

Game for learning Basic letters of Devanagari Script for Children using OCR technology

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Semester IV Project Report

Piyush Churad | 136330007

Guided by Prof. Anirudha Joshi

Industrial Design Centre,
Indian Institute of Technology,
Bombay

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A Report on

Game System for learning Basic letters of Devanagari Script for Children using OCR technology

submitted in partial fulfillment of the
requirements for the award of the degree of
Masters of Design
in
Interaction Design

submitted by
Piyush Churad
136330007

under the guidance of
Prof. Anirudha Joshi

Industrial Design Center
Indian Institute of Technology, Bombay

Declaration

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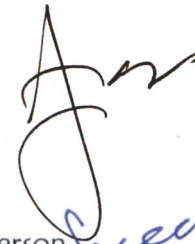


Piyush Churad
136330007
Industrial Design Centre,
Indian Institute of Technology, Bombay

Approval Sheet

The project titled 'Toy for Learning Devanagari Script for Children' by Piyush Churad, is approved for partial fulfilment of the requirement for the degree of 'Master of Design' in Interaction Design.

Guide



Chairperson



Internal Examiner



External Examiner



Date 20/06/2015

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Piyush Churad



Abstract

With the increase in English medium schools in urban areas, children start learning A B C D first and they find it difficult to learn क ख ग घ. The language learning of their own mother tongue falls into second priority.

The aim of this project is to design a game which helps children of 1st & 2nd standard in learning the basic letters (मुळाक्षरे) of Devanagari script using the capabilities of OCR. Using the hypothesis that **“If users play with the primitives, they can learn Devanagari letters”**, several explorations, experiments and research were done considering the OCR technology constraints.

‘अक्षरमाळ’, a 2D digital video game was designed based on the concept of tangible primitives and their graphical similarity that could best exploit the OCR technology features and enhance the learning experience of a child through a unique gameplay. The game consists of 28 tangible primitives derived from a modular font. A sequence of letters to be taught to the users was decided and structured in order to reduce the complexity in recognition by the users. The game motivates and gives feedback using a set of animations.

This prototype was then used to validate the proposed hypothesis. Through usability evaluation and user feedback, several iterations in design were made to reach the final game. During evaluation, users could play the game successfully with most of them being able to recognize and learn the given set of Devanagari letters easily.

Future scope lies in developing a scalable game system and exhaustive evaluation to make the game system more usable in terms of learning and engagement.

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वरदान

आय. ए. पी. चाईल्ड वेलफेअर

इ. ए. ललित

बाल हक्क केंद्र

1 | Introduction

1.1 Motivation

In India, there is a literacy problem in rural schools, be it English or the regional languages. As of 2011, after five years of classes, fewer than 60% can read a short story [1]. A third of all grade-three students can't read at all in their native language [5]. Enrollment rates are 58% for pre-primary, 93% for primary, 69% for secondary education. Despite the high overall enrollment rate for primary education, among rural children of age 10, half cannot read at a basic level [4].

According to current estimates, 29% of Indian children study in private schools. With more than 50% children enrolling in English private schools in urban areas, nearly 20% of the children were enrolled in private schools in rural areas. Most middle class families send their children to private schools. In such schools, the medium of instruction is often English, though Hindi and the state's official language is also taught but as secondary language [4].

Education in India has the primary languages as Hindi, English and State languages. The language learning starts at home and continues at schools. A child learns his mother tongue from his parents, Teachers then induce regional language which at times might be different from the mother tongue

Most private schools in India teach English as a first language and then the state languages as a second language. It is a part of their academic syllabus which is followed by the schools. The basic letters are taught in the first semester followed by 'Murtas' in the very next semester. So a child has to learn such complexity in a span of a 5 to 6 months.

From the above facts it can be inferred that despite high literacy rates in the younger groups and the enrollment rates in private schools the language literacy is still a problem. The available materials for learning Devanagari scripts are very less. Most of the materials just try to copy the materials available for Roman Scripts.

Children have access to computers and technology but they don't have access to learning toys to learn Indian languages. In the Indian market and the game stores, compared to the fun filled and fancy games available for learning A B C D, those for learning अ आ इ ई are becoming less important. Also Toys, Games related to Devanagari letters are quite less in number. For regional languages, the number is even smaller. The available interactive mediums of learning English is much more appealing and engaging than Devanagari.



1.2 Project Brief

There are a number of games in the market which helps children learn the English language, but there are few for learning Marathi or Hindi. Even for learning English pronunciations, Devanagari script is used in many books. While in many of the available games English is used for giving guides for gameplay. When asked to recognize letters from both English and Marathi languages, children were quick and spontaneous for the former one, whereas they failed to recognize many letters in Marathi.

TDIL project by the DIT has been funding a consortium to develop OCR technology for Indian Language. This project aims to build a toy which would help children to learn ‘मुळाक्षरे’ basic alphabets in Devanagari script using OCR technology. Use of an Optical Character Recognition technology provides this toy a unique way of play and fun element. The Project explores the use of primitives for learning of a Devanagari Script for children of age 7-8 years and the users who fail to recognize Devanagari Script.

1.3 Design Process

Understanding the different aspects and complexities in Devanagari Script comprises a large part of my secondary research. Developmental theories and teaching methods were studied to understand the approach for teaching Devanagari Script to children. Existing materials along with previous projects done using OCR technologies were analyzed and implications were drawn towards the final concept.

User study was done to understand the issues faced by children to recognize Devanagari script and teachers to teach the script. Various ideas were explored considering the OCR technology constraints. The design concepts were prototyped followed by user feedback before arriving on the final concept. Various iterations were tried before developing the final prototype.

The report is divided in three parts. The research part discusses the work done in Devanagari Script learning, existing material and insights drawn from the interviews of potential users. The Modular font design is covered in the middle part which discusses the study about primitives and their use in the final design concept. The final part explains the final design concept in detail and the Evaluation.

2 | Secondary Research

2.1 About Devanagari Script

Alphabets are the basic building blocks of any script and basic written symbols language. They can be used to write one or more languages. Along with Hindi and Marathi, Devanagari is also used to write other languages, like Sanskrit, Nepali, Marwadi, Konkani, etc.

There are 14 vowels, 2 diacritics, 34 consonants and 2 conjunct consonants included in Marathi Language [24].

The order of letters in Devanagari script is based on phonetic principles that consider both the manner and place of articulation of the consonants and vowels they represents. Devanagari is a segmental writing Speech in which consonant–vowel sequences are written as a unit [24].

Vowels:

अ आ इ ई उ ऊ ऋ ॠ लृ लृ ए ऐ ओ औ

Diacritics:

अं अः

Consonants:

क ख ग घ ङ च छ ज झ ञ ट ठ ड ढ ण त थ
द ध न प फ ब भ म य र ल व ष श स ह ळ

Diacritics:

क्ष ज्ञ

About Primitives in Devanagari Script

Mr. Sripad Bhagvat in his Marathi book about Marathi Vyakaran mentions the origins of Devanagari script and the use of primitives in it. Script researcher Mr. Wakankar informs that the verses from 'Atharvashirsha', a Hindu Scripture dedicated to the god Ganesha, are the sources of Devanagari script. The form of letters and the pronunciation are nothing but the symbolic forms of Lord Ganesha [10].

Mr. Wakankar infers - vertical, horizontal and skewed segments of a Circular Full moon with different lengths of vertical, horizontal and skewed lines can form Devanagari letters. For sample the first row contains line segments and circular segments followed by the letters they form are below [10].

One or more primitives merge together and turn in to a visual entity called letterform. Primitives here can also be considered as basic segment of the letterform. They have a very peculiar representative visual character of the script [27].

ॐ	ॐ	ॐ	ॐ	ॐ	ॐ	ॐ	ॐ	
अ	इ	उ	ऊ	ए	ग	व	ब	
ॐ	ॐ	ॐ	ॐ	ॐ	ॐ	ॐ	ॐ	ॐ
क	प	फ	ल	ळ	ट	ठ	ड	ढ

2.2 Challenges in learning Devanagari Script

A devanagari script has many facts, which can often leave the child hunting around in the dark. The basic constructs are:

- Number of Letters

The number of letters in Devanagari Scripts is quite large for a child to learn. (14 vowels + 2 diacritics + 34 consonants + 2 conduct consonants)
(Refer p. 4)

- Complexity of letterforms

Devanagari Script contains complex letters forms such as ख छ झ क्ष ज्ञ, in which child a may face difficulties in recognizing the basic character of the particular letter and the defining characteristics of those letters such as knots or loops. [27] [28]

- Graphical Similarity

Graphical similarity can be easily found in Devanagari letters, which creates a confusion for a child to distinguish between two similar looking letters as in च - ज, य - थ, घ - ध, प - ष, व - ब it can be noticed.

- Differences in phonetics

Each Devanagari letter transcribes a distinct sound. Children sometimes cannot differentiate between subtle sound differences

- Usage of letters

Unless used repeatedly while speaking or hearing, it is difficult to use or relate Devanagari letters with surrounding events or real life objects. For ex. A child learns to use a letter ग for गाय, but ड, ज्ञ or ष is not associated with common objects.

2.3 Primitives in learning Devanagari

Learning to Write Devanagari:

Santosh Kshirsagar, in his experimental case study of a doctoral thesis on “How children learn to write Devanagari” [27], has mentioned that a child is visually exposed extensively to a letter form at an early stage. Association of a phonetic with form is like a dent on child’s brain in the learning process. Actual writing process comes much after that.

He infers that writing is a mark making activity which a child needs to learn rigorously. Making a letterform has many constraints. Unless visually exposed to the letterforms deliberately, child faces difficulties in learning the Devanagari script.

Girish Dalavi in his doctoral thesis on ‘Devanagari typography’ discusses ‘Anatomy of Devanagari Typefaces’. He describes certain key parts and ideal characteristics within the letters of Devanagari scripts For ex. Loops, Knots and Joints [28].

Segmentation of a script is important for recognition of the script. It helps in improving the identification of a particular script. Devanagari is complex structured script in which child learns to write letters from the basic segments such as straight and curved lines, the most distinctive look about it is the horizontal line ‘Shirorekha’, that’s above almost all the letters followed by the discrete structural form.

Devanagari is a segmental speech where vowels and consonants represent discrete speech sounds. In schools Devanagari letters are taught according to the phonetics, a place within the mouth that they are articulated [31].

Considering the tangible form of the game, the concept of primitives and their graphical similarities was taken to explore its use for learning of Devanagari script and the several prototypes were created.

OCR Technonlogy and Devanagri

In recognition process it becomes difficult to visualize a letter just by its phonetic, whereas it becomes easier when given a visual reference. Compared to the classification of letters according to the place within the mouth that they are articulated, classifying them graphically based on the similarities they possess it becomes easier in the earlier stages of learning for recognition purpose.



2.4 Developmental Theories and Teaching Methods

Each child has a distinct and unique learning curve, which is moulded & influenced by the atmosphere around him and the people & places that nurture & stimulate learning. For children to construct knowledge, they need the opportunity to discover for themselves and practice skills in authentic situations. Providing children access to hands-on activities and allowing adequate time and space creates an opportunity for individual discovery and construction of knowledge to occur [6].

In the Piaget's theory of child development, it is stated that children acquire knowledge through sensory experiences and manipulating objects [2].

According to Vygotsky's Theory, child develops language and ability to think symbolically between 2 - 7 years [3].

Jane Healy, a well-respected educational psychologist says, "Early childhood programs that implement a directed academic curriculum often replace essential, hands-on learning activities with skill-based performance and rote learning tasks. In

doing so, they risk the developmental growth necessary for children's future academic success." [13]

Thus at the early stages of the learning activities, games, puzzles or toys which are tangible in form and easy to use can prove to be an aid for developmental growth of the child. They can motivate a child to play, explore and interact with it while learning simultaneously. Games can support language development and overall learning in children. Children learn language, cognitive and other skills by playing with such games. They get to learn about concepts like Proportion, Color, Shape, Letters as well as Number concepts, Size concepts and can enhance their problem solving skills.

Reading vs. Writing

Child has a clear visual reference available of the objects in outside world. But in case of letter forms, parents or teachers need to expose the child to the letter related information in terms of its form, phonetic, related objects, reading and writing it repetitively. Since learning a language is a multi-sensory process, in schools or at home, a child is exposed to visual form of a letter first. The repetition of the visuals

along with the speech sounds or phonetics make a child to understand the letter forms. When a child has to draw a line or a circle, he is supposed to know what line or a circle looks like, which one is a line or circle. He first visualizes, identifies and then draws one.

Because to reading requires the comprehension of letterforms and understanding them, and writing is just like copying the movements or sometimes doodling. Reading puts voice to a letterform and if child is not able to internalise it then it may create confusion in the later. The process of reading is a brain work and writing it is a motor skill. If a child doesn't comprehend what is a mountain, then he won't be able to draw it while maintaining its mountain-ness. Similarly unless a child understands the letterforms he/she won't succeed in learning the writing part. It is easier to read what is printed at a much faster rate than writing it down. Writing is important but it can slow down the process of learning.

Thus visualization, identification and reading of the letters should happen before a child starts writing them. Generally a child can be taught to write after the age of 4 years.

2.5 OCR

Optical character recognition (OCR) is an image processing technology which uses the mechanical or electronic conversion of images of typewritten or printed text into machine-encoded text. It is a utility tool for digitizing the content and is essential for development of knowledge networks such as digital libraries. [32]

OCR technology offers the facility to scan and store the printed text. There are three basic elements of OCR technology - scanning, recognition and then reading text. It is a common method of digitizing printed texts. OCR technology can be used to recognize tangible letterforms so that it can be electronically edited.



Various technologies can be used to detect the tangible letter forms. For example,

- Optical Mark Recognition (OCM),
- Radio Frequency Identification (RFID),
- Bar Code Recognition (BCR),
- Magnetic Ink Character Recognition Code (MICR Code)

These technologies were analyzed and found that OCR technology has advantages over others, in terms of, dynamic, real-time character recognition. OCR technology allows you to save a lot of time and effort when creating, processing and repurposing various shapes and forms. Use of Camera for detection makes it familiar to the user.

OCR Limitations

The limitations for OCR which affect the detection process.

- Surface of the material being detected
- Color of the material in terms of opacity
- Subtleties of the shape of the objects being recognized for example '0' & 'O'
- Surrounding light
- Shadows formed by the object
- Angle of projection of the camera mounted. Ideal Angle of projection is 90 degrees.

2.6 Existing Products

OCR Toy

This toy is developed by CDAC Pune. It was a part of OCR consortium project. The toy uses camera for image processing thus recognizing the shape and characters placed in front of the camera. The toy has a software support and few constraints.

The initial concepts are designed considering these OCR technology constraints. The setup contains a Laptop and a web camera mounted at particular height. (Fig.2)

The OCR toy interface shows a picture of Fish and three boxes with last box containing 'ी'. The child is supposed to place letters म छ ल separately on the table or surface which would then constitute a word "मछली".

This setup uses the inbuilt web camera of a laptop and the wooden surface. The initial few concepts uses this setup. (fig.1)

All the concepts use OCR technology and the primitives of Devanagari letters. The ideation process includes trying out several concepts and their low fidelity prototypes. The final design concept is evolved through this iterative process.

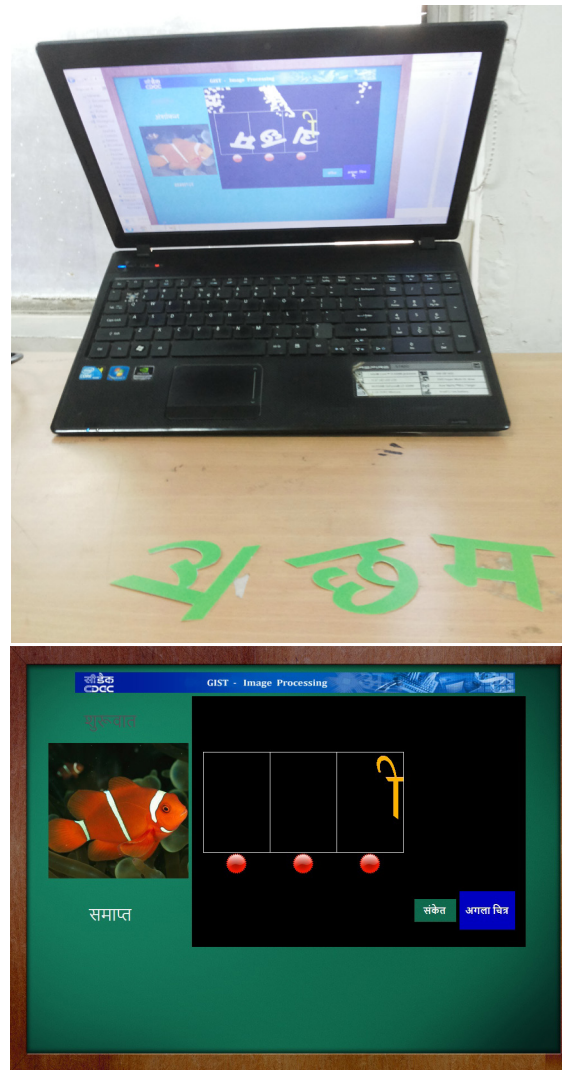


Fig 1: Setup using Inbuilt Web Camera of a Laptop



Fig 2: Setup using a separate Web Camera

Toy for Learning Indian Languages [29]

This concept is an electronic toy for kids aged 1-6 years, that aids the introduction and learning of Indian languages through an innovative method of play and using the capabilities of OCR technology. The toy is based on play and learn concepts that which exploits the OCR technology features and offers an enhanced learning experience to the child.

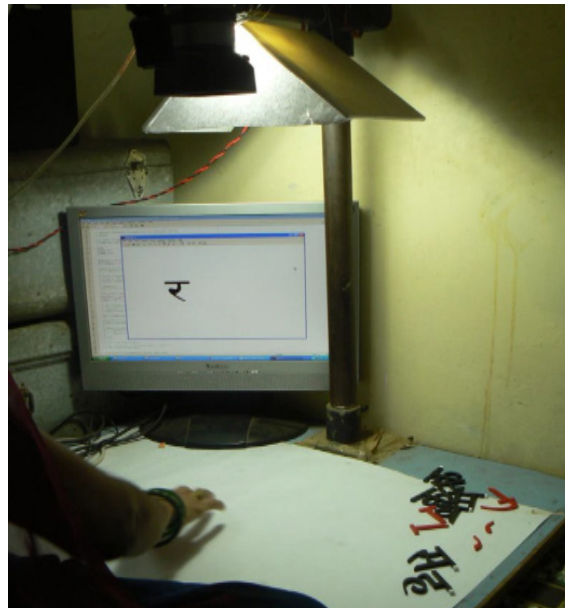
The toy consists of a unique and enjoyable gameplay that involves use of certain simple shapes to create different Hindi alphabets. The product was designed for different levels of gameplay.

