Interactive Tool to Aid Conceptual Learning of Light in Rural Children

INTERACTION DESIGN PROJECT III
IN III – 108

By
Saloni Mehta
Roll No. 156330005

Guide:
Prof. Anirudha Joshi

INDUSTRIAL DESIGN CENTRE
INDIAN INSTITUTE OF TECHNOLOGY BOMBAY
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Project Approval

The project titled "Interactive Tool to Aid Conceptual Learning of Light in Rural Children" by Saloni Mehta, is approved for partial fulfillment of the requirement for the degree of 'Master of Design' in Interaction Design at Industrial Design Centre, IIT Bombay.

Guide:

Chairperson:

Internal Examiner:

External Examiner:

Date: 15 JUNE 2017

Declaration

I declare that this written document represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources.

I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission.

I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources, which have thus not been properly cited, or from whom proper permission has not been taken when needed.

Saloni Mehta
156330005

Interaction Design
Industrial Design Center
Indian Institute of Technology, Bombay

Acknowledgement

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Cheers!

Saloni

Abstract

Several million rural first generation learners are now a part of India's massive education system. They get negligible help at home and often have less than motivated teachers at school. Moreover, the curriculum is largely designed by urban natives and for enabling people to live in an urban society. This disconnects the rural student's classroom learning from their real life experiences, and raises questions of relevance and utility of learning.

In this project, I work on developing a learning tool to supplement school education by enabling self-learning. The tool is an aggregator of concept-wise interactives that take an application-first approach. Each interactive would incorporate local context to improve relevance, and add interactivity for increased engagement with content, which provides conceptual clarity.

Using the context derived from primary field studies, I developed a sample application for teaching 'lenses in the human eye'. It is uses a guided discovery approach, which combines both direct instruction using animated audio-visuals, and experiential learning via manipulatable interactive screens that simulate a locally-relevant real world application.

The prototype was evaluated for usability and engagement using think-aloud tests with students from villages in Rajasthan. Post that they were asked applicative questions in the form of a real life scenario. This preliminary testing indicated positive impact of interactivity to improve engagement with content. The self-paced learning style also allowed them to refer back to and replay the content till the student perceived conceptual clarity. The testing also uncovered some issues with the content, presentation and interactivity. Design ideas to overcome these were identified and implemented.

Prologue

It all starts with the two days spent with Radha at Kharpundi village in 2014. She goes to college at the nearest town – Gadchiroli – 10kms away. The nearest major railway station is almost 200kms away at Nagpur (Maharashtra, IN).

She has two younger brothers, both of who attend school. Her parents are seasonal farmers, with two small patches of land cultivating rice. To fend for the off-season and to pay for their children's education, they rear goats. The rice and the goats fetch them about 25,000 rupees a year.

Radha, like most village girls, helps with the chores at both the farm and the home. The fact that a village girl does all this, and gets to focus on her higher education has been repudiating all I have heard about the state of affairs in remote Indian Villages. At college she is studying science and is doing well. Recently however she has been thinking of giving up on education.

At her home, this December afternoon, we engage in a debate about her marriage plans with her mother. It is revealed that, in spite of her being highly educated, there is no way by which she'll be allowed to leave the village for a job. Her education level will help fetch her a good husband. That explained her parent's support for her education, but what had kept Radha going till now? What was stopping her now? She didn't want to get married yet. She wanted to stay home and help.

She had hoped that education would make her more capable. She wanted her education to be directly useful for her farms. But it wasn't. At-least she felt it wasn't. And she quit.

This got me wondering – was education really irrelevant to her life? Did she make the right choice? Did the educators get it wrong?

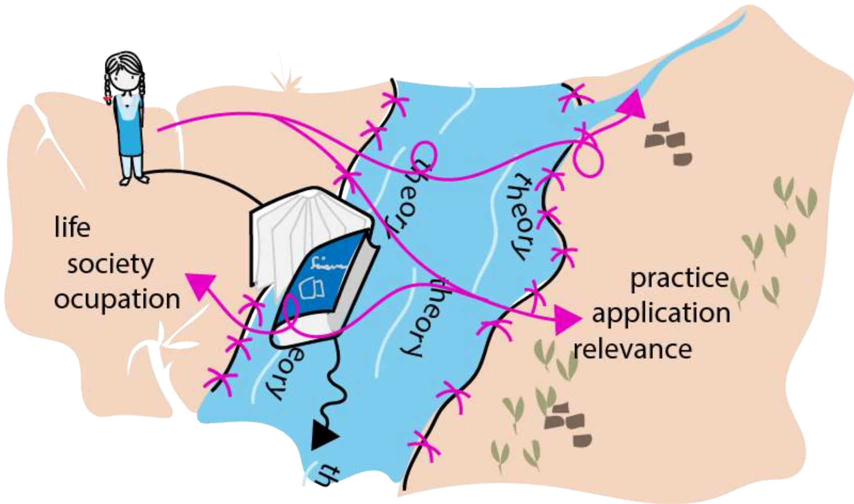
I think not. She was definitely much better off than those who didn't get to go to school ever. She learnt to make more informed choices.

She still did quit, because she felt education was irrelevant.

It seems to me to be a case of *lost in translation*. The attempt made by education, drowned in the river of theory before reaching the land of relevance and applicability.

How many such students quit modern education because of perceived irrelevance? We don't know.

This project is an attempt at working along the shoreline, where theory and practice are inseparable.



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Chapter 1:

Introduction

Before the British era, in India, Gurus in Gurukuls, Madrasas and other such traditional institutions imparted education. These however, largely catered to only the upper castes and a vast majority of the mass was denied any education. Since then India has taken large strides in the field of education (visible in Fig. 1). However, as mentioned by Muralidharan (2013) – in-spite of the considerable progress in access, infrastructure, pupil-teacher ratios, salaries and student enrollment – student-learning numbers remain disturbingly low.

In-spite of directed efforts towards inclusion, the mainstream education system favours those students with help at home, access to books and libraries, enthusiastic teachers, and an environment with intellectually stimulating conversations. Most of the increase in enrollment has been achieved by getting first generation learners to school i.e. students whose parents never went to a school. Usually much less is demanded from these students (both at home and at school), creating a group that is conditioned to lack educational drive (Haycock, 2001).

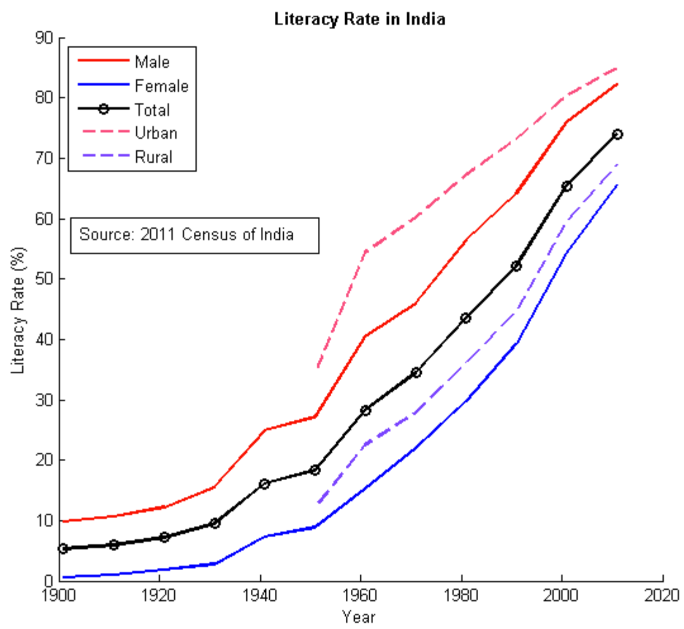
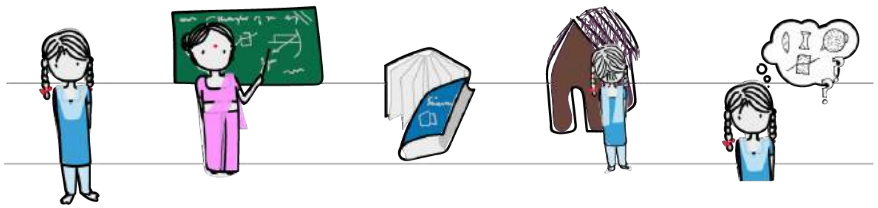


Fig. 1: Literacy in India has grown steeply since independence, and especially after 1991

Beyond literacy, education today is primarily seen as a means to 'get a job'. Urbanization is often considered the pathway to progress, and is supported by the numbers. As reported by Barclays (2015), "Urban areas have powered India's growth over the past two decades and now generate 63% of India's GDP – up from 45% in 1990". Hence, being urban ready is a key aim for curriculum designers.

After following a pre-set structure of primary-to-secondary-to-college learning, a student is expected to have the tools to better face the world (by being more knowledgeable, and capable of earning money). A curriculum designed for urban readiness should however not become alien for a rural student. In India, where almost 70% of people live in villages (Census 2011) and about 47% of the workforce is engaged in agriculture and allied sectors (The World Fact Book: India, FY 2014 est.), a curriculum that students can't relate to due to inapplicability to their real local world will always leave something to be desired.



A child | goes to school | is taught something | goes home | wonders, "Ok. So this happens. BUT, why did I study this?"

Hence, while we push for increased academic achievement, we also need to push for educational relevance – one that connects the bookish learning to that of their natural surroundings. This would keep the student interested; allow systematic observation of the world around and internalization of learning. This would further enable them to effectively use what they have learnt and positively influence the local economy.

1.1. Scope

The students studied, and the content analysed for this project are mid-school (7th to 10th grade) physics, in particular concepts covered under teaching 'light'. The prototype has been developed for teaching "Lenses in the Human Eye".

1.2. Approach

As discussed before, most of the target audience are first generation learners whose education lack parental guidance and supervision. Hence, the goal is to create auxiliary learning tool to school education for self-learning, that can be played around with for gaining additional conceptual clarity.

In this project, I make an attempt towards bridging the gap between the conceptual content and the application, by taking an application-first approach. At its core, the tool brings forth relevance and interactivity, as means to increase engagement, clear misconceptions and provide instant feedback for effective learning.

This should in turn allow the students to relate their learning to their immediate surroundings.

1.3. Methodology

I began by familiarizing self with the current state of rural education, its pain points etc. via secondary research. I also took up a teaching position at a local tutorial to gain first hand teaching experience and understand its nuances.

To focus trials and development efforts, I selected an appropriate broad topic – Light. Content under this topic was chunked into topics and a content map was built.

To set context and further understanding rural requirements, I visited and taught (the content chunked earlier) at a rural school in Rajasthan. Herewith, I also held conversations with students, teachers and local inhabitants to understand their roles, priorities, and view points. Here, I also checked for viability of using a mobile device as a learning tool, and gained practical insights.

Post returning from Rajasthan, I reviewed multiple learning theories and teaching methods with particular focus on how to make education more relevant and engaging. I also reviewed existing products to gain product and interactivity insights.

All insights were combined to form the final design brief. I followed by ideating via brainstorming, and developing intermediary prototypes.

For the purpose of evaluation, in-depth content and interactions were developed for a single topic – Lenses in the Human Eye. A working prototype for the same was developed using Unity3D. I made multiple versions to incorporate feedback collected through quick testing and heuristic evaluations (conducted by multiple city-dwelling adults).

The final prototype was evaluated against the design objectives with rural children in Rajasthan. Issues were identified and sorted, and design ideas were generated to correct these issues. Later, I included some of these in the final proposed design.

Chapter 2:

Setting Context via Field Studies

To set the context, I spent 4 days doing exploratory studies at Mori Joshiyan village, situated 30km away from sub-district headquarter Luni and 38km away from district headquarter Jodhpur, in Rajasthan. It is one of 170 villages in Luni Block. There are 7 such blocks in Jodhpur district alone. Rajasthan has ~45k of India's ~6.5k villages. (Government of India, 2011)

As per the census (2011), the total geographical area of Mori Joshiyan is 885.6 hectares. It houses a total population of 1,744 in its 303 households. The village has a lower literacy rate (65.5%) compared to the whole of Rajasthan (66.11%). The village is very weakly connected, with no public transport station (train or bus) within 10+ kms radius. All commute to the location I made was via personal vehicles (teachers' rented van and personal scooter). The primary language of the locals is Marwadi. Most people also speak and understand Hindi.

Because of its low literacy rate many reforms have been introduced for increasing access to education. Also since 66% of the working population is engaged in cultivation related activities (Government of India, 2011), and not other conventional commercial activities, it becomes an interesting place to do the primary studies.

Fig. 2: Most part of the studies was conducted over 4 days at the local State Board School, which runs classes for grades 1 to 10. The primary language of instruction is Hindi.

2.1. Understanding Context

To build context and better understand the student's routines, backgrounds and motivations, I spent most of the 4 days I was there with them. I participated in the school assemblies, English and Science classes for grade 9 and 10, Republic day practice sessions, visited their homes and played their traditional games during lunch breaks.

Half a day was also spent exploring the village, the farms and having conversations' with student's parents regarding their aspirations for their children.

Some attempt was made to understand the teachers' context as well. A majority of the time spent with them was in the van journey to and fro Jodhpur (where most of the teachers resided) that spanned a total of 3 hours per day. Other inferences were made through observation during and post school hours.

Fig. 3: A conversation with a few local ladies at a farm, about their histories, aspirations for their children, limitations etc.

