the addition of bits of Theory while conducting the activities. Following were the observations:

- Activity 2 (Forming Numbers while rearranging digits) saw a much better outcome. Many students were able to form 6 numbers with the given 3 digits.
- They were also able to identify the greatest and smallest numbers out of it since they were aware that they had to place the highest digit in Hundred's place. Results were even better than Method A (Traditional Method)
- Activity 3 (Drawing and adding squares) did not see much difference in results. In fact, it seemed like a waste of time. There was no substantial learning in both the sessions (Method B, Method C). Something that could be easily explained in a theoretical way seemed to be made complicated by colouring and counting boxes.
- Although the students managed to get the sums right, the concept of grouping (Selecting which shapes to be under 40) was unclear. We had to shift using theoretical method in the end.
- Perhaps better results would be seen had this activity been conducted over multiple sessions, but the doubt still remains if it would be worthwhile.

Session 6: Evaluation Assessment given to be solved. (43 students)

Type of Question	Average Correct	Average Incorrect	Incorrect per 100 Students
Place Value and Forming Numbers	32.1	7.9	18.3
Number Series	28.33	11.67	27.2
Word Problems	32.75	7.25	17

Students taught using Theoretical Method performed way better in Number Series and Word Problems. It also saved multiple sessions of teaching. However, the concept of Place Value and Forming numbers was the most efficient (18.3 incorrect vs 29.4 vs 31) in Method C- using the Design Thinking technique with theory.

Overall Evaluation Table

	METHOD A			METHOD B			METHOD C		
	Correct	Incorrect	Inc. Per 100 Students	Correct	Incorrect	Inc. Per 100 Students	Correct	Incorrect	Inc. Per 100 Students
Observing Mirror Images	39.67	4.3	9.7	31.2	9.8	23.9	34.8	6.2	15.04
Drawing Axis to make Mirror Halves	38.5	5.5	12.5	34.2	6.8	16.5	36.3	4.7	11.38
Pattern Recreation	36	8	18.2	27	14	44.3	36.3	4.7	11.38
True/False	38.3	5.67	12.8	24	17	31.2	33.7	7.3	17.8
Overall			13.3			28.975			13.9
Place Value and Forming Numbers	29.4	7.6	29.4	31	12	28	32.1	7.9	18.3
Number Series	30.67	6.33	17	28.33	14.67	34	28.33	11.67	27.2
Word Problems	31.75	5.25	14	31.25	11.75	27.3	32.75	7.25	17
Overall			20.1333			29.7667			20.8333