It was also part of OCR consortium Project



Learning Aid for Illiterates [30]

This project is about teaching illiterates how to read Hindi (Devnagri Script) which is the first step in learning any language. It explores the idea of making the system independent so that it can be used anywhere and anytime of the day. It also tries to reduce the involvement of the teacher/mediator and make the whole process more self learning, interactive and enjoyable.



Review:

The projects use the concept of Tangible letters. The learning happens through the concept of shape similarities with common real life objects. A voice and visual feedback adds to the learning and play value when incorporated with the tangible feature of toy.

Work on Devanagari Fonts

Inspiration of designing a modular font was taken from previous work done by Deepali Karanjgaokar. The modular font is child friendly, colorful and playful when printed and cut on sustainable materials. There are 28 primitives in all which can form all consonants from Devanagari script. The modular font is shown below.

It was a part of the OCR consortium project.



Review:

- It has dove-tail joinery which is difficult for children to comprehend and use, when taken as tangible cutouts from a solid material.
- The overlapping primitives in this case cannot be held together as a single unit as there is no base.
- The font lacks typographic proportions.
- 28 primitives add to the cognitive overload for the children.
- The subtle differences in some of the primitives creates confusion while choosing the correct primitives. The examples are shown in the the encircled primitives in the adjacent font.
- It is easier to differentiate between different types of primitives by their colors, but it difficult for OCR software to detect colorful software.

Materials for Devanagari Script

There is material available which uses written and non-written approaches to teach or aid learning. Numerous toys, mobile applications, articles, papers and other kind of work have been already done on language learning. Many experiments and explorations are done with OCR technology and Devanagari Script. Some of them are discussed below.

Books

Balbharti Prakashan, Sachitra and Jivandip are the major publications used in schools in Maharashtra state to teach Marathi and Hindi languages from basics. These books contain lessons, poems, assignments,

instructions for children as well as for teachers to follow.

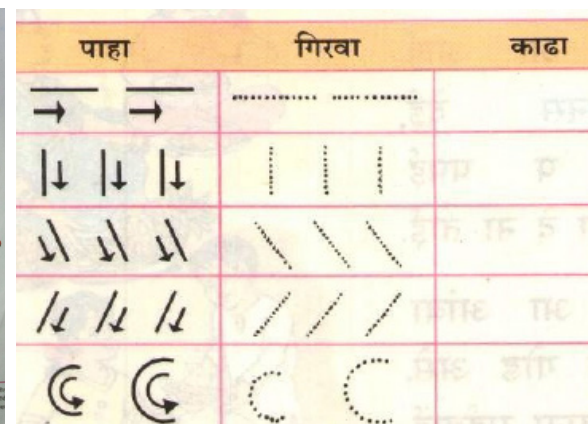
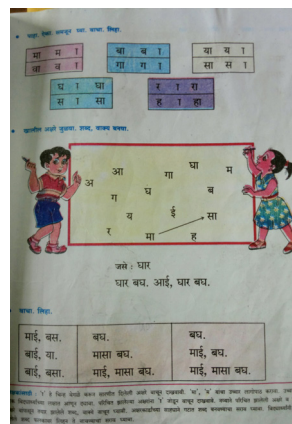
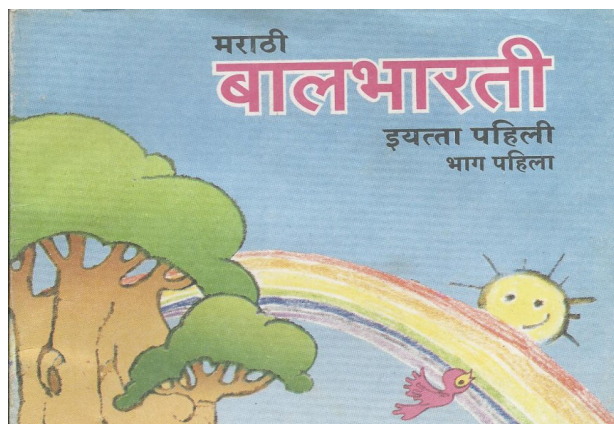
By reading and discussing about the picture containing letters, children guess and tell. The stepwise instructions about writing letters is given at different stages of the curriculum

The curriculum starts with the practicing of basic shapes such as straight and curved lines. Then children are taught to pronounce the letters through wordlists, poems or objects from daily use such as fruits, animals, etc. Parallel to that they are taught the formation of letters and how to write them. Sometimes teachers try to mimic the shapes to find analogy of a letter with surrounding objects, sometimes child is

forced for a rote learning of these symbols. Schools uses both writing and non-writing approaches but mainly focus on the writing approach of learning.

Since every individual child is unique in terms of learning tasks and development of his/hers skills, it may be difficult for him to pick up the symbols with every other child in school. It requires a lot of practice for a child to learn different symbols to recognize, read and write for the first time.

Books can play an important role in learning and providing the necessary required content in steps. Books can be used to design the guidelines and the instructions.



Toys available in Indian market:

There are various types of fancy fun filled and colorful toys available in the Indian market. Most of the toys are engaging and interactive considering the increased use of technology in toys these days. They are designed so that a child can play by himself without any support needed. The educational toys available in the market for language learning help children in improving skills such as handwriting, learning vocabulary, alphabets and foreign language, reading and word games.

All that we discussed earlier is mostly a case of English alphabet learning toys. For Devanagari letters there are less number of good toys and games available in the market. Filtering out this number with an OCR technology use in them, would result in hardly any toy available for playing for children.

Looking at the current scenario, municipal schools in urban areas and schools in rural areas don't have toys which can be used to teach Devanagari letterforms to children. All they have is letter charts, wall paintings and worksheets.

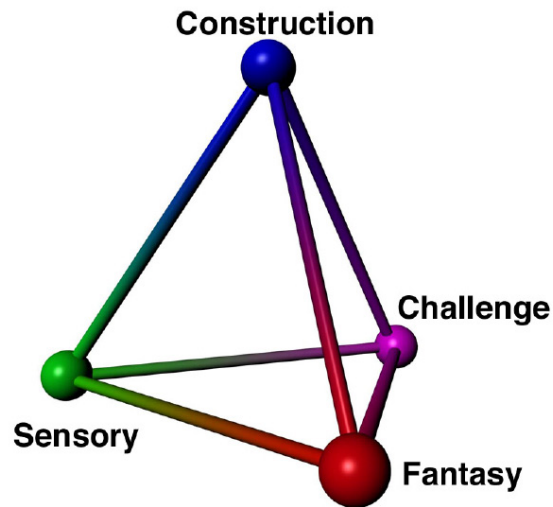


The most common type of toys available are the ones with tangible letters forms. Some of them are magnetic, based on blocks, Flash cards and puzzles, etc.

The Play Pyramid can be used in classification of toys and games by taking a toy concept and moving it around inside the Pyramid. The likeness of the toy and the benefit of the toy to the children which can be called as Play value is classified by the Play Pyramid.

The Play Pyramid

Based upon Piaget's Stages of Cognitive Development a concise and complete classification of play is defined four general categories, [26].



The Play Pyramid

- Sensory - Sensory-Motor Period (0 - 18 Months) the child engages in sensory play and play involving moving objects to produce reactions.
- Fantasy - Preoperational Stage (18 Months - 6 Years) the child engages in symbolic play. Rules are not developed. (4 - 7 years) the child can perceive and imagine.
- Construction - Period of Concrete Operations (6 - 12) the child engages in more problem-solving play. Play involves classification and rules.
- Challenge - Period of Formal Operations (12 - 15) Thought and play become more abstract. Play becomes more social and refined.

The edges consist of play that falls between two categories. The faces consist of play that falls between three categories. The space inside the tetrahedron is for play that has elements from all the categories of play.



Fig.3 The edges of play pyramid

The game should stimulate multiple senses. It should allow the child to construct meaning. It should give an element of fantasy and surprise to the child. It should challenge the child every time he plays.

The following existing toys and games can be classified with the help of Play pyramid.



Magnetic Wooden Alphabets [15]:

Magnetic Hindi varnamala have Varna, Vyanjana & Matras that make a colorful jumble of learning possibilities, for letter recognition, matching, and stenciling, Magnetic Wooden Alphabets Completely Safe to be used by kids, as it does not have loose magnets and are made of superfine wood without splinters or rough edges.

The strength of this toy is colorful tangible wooden letters. A solid material like wood or colorful plastic can be used to make tangible letters which can be playful.

Play Values : Construction and sensory



Skilofun Capital Alphabet Tray with Picture [17]:

Each Side has Four Cavities of Different Categories – Transport, Animals, Fruits and Shapes. The child is supposed to identify Each Object and its Respective Cavity and ‘Post’ it in the Correct Cavity. It’s again a toy which focuses mainly on non-writing part.

The strengths of this toy is a puzzle in which child has to fill the wooden cavities with letter forms. It provides hints to child with real life object illustration.

Play Values : Construction, sensory and Challenge



Alphabet Blocks [18]:

It’s created from wood with oversized letters, beautiful illustrations and color coordinated words. It has a playfulness in terms of blocks and illustrations corresponding to the letters. It also focuses mainly on non-writing part.

The strength of this toy is the blocks which has letters and illustrations of related object on adjacent faces of same block. It’s playful in terms of making words from letters.

Play Values : Construction and sensory



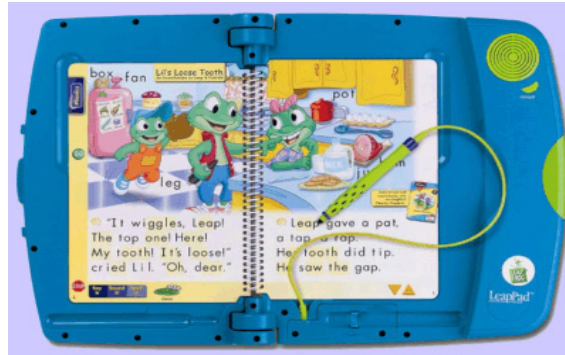
बतस
फल
घर

Movable Hindi Alphabet [16]:

It contains the child friendly cutouts of letters. Here a child is asked to play with the letters and make meaningful sentences. It doesn't use any tacit technology but focuses on the non-writing approach.

The strength of this toy is also the soft textured tangible letter cutouts. Such textured cutouts can be used for OCR detection purpose.

Play Values : Construction, sensory.



Leap frog [14]:

Hear board books come to life with sounds, Trace letters to learn how to write with step-by-step guidance. It focuses on the writing approach for learning along with speech sounds.

The strength of this toy is the added technology in terms of speech sound. It can be used for hint provision or a narrator for peer support.

Play Values : Construction, sensory

Review:

The existing toys with non-writing approach, helps children in learning the devanagari script in terms of total number and the usage of Devanagari letters in words or relation with surrounding objects. But they don't facilitate the complexity of letters or graphical similarity and phonetics. Reasons could be the technological and cost constraints.

Most toys have a play value which lies on the line between Construction and Sensory, but they lack in challenge and fantasy values.

The tangible feature of letter cutouts with solid materials suits best for OCR detection purpose. But it lacks in certain aspects such as animations or sounds which can be found out in smartphone games and applications.

Mobile Games / Applications

Since mobile phones have become a part and parcel of our daily lives, children can easily access their parent's phones and thus can play games under parents' supervision. As a result of these children are getting more familiar with the English alphabets before or during preprimary schooling. There are more games and applications available for English than Hindi or Marathi alphabets.

The existing mobile games and teaching applications focuses mainly on the practice of writing alphabets through touch based smart phones. The ones available for Devanagari letters have copied concepts from those available for English letters. A child is given puzzles to solve, which are related to the letters and corresponding objects.

In the current scenario, it is better to have them practicing as well as fun and learning new skills. Use of interactive media, animations and audio visuals engages a child in learning things through tablets and smart phones easily.

The number of toys which make use of OCR technology are very few in number. OCR toys require an integrated software and hardware including a camera, with the toy. More over they are also costlier.



OSMO [12]:

Osmo is a new, fun and educational gaming platform for kids. It converts iPad into a dynamic, responsive interactive learning toy. It uses geometrical shapes and letter tiles and day to day objects. It has a reflector which directs the iPad's front camera to the table or floor surface where child can play. OSMO uses OCR technology and a unique game for kids to play around with. It uses a non-writing approach and enhance child's creative skills with its various games.

It is a dynamic game system which provides real time feedback. It has a variety of games which engages children's attention.

Play Values : Construction, sensory and Challenge



Alfie's Hindi Alphabet [19]:

A colorful and interactive mobile application which teaches children Hindi letters via play on screen. For each Devanagari letter it gives a picture puzzle and a narrator helps the player to solve those puzzles. After each stage player gets to choose a sticker.

There is an animal puzzle for each letter. As a reward the player gets stickers which adds player's interest in the game. The puzzles related to each letter and a good narration adds engagement factor in the gameplay.

Play Values : Construction, sensory and Challenge



Hindi Play and Learn App [20]:

It focuses on the writing and non-writing approach both. It has letters to trace out and puzzles corresponding to each letter for a child to solve.

The tracing out of letters adds a different feature to it with which child gets amused to write on a smart phone. There is a jigsaw puzzle for each letter which adds a fun element in the gameplay.

Play Values : Construction, sensory and Challenge



Hindi Alphabets – Consonants for iPad and iPhone [21]:

Unlike other mobile applications few provide features other than only tracing the letters. One of such examples is this.

The relation of letters to real life objects is done with simple concepts like match the pair, find the missing letter, etc.

Play Values : Construction, sensory and Challenge

Review:

Smartphone applications and digital games have made use of the technologies and are available for free of cost. They help children in learning the Devanagari script in terms total number of letters, speech sounds or phonetics, relation and usage of the letters through animations. Most of them have taken the writing approach, providing a platform for practicing writing these letters through touch base technologies in smartphones. But they lack in resolving the letterform complexity and the graphical similarity.

All the mobile games have a play value which lies on the pyramid face consisting of Construction, challenge and Sensory play values but they lack in fantasy.

Digital on screen games cannot provide the tangible feel of letters to the children. Hence to add the tangible feature a mixture of toy and digital game is required.

TV shows

Looking at the digital mediums, TV is medium through which a large number of audience or users can be covered. For children it's always a fun to watch TV shows and especially cartoons. They learn, imitate, play, eat, sleep in the imaginary world of cartoons they follow on TV. This approach for teaching is a non-writing approach where a narrator is either a person or a cartoon character imitating a teacher or parent at home. They are designed in such a way that the child who is watching gets involved in it completely. Some of the examples are shown below.



Dora the Explorer [22]:

In each episode, viewers join Dora on an adventure in an animated world set inside a computer. The titular character seeks viewers' help in solving a puzzle or mystery she faces in each episode.



Sesame Street [23]:

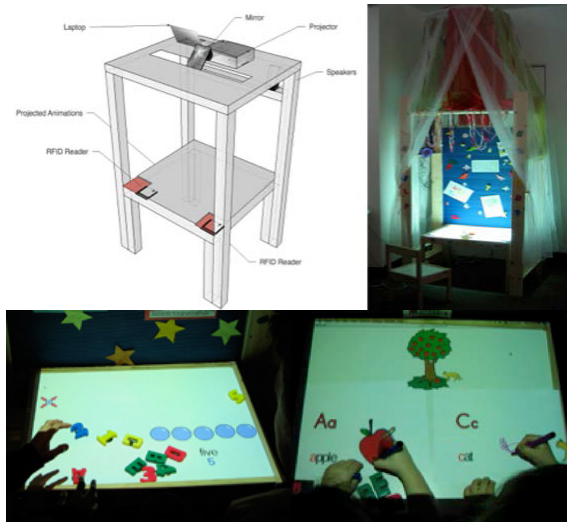
Their goal was to create a children's television show that would "master the addictive qualities of television and do something good with them", such as helping young children prepare for school.

Review:

These TV shows add a sensory and fantasy value to child's learning.

A narrator and a storyline add to the play value and learning in terms of a providing hints to the viewer as a teacher or peer supporter and providing motivation to achieve the desired goal.

Literature Review



The Discovery Table [8]:

It uses RFID technology to allow symbols of letters and numbers to be placed on a technology augmented table and provides visual, audible and tangible feedback to the children. Discovery Table demonstrates a first step towards more fundamental work towards exploring the design for tangible and ubiquitous learning for children.

Use of digital screen with tangible letter forms along with RFID technology makes it more interesting.



The Spell Bound [9]:

A “Multiple Intelligence” theory approach is used for teaching letters and connecting them to make words with certain associated meaning, to dyslexic children of the age 8-12 years. . It is an activity based learning tool which uses color, visuals, and tangible shapes for teaching Basic English vocabulary to dyslexic children.

It has letter cutouts and primitives which can be flipped or rotated and used as a Lego structure in the game play

Review:

The Tangible user interfaces (TUIs) have the potential to support children learning to read and learn language. **With varieties of technologies put together with tangible user interfaces in addition to design intervention can create interesting tools and learning aids for children.**

Easy availability of the Low cost technologies with low cost computing could make it possible to create a low cost toy for Devanagari letters keeping the tangible properties constant.

3.2 User Studies

Based on the inferences and literature study done in secondary research, primary research was done.

The primary research included field study to A Government school, 'Tirandaz Village Municipal School, Powai, Mumbai'. 2 teachers assigned for 1st grade and 1 teacher assigned for 2nd grade were interviewed. A group of children from 1st grade and 2nd grade were given few activities.

A group of 3 students at their home were given the same kind of activities. The observations were noted down.

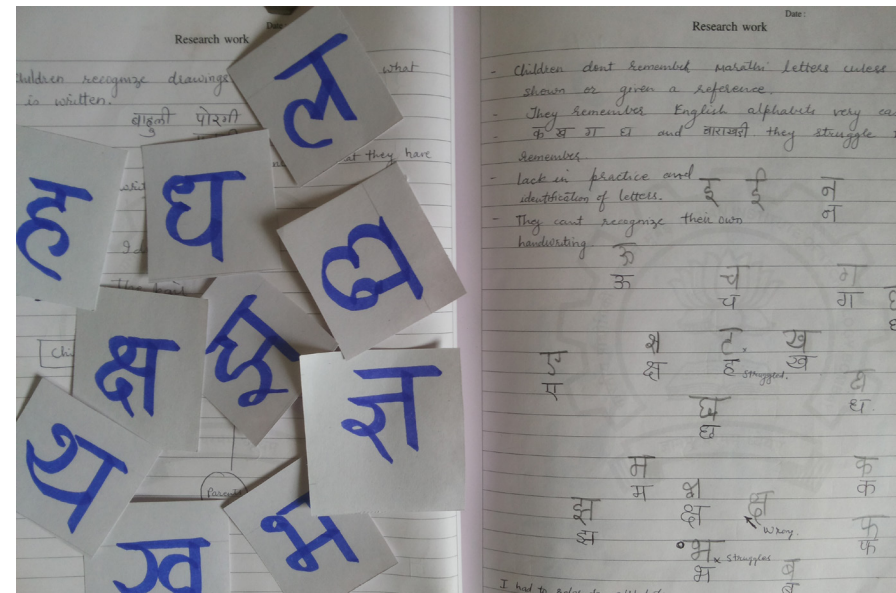
The activities are as follows.