Fig. 5: Classrooms at the State Board School, Mori Joshiyan. Some classes are conducted outside in the open.

Fig. 4: The wheat farms: The villagers wait for the gods to send water (monsoons). No planned irrigation is done here.

Fig. 6: Student reading headlines from the local newspaper at the daily morning assembly

Fig. 7: Primary section students. The walls of the primary section classrooms are colourful, with illustrate content, but used as a storeroom.

Fig. 8: Secondary classrooms: The walls are white with remnants of some charts made by students

Fig. 9: Learning aids for math classes at the staff room

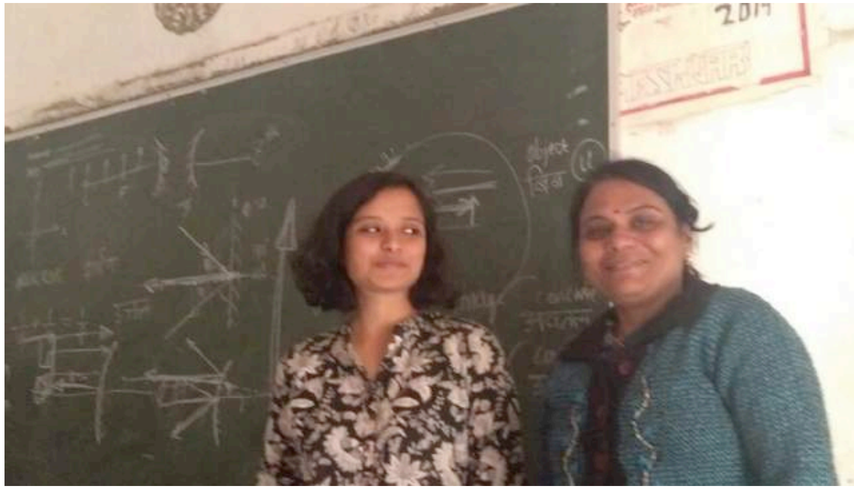


Fig. 10: Me with the headmistress while conducting a class on spherical mirrors

2.2. Teaching at the Local School

For two days (the 3rd and 4th day), I conducted English and Science lessons for grades 8, 9 and 10.

Topics covered under English for class 9th (~2hrs):

- Punctuations and their use
- Letter writing

Topics covered under Science for classes 8th, 9th and 10th (~6hrs spread across 2 days):

- Shadows, Phases of the moon
- Refraction (definition, optical density, Snell's law, refraction though the glass slab & through the prism, mirage, bent pencil, fishing)
- Colours (the light spectrum, newton's wheel)
- Curved mirror formula & the Cartesian system for sign conventions

Using direct definitions and ray diagrams

When I began, I struggled with teaching in the Hindi language. Hence, the initial lessons were straight off the book i.e. using standard definitions and ray diagrams on the board.

I soon realized that this method did not help the students understand the concepts well. Even the bright students would just reiterate the definition and not be able to explain what the concept meant, and where it was used. For example: Students remembered that magnification was $\frac{height\ of\ image}{height\ of\ object}$ but did not understand that it could be used to determine how large or small the image we see would be. Hence, in comparison to the direct formula it would be more useful to define it as "the degree to which an object is enlarged in appearance".

Using contextual examples

To help the students visualize, and to ground their understanding of the concepts I was teaching, I soon started using applications as examples. I began with the usual examples given at the end of chapters in the textbooks – such as bending of the pencil to teach refraction of light, fishes appearing higher than they actually are in water bodies, and such. It was very apparent that examples that the student's had witnessed themselves, such as twinkling of light and mirage captured more of the student's interest than examples they had not witnessed in their beyond-textbook lives.

Note that, though experiments can be performed to witness a phenomenon, they need to be designed appropriately for the context. For example, the pencil bending in a glass of water doesn't work in Mori Joshiyan, since they use opaque glasses (utensils), which do not display the concept accurately and need a large lateral angle.

Using act-out activities for understanding how-things-work

For micro concepts, such as 'bending of light while entering another medium', I also used analogies and student activities to clarify the working (refer Fig. 11). This method was also used to teach phases of the moon, solar and lunar eclipses, duration of eclipse etc. by making the students enact out the earth, moon and the sun (Note that this could be substituted with props, if available).

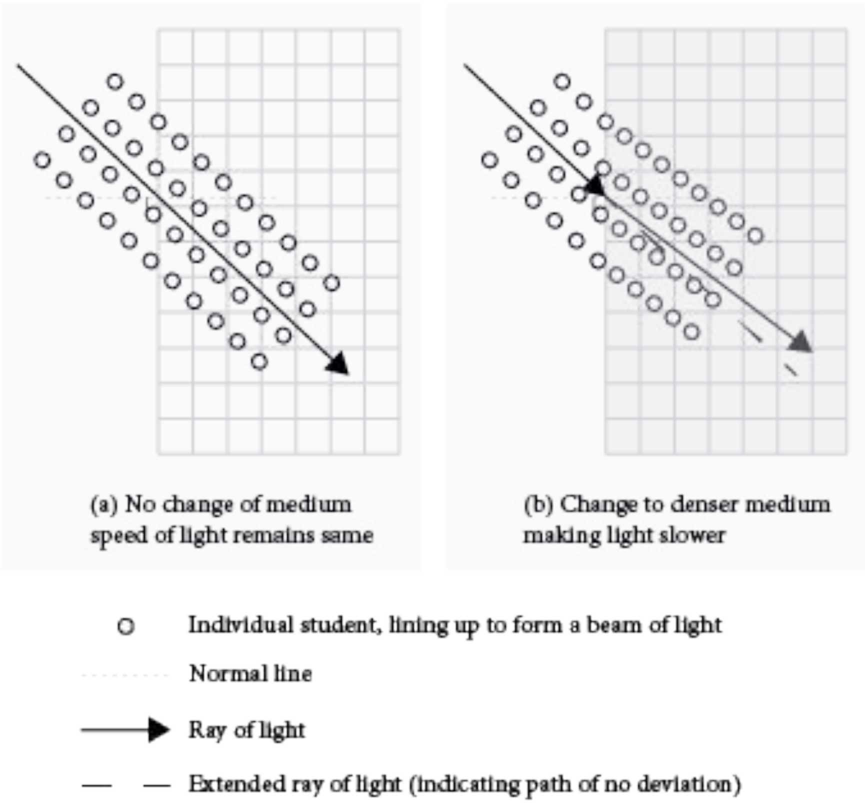


Fig. 11: Students enacting out the properties of light as it enters a new medium. By just varying their speeds and trying to keep together (holding hands), they naturally bend. Hence, illustrating 'bending of light'.

Using multiple point of views

Typically, if a method is used to teach a particular concept/ process, students memorize it as is. They are then not able to apply the same concept to altered use cases. This leads to rigid understanding of how things work, further leading to confusion and misconceptions. I used multiple alternate orientations (see **Error! Reference source not found.**), examples and non-examples to introduce flexibility in understanding.

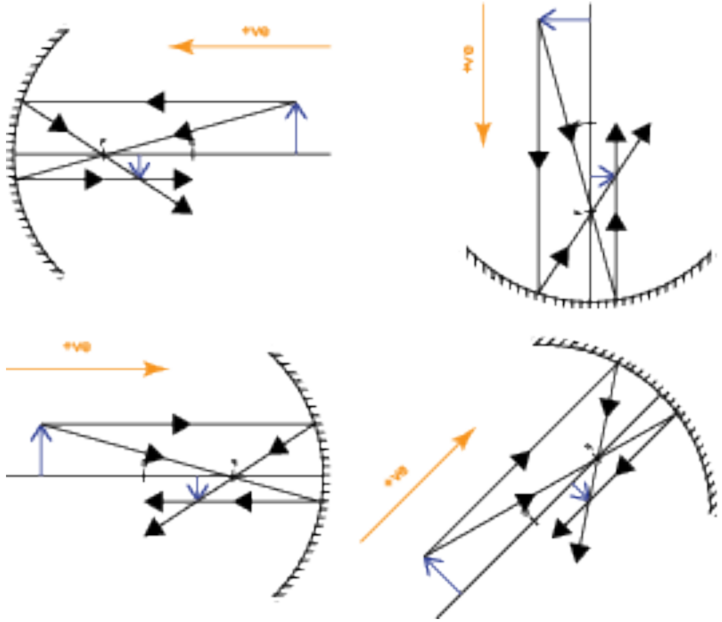


Fig. 12: Drawing the regular ray diagram for curved mirrors in multiple orientations, to explain how the coordinate system would vary to determine values for some parameters.

2.3. Other Observations

Pre-high school curriculum covers ‘Light’ largely as something enabling vision. This however is not carried forward to sub-topics, where the focus shifts to drawing the correct ray diagrams and using formulae. Even while covering ‘the human eye’, most of the content focuses on the location of ray convergence and image formation, rather than its effect on vision. Consequently, many students find it difficult to connect their school learning to real world application.

Teachers are frequently absent, or unable to take classes due to other administrative duties. Muralidharan (2013) also discussed this as a nationwide phenomenon in his article - Priorities for Primary Education Policy in India’s 12th Five-year Plan.

Many students also frequently miss classes. Notwithstanding a multitude of other reasons, most students have to help out at their farms (especially during the sowing and harvest seasons). Missed classes and non-understood topics act as barriers to further learning.

No one asks questions! The fear of being ridiculed or ignored and an absence of adequate answers to their previous questions have progressively led to curbing of curiosity and of asking doubts.

All this has led to heavy dependence on answer books (or guides). Most students memorize this material without understanding the ‘what & whys’.

2.4. Opportunity for the Project

The noticeable hampering of affective learning due to lack of guidance and engagement with content, calls for major self-learning interventions. Since during the primary studies, I also observed good network reception, ownership of feature phones and access to smartphones, it was concluded that smartphone based distribution of content can be made a reality in the near future (especially considering access to shared devices).

However, access to smart devices for the sole purpose of a child’s education didn’t feature on the locality’s priorities. Hence, any smart-device based intervention needed to be based off the widely adopted smartphones, and cannot be developed for devices such as tablets and laptops, which would limit distribution.

Hence, I decided to design a self-learn, interactive learning aid for the mobile phone. Students can utilize this in their idle time at home, while travelling, at farms etc. to better understand concepts and their contextual significance.

Chapter 3: Literature Review

In this section I discuss what I mean by relevance, and its role. It's followed by the learning theories and teaching methods I reviewed and took inspiration from on how to make education more relevant and engaging. This section also includes a short note on mobile education, especially in the context of remote, low-income educational environments.

3.1. Relevance

"Relevance is the perception that something is interesting and worth knowing" (Roberson, 2013).

In this project, I deal with two components of relevance – relevant content and relevant content delivery.

Relevant content

This includes what is being taught. Is the content appropriate and useful for the student's current and future needs? Does the content consider the social, geographical etc. aspects of learning relevant for the student?

At a higher level, this pertains to curriculum design. At a more macro level however, it also includes the components of teaching tools, such as what examples are used.

It has been shown that increased content relevance is strongly related to total affective learning outcomes (Mottet, Garza, Beebe, Houser, Jurrells, & Furler, 2008) as it increases motivation to learn (Frymier & Shulman, 1995). It is also recommended to build relevant content on "the students' existing skills, using analogies and examples familiar to students, … relates to future activities of students" (Mottet, Garza, Beebe, Houser, Jurrells, & Furler, 2008, p. 351).

This is also supported by neurology. To make a concept or a new piece of information stick, one needs to link it to an existing piece of information. This helps content stored in the long-term memory easier to retrieve.

Relevant content delivery

This includes how something is being taught. Is the language appropriate? Is the speed of delivery apt? Where is the lesson being conducted? Who is conducting it?

However, since "relevance is a receiver perception of a message that can vary from person to person, … making content relevant to every student sitting in class (particularly large classes) is generally an unrealistic expectation" (Frymier, 2002, p. 83). Hence, building content relevant for entire states (and at times, the entire nation) for a community as diverse as India has been a mammoth task.

In this project, an attempt has been made to make this possible by allowing for localized customization. An application-first approach would help contextualize knowledge and give students the skills to apply their understanding to authentic complex environments and experiencing how and when the concept is used.

Many guidelines exist for teachers and parents to help them make education more utilitarian and relevant for students. I have consolidated the recommendations from (Kelly, 2017), (Myracle) & (Roberson, 2013) into the following:

1. Connect concepts to real life scenarios.
2. Start with a real world problem. Point out the problem solving power of knowledge.
3. Use hands-on learning. Use simulations when hands-on is not possible physically.
4. Encourage students to make their own connections.
5. Indicate potential future benefits and careers.

3.2. *Learning & Teaching Methods*

Constructionism, Guided-Discovery & Situated Learning

Constructionism advocates student-centered, discovery learning where students use information they already know to acquire more knowledge (Alesandrini & Larson, 2002). It is based on the constructivist philosophy of active involvement for constructing knowledge for self.

Part of Seymour Papert's definition of constructionism mentions "… a view of learning as a reconstruction rather than as a transmission of knowledge. Then we extend the idea of manipulative materials to the idea that learning is most effective when part of an activity the learner experiences as constructing a meaningful product."

Constructionism is often perceived and incorporated as pure-discovery. However, Mayer (2004) argues against purely discovery based teaching methods and extensively argues for guided discovery. Brown, Collins & Duguid (1989) talk about situated learning, wherein, the student takes part in activities directly relevant to the application of learning and that take place within a culture similar to the applied setting.