Activity 1:

Children were asked to identify and pronounce the letters from given set of cards in a random sequence. The activity was repeated for English and Marathi alphabets.

Activity 2:

Children were asked to hear pronounced letter in random sequence and then write it down on a sheet of paper one after the other.



3.3 Findings

- Children were confused with the pronunciations.
- Simple letters like म प व ग न were easily recognized by children.
- They took more time in recognizing complex letters such as ह छ क्ष भ ख.
- Children needed support every time they were asked to recognize letters. They don't remember Marathi letters unless shown or given a reference.
- They remembered the English alphabets by heart but struggled to remember the Marathi Varnamala.
- Children can recognize the illustration from the books but can't recognize the letterforms.
- Some of them can't recognize their own handwriting. They might have just copied it from the board.
- They lack in practice and homework which could be a main cause that they tend to forget what was taught in previous classes.
- There are no toys in schools to teach Devanagari letters, except Charts and illustrations on the walls.



3.4 Insights

- From the user studies and findings these insights were drawn.
- Children find it difficult to recognize letters. Sometimes they recognize the shape but fail in pronouncing it correctly. Ex. Children write ज instead of च, so they fail to visualize some complex letters for example

ह छ भ ख.

- They face problems in identifying letters which are not in regular use for example.

क्ष ळ ह ऋ त्र

- Children face difficulties and confusion when asked to find a specific letter from a set of letters or from a word.
- The mixture of English and Marathi creates confusion for most of the children. It results in wrong pronunciations and identification.
- There is a lack of sufficient practice, since writing seems to be a boring and hard task.

4 | Restated Design Brief

Initial brief was to design a Toy for learning Devanagari Script for Children. Considering the Research and Insights drawn from it, the design brief was converged to only learning basic letters. The use of technology and digital game reinstated the design brief.

Design a Game for learning 'मुळाक्षरे', basic letters in Devanagari Script using primitives and OCR technology, in terms of recognition and Identification.

Goals:

- The Game should be educational, interactive and have fun elements in it for children.
- At each stage of the gameplay, children should be able to understand the gameplay easily and learn devanagari letters while playing.
- Children should be able to recollect and recognize letters during and after the gameplay.
- It should invite repeat play and should engage children in playing again and again. Thus help in reinforcing the letters.
- The toy should be stimulating and rewarding and should not induce cognitive overload on children.
- The target users are the children from 1st and 2nd grade, who lack in recognition and identification skills for Devanagari letters.
- The game should have all the play values i.e. Sensory, fantasy, construction and challenge.

5 | Initial Design Concepts

“It is dangerous to pretend we know what a child will do with a toy just from its characteristics alone; children have a way of doing things with toys over and beyond the apparent character of the toy [25].” - Brian Sutton Smith

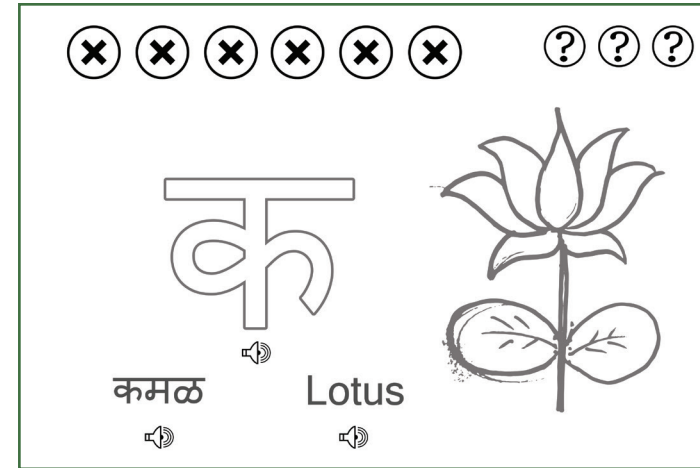
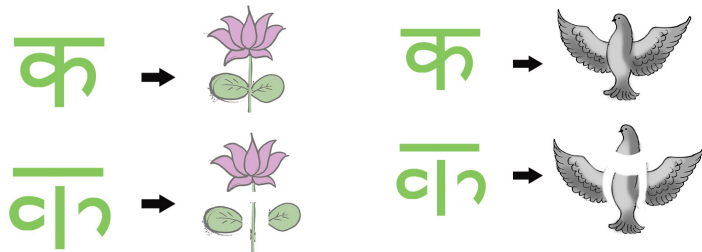
Concept 1 -

This concept constitutes the premise of child relating the letter and its primitive units via object based analogies. Here letters are made from segments.

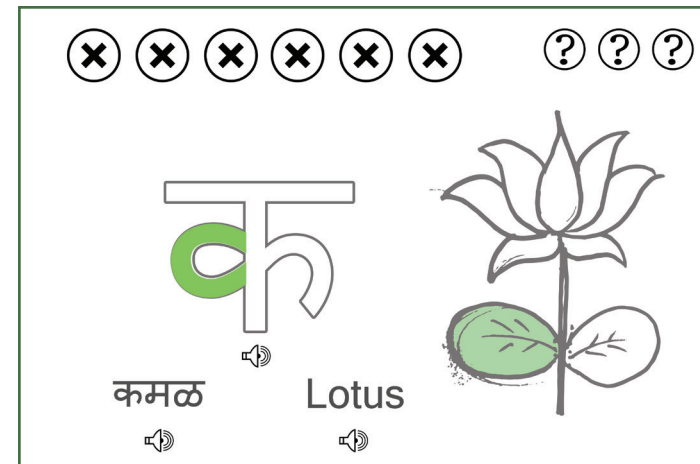


This concept augments the previous idea using narration. Here narration aids in pronunciation of letters and hence objects associated with it.

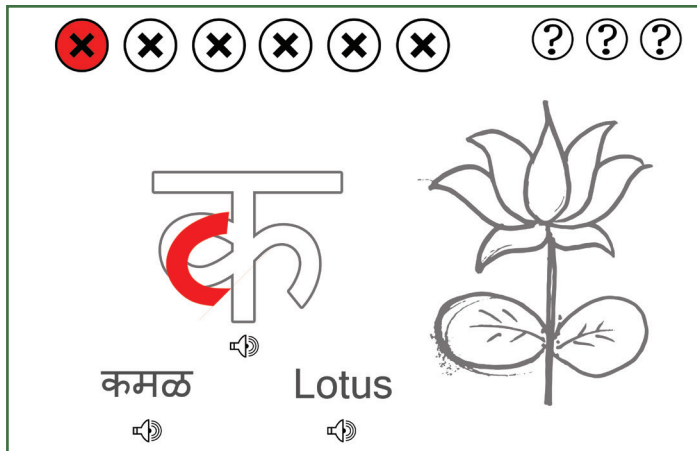
क → का c → d → क → क



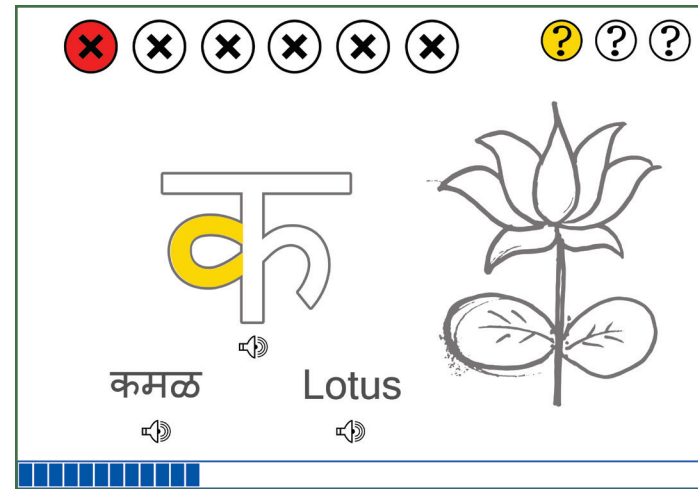
1: A Watermark of 'क' appears on the screen



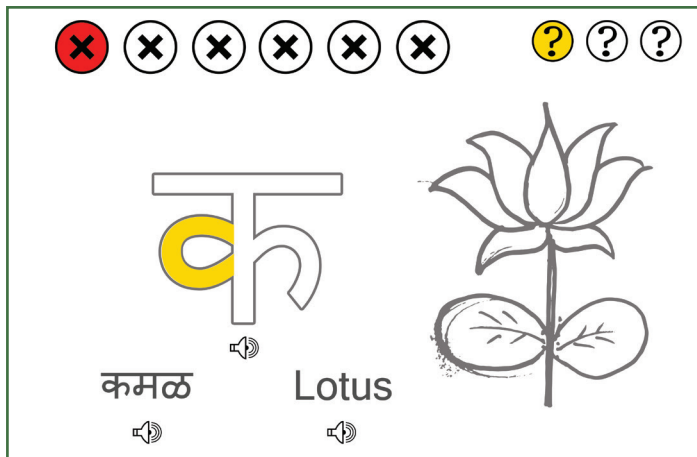
2: The child tries to match the primitive, which is correct. The Leaf of lotus is colored without any red cross.



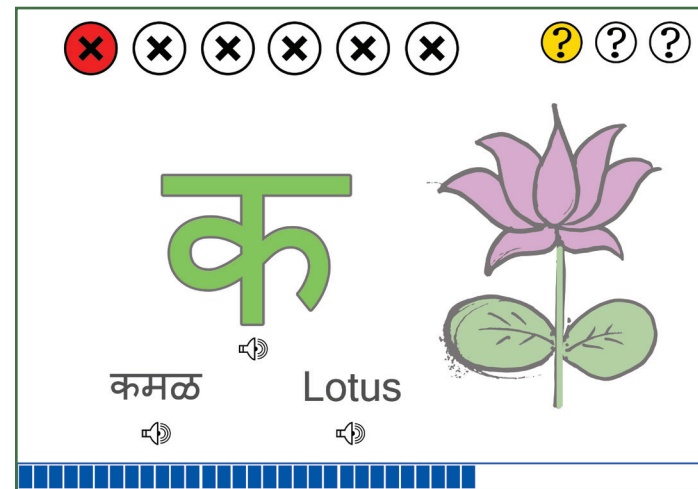
3. The child tries to match the primitive, which is wrong. The red cross detects error or wrong primitive placed.



5. Progress bar to increase the difficulty level.



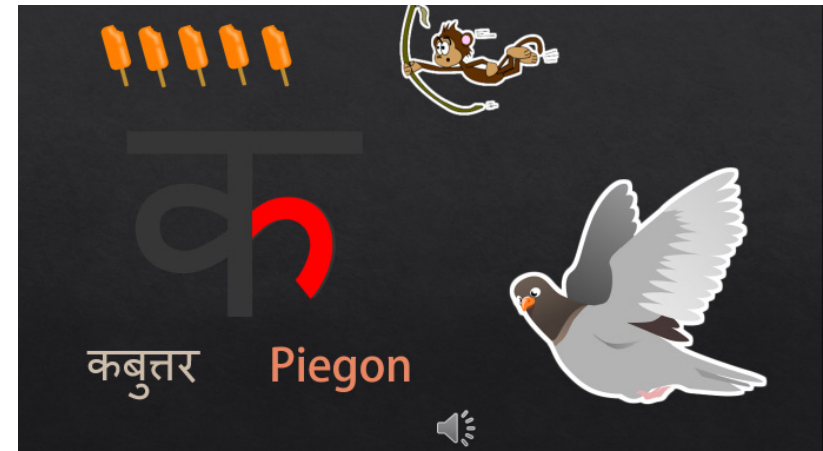
4. The child takes a hint. The primitive is shown in yellow color and hint option is used.



3. The Child completes the task and makes a complete letter.



1. Monkey is the narrator, which is teasing the children to play with him and take the challenge.



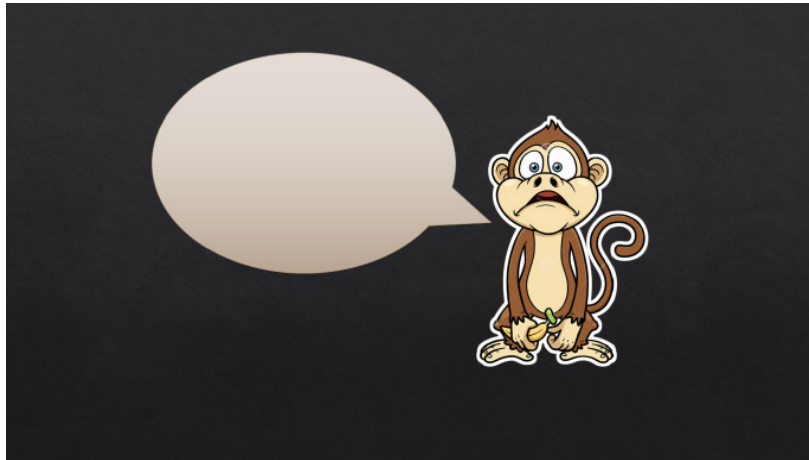
2. When a primitive placed is wrong, monkey takes away the perks/chances.



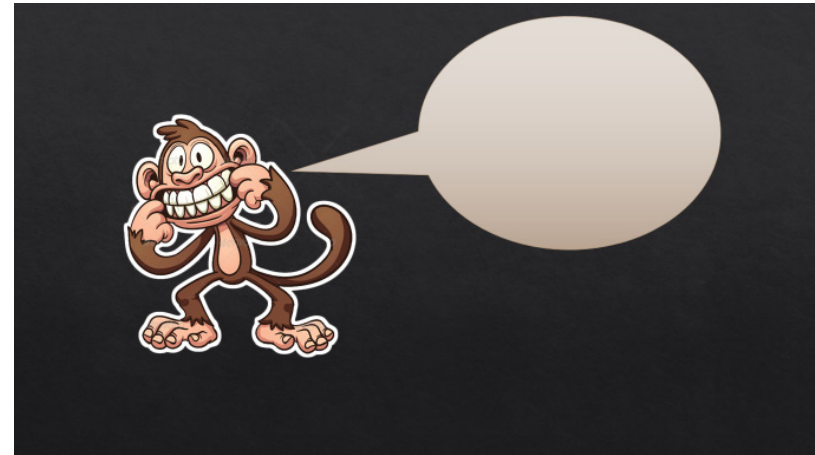
2. When a primitive placed is correct, the monkey becomes sad, because he is losing the challenge.



3. Child places all the primitives correctly and wins the challenge.



5. After losing the challenge he asks for one more challenge to make it even.



7. After winning the challenge he asks for one more challenge to make it even.



6. When a child fails in placing correct primitives in given number of chances, the monkey becomes happy and teases the child to play again.

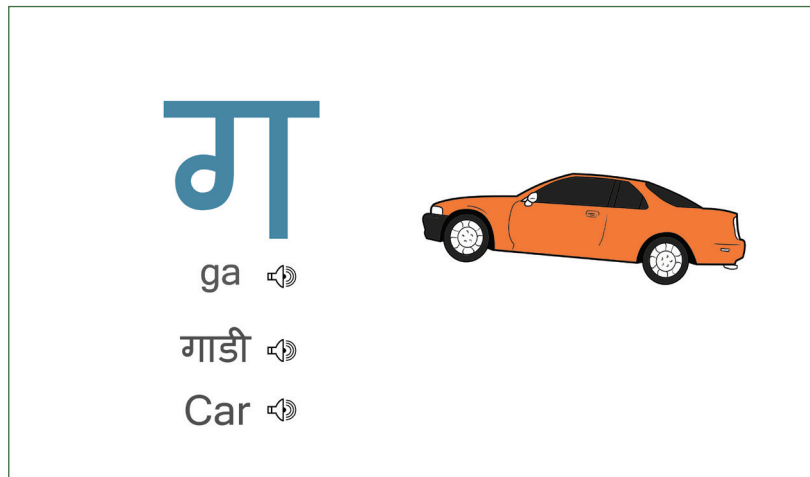
Review :

This concept focuses on the sequence in which a letter is written, it contains a narrator which helps and teases a child to play again. The analogy of primitives and object works, but it lacks the element of fun and is poor in terms of engagement.

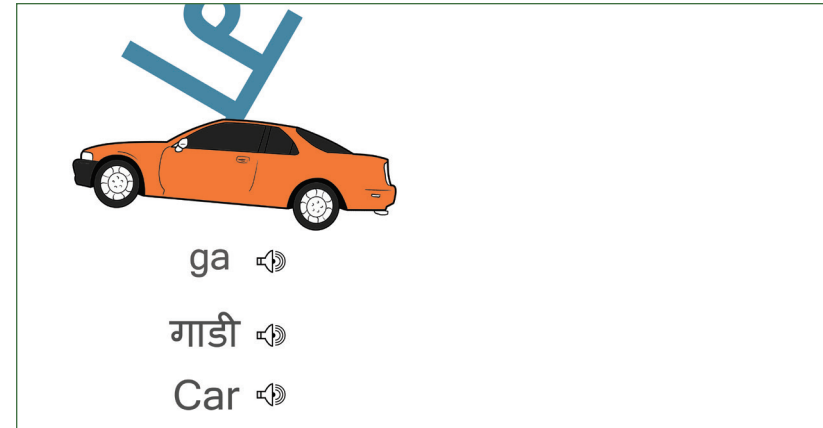
Concept 2 -

This concept is also about constructing letters from the primitive segments. Each letter is made up of a certain number of primitive units and initiates a word of an object or animal, etc. (ex. ग - गाडी) This concept has the child being engaged in a playful task, where he completes the task which also allows him making a letter form out of its segments.