Hence, in my application first approach I use directly relevant applications. Also, though the focus is on learning by doing (experiencing), there is equivalent focus on well-structured direct instructions to provide scaffolding for learning and preventing misconceptions.

Using External Representations

Through my primary research at Mori Joshiyan, I realized that use of visual external representations helps quicker and clearer learning. This was best explained by Kirsch (2010), who discusses 7 ways external representations enhance cognitive power. In addition to saving internal memory and computation,

- They change the cost structure of the inferential landscape
- They provide a structure that can serve as a shareable object of thought
- They create persistent referents
- They facilitate re-representation
- They are often a more natural representation of structure than mental representations
- They facilitate the computation of more explicit encoding of information
- They enable the construction of arbitrarily complex structure and they lower the cost of controlling thought—they help coordinate thought.

External representations can be both 2D (images, tables, flowcharts usually on paper or screens) and 3D (models, props, tangible artifacts, games etc.). Their use in both learning and teaching, can allow people to think much more powerfully.

However, inappropriate use of external representations can also lead to development of misconceptions (for example: due to the popular representation of planetary orbits in perspective view, most students believe these orbits to be elliptical).

With increase in use of technology for education, we are also witnessing a rise in use of manipulable/ interactive representations. These are interactive models that allow the user to manipulate the view that has been generated for the given information. Some examples of these are reviewed later in this report, and insights derived have been extensively used for the development of the prototype.

Feedback for Learning

The best part of interactivity is that it provides instant feedback. Feedback is information about how we are doing in our efforts to reach a goal. Less "teaching", more feedback equals better results (Wiggins, 2012).

Most effective feedback is

- Instant/ Timely
- Frequent and continuous
- Consistent
- Actionable
- Deliberate and explicit
- Noticeable or observable

Hence, the interactions in the final design provide real time visual feedback. While introducing new functions, bright colours & indicative animations have been used to make them easily noticeable.

Experiential Learning

"Tell me and I forget, teach me and I remember, involve me and I will learn." – Benjamin Franklin, 18th century

Experiential learning is defined as "learning through reflection on doing" (Patrick, 2011).

This type of learning helps motivate students by involving them directly in an ongoing learning experience and in meaningful discovery rather than them being passive recipients of ready-made content in the form of lectures (University of Waterloo: Centre for teaching excellence).

One disadvantage of experiential learning is its relatively slower pace, because of which teachers often revert to direct instruction and lectures for most teaching. However, this method can also result in 'deeper' learning allowing the student to transfer what they have learnt from one context to another, hence mitigating the affect of the aforementioned disadvantage, since they can use their better understanding to apprehend the later chapters quickly.

Kolb & Fry (1975) developed the Experiential Learning Model (ELM) which describes learning as a four-stage cycle as shown in the figure below. As a process, ELM is constructivist. This cycle can begin with any of the four elements, but typically begins with a concrete experience.

By using/ adding interactivity, I have provided a way for the student to navigate through this circle of experiential learning.

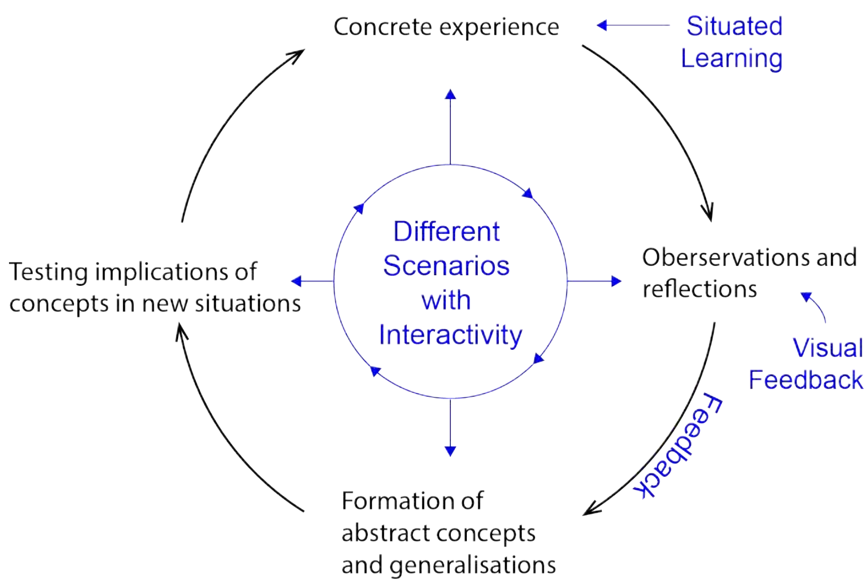


Fig. 13: The Experiential Learning Model (Kolb's Cycle) overlaid in blue with role of other interventions made by me as design response

I have used Jacobson & Ruddy (2004)'s "5 Questions model" to help form the questionnaire at the end of the interactive which promotes critical reflection on the concrete experiences. The 5 Questions model is as below –

- Did you notice...?
- Why did that happen?
- Does that happen in life?
- Why does that happen?
- How can you use that?

Cognitive & Knowledge Matrix

Bloom, Engelhart, Furst, Hill, & Krathwohl (1956) created the Bloom's taxonomy in order to promote higher forms of thinking in education rather than just remembering facts (rote learning). It identified 3 categories for the goals of the learning process – Cognitive (knowledge), Affective (attitudes), and Psychomotor (skills). They describe 6 major categories of cognitive processes which were later rearranged and changed to verbs to form the "Bloom's revised taxonomy" (Anderson, et al., 2001) –

- Remembering
- Understanding
- Applying
- Analyzing
- Evaluating
- Creating

The revised taxonomy also lists content types as levels of knowledge –

- Factual
- Conceptual
- Procedural
- Meta-cognitive

These can be put together as a cognitive and knowledge matrix that aids creation of performance objectives. I have used this later to determine teaching methods (refer
).

Over time, multiple types of content have been identified and added to the matrix (Table 1) ((Merrill, 1983); (Clark & Chopeta, 2004); (Clark & Mayer, 2008)).

I have categorized content into these content types in Chapter 4, while working with content for "Lenses in the Human Eye".

Knowledge dimension ► ▼ Cognitive dimension	Facts	Concepts	Processes	Procedures	Principles	Meta-Cognitive
Remembering						
Understanding						
Applying						
Analyzing						
Evaluating						
Creating						

Table 1: The cumulative cognitive and knowledge matrix

Self-Paced Learning Outside of the School Setting

Self-paced learning refers to a student undertaking learning activities in his/her own time.

Advantages:

- Access to learning in any setting at any time – at home, at the farms, while travelling etc.
- Allows repetition as required without pushing the student to move ahead without understanding

Disadvantages:

- Learners with time-management and motivation issues can fall behind
- Instant help might not be available on the system

3.3. Mobile Education

It is often stated that technology (especially mobile phones) will be path breaking in making education more accessible for the communities that have been, thus far, lesser privileged.

It has been established to some extent that, there is scope for self-learning by children through unsupervised access to technology and learning material (Dangwal, Jha, Chatterjee, & Mitra, 2005) & (Kumar, Tewari, Shroff, Chittamuru, Kam, & Canny, 2010).

Traxler (2009) comments on how mobile devices are increasingly changing the nature of discourse and the nature of knowledge itself. He mentions,

"Finding information rather than possessing it or knowing it becomes the defining characteristic of learning generally and of mobile learning especially, and this may take learning back into the community … Learning that used to be delivered 'just-in-case', can now be delivered 'just-in-time, just enough, and just-for-me'" (Traxler, 2009, p. 14).

As per Narayanan Rangaswamy, head-education at KPMG India, "[Educational] technology advancements have contributed to students getting bolder about what they want to learn" (Vignesh & Bansal, 2016).

Similar things have been said about mobile learning games. They are not only engaging but also capable of accounting for the user's context and environment to improve on the learning process ((Klopfer, 2008) as cited in (Kumar, Tewari, Shroff, Chittamuru, Kam, & Canny, 2010)). The number of educational mobile gaming applications has increased multifold in India and worldwide, suggesting a greater push towards bringing gaming technologies into the classroom.

Multimedia educational games also provide the opportunity of bridging some social gaps currently existing in the society. Kumar et. al. (2010) show that mobile learning games create a shared context that encourage new social ties to be formed across caste, gender and village boundaries.

As discussed in Chapter 2, I soon decided to use the mobile phone as the device on which the intervention would be built and distributed. Hence, before continuing with the design process, it was important to study and be aware of both the best and worst practices, and the common pitfalls that ICT implementations in rural areas face.

Trucano (2013) from the World Bank lists out principles to consider when introducing ICT in remote, low-income educational environments. These principles reinforce the use of the mobile phone as the medium of distribution as “the best technology is the one you already have, know how to use, and can afford”. They also recommend starting work directly in the difficult areas (which is why all my user research and evaluation is done in rural locations, and not just semi-urban sites). He has also published a list of the worst practices in ICT for education[1].

[1] http://blogs.worldbank.org/edutech/worst-practice

Chapter 4:

Working with Content

As mentioned before, to focus trials and development efforts, I selected an appropriate broad topic – Light. Content was pooled in from brainstorming, 6th – 10th standard textbooks (NCERT, Maharashtra State Board, and Rajasthan State Board) and online resources (discussed in chapter 5). Content thus collected was chunked into topics and a content map was built.

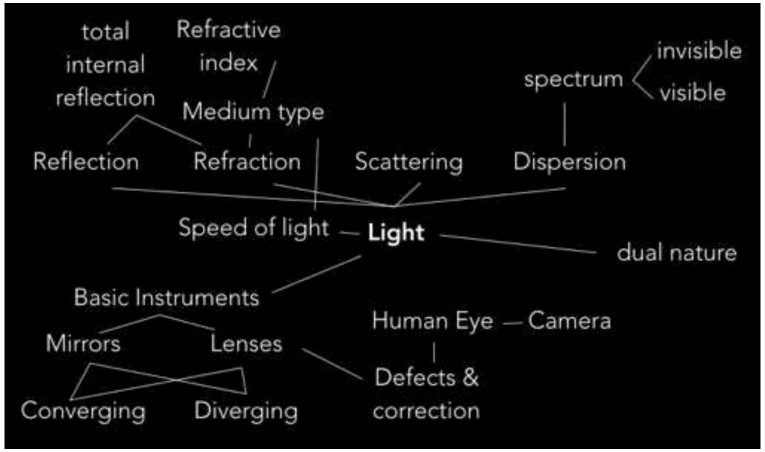


Fig. 14: Concept map generated as result of chunking topics under 'Light'

For the final prototype, I worked with the topic 'lenses in the human eye'. For this I analyzed the teaching methods used and content covered from multiple sources (details appended in Appendix I – Content Analysis – 'Lenses in the Human Eye').

I used the content types (listed earlier in chapter 3) to categorize how these sources treated the content. Using this, and content from the Rajasthan Board's 10th standard physics textbook, the final content to be covered was collated and is classified in **Error! Reference source not found.**.

I used the cognitive and knowledge matrix (refer chapter 3) to identify learning goals and identify appropriate teaching/learning methods for each category. These decisions were guided partly by the learning from the literation reviewed (discussed in chapter 3) and partly by insights from reviewing other existing products (discussed in chapter 5).

Table 2: Content collated to be covered by the prototype

Code	Content	Data-Type	Alt Data-Type
C01	Everything around us reflects light	Fact	Concept
C02	The human eye is made of many parts, each part plays a specific role enabling us to see	Fact	Process
C03	Eyes have a convex lens that converges light to form an inverted real image	Process	Concept applied
C04	Only an image formed on the retina is seen clearly	Principle	
C05	Changing curvature of the lens changes its focal distance; More curvature - higher convergence lesser focal distance, Less curvature - lesser convergence more focal distance	Principle	
C06	A suitable power corrective concave/ convex lens can be used to diverge/converge incident light to bring the formed image onto the retina	Concept	Procedure
C07	Defects in any part of the human eye can cause defects in vision	Fact	
C08	Issues in the eye's lens cause refractive errors	Fact	Concept applied
C09	These refractive errors cause the image to not form on the retina, hence causing blurry vision	Process	Concept applied
C10	Common types of refractive defects - Myopia, Hyperopia & Presbyopia	Fact	
C11	Defects - Cause (In-appropriate lens power of convergence)	Fact	Concept applied
C12	Defects - Cause (Weakening of muscles leading to inappropriate curvature)	Fact	Process
C13	Defects - Effect (Position of image formation & blurry image)	Concept applied	
C14	These defects can be corrected through uses of corrective lenses (in specs/ contacts etc.)	Fact	
C15	The corrective lens needs to negate the effect of the refractive error	Concept applied	
C16*	Not correcting defects causes strain, which can lead to further injury	Fact	Application
C17*	Exercising muscles keeps muscles healthy	Principle	
C18*	Exercising eye muscles can help prevent defects to some extent	Concept applied	

* Was added after evaluation, to add direct relevance

Table 3: Content sorted as per content type and learning goals (The cognitive & knowledge matrix)

	Facts	**Concepts**	**Processes**	**Procedures**	**Principles**	**Meta-Cognitive**
Remembering	C07		C2			
Understanding	C01, C08, C10, C11, C12	C13	C9			
Applying	C14	C15	C3	C6	C4, C5	
Analyzing						
Evaluating						
Creating						

Table 4: Teaching methods identified according to content type and learning goals

	Facts	**Concepts**	**Processes**	**Procedures**	**Principles**	**Meta-Cognitive**
Remembering	Audio-visual	Audio-visual	Audio-visual			
Understanding	Audio-visual	Audio-visual + Interactive	Audio-visual + Interactive			
Applying	Questionnaire	Interactive	Interactive	Interactive	Interactive	
Analyzing		Questionnaire	Display			Open ended questions
Evaluating						
Creating						

Chapter 5:

Existing Products

Existing educational products were reviewed for two purposes –

i. To collate content (as discussed in chapter 4 and detailed in Appendix-I), and
ii. To identify teaching methods and design strategies

In this section we'll discuss the products reviewed for the latter purpose. Largely, the products reviewed were – textbooks, video lectures, props and models, quizzing applications, games, interactive applications and simulations.