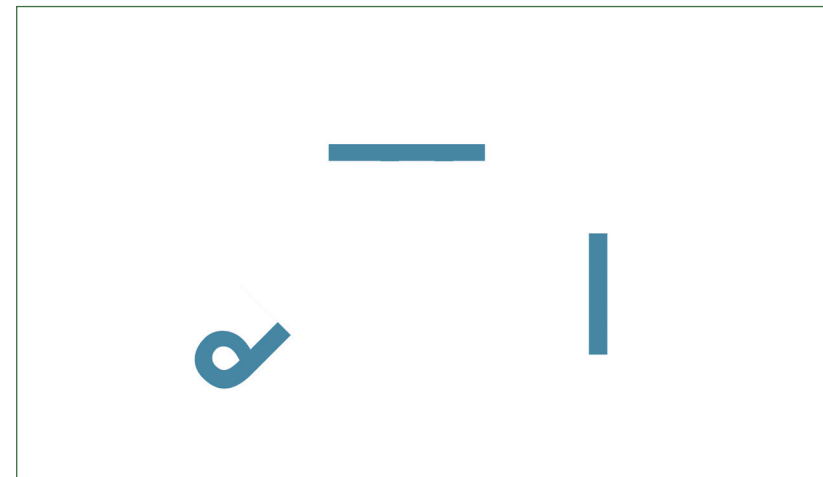
The child sees a letter on the screen which then breaks and disperses in to its segments. The child is then supposed to place the correct primitives in front of the camera to activate and collect the primitives and gain the letters.



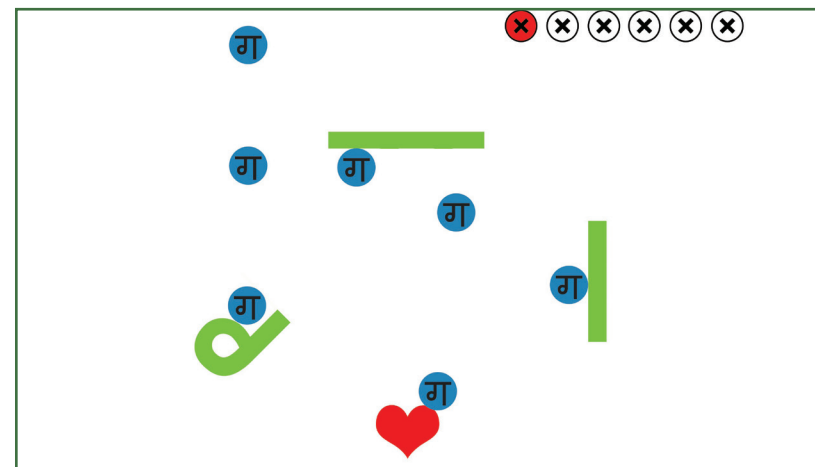
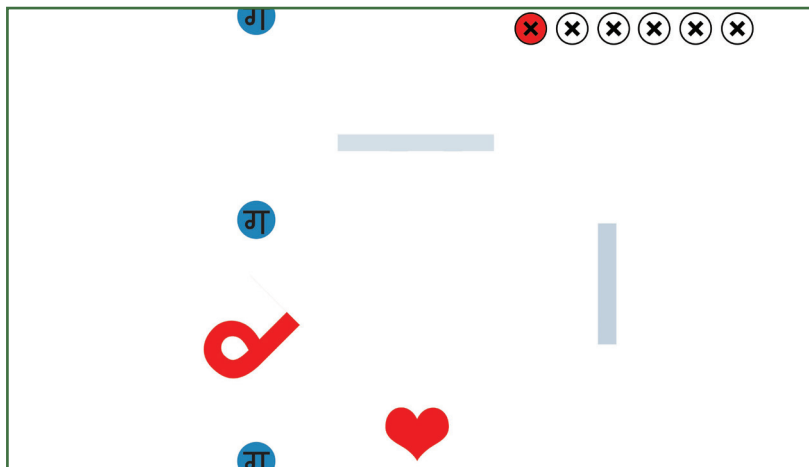
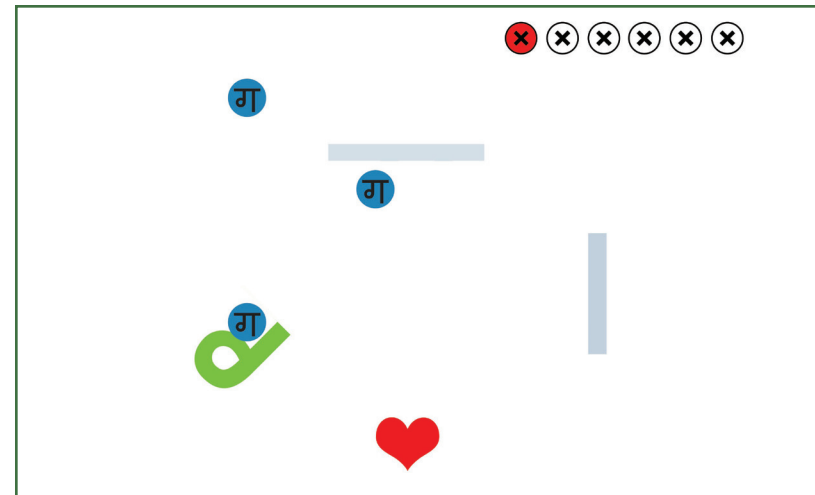
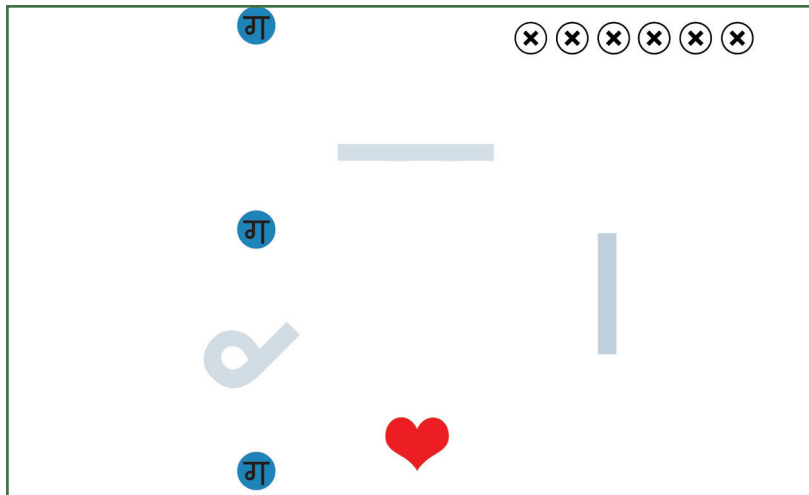
1. Letter with its pronunciation along with one of the objects which starts from the letter.



2. The object disturbs the letter.

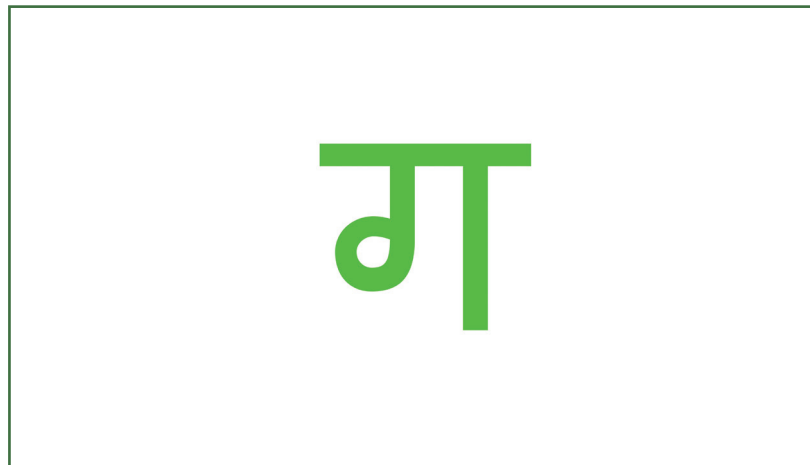
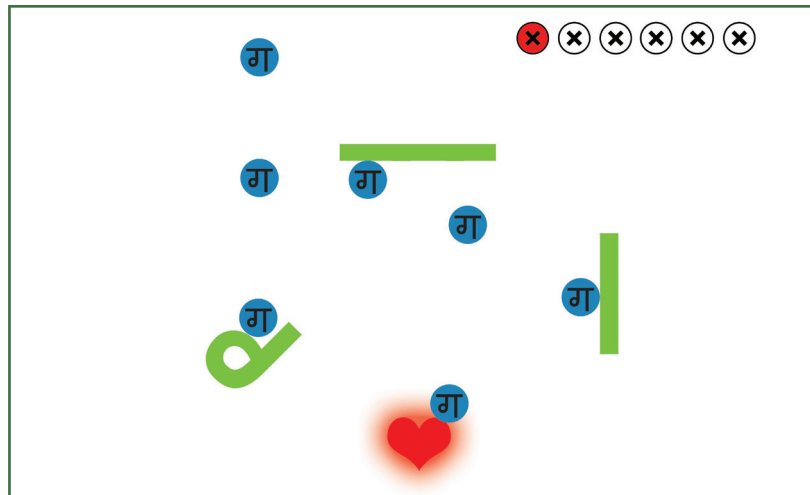


3. The object is scattered and the task is to make the letter out of given primitives shown on the screen.



4. The task is to match the correct primitive so that the ball reaches the heart by bouncing through these primitives.

5. The balls reach the heart which then combines the primitives to initial letter form.



5. Task is completed.

Review:

This concept makes it easier to relate to letters and objects related to it.

The focus was more on completing the task rather than learning and associating the letters to the object.

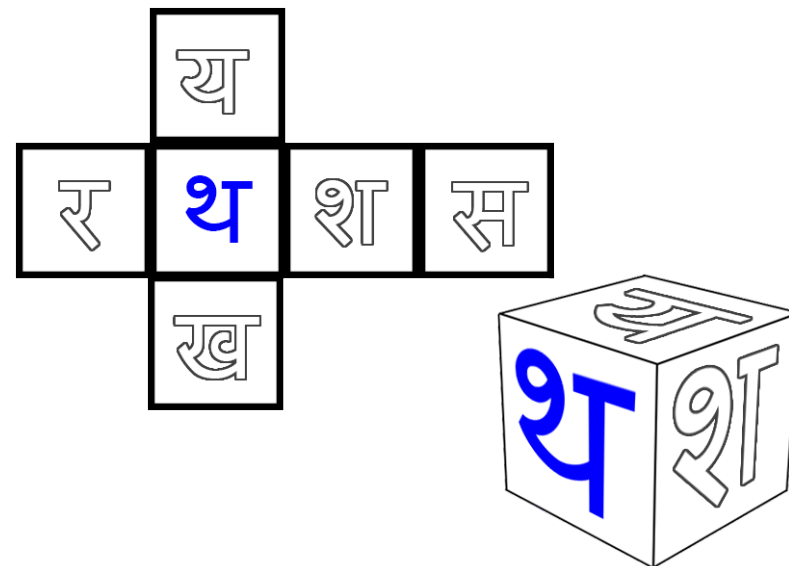
Concept 3 -

This concept uses the existing software provided by CDAC-Pune for experimentation purpose. But uses different setup altogether in terms of the positions of each component. The camera is kept in front of the screen. The idea was to change the playing area. So the primitive units are to be placed on the cube, which is to be placed in front of the camera. The surfaces of cube contains watermarks of similar looking letters which helps child in understanding the graphical similarity between the letters. This helps the child in memorising and recognizing letters.

At the background of this block is a digital screen which has the



software running and gives a continuous feedback to the player. It also shows the objects related to the corresponding letter. This allows the interaction between child and the letters to transcend from a static to dynamic experience.



Review:

The playing area is compact and encourages tactile learning as the child can play around with the cube.

The background screen creates interference with the OCR and it may fail to detect the letters with changing background colors.

Concept 4 -

The concept – मराठी-मुळाक्षरे is about naming, recognizing, making .letters and making words

In this concept the child is given playful tasks, where he completes the task enabling him to pronounce and identify letters, making a letter form out of its segments and making words.

It provides an audio visual feedback along with a narrator which helps the child learn letters.

The playing area is a part of the screen itself. The screen provides a background for playing as well as feedback for learning.

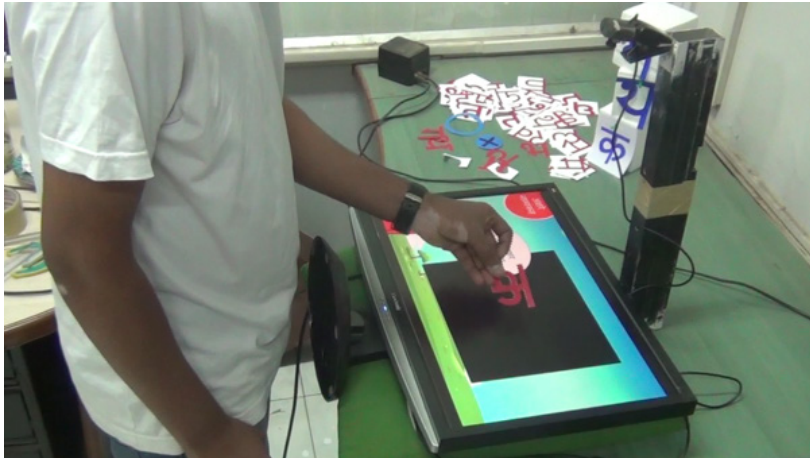
The screen has a over head camera mount. The player is supposed to place different markers for navigation.

Review:

It turns the screen in to a playful area and doesnt need an extra surface or dimension for visual feedback.

The background screen creates intereference with the OCR and it may fail to detect the letters with changing background colors.





Concept 5 -

In this iteration, the screen is separated from the playing area.

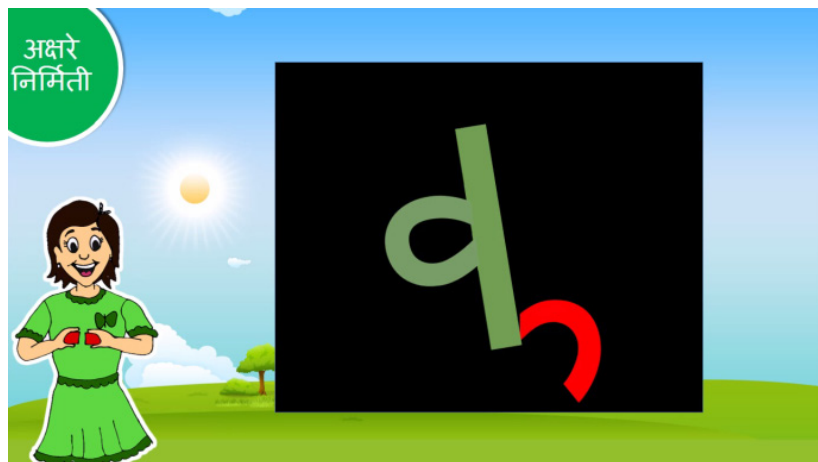
Here a group of children provide an auxiliary narrative for the player to learn devanagari letters adding to the play value and enriching the learning experience.

The idea was inspired from the teaching method of peer learning within the students in a class.

It has a dedicated playing area with buttons for navigation purpose and a ring marker for selection purpose.

It has an additional feature wherein a player can place any object in front of the camera and the toy would give him a letter having a graphical similarity with it. The toy would continue this till the object is placed in the playing area. For Ex. A circular shape can relate with letters like व, क, अ, त, etc.







Review:

It turns the screen in to a playful area and doesnt need an extra surface or dimension for visual feedback.

The background screen creates intereference with the OCR and it may fail to detect the letters with changing background colors.

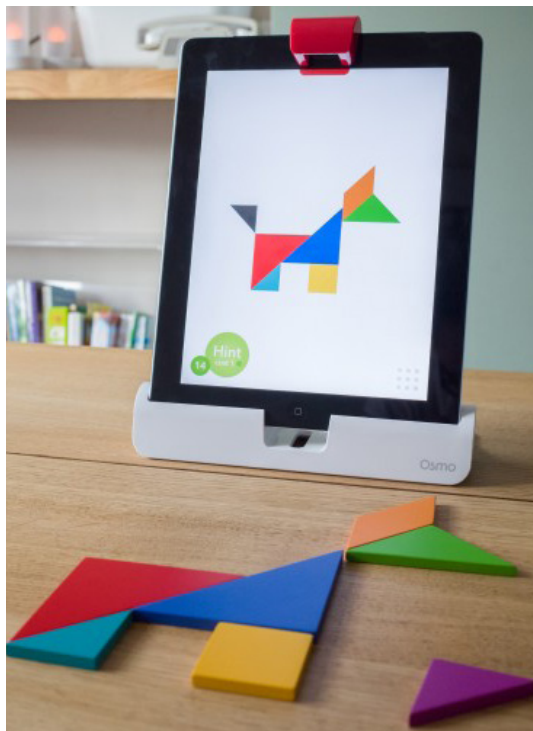
Concept 6-

This could be called as a Devanagari version of OSMO. Osmo is a new, fun and educational gaming platform for kids. It converts an iPad into a dynamic, responsive interactive learning toy. It uses geometrical shapes, letter tiles and day to day objects. It has a plastic mirror cap which directs the iPad's front camera to the table or floor surface where child can play [12].

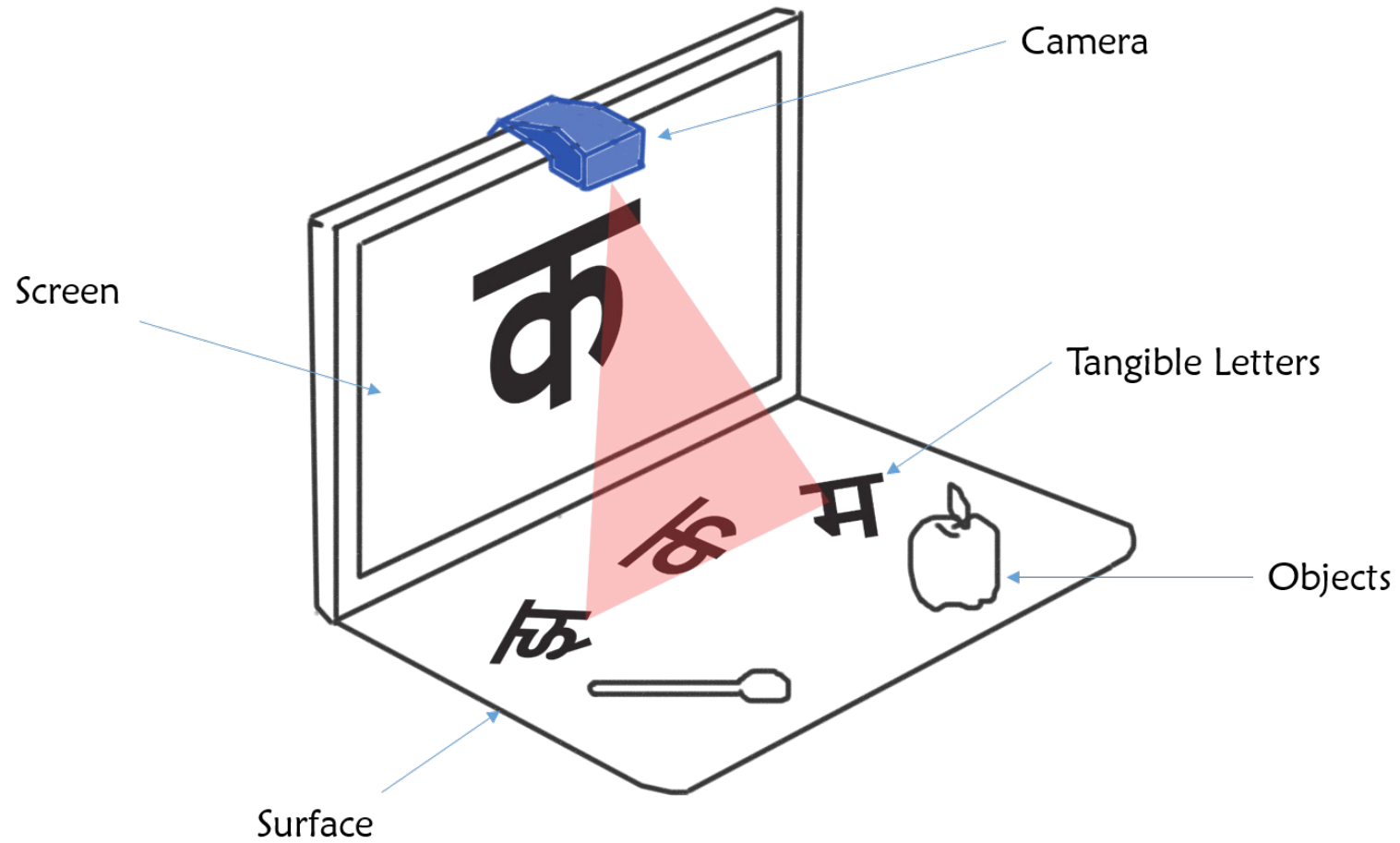
The setup is inspired from OSMO and the initial prototype was an alternative low cost version of it. The initial idea was to take good

points from the toy and observe the dynamic feedback system and interactive gameplay that it provides to child.