5.1. Regularly used in classrooms today

School textbooks

Reviewed content and teaching methods used by

- NCERT 6th – 10th (CBSE board)
- MSBTPCR 6th – 10th (Maharashtra state board)
- BSER 6th – 10th (Rajasthan state board)

The new MSBTPCR textbooks use many images & activities for the children to do to understand concepts. However, preliminary inquiry with students reveals that these activities are rarely tried and remain theoretically understood.

The BSER textbook incorporates relevance by asking scenario-based questions, and adding interesting "did you know" content. It however lacks in terms of the imagery used to explain most concepts.

Teaching with images, models and toolkits

Many school and teachers associations develop and use props, models and images as external representations and learning aids. These come with the benefits as listed under the "Using external representations" section in chapter 3.

However, distribution of physical props and toolkits poses a major disadvantage, as they are usually limited to school level, where each student does not get the opportunity to interact with them.

Fig. 15: Model of the Sun, Earth and the Moon to teach shadows, eclipses, phases of the moon etc. (Source: www.teaching.com.au)

Fig. 16: Colours of light toolkit (Source: intunis.net/physics-light-lab)

5.2. Commercial digital educational products

Instructive videos

Example: (Khan Academy), (Byju's) and other topical videos on youtube.

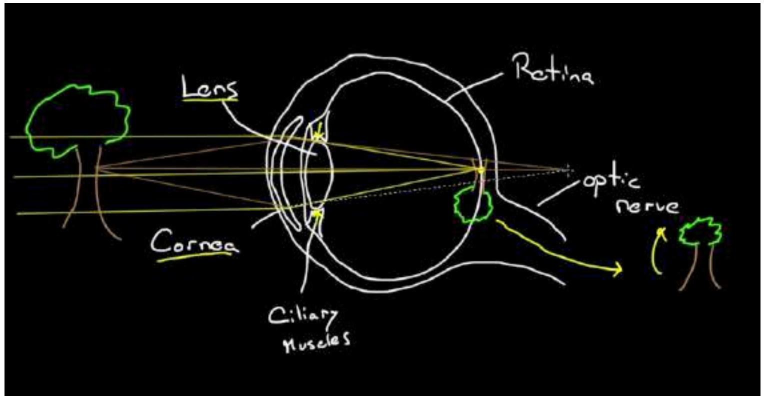


Fig. 17: Khan Academy illustrating far-sightedness accompanied with audio instructions

Khan academy videos are chunked well and are to the point. Though the videos are largely a screen-record of a digital screen, the topics in light are covered using many sketches hence adding visual value. Hand drawn ray diagrams are however rarely accurate, which might lead to misconceptions.

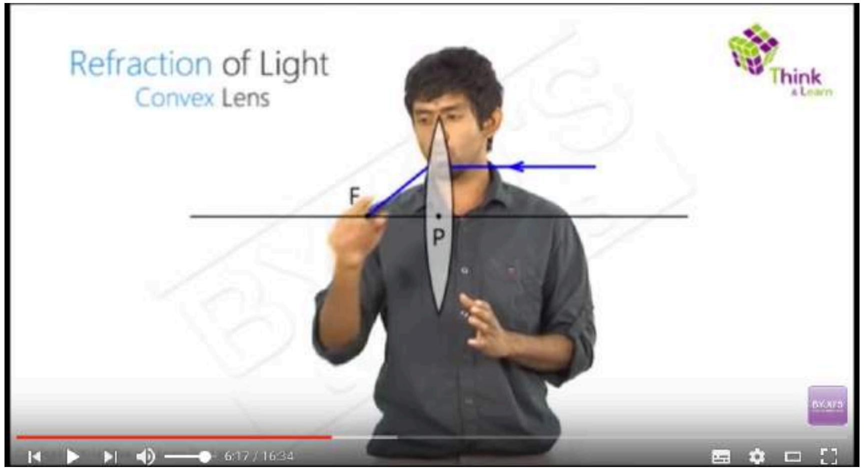


Fig. 18: Animated overlays accompany instruction in Byju's videos (Source: youtu.be/_heyzqbdKtU)

Byju’s videos have an instructor talking to the student directly, while animated overlays illustrate what he is teaching. A missing overlay, however, completely renders that segment unusable. The instructions have a casual-formal tone, like an elder sibling teaching you. This helps build familiarity and aids understanding of concepts.

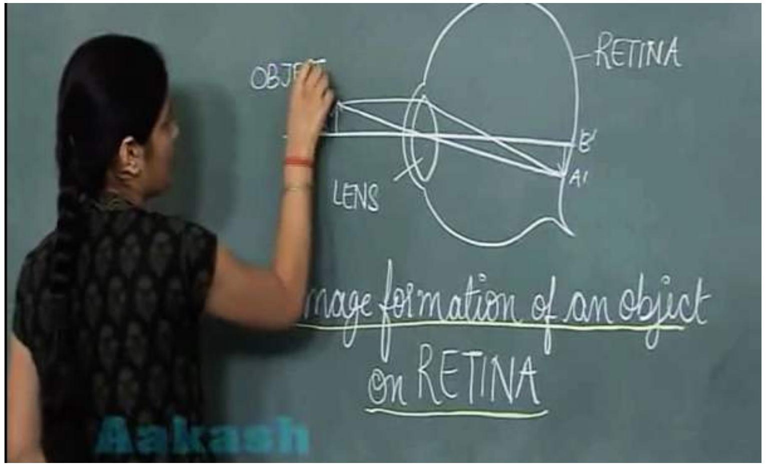


Fig. 19: Aakash iTutor instructor using blackboard to take a class, with her back to the viewer

Aakash iTutor[2] has detailed explanation of all concepts covered in the textbooks plus some additional concepts and facts. An attempt has been made to bring involve the student using questions, but they fail to do so because of being close-ended. Also, the tone is monotonous and the teacher rarely makes eye contact, hence making it very easy to lose attention.

[2] www.youtube.com/watch?v=7MVN9tQp2Oo, and https://www.youtube.com/watch?v=cxPmd5F_46A

Fig. 20:Amrita Create divides the screen into two to display views of the same scene while explaining a concept

Amrita Create[3] uses 3D graphics, first person perspective, and audio-visuals to cover most content. At many places, content could be made more relevant by using objects/ imagery from real life.

PROS: Use of first person perspective and real life scenarios to explain and visualize refractive defects.

CONS: Errors is visual representation lead to misconceptions.

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[3] www.youtube.com/watch?v=U_wTfpYK_ms
An animated video with 3D graphics that covers parts of the human eye, how they function, common refractive defects and their correction.

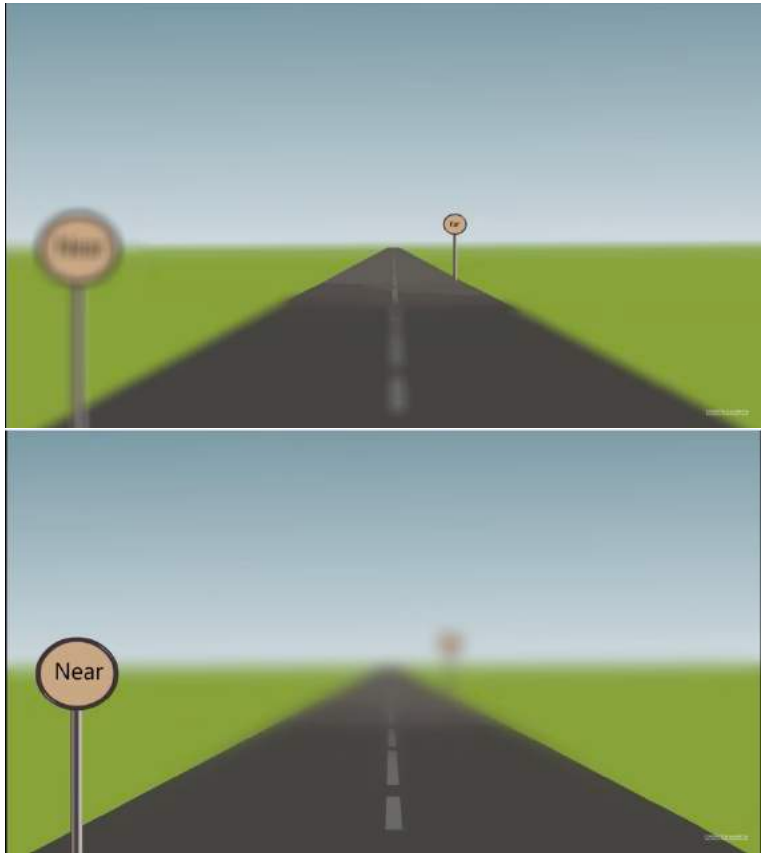


Fig. 21: Using first person view in a scenario to show and differentiate between far & near sightedness

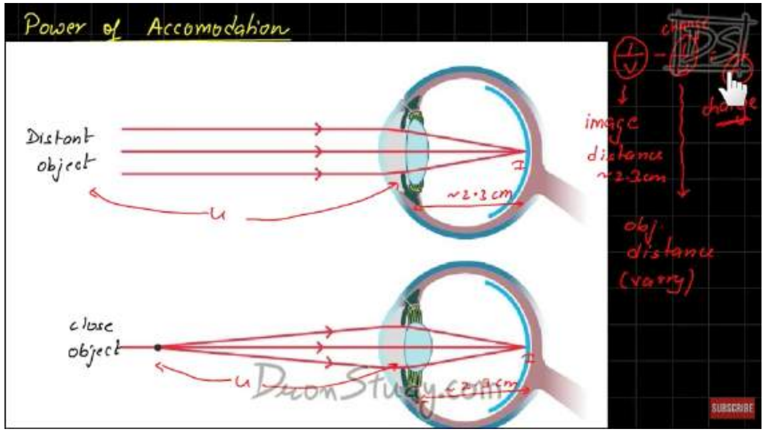


Fig. 22: Explanations using correlations with previously learnt concepts and formulae, overlaid with marker text and a pointer indicates the current position of focus

Dron Study[4] uses an explanatory tone, which is inundated with questioning and reasoning throughout. It uses visual markers to pull attention to the relevant section of the screen. Also, the use of Hinglish language would make the content much easier to absorb for students who have difficulty with the English language.

[4] www.youtube.com/watch?v=EmhHGFLXQXM, https://www.youtube.com/watch?v=U6jcditL7gA, and https://www.youtube.com/watch?v=VwLiZRrorts
An audiovisual that uses screen recording with Hinglish voiceover.

Many other topical videos have been made. Unfortunately, many

- Suffer from wrong/ misleading content
- Are recordings of teachers teaching on the board, with their back to the viewer
- Use visuals too complex or too alien

Instruction + Quiz based applications

Example: (Brilliant.org)

Lessons on Brilliant.org application use a combination of instruction + quizzing. The instructions use day-to-day examples to explain a concept and help build a clear mental map. These examples are however evidently urban (their target market).

A user may use most functionality only when connected to the Internet, which limits its use to locations and devices with good Internet connectivity.

Other quiz-based applications also exist that are too focused on the textbook syllabus, and mimic that as is.

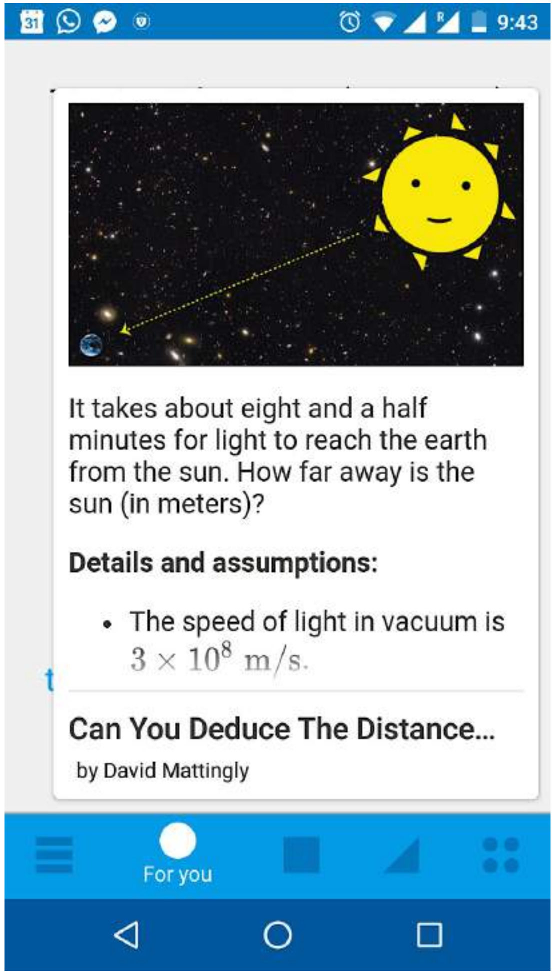


Fig. 23: A page from the Brilliant.org application

5.3. Games

Games are built to be engaging and mobile games in particular are very interactive. Hence, I reviewed a few games available in the market to teach light and other such concepts.