The further concepts and prototypes were modified after observing the gameplay in Osmo and an altered or modified version of the plastic mirror assembly is used in further design concepts.



Setup for the design concept :





Review:

The gameplay was not working in terms of learning of devanagari letters. It was lacking in interactivity in terms of error correction, story, font, layouting of playing area and the connection of playing area with screen.



6 | Final Concept

Use of primitives as a design solution

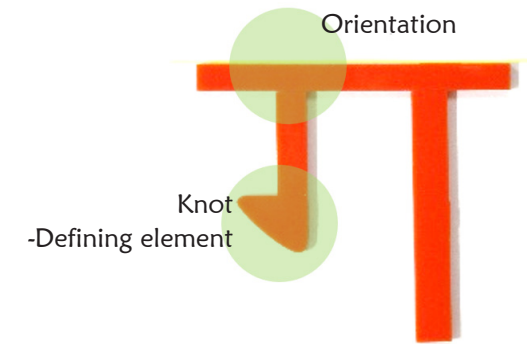
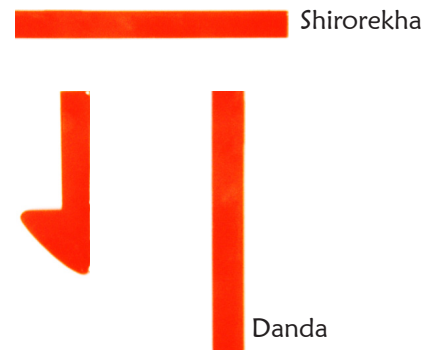
Primitives are the straight, skewed and curved line segments. They are the integral part of Devanagari script. Devanagari letters have distinguishing structural properties.

Conventionally children in primary schools are taught to draw straight, skewed and curved lines, early on with the aid of the element that constitute a primitive.

The straight lines mostly represents the 'Shirokekha', horizontal line and the 'Danda' vertical line. The curves, loops and knots denotes the defining element or the properties of the devanagari letters.

If a child can understand these properties while playing with the set of primitives, he/she would pick up the Devanagari letters easily.

Given this set of tangible primitives, a child treats it as a puzzle and explores it. In the process of exploration and trying out various possibilities of formation of letters, child learns about the orientation of primitives and the defining element in the particular letter. This helps the child in recognizing and recalling the Devanagari letter.



Visual reference helps in recognition more easily than phonetics (p. 20). There is a graphical similarity between the Devanagari letters. This character similarity can be seen in the following groups.

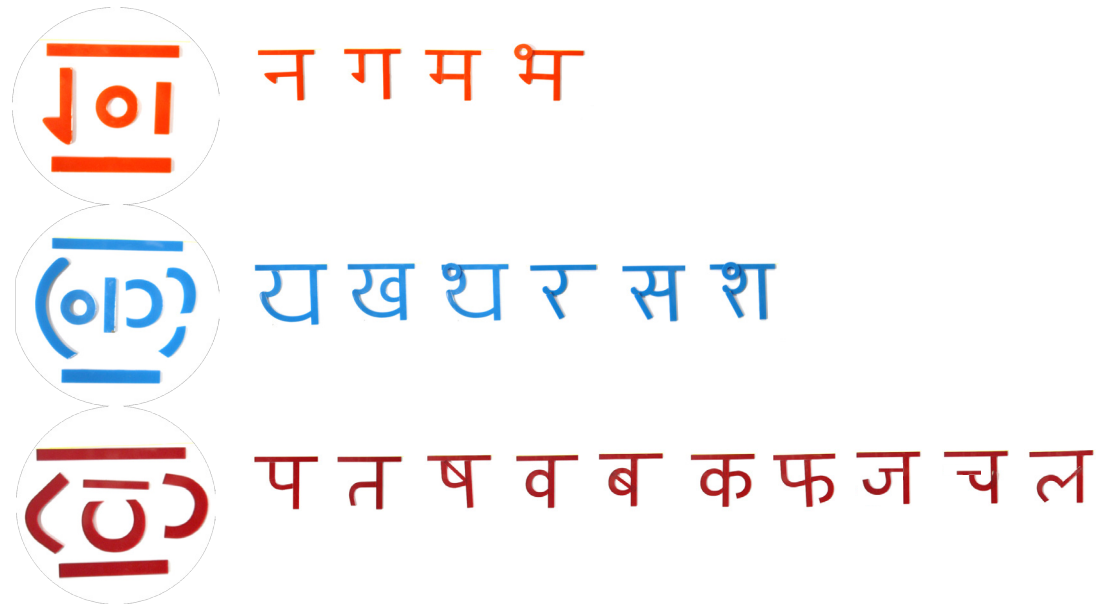
It can be seen from the image that one primitive can be used to represent more than one Devanagari letter. Sometimes rotating, flipping the primitive vertically or horizontally may work, though sometimes the typographic proportion of some letters is compromised.



The idea of designing such primitives was to make a modular font, in which different combinations of primitives would give a form which may or may not look like a Devanagari letter. A child can play around with these primitives and in case it doesn't form a letter then he/she can learn from the mistakes.

Example of Modular Font:

The font was not proportional and not suitable for a child to learn letters in early stages of learning Process. Then further modified and redesigned according to the OCR technology constraints and the typographic proportions. (p. 82)



Aksharmaal:

Based on the explorations done in previous concepts, some of the features such as playing area, reflector mirror assembly and the use of a separate digital screen have all cumulatively the final concept.

Aksharmaal is a platform based game, which is inspired from the famous game 'Mario' [33], in which the player runs on a platform collecting points. In Aksharmaal the player runs on a platform collecting the primitive units in a particular level.

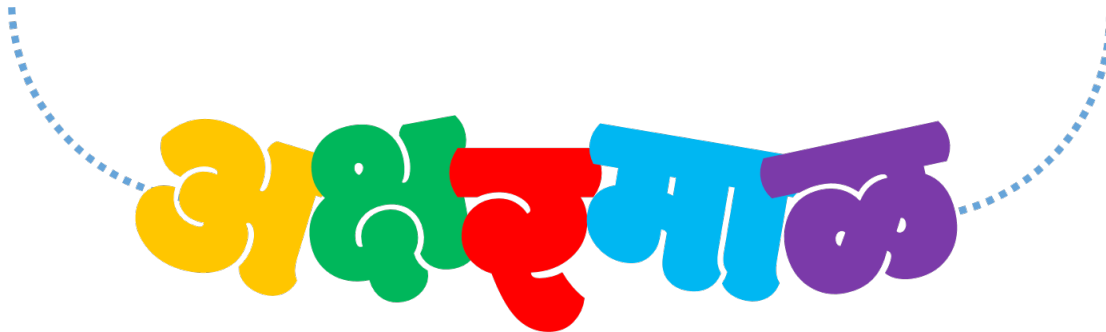
A child puts primitive units in the playing area which acts as a stimulus. Based on the the correct positioning of the primitive in the playing area, an audio visual feedback is provided by the game on a digital screen. To move further in the gameplay child has to put primitives correctly untill he build a complete letterform in the playing area.

In this game, a child learns how to build

a letter using its primitives in a playful manner. These primitive units help the player in overcoming the hurdles in his path in the gameplay. The player has to build letters from primitives in real world and to achieve letters in each stage in the digital game.

Each level belongs to a letter which helps the child in understanding the basic characteristics of the letter. Child learns about the basic segments and the whole letterforms in Devanagari script through this game.

The play value of this concept lies between a toy and a digital game. The player has some amount of authorship which makes it a toy. He also is an actor following some of the guides of the toy to a certain extent which makes it a game. It has some accessories which makes it as a Game system for learning Devanagari letters.



7.1 Components:

Aksharmaal has following five components
– Device with a Web/front camera, a Mirror assembly, a booklet, Primitives, a stand (for tablets).

Device with front camera:

The computer device used could be a laptop or a tablet with a front camera with a good enough image quality (min 1.3 Megapixel). The front camera should be at the center top of the device. In case of tablet use the stand to fix the device.



Front camera Device

Mirror Assembly:

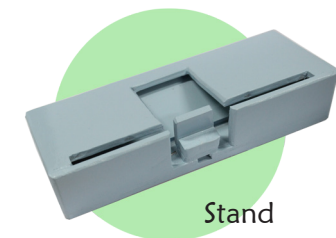
The mirror assembly should be placed on top of the web/front camera of the device. The mirror is tilted at an angle of approximately 30 degree with respect to the device screen. It thus reflects back the image of the surface perpendicular to the screen, which is then used for image processing by the OCR engine.



Mirror Assembly

Stand:

Stand is used when a tablet is used for playing Aksharmaal. Stand helps the tablet to mount in vertical position.



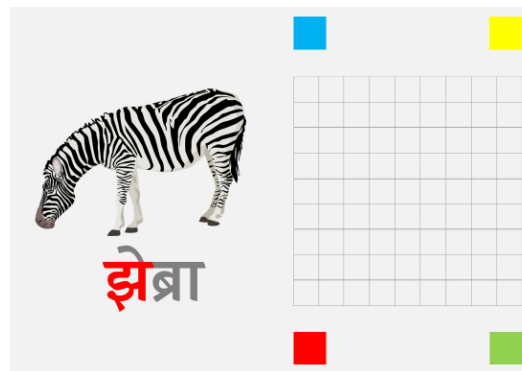
Stand

The Booklet:

It is used for navigation purpose in the gameplay. Each page in the booklet has different letters which then represent a different stages in the gameplay. When the page is turned or a new page is opened, the level corresponding to that letter starts on the device screen.

The booklet has a designated playing area on right pages and the corresponding images on the left hand side. Each page has a marker/ code which OCR can detect as well as a boundary for playing area. Inside the playing area is box layout in which child is supposed to place the primitive units.

When not using for playing purpose, the child can still use the booklet for writing practice.



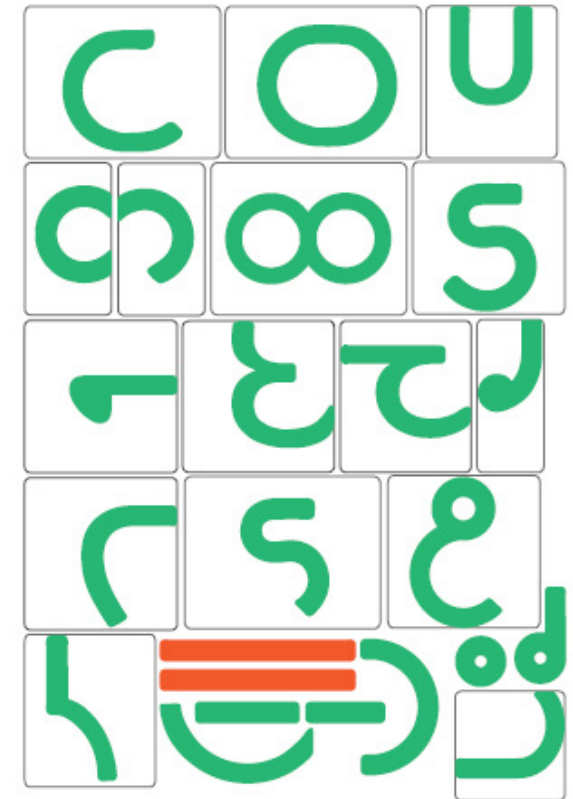
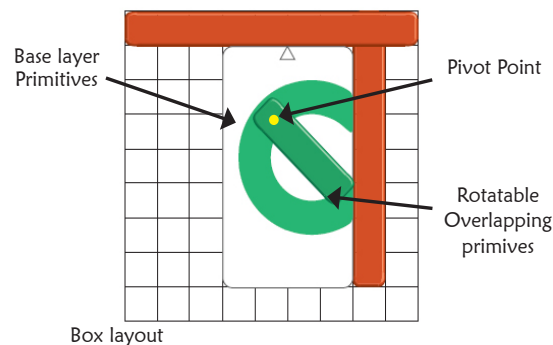
Primitive Set:

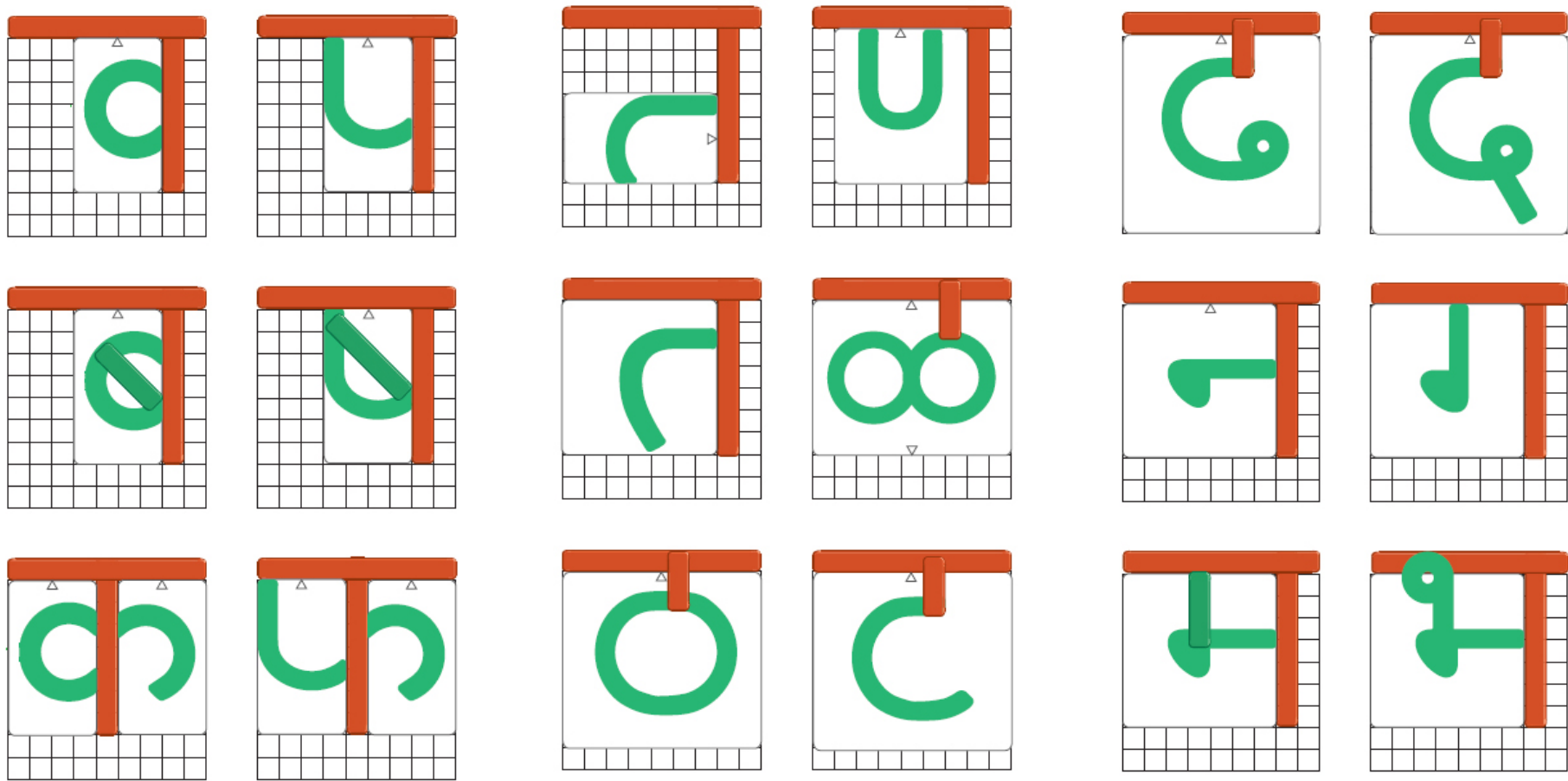
The modular font being used in the concept is designed such that less number of primitive units would represent almost all Devanagari letters. Thus the modified modular font consist of two types of primitives.

Base layer tiles and the overlapping primitive units. These primitive units are then supposed to be placed in Box layout and position of which can be adjusted with rotation along the pivot point.

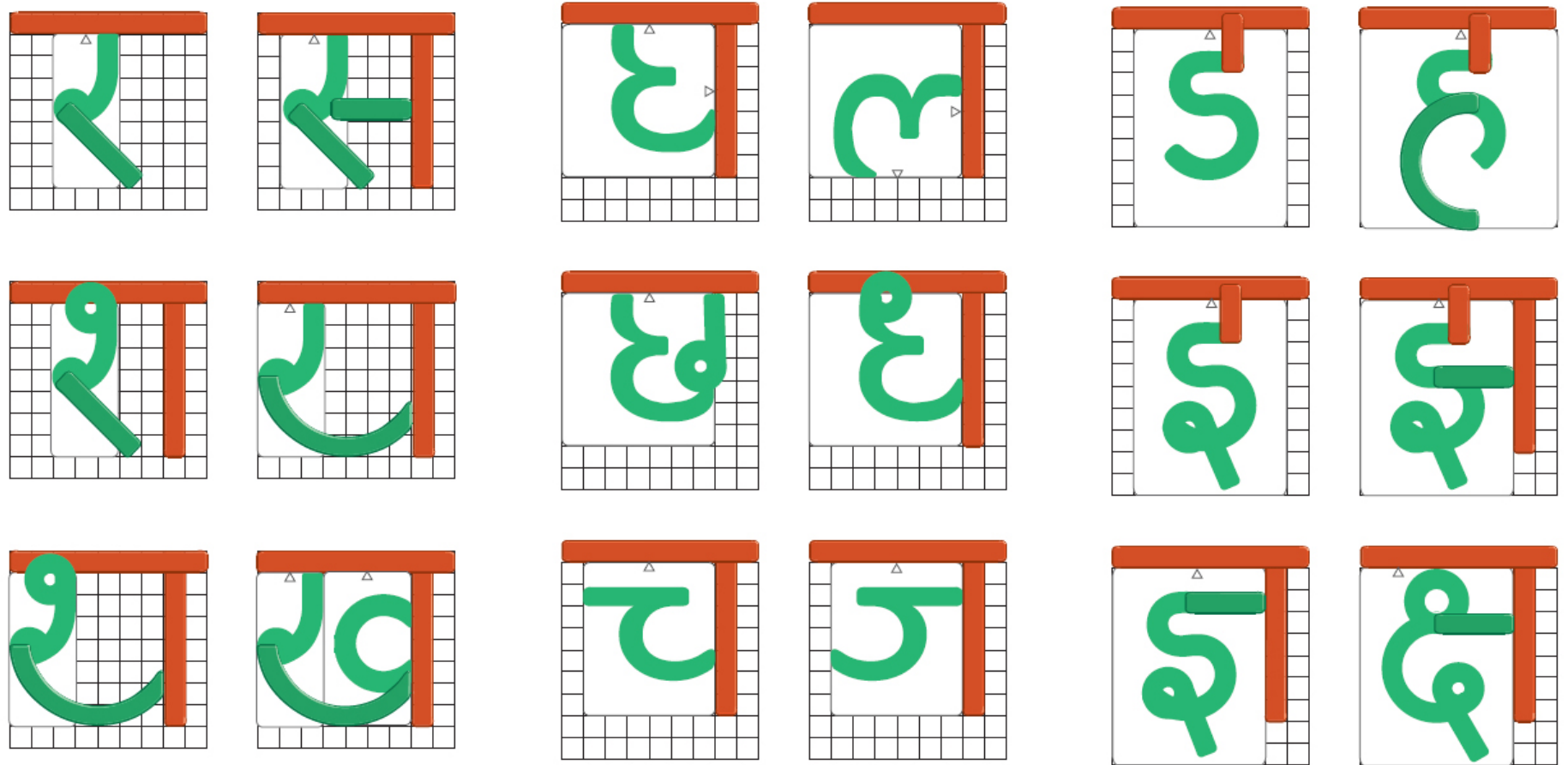
The font is designed considering typographic grid and proportions. On account of keeping the number of primitive units lower, the grid and proportions were compromised up to certain extent. Also refer (p.83)

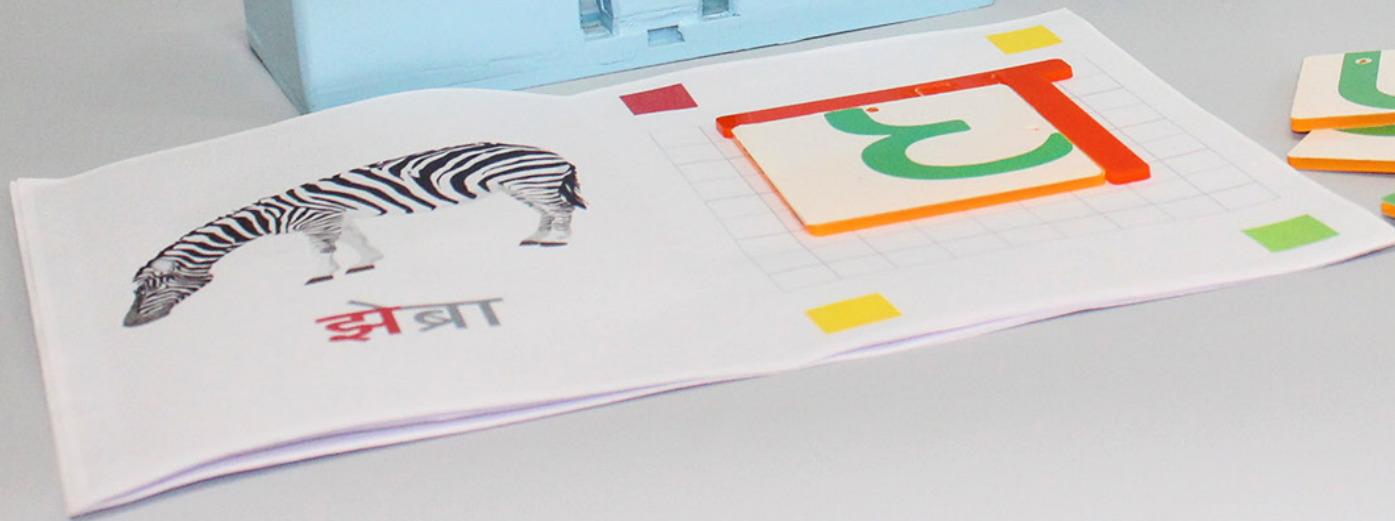
The Final set of primitives contains total 24 primitives.





The final font design with explorations of possible letterforms.

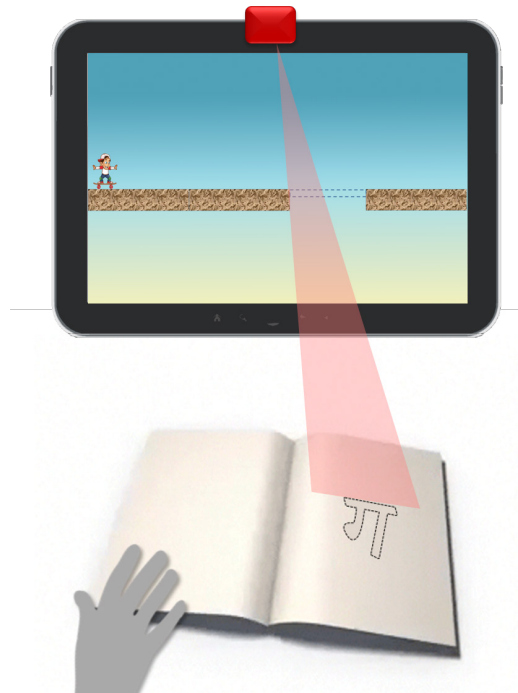




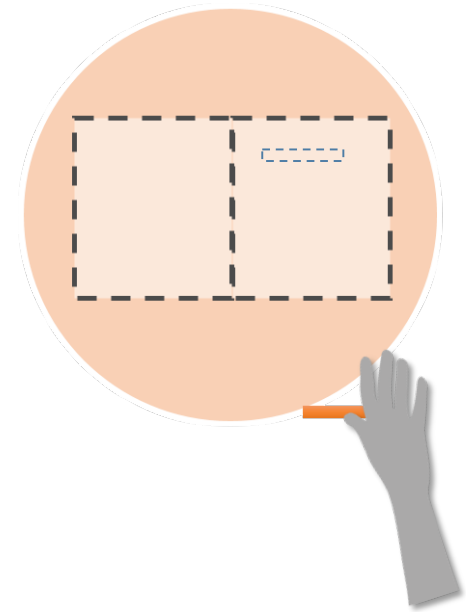
7.2 Interactions with the toy:



- The mirror assembly is to be fixed on the front camera of the device.
- The primitives are to be placed in the playing area in front of the device.
- The mirror assembly reflects back the image of primitives placed on the surface.



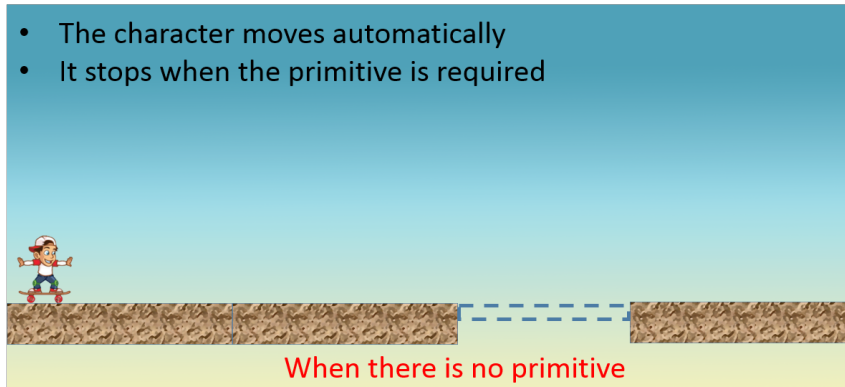
- The book is to be placed in front of the device. Player needs to open the page corresponding to the letter he wants to learn or click/tap on the letter given on the screen.
(Player can take support from parent or teacher)



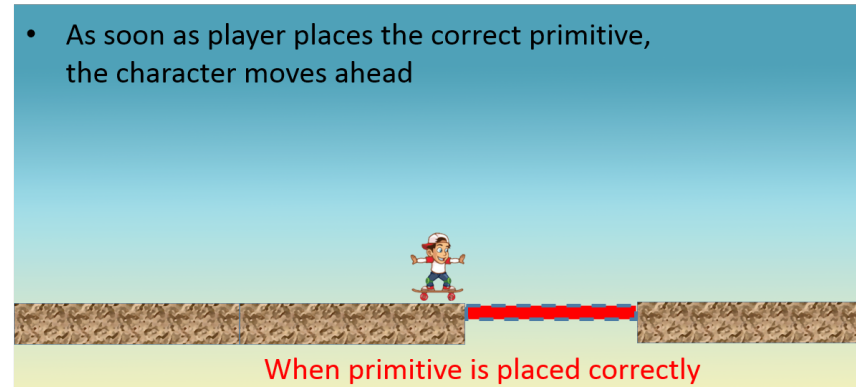
- At start of the play, player gets hints about 'how to place the primitive' through animations on the screen each time is makes a mistake.
- If the primitive is placed correctly, the gameplay proceeds further.
- Similarly the player puts the required number of primitives to form a letter.

Gameplay :

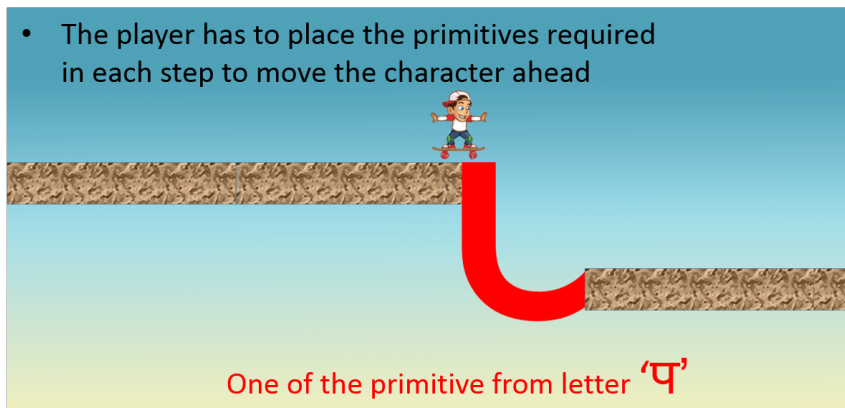
- The character moves automatically
- It stops when the primitive is required



- As soon as player places the correct primitive, the character moves ahead

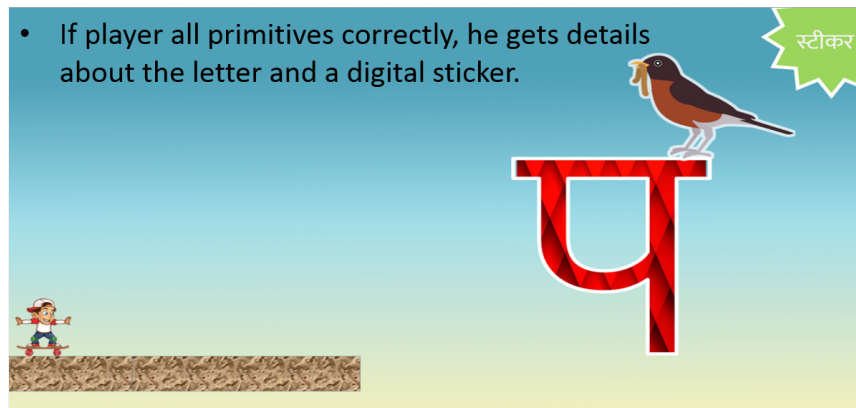


- The player has to place the primitives required in each step to move the character ahead



Initial gameplay based on the concept of bridging between two platforms with the help of primitives.

- If player places all primitives correctly, he gets details about the letter and a digital sticker.



Version 1:

When the user opens a page from the booklet the game takes him to that letter stage. The user gets to build and learn the corresponding letterform. Since it is a platform game, the character in the game moves only on the solid platform. The character moves automatically without any direction control on the screen or keyboard. The player is supposed to keep right primitives in the playing area in order to keep the player moving. The initial version of this game was prototypes taking a concept of using primitives as a bridge between two platforms.

Unless the primitive is required the character keeps on moving ahead. If the player keeps a wrong primitive he falls down and starts again unless he puts it correctly. While playing the player is given Hints at regular intervals about how to the primitive in the playing area. In the initial stages of the gameplay, watermarks of letterforms are provided, to get familiarize the guides of the gameplays.

When the player puts all the primitives correctly, he gets to learn a letter and gets a sticker of an object related to that letter.

User Feedback & Review:

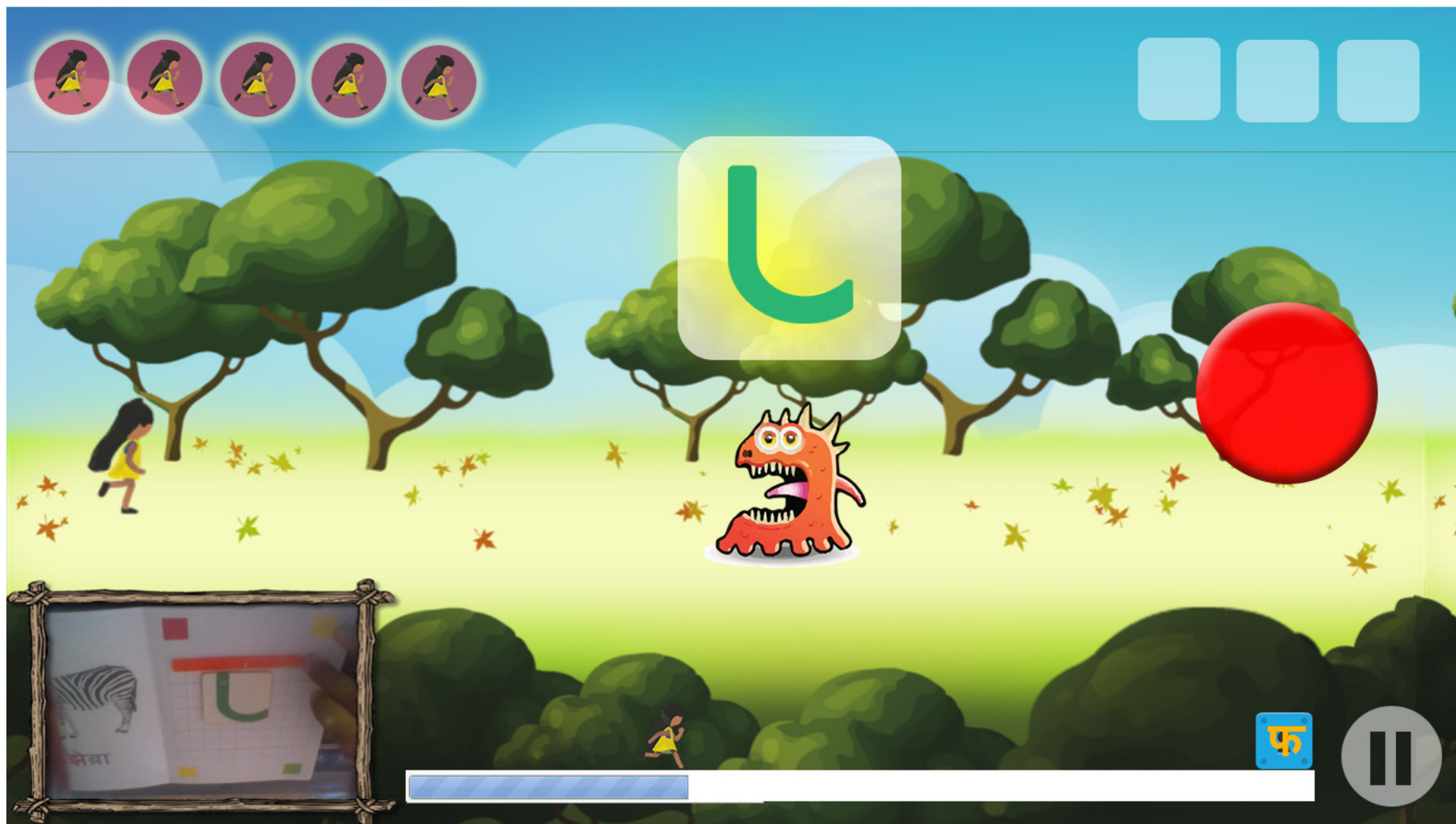
- There is no story or a narrator to help children in the gameplay.
- It becomes difficult for a child to pick correct primitives from 20-28 primitive set on each single turn, it tends to increase the cognitive load on the users.
- Children faced difficulties in layouting of the primitives.
- The bridging concept is repetitive and becomes boring after a certain point.

- There is no reinforcement happening in the gameplay while learning.
- There is no connection between the playing area and the digital screen.

Version 2:

In this version of the gameplay, additional features are, the child has to achieve something at each stage of the game. The child is shown a letterform and a thing related to it. The thing moves away from the character and letterform breaks into its segments. Now the player has to catch that thing by using those primitives. The video feed on the digital screen shows the player how he is building the letterform and what is being fed to the OCR.