Games reviewed: God of Light, Physics Kombat, Transmission, Lazors, Glass, Block Craft 3D etc.

Fig. 24: God of Light - a path building game that includes components inspired from and based on mirrors, lenses, prisms, colour filters etc.

PROS: Colours, music and levels are used to happily engage the player. Games like Transmission also indicate well linkages and progression between multiple concepts.

CONS: Often twist properties of components to fit game objectives. Many games can played using hit & trial, without ever understanding the concepts at work, and hence not be able to apply these concepts in alternate scenarios.

5.4. Screen-based interactive products

Smart phone interactive applications

Examples: (Pocket Optics, 2016), (Ray Optics, 2017), (Light Wave Studio, 2015)

Most of these applications depicted use of abstracted visual representations that helped student's clarify their understanding by manipulating the given controls. However, no instruction is provided, which renders these applications useless for learners with no prior knowledge of the subject.

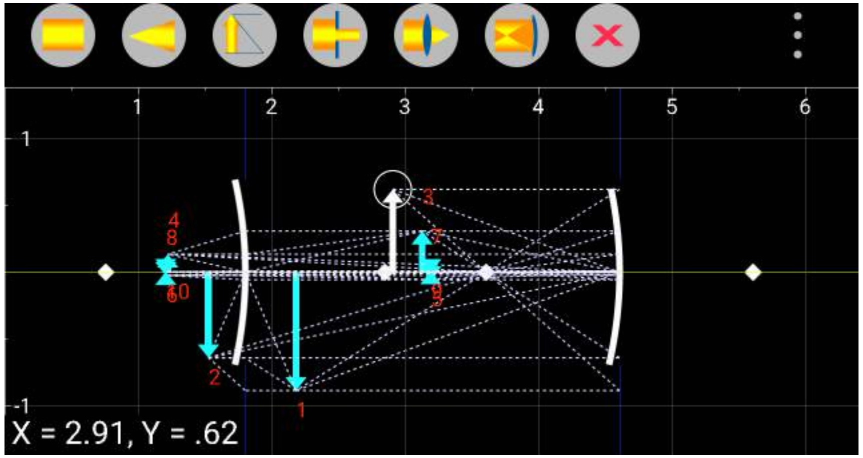


Fig. 25: Sample optical bench in Pocket Optics

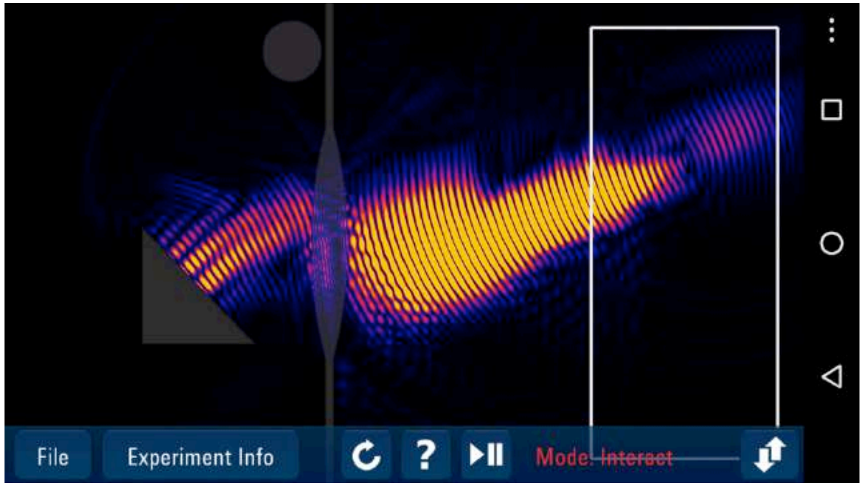


Fig. 26: Sample experiment from Light Wave Studio

Web based interactive explanations and manipulables

So far, I had not found an existing application that covered appropriate content, included basic instruction and allowed learning via manipulating components.

The search for such a tool or collection of tools led to the products listed in Table 5. I analyzed them for (a) content delivery methods, and (b) modes of manipulability & the role they play.

Table 5: Some of the key interactive learning aids analyzed

Product Name	**Description**
(Physics classroom)	Topic level interactive activity zones
Cambridge: (The Alien Attack) + (The Real Deal)	Game + Teaching module
(Freezeray)	Topic based simple interactives
(Shadow Animals)	Interactive: Making animal shadows by blocking light
(Bending Light)	Interactive tool to play with instruments, lights and medium
(Physics-Chemistry Interactive): (Focus) + (Moon Phases)	Explaining the concept of focusing using Camera

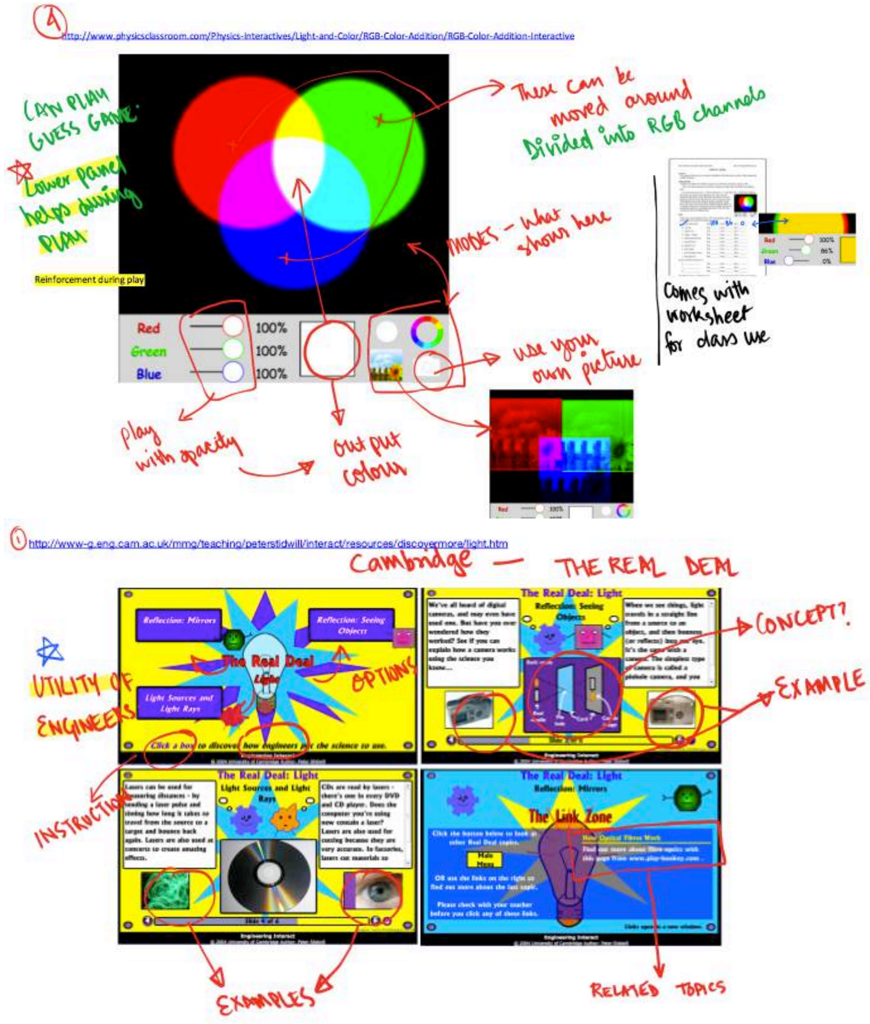


Fig. 27: Example of reviews done for web based interactive aids

Fig. 28: Topical interactive experiments at freezray.com

5.5. Design implications

Let students play with the tool and develop intuition by practice. This also helps them with their school curriculum. Do this by –

1. Adding manipulability – it helps engage and aids deeper learning
2. Allowing multiple combinations and providing feedback on whether the right choice was made or not (Constructivist + direct instruction)
3. Include tasks for reinforcing concepts during play
   Warning: Be vary of the concept being reinforced.
4. Giving insights into applicability
   "Where do you use this concept?"
5. Award!
   A simple 'YOU WIN!', 'EXCELLENT', 'WOO HOO' go a long way in keeping the student motivated.

Chapter 6: Design Brief & Goals

The main goal for this tool is to enable guided-discovery. Hence, the brief constitutes of (a) guidance goals, and (b) ease of discovery.

Guidance Goals

The application must provide adequate instruction (the learning goals will be specific to the content) and prevent misconceptions.

Ease of Discovery

The application must be easy to use and engaging. Sections of the application must be easily identifiable and navigable by novice users.

It must allow for manipulation of various input parameters that lead to instant and clear output as feedback.

Since, it is an auxiliary tool, a major function of the tool is to act as a reference. The student must find it comfortable to return to the application in case of doubts as many times as required. Hence, no form of evaluation can be a dead end, and must lead on to further learning and relearning opportunities.

Overall, A student must be able to personally relate to the content and find the learning valuable. The student must be able to apply the learning to a real world use-case and propose multiple solutions (if possible).

Chapter 7: Ideation

7.1. Light Around You – Involving the Analog World

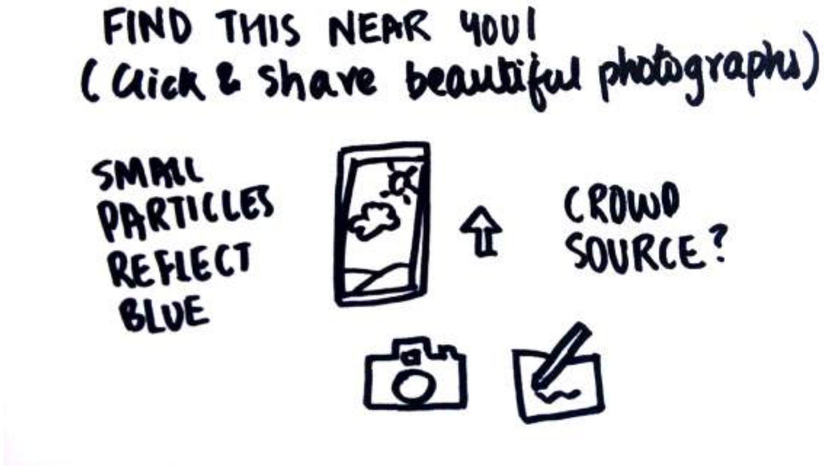
Idea 1: AR animated explanations

Student points the camera at a scene (or clicks a picture). An image processing software analyses this picture, and overlays with ray diagrams to explain the phenomenon at play in the image.

PROS: Direct relation to surroundings + Instructive

CONS: Limited by technical capabilities – picture quality, image IDing and appropriate content database creation

Idea 2: Find & Share



After explaining a topic, the student is asked to look around for examples. He/she must then click pictures of the same and shares on the platform and/or with friends.

PROS: Instructive, relevant and has social involvement

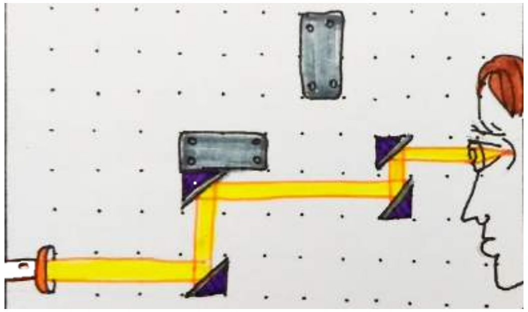
CONS: useful for teaching observable phenomenon, but not the underlying abstract concepts.

7.2. Task Based Games

Idea 3: Being Light: Character based gameplay

Here, the student is light. After introducing the properties of light, 'light' has to fulfill certain tasks. Strategizing using your own powers (properties of light), would clarify concepts and improve learning.

Idea 4: Path Making



Here, students need to manipulate positions, sizes and orientations of mirrors, lenses, etc. to reach a goal or to complete a task. For example: In the image above, the task is to make light reach the eye.

PROS: Scope for covering a range on optical instruments & materials, and the associated light's behaviour

CONS: Low instructive value, can be played by hit & trial

Idea 5: Drawing ray diagrams

This idea placed a special focus on drawing correct rays diagrams. It's an interactive tool wherein the light source is marked and the rest of the scene is drawn. The student needs to draw a fixed number of rays to explain the phenomenon shown in the image. He/she is rated according to the correctness of the ray diagrams.

CONS: Very specific use case and needs to be adapted to include local relevance

This can however, still be incorporated in other interactives or follow up questionnaires wherever ray diagrams are being used.

7.3. Constructive Games

To allow customization and localization, and have more flexibility

Idea 5: Build and Share

Using an available toolkit and assets, the student can create custom optical instruments, which can be used as camera filters. This can be annotated and shared peer-to-peer, who can further develop on these creations.

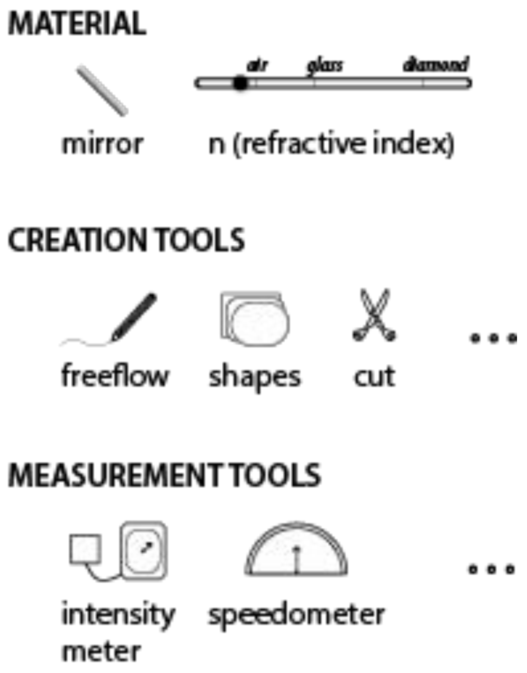


Fig. 29: Sample toolkit

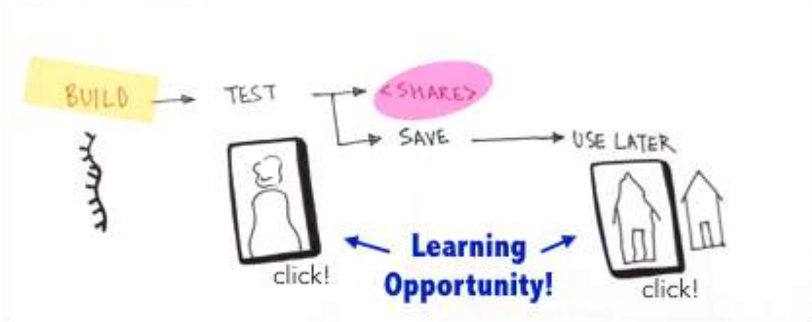


Fig. 30: The user flow

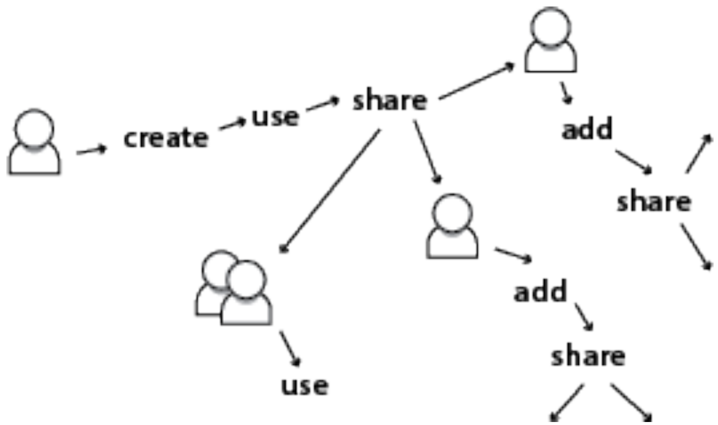


Fig. 31: Share-edit-share flow

PROS: High creative engagement and scope for social involvement

CONS: No clear learning objective and low in guidance/ instructive value

Merging task-based games (for instructional value) with the constructive game, I developed the 1st concept, a 3D sandbox type game called,

7.4. LUMOS

Its gameplay is a three-dimensional sandbox game i.e. it has minimal character limitations, allowing students to roam and change the virtual world at will.

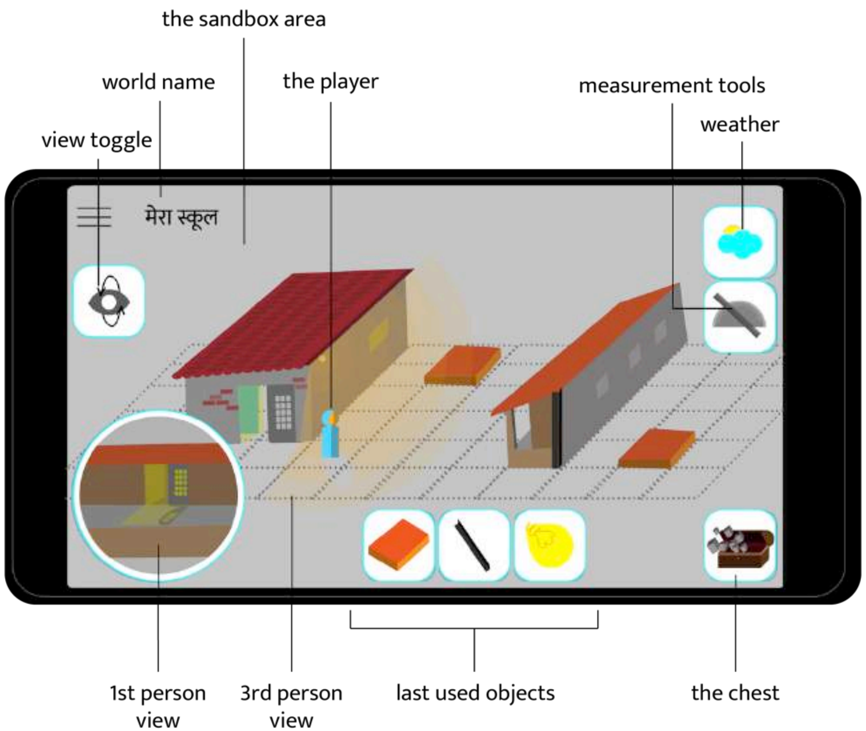
The worlds mimic real world rules of light.
The in-game time system follows a day and night cycle, and other weather conditions can be set at will.

The game world is composed of 3D objects – inspired from real objects from the student's context – that can be placed anywhere in the three-dimensional space, and can be edited to change physical and spatial properties.

Includes structured sub-games – such as mini-games, tasks, submissions and storylines – that may be ignored by gamers, but unlock certain locked objects in the game. (For example: Idea 4 & 5 mentioned earlier).

Tasks and side missions are based on a concept to be taught and largely follow a progression, where a more advanced task is made available only upon successful completion of a relatively easier task.

This game takes a platform-based approach on which other subjects of science can also be taught.



Game Screen Components

1. The Sandbox Area
2. The Player
3. The Chest (Sandook: The asset store)
4. Last used objects
5. 1st and 3rd person views
6. Header: World Description
7. Weather control
8. Measurements tools

Instructive Tasks

Similar to ideas 4 & 5, the purpose is to instruct via play.

Students need to complete tasks in order to unlock new assets in the asset store. These tasks would involve the using this new asset, thus explaining it's properties and/or the working of a phenomenon.

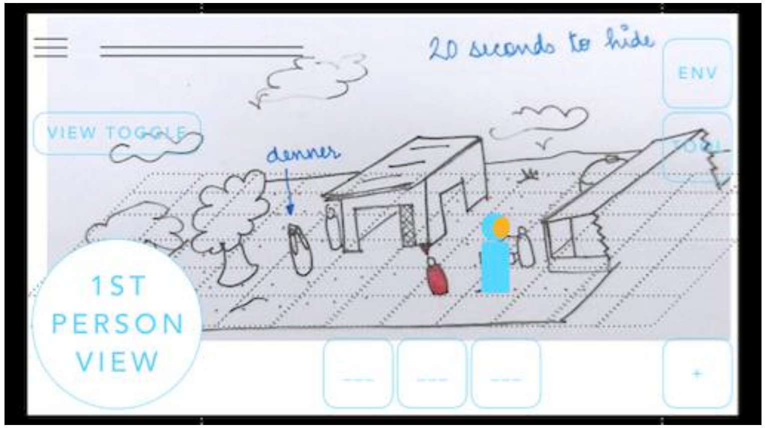


Fig. 32: Task designed using 'Hide & Seek' to teach material opacities and that 'light travels in a straight line'

Examples of possible tasks to teach a particular topic –

- Hide & Seek to teach light travels in a straight line,
- Coloured light filter's effect on plant growth,
- Seeing objects at angles using mirrors,
- The human eye & its defects – manipulate lenses to get the correct live view,
- Total internal reflection using Mirage & Floating ships,
- Speed of light in media using a racing game, etc.

Navigation in 3D space

Ideally one would need 9 degrees of freedom (9 dof) – 3 character positioning + 3 character orientating + 3 world space orienting; however controlling all 9 would be very confusing. Hence, this was limited to 6dof by

- fixing character position relative to main camera. This reduces character to 4 dof – 2 (x,y) positional and 2 (x,y) rotational
- removing direct control for z-axis rotation. This can be achieved intutively by x-axis and y-axis rotation combinations

Lay outing & Interaction

Fig. 33: Ink tracing done to determine accessible regions on different screen sizes & orientations

Social & Multiplayer

People (students & teachers) can create worlds and teachers/moderators can create tasks that can be visited and rated by others. While promoting freedom of creation and ownership, this allows for creation of locally relevant scenarios and multiple examples for the same concept.

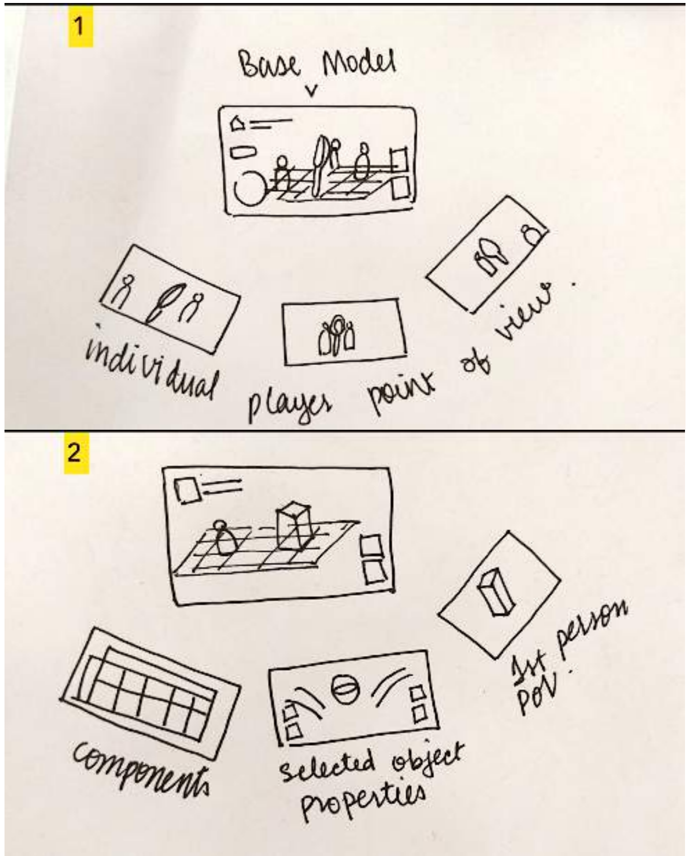


Fig. 34: Using the better together framework for (1) multiplayer games, and (2) multiple simultaneous views

CONS: On further development of concept, it was realized that the concept has high chances of having very low instructive value. Plus it is too complex to develop and test and hence slipped beyond the scope of this project.

Chapter 8: The Final Product – Science World

A self-help use-after-school collection of concept-wise interactives that would

- Make visible links between multiple concepts
- Use applications of a concept to understand the concept
- Be experiential; engages students with the components and helps them make connections with real life
- Be easy to use and re-use, and
- Act as a reference material

Target user: 7^{th} - 10th standard Hindi medium rural students

8.1. The Design

Major components –

i. THE MENU
A listicle of all individual learning interactives

ii. THE INTERACTIVE
A guided-discovery interactive that fulfills all the objectives listed in chapter 6 – the design brief. This would cover content for a particular topic.

Designing the Menu

This is where all individual learning interactives will be listed. Apart from listing, the main function of this page is to make visible the linkages between the various concepts.