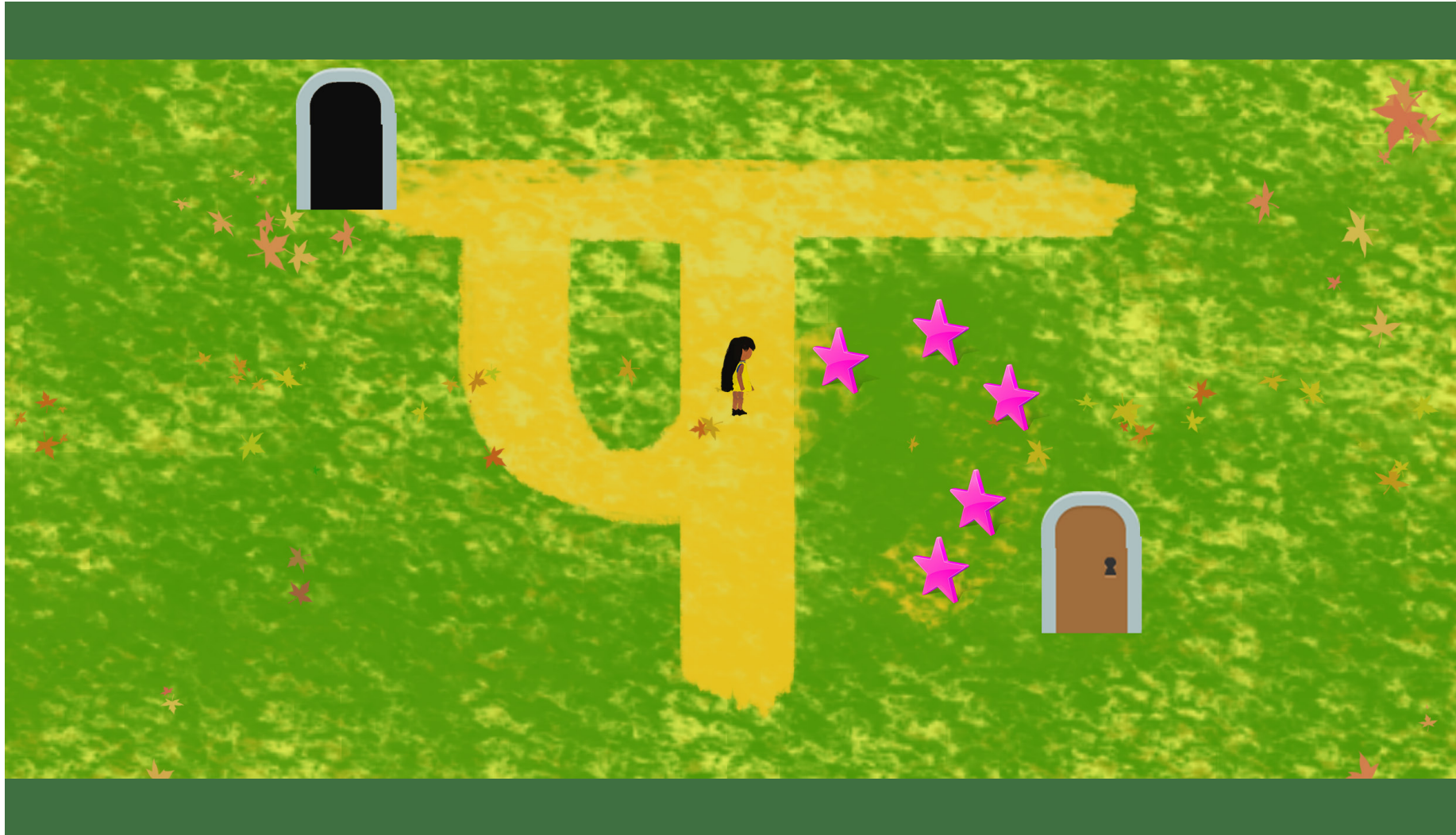
Version 2 was later again modified and added few more levels. The idea is to teach a child by comparison and correction between 2 or more graphically similar looking letters. The player is asked to collect all required primitive of similar letters to get familiar with them, in the initial stages of the gameplay.

The confusing and boring task of searching a primitive while building a letter, was translated in this concept. The child is supposed to collect only relevant primitives to avoid confusion in the later part of the gameplay. The child is asked to put a tangible primitive in the playing area when a picture of primitive appears along with a creature on the screen. The idea



behind including creatures was to make it more interesting for children and give them some kind of authorship in the gameplay. The letter practicing is generally found not much exciting [27]. It also add the fun element to the game where children find it funny when the primitive falls on the creature and it disappears. When primitive is put correctly. The creature vanishes

and player moves ahead. After putting the primitive in the playing area either the OCR will take input after 10 seconds or a child can use the red button to submit before 10 seconds.



As a redundancy in learning the same characteristic of a letter, a primitive is shown along with objects related to it. The player is sometimes asked to put the primitive in the playing area.

To learn the layouting of each primitive correctly the player goes through a level where he has to put primitives in correct order and complete the letterform.



In the final stage of the level, to destroy the bigger creature, the player has to build a letterform. If it's a level for letter फ then he is asked to form प and फ. So that the player gets to learn about the similarity of letters and becomes easier to differentiate between them by identifying the defining elements in them.

At last the player gets some more information about the letter. He catches the thing and earns a sticker of the same as an achievement.



The gameplay is designed in attempt to cover the factors affecting learning which can be classified as,

- Observation of letters,
- Recall the letterform,
- Repetition of letters,
- Association with surrounding objects,
- Motivation,
- Reinforcement,
- Practice,
- Attention Span,
- Quality of Stimulus



Boy



Teacher



Creature 1



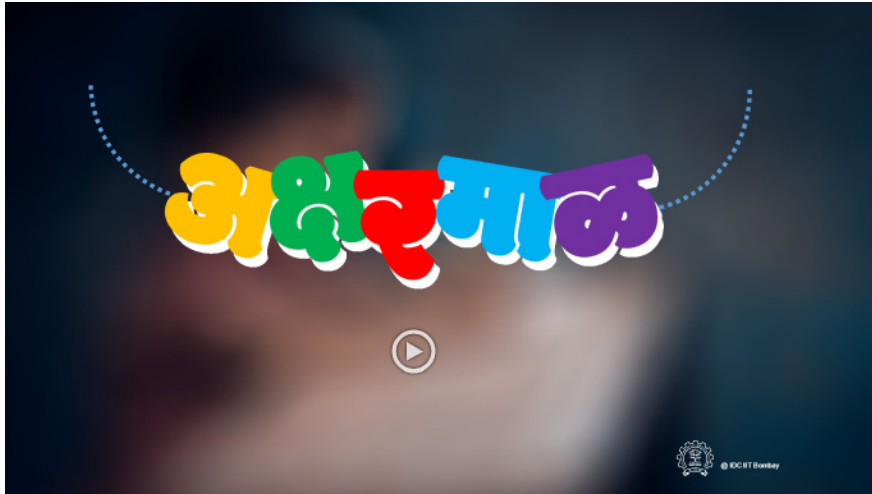
Creature 2



Creature 3

Version 3:

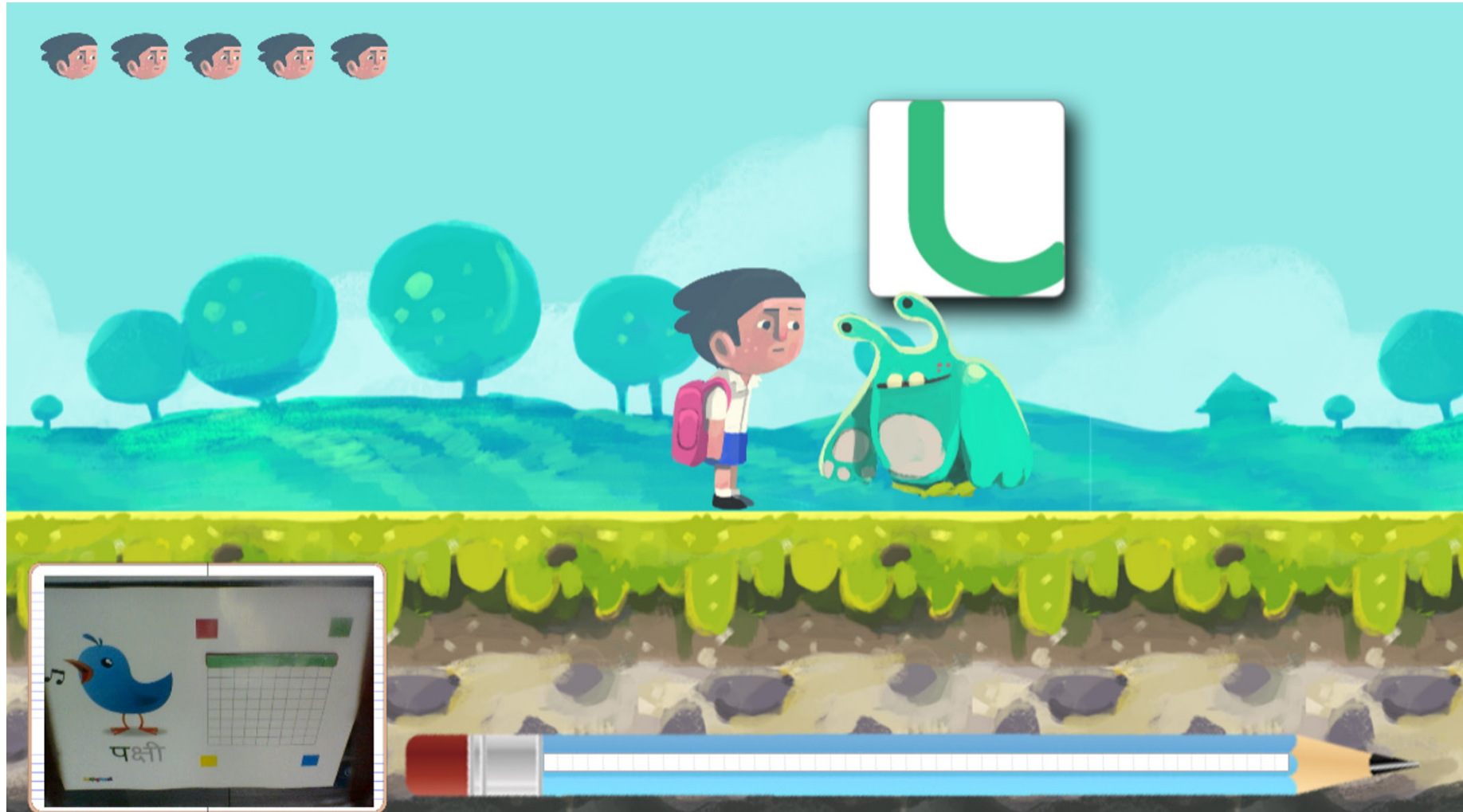
In this version of the gameplay, various visual elements were changed and redesigned. The characters were redesigned in terms of animation. An extra character of a teacher was added as a narrator of the story who provides hint to the player at each stage of the game wherever player is stuck during the gameplay.

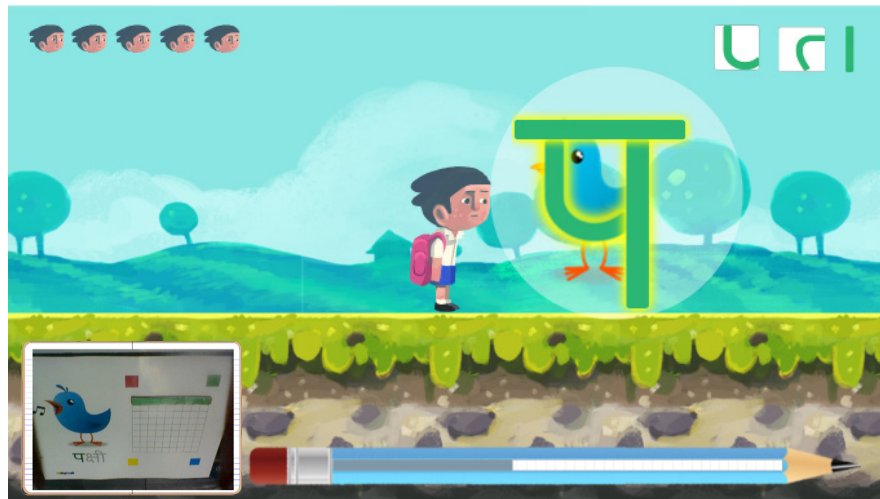


The game starts with a story in which a boy is going to his school and he is learning letters. But in between the letters disappear and go into the clouds. The player needs to help the boy to regain his letters back.

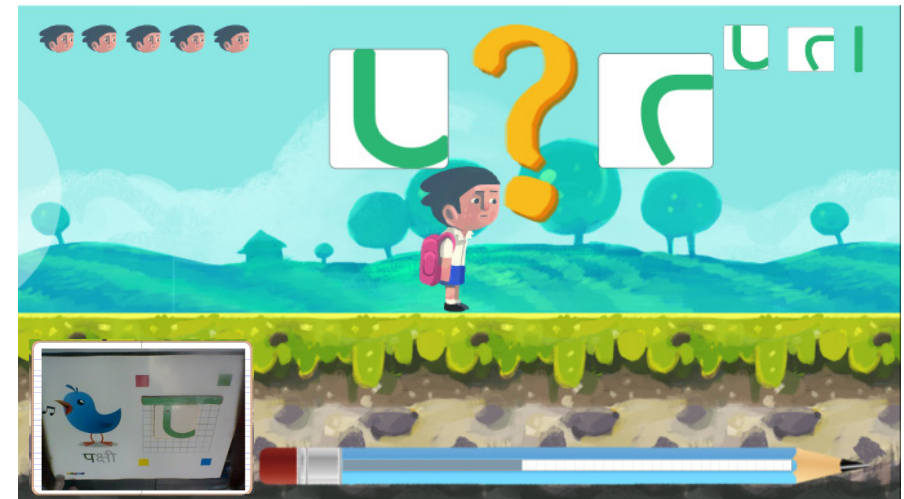
To regain the letters the player must use the tangible primitives. There are few creatures who are blocking player's way to letters. When creature appears player is asked to put a primitive. As soon as player puts the correct primitives they fall on the creatures and they disappear.