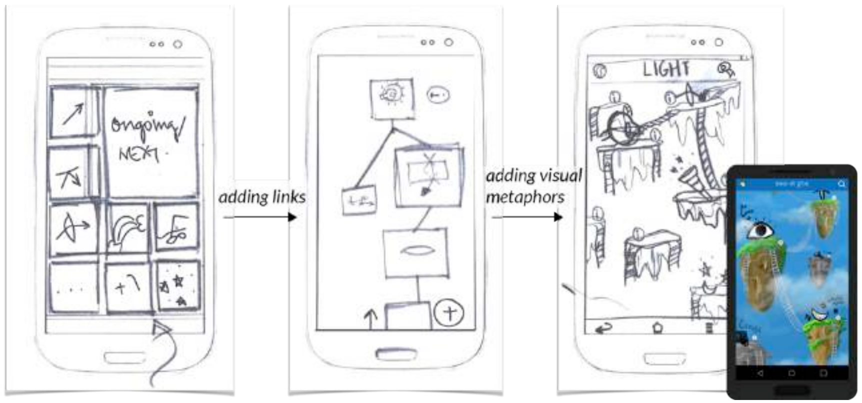


Fig. 35: Development of the Menu of Interactives: The Floating Islands

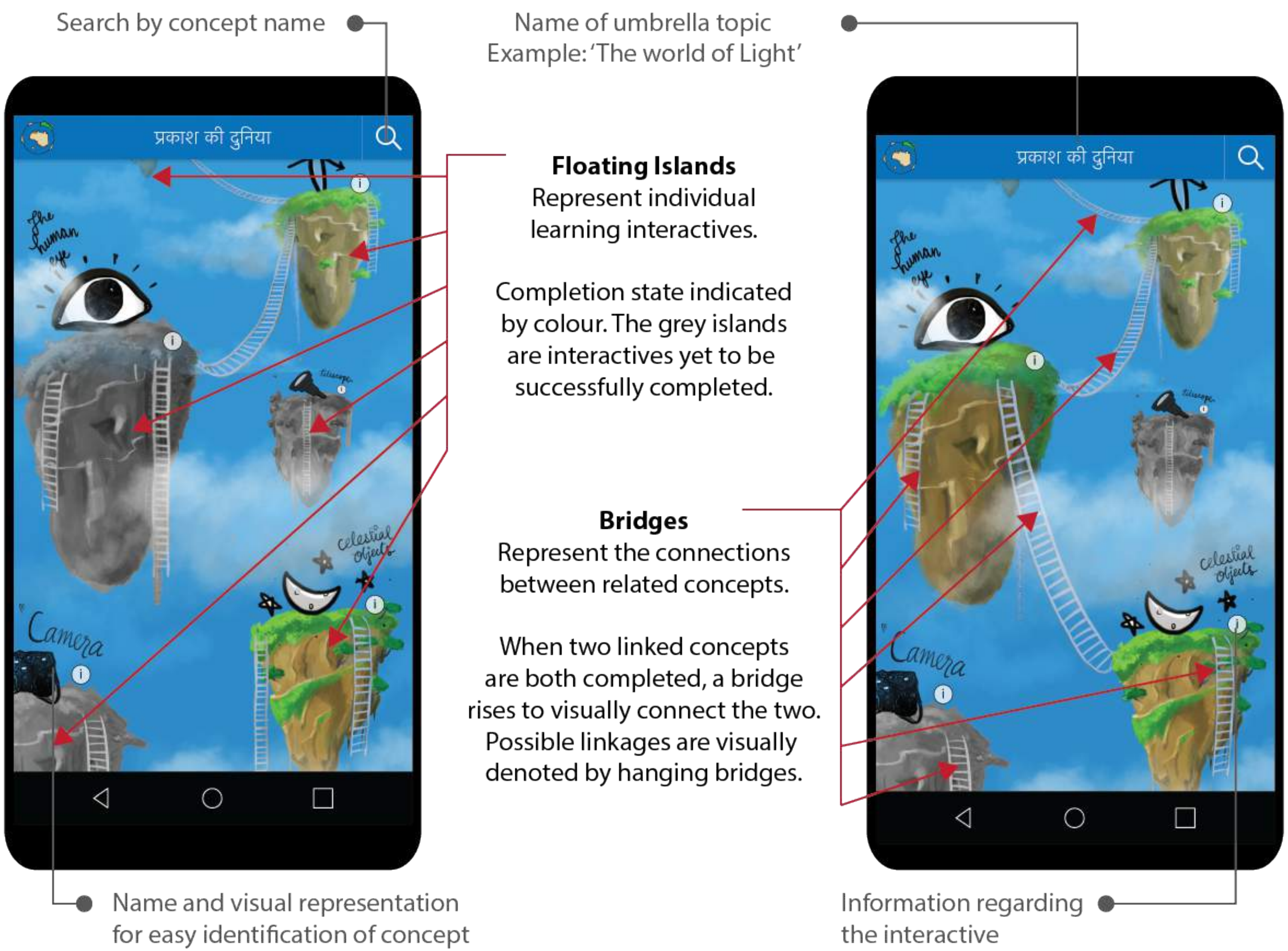


Fig. 36: Details of the Menu of Interactives

The User Flow

On beginning the application, a student would land on globe depicting the Science World. Swiping right and left to rotate, and tap to select an umbrella topic such as Light are available navigation options here.

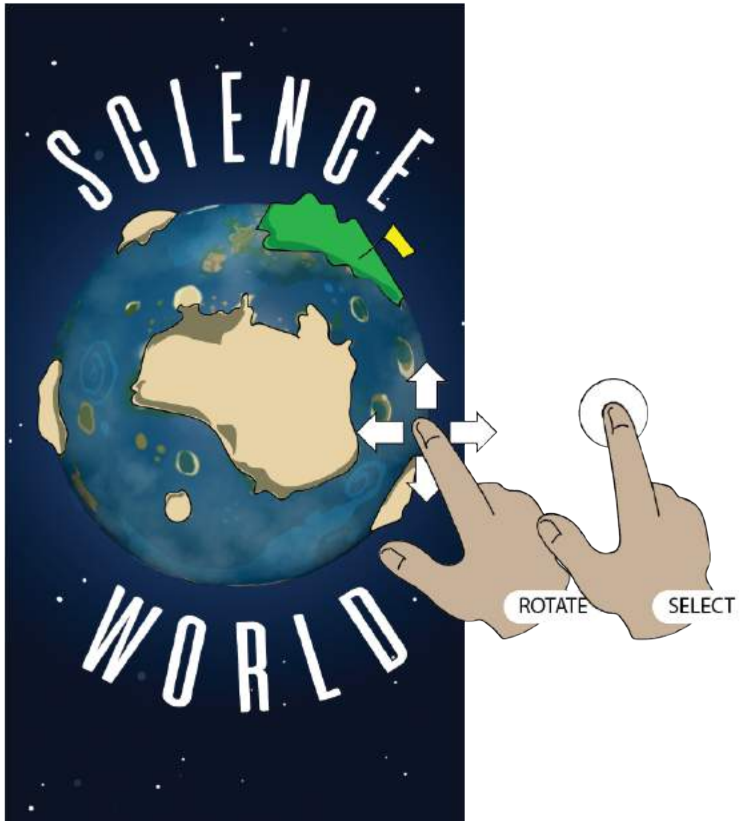


Fig. 37: Landing page: Science World

This would lead to the menu of interactives on all concepts under this umbrella topic (refer Fig. 36 above). Here, the student can pan to navigate (or use textual search) to next interactive, and tap to launch. The most appropriate concept to be learnt at any moment would by default be set as the largest island (most clickable).

Launching an interactive gets the student to an entry gate (Fig. 38), where in the student is given the option to claim full knowledge of the concept. In case the student does in-fact know the concept before hand, this saves him/her time and boosts their confidence. It also prevents them getting bored and leaving the application.

Claiming full knowledge of a concept launches a quiz with applicative questions (Fig. 39). Successful completion awards the student with praise, and suggestions are made regarding the best concept to move to next. In case the student is unable to clear the quiz, instant feedback is given regarding the students strong and weak points, and the student is asked to go through the Learning Interactive.

Each learning-interactive can have a separate flow as appropriate for the concept. A prototype was built (as discussed later) on 'Lenses in the Human Eye' to demonstrate a sample interactive. Completion of every interactive leads to the applicative quiz for final reinforcement of concepts and evaluation against learning objectives.

Successful completion of the quiz would lead to its island becoming active, and the associated bridges linking up.

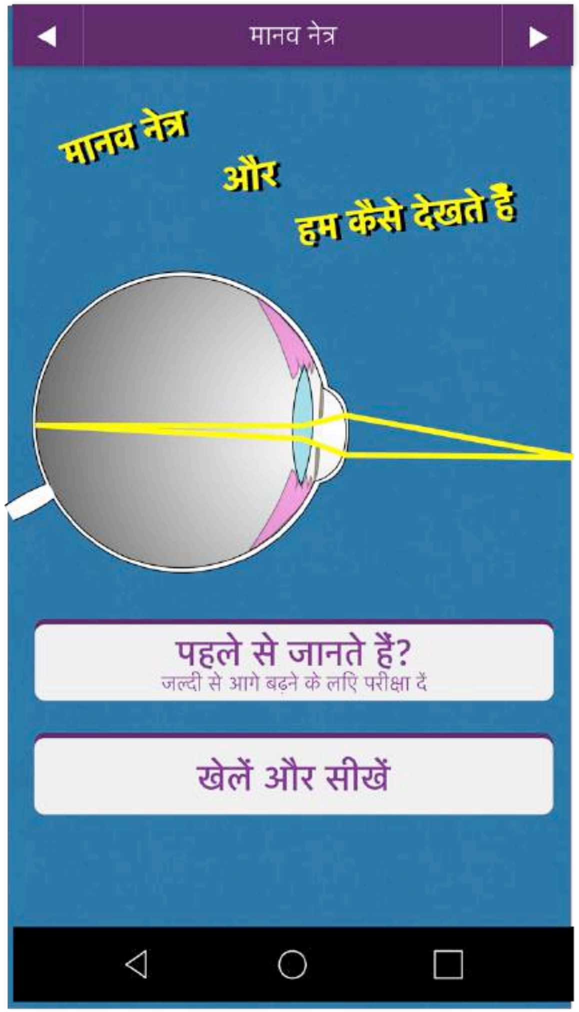


Fig. 38: Entry gate to the Learning Interactive

Fig. 39: Sample Applicative Quiz for Lenses in the Human Eye

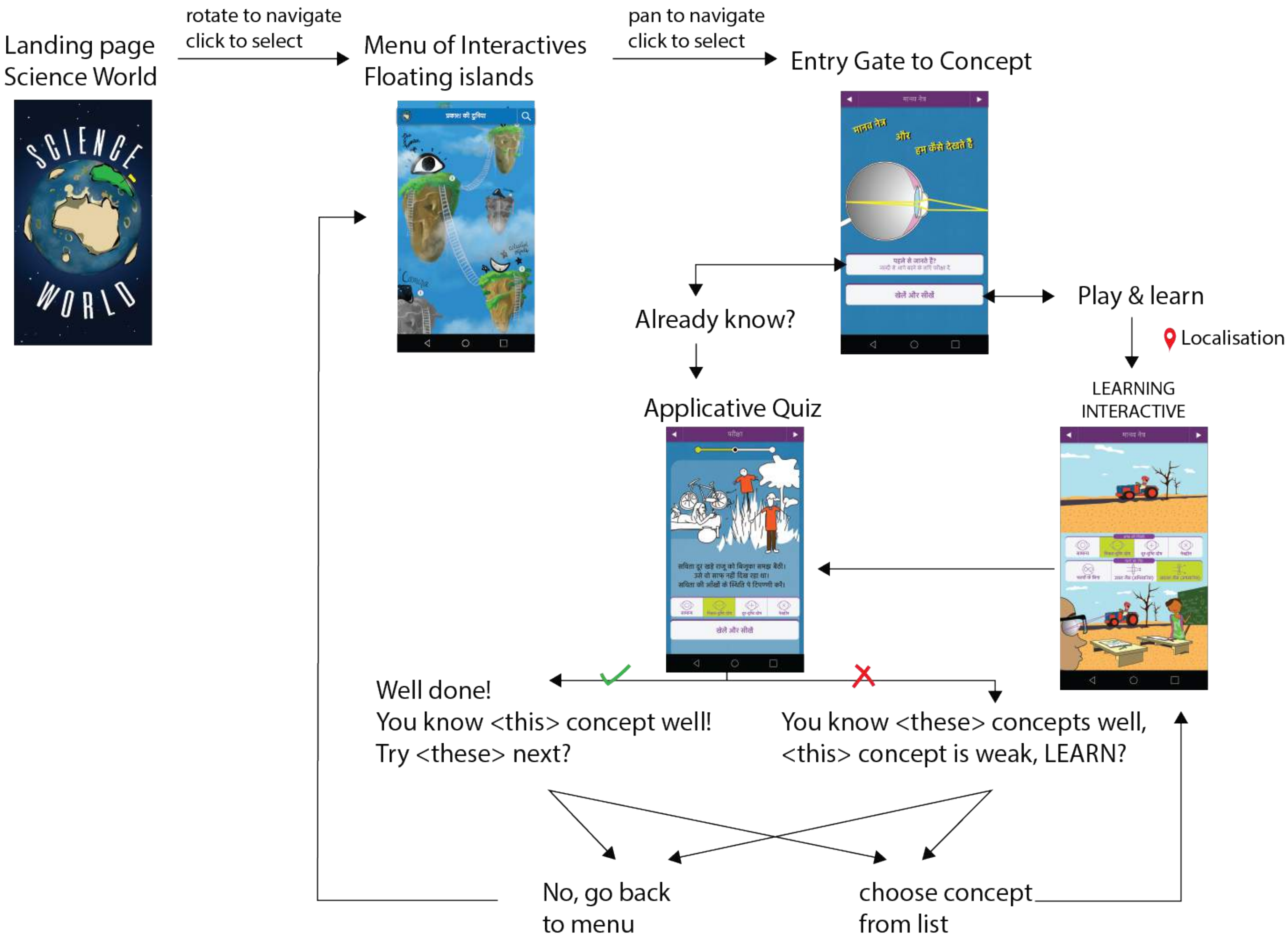


Fig. 40: The Overall User Flow

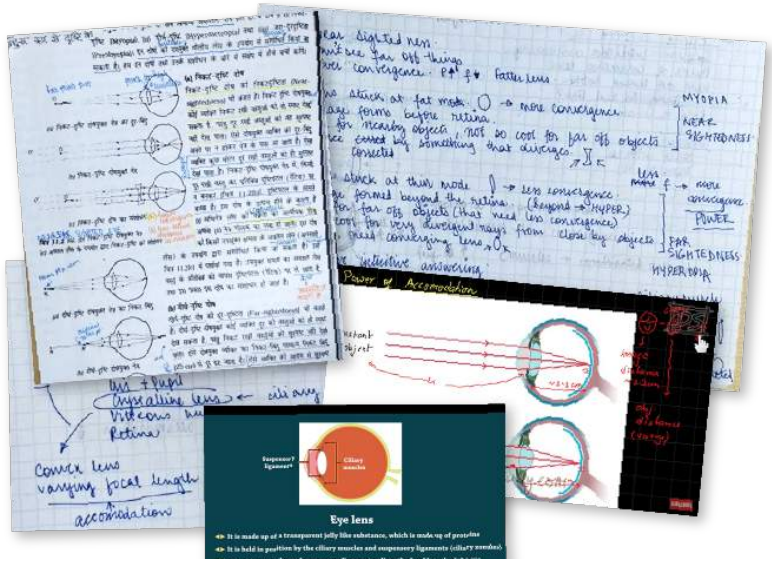
8.2. *Prototyping the Interactive*

Preliminary options were developed for multiple topics such as – colours, curved mirrors, spectacles and the human eye, light travels in a straight line etc.