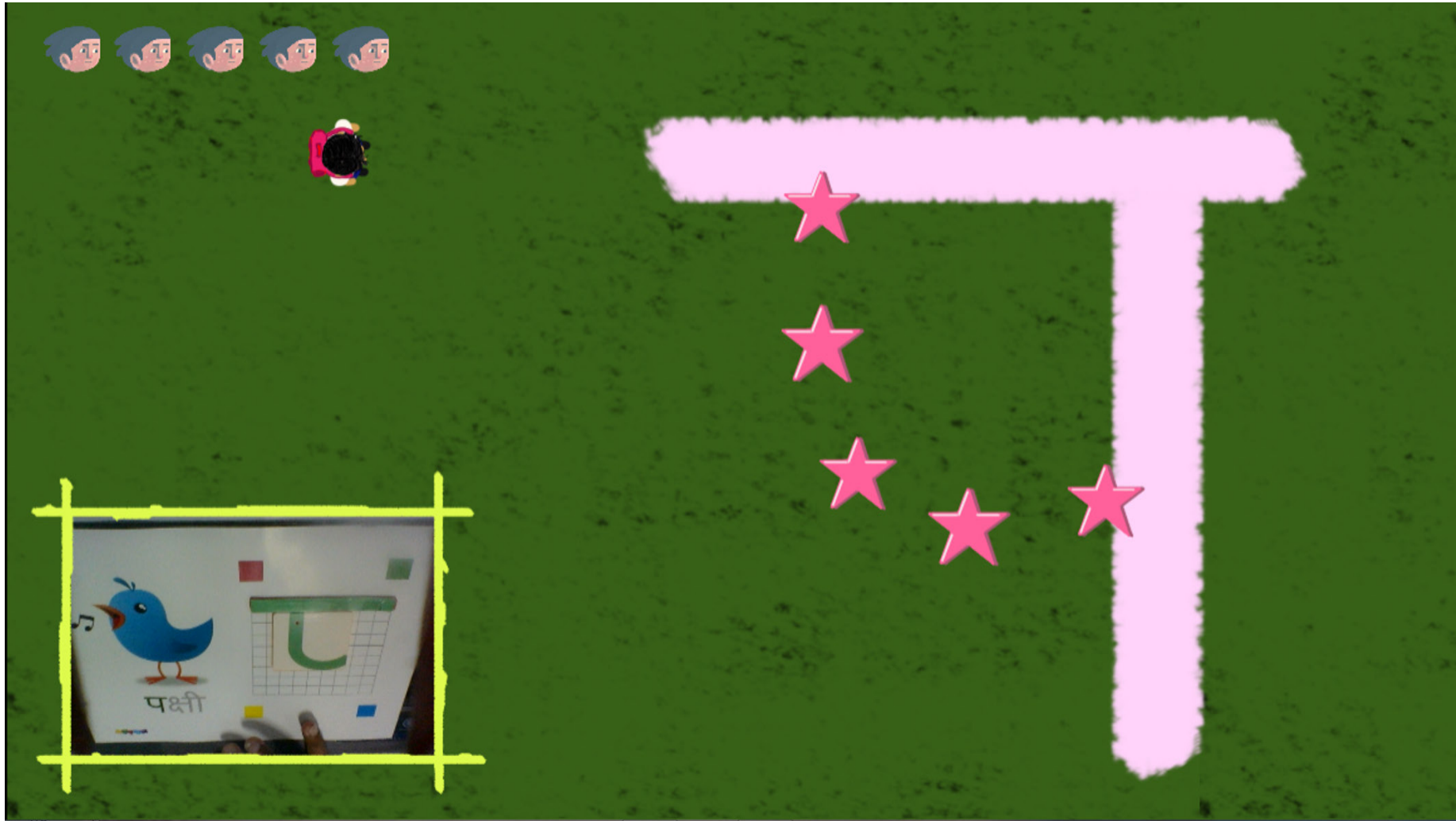


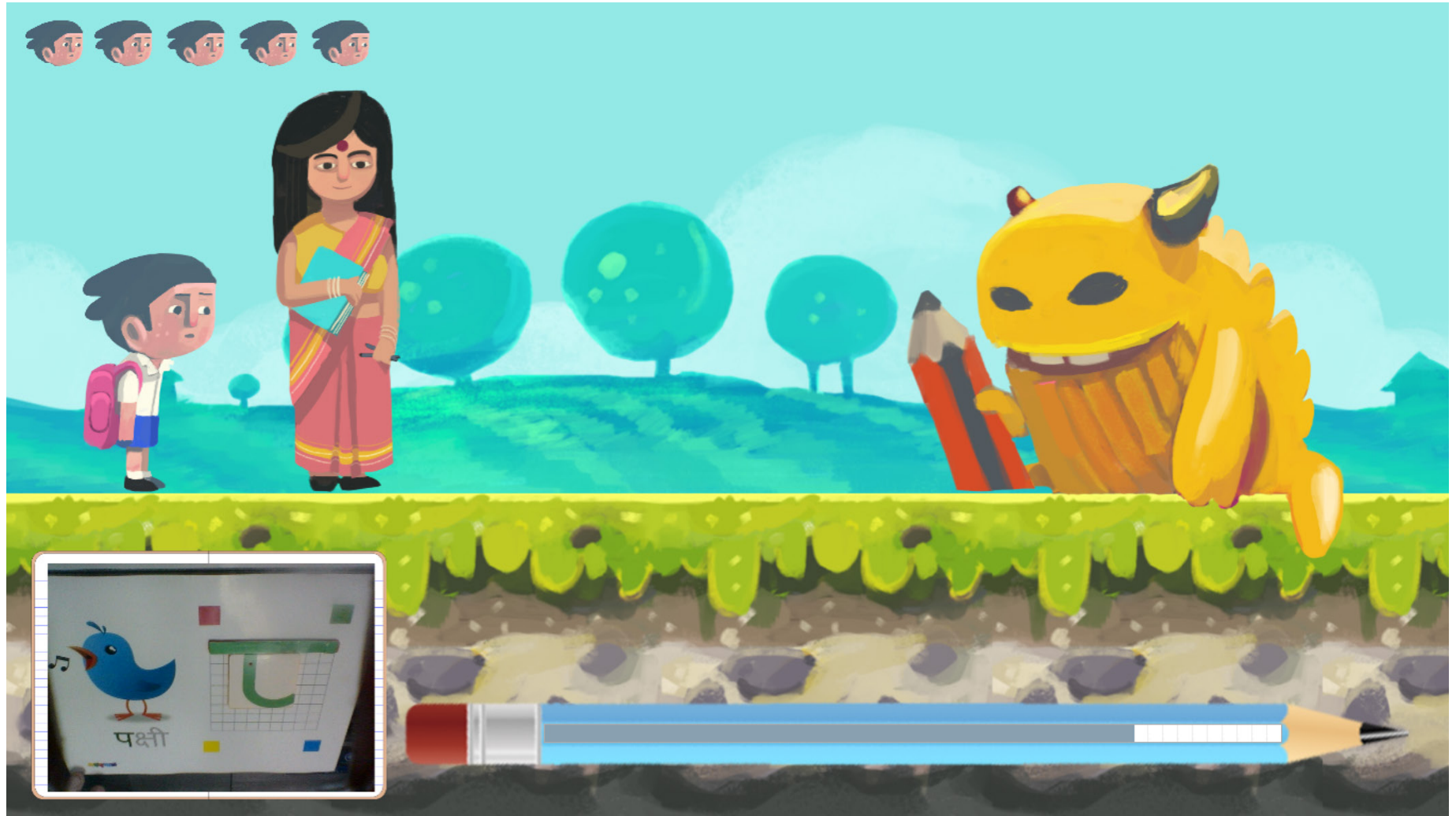


Through the gameplay the child is shown different objects which relate with the letters. It helps the child to build analogy and graphical similarity.



There are certain cases where the child gets confused between the primitives or the letterforms. The game helps child to differentiate between such letterforms. It shows which primitive make the required letterform.







When the player learns about the defining primitives for required letterform in initial stages of the gameplay, he is asked to make a whole letter in the final stage. But there is an uncertainty whether he has to make only one letter or two or three letters in case of complex letters.

In the end the child regains the letter and the level for required letter is achieved.

7.3 Ecology:

Aksharmaal can be used in the classrooms for teaching students from individual level to group level. It is fun while teaching the letters to children, which seems apparently a difficult task for teachers in the initial stages of the syllabus.

Aksharmaal helps teachers in bringing up the tangible feel to letters which adds to the learning value. A toy and a digital game makes it interesting for a child to learn while playing at school and to play while learning at home.

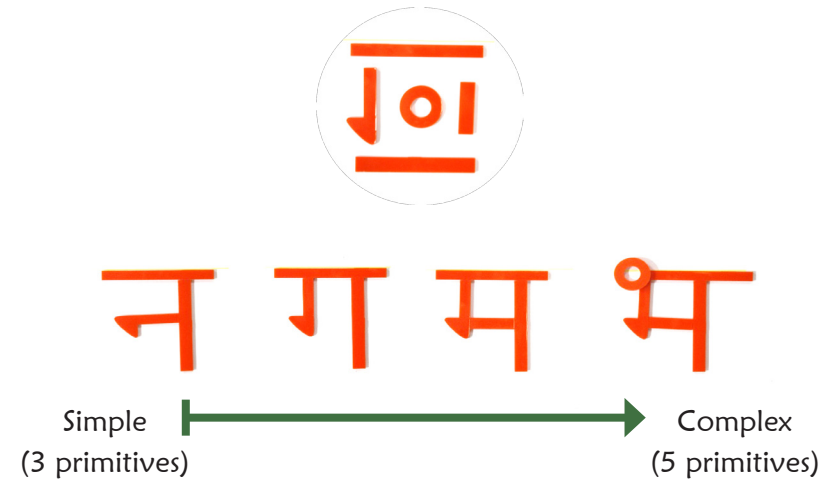
Teachers and parents can provide the child full or peer support when needed. In the initial stages of the gameplay child may need the full support for understanding the gameplay.

It can be used for learning, practicing and evaluation purpose as well for teachers and parents while teaching Devanagari script in schools and home.

7.4 Design Decisions:

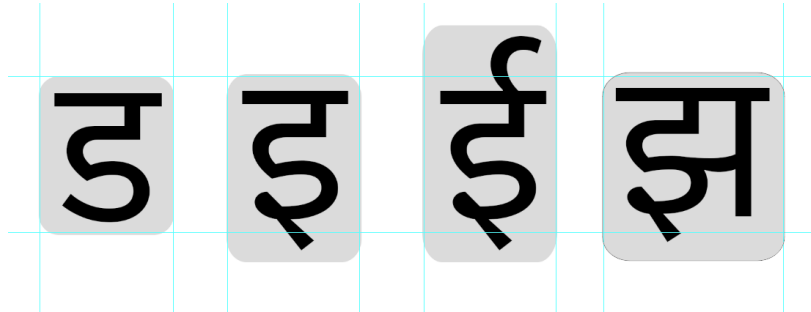


For a single devanagari letter there can be more than one combination of merging primitives. Not all of them will be proportionate but they can be correct in terms of characteristics. The evaluation for finding out these combinations and how learning happens in such case was not carried out considering the timeline. Instead a font was decided where proportions of letters was given higher priority compared to the characteristics. In further iterations layouting with the box tiles helped in limiting the errors made during letterform building.

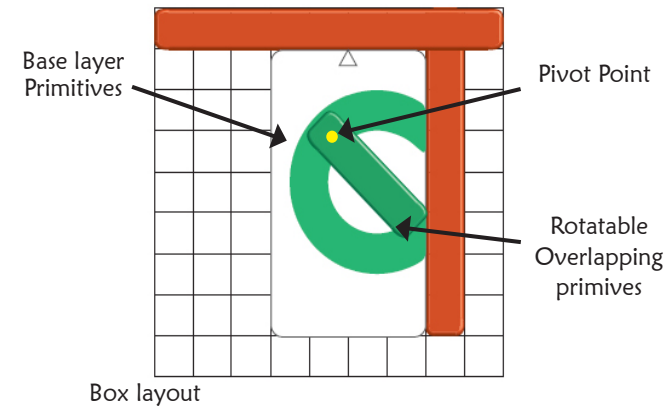


As discussed earlier (p.20), the graphical similarity between Devanagari letters lead to the classification of primitive units. For Ex. न ग म भ fall in a group.

न and ग being the simple letters with just 3 primitives required for their formation, भ is the complex letter with required number of 5 primitives. Thus the sequence of the letters to be taught to children is decided for each group of primitives i.e. from simple to complex. It was found that children couldn't recognize and recall complex letters, this grouping could help them improving their skills.



With more number of primitives the cognitive load on the user also increases. In addition to that the alignment and layout of the primitives causes difficulties in understanding and learning letters. To solve these problems, tangible primitives were modified into rectangular tiles. The idea behind taking the tiles concept is, sometimes a child perceives the letters by its overall shape or the boundary of it as a whole in terms of height and width. So in case of graphically similar letters, it becomes easier for a child to differentiate between letters. Also it could help the child in visualizing the overall structure or layout of the letter.



The shirokekha and danda primitives are kept in different color to avoid confusion. The font is child friendly without sharp edges. It is big enough in size so that user can play around with them and get a tactile feel of it while playing.

The colors are green and orange which are easily detected by the OCR engine. Shirokekha and danda are given orange colors, as orange gives a contrast to green and ergonomically it stands out of all the colors. Therefore the player should pick them up easily as they would be required while forming all the letters.

After taking user feedback it was found that Shirokekha being common in all letters, children tend to ignore it while playing with the primitives. Hence in the gameplay the Shirokekha was kept stuck in the booklet and children have to put only the remaining primitives.

Adding Creatures in the gameplay as Fun element

The challenge in adding fun element for children of age 7-8 years is matching the mental gap. Few more factors taken into consideration were,

- Control over things
- Access to objects
- Their favorite show / Cartoon / Story Characters

Control over creatures and as portraying them as cartoon characters which can add a fantasy parameter to the play value as explained in the play pyramid [26].

8 | Evaluation

8.1 Lesson Plan:

A child of age 6-7 years gets tired of repetitive activity of practising letters and hence the number of letters for exercise should be limited to 4 or 5 [27]. Using the 24 primitives, child may get confused at times. It can also add to the cognitive overload. In such case the Devanagari letters can be taught in following word sets.

Each word sets are classified from being simple to complex letterforms. There can be two ways in which Devanagari letters can be taught.

a) A word set can be taught completely from simple to complex letters, in which graphical similarity can be used to reduce the complexity between letters. (p. 82)

b) Words which are simple can be taught first and then in steps the level of complexity can be increased.(p. 82)

Two sets were selected based on the number of primitives required to build a letterform, complexity and variations of letters. Children were asked to build letters from two sets which include letters प त ड इ झ र. An evaluation was done with pre and post test as an evaluation method.

Simple $\longrightarrow$ Complex

व	ब	क	ळ	
प	त	ष	फ	
ग	न	म	भ	
ट	ठ	ढ	द	क्ष
र	स	श		
य	थ	ख		
ल	घ	ध	छ	
उ	अ			
च	ज			
ड	इ	झ	ज्ञ	

8.2 Goals:

Usability:

Children should be able to understand the basic interactions of the game on their own and start playing the game

Children should be able to play with the help of parent or teacher at the start of the game without any other instruction other than coming on the screen.

Players should be able to understand the interactions/hints unambiguously and consistently.

After playing the game for about 15-20 minutes, most players should be able to play most steps of the game.

Engagement:

Children should feel engaged with the game for at least 20-30 mins.

Children should get in a state of flow and lose track of time.

Teachers and Parents should feel that the game is appropriate for them.

Learning:

Do students remember the Devanagari letters they learn from playing?

How many letters from Devanagari Script the child can retain?

Is it helping teachers and parents for teaching their children?

Feedback:

What additional motivation or perks are needed to attract children to game play?

What improvements do Teachers want made to the game?

Key Questions:

Is toy/game playing an effective approach for teaching children Devanagari Script?

Is the toy engaging?

When do students prefer gaming for learning Devanagari Scripts over more traditional teaching methods and why?

Method for evaluation:

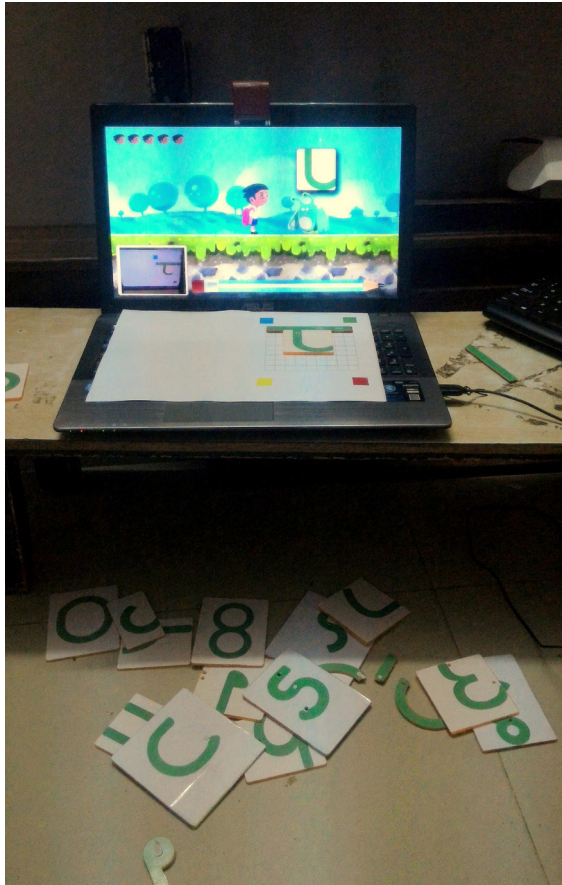
Pre test and Post test:

Users are given a set of printed cards of letters and are asked to identify them. Letters are shown individually and in set of similar looking letters. After playing with Aksharmaal, they are again given the cards and asked to identify the letters.

Users Criteria:

- Children from 1st and 2nd grade, who lack in recognition and identification skills for devanagari letters.
- Children in the preoperational stages.
- Native language hindi or marathi.

8.4 User Feedback:



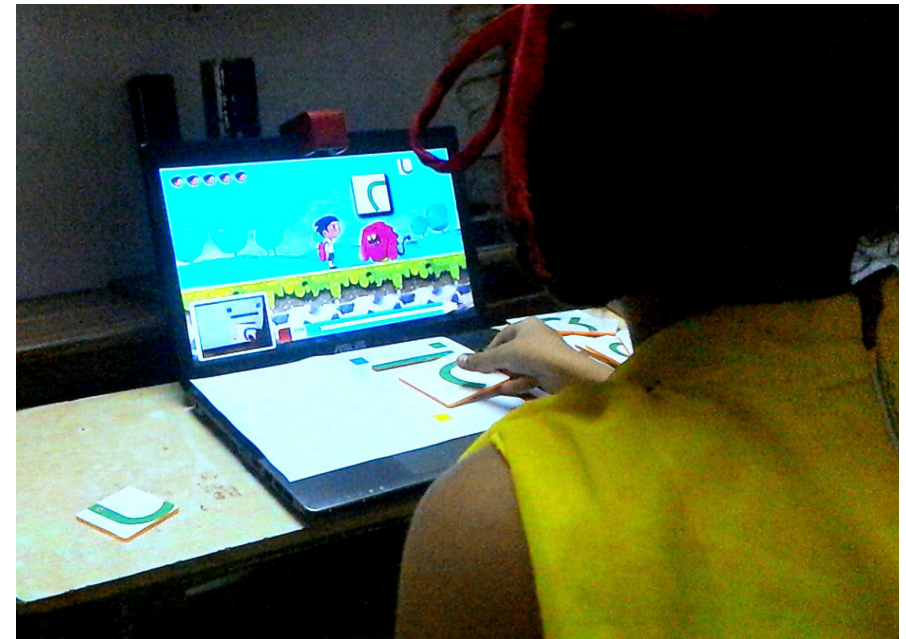
The user feedback was taken after building every prototype. The user feedback came from School teachers, students and visitors from Design Degree Show'15 where the project was exhibited.

- Use of only one color for the modular font instead of two colors
- Use of simple graphics in the digital game in the background to avoid confusion.
- Giving the control of the game to the child by reducing few guides and rules.
- Adding more fun elements in the game play to engage children in further levels.
- Avoid relation with surrounding objects, as player might relate every object in the gameplay even if it is not meant to.
- In preoperational stage different children may not have fully developed brain and might take different amount of time to learn a letter. Instead recruiting a foreign language user with developed brain might be helpful.

A brief user feedback was taken from a school teacher of 1st and 2nd grade. The feedback included following key points.

- Teaching of devanagri letters can be done through repetitions only
- Current structure of letters is according to pronunciation of letters whereas students learn letters based on graphical similarity of shapes.
- Teaching of letterforms can be effectively done with help of similar looking real life objects. Teacher teaches the letters by relating them with real life objects. To encourage the children to notice that letters are all around them.
- How letters are formed can be done with hand gestures. Making them visualize the letter, the shape of the letter in other object can be helpful.
- Also to encourage the children to play with letters and explore the primitives.
- Only basic understanding of structure of letters is required. Many number of primitives increase the cognitive overload.

Based on user feedback taken during initial prototypes, several iterations were created and again tested with the users. The Final prototype was tested with 6 users. The evaluation was carried based on the usability, engagement and learning.



8.4 Findings

Usability:

- All children took more time for the first letter, for getting acquainted with the game system.
- Children needed support to get familiar with the game at first.
- The use of many primitives creates confusion in children.
- Children placed primitives before it was asked in the gameplay. They anticipated what will the next step in the game level when played again and again.
- Use of 3 layers of primitives is not clear at start. But users got acquainted with the layouting of primitives after playing the first level.
- Hints were needed in the initial few moments of gameplay.
- Users use of floor instead of the grid in the playing area. But they liked the idea of using playful primitive tiles in hand and feel the letterforms.

Learning:

- Effective learning was happening in group work and also when taken peer support.
- Children remembered the letters which are graphically similar.
- They could retain 4 out of 6 devanagari letters. The table shows the observations noted during the gameplay.
- Letters like झ, ञ took more time.
- After the first level children were quick in placing correct primitives.

Engagement:

- Children felt engaged with the game.
- They got engaged with playful primitive and started exploring them in hand only.
- When played with peer support other players were more interested in playing.

The table shows the observations noted during the gameplay.

	User1		User2		User3		User4		User5	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
प	1	1	1	1	0	1	1	1	1	1
फ	1	1	1	1	1	1	0	1	1	1
ड	0	1	0	1	1	1	1	0	1	1
ह	0	1	1	1	1	1	0	1	1	1
झ	0	0	0	1	0	1	0	1	1	1
ज्ञ	0	1	0	1	0	0	0	0	0	1

9 | Conclusion

The attempts to teach children the Devanagari letterforms through a digital game and tangible primitives proved to be an exciting and fun filled project.

From all the user testing and evaluation, the following were concluded.

- If children play with the primitives, they learn to recognize Devanagari letters, but the process may require more time than the conventional methods such as rote learning or repetitive writing practices.
- The learning happens through the graphical similarity, in which children were able to recognize the base layer primitives and then the complex letters.
- Compared to Phonetics, Graphical similarity works effectively for Devanagari letter recognition.
- However, Santosh Kshirsagar in his case study, expresses curiosity about the understanding of Devanagari script in children. How it can be measured? How these letter form characteristics be analyzed? [27].
- The game system and use of primitives requires rigourous evaluation in terms of number of possible combinations of primitives.

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