Eventually, I decided to make the interactive to teach – **lenses in the human eye** – which a high level topic, and has applicative value.

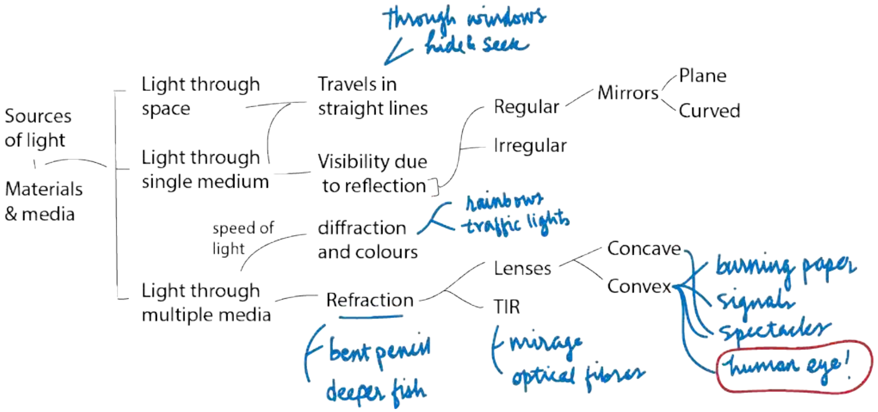
Collecting, assessing, simplifying content

Content was collected from multiple sources and chunked as described earlier in Chapter 4:
Working with Content.

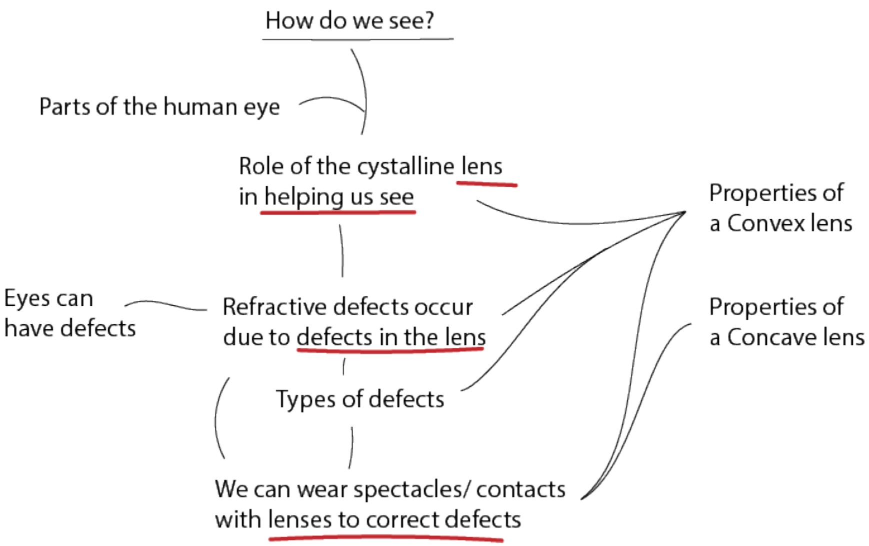


Linking concepts and assessing it's role in the application

I starting with 'Light',



Followed by the lens's role in the Human Eye,



Setting learning objectives

- Know that the human eye has a convex lens
- Understand when you see clearly and when not, and why
- Understand the role of the lens in helping us see – focusing and accommodation
- Understand why refractive defects occur
- Know that you can use lenses to correct some of these defects
- Recognize these defects in low vision scenarios
- Determine which lens can correct the identified defect
- Reflect on why it is important to take care of your eyes & how you can do so

Identify teaching methods

As described earlier in Chapter 4:
Working with Content, appropriate teaching methods were decided for different content-types according the level of learning objective.

Identify relevant applications

Here we answer the key question: "What did I learn and why?"

- You can see objects far and close
- If you have trouble focusing, then an optician can correct it!
- If you need spectacles, you can't see all things clearly without it.
- When adults in your house have trouble reading the paper, you can surprise them with telling them why, and helping them get appropriate spectacles.
- Not all defects are refractive, but most defects can be treated with replacement operations. You can pledge to donate your eyes!

Linking application and content.

Using known applications to explain the content – This was integrated in the design of the prototype which is a tool that allows student's to experience how their vision would be and how they would see things near & far according to the defect in their eyes and which corrective lens they are wearing.

Using the newly learnt content to expand knowledge base by introducing new applications – this was done by introducing applicative questions at the end of the interactive. This is also covered by later adding interactives for unfamiliar topics under the same concept.

Step 9. Building, testing and iterating

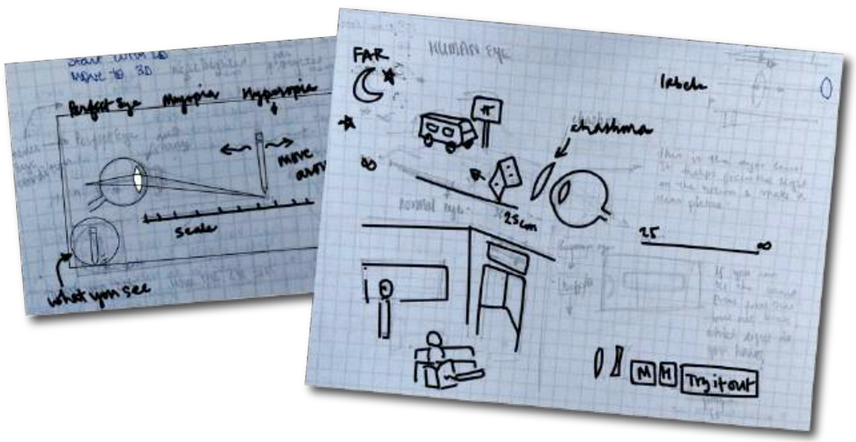


Fig. 41: Early layouting and scenario design

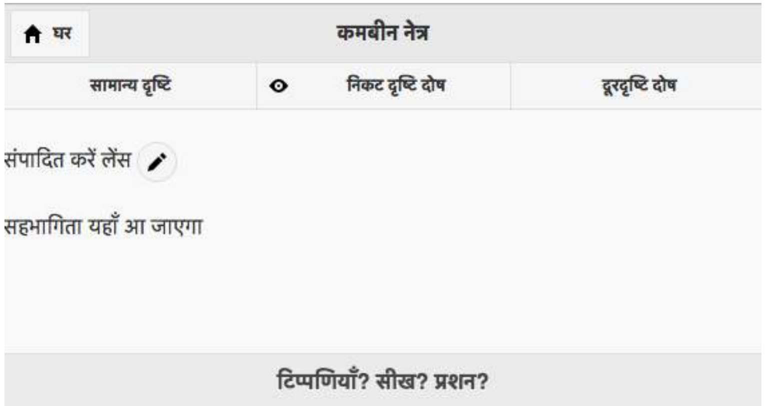


Fig. 42: Early prototyping for web-based tool

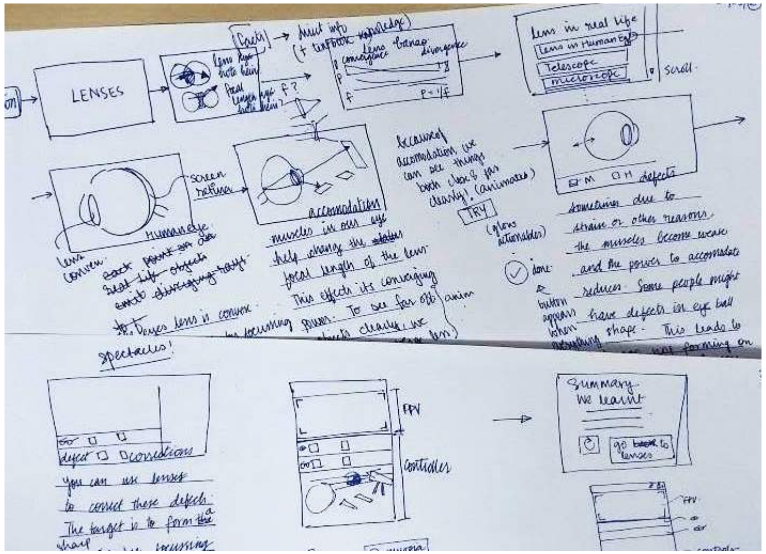


Fig. 43: Information flow and instruction scripting

8.3. Prototype Used for the Formative Evaluation

- Audio instructions for factual learning
- Scenarios and elements from relevant settings
- Interactive digital maniplables for self learning

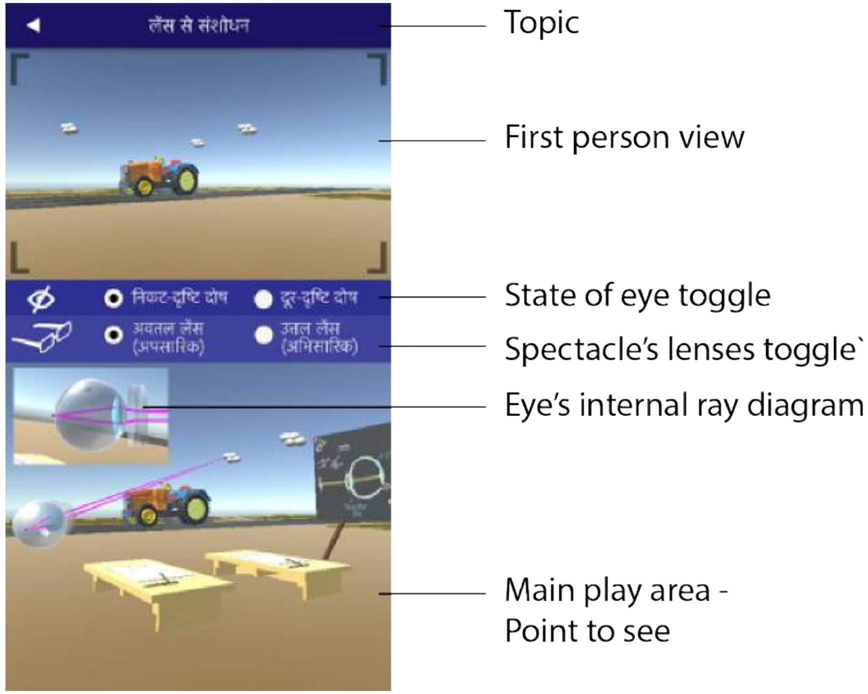


Fig. 44: Prototype for evaluation: Sections of the main screen & its functions

Interactive Prototype's Flow & Audio Script

SCREENS + SCRIPT STUCK HERE

(Included separately in DVD in case of soft copy)

Chapter 9: Evaluation

Aligned to the design brief (chapter 6), the evaluation tested for:

- Ensuring adequate instructional value
- Ease of use and navigation
- Identifiable sections
- Engaging, and comfortable to come back to for referencing

9.1. Evaluation Method

Formative user testing was done via think-aloud testing with 6 students at Sangriya (S1, S2, S3, S4) and Mori Joshiyan (M1, M2) villages in Rajasthan. Sangriya village is much more closer to the district headquarters Jodhpur (12kms) than Mori Joshiyan (38kms).

All students other than M1 had used a smartphone previously. Hence, their response could demonstrate well the behaviour of rural students with basic access to smartphones. The students all had just completed 10th standard. They had covered/revised the content under 'Human Eye' about a month earlier.

Before the Think-Aloud

The student's name, age, medium of education, parent's education levels were recorded. I followed by asking if they use/need spectacles. The students were then informed that they'd be helping me test a learning application.

I followed by demonstrating a think-aloud test with the Whatsapp application, to explain what they need to do. To ease anxiety, they were clearly told that it is the test of the application, and not a test for them. Hence, they must relax and speak out everything they think of.

During the Think-Aloud

While the student thought-out-loud, I jotted down user statements and observations regarding common errors, student involvement, section identification, navigation etc.

After the Think-Aloud

I orally simulated the Responsive Quiz section. The students were given a scenario and asked what they would do to resolve the issues.

Me: You are in a class sitting on the first bench, you can see the leaves on the tree outside clearly, but find it difficult to read the text on the board. What will you do?

The student can now give a response. It was noted if the student referred to the application in case of doubts.

Me: What if you lost your spectacles. What would you do then?

It was noted if the students could apply the concepts learnt to find an alternate solution to the obvious use of a spectacle. One correct answer here is (the otherwise non-intuitive) shifting to a seat further away from the board.

9.2. Issues Identified and Design Response

The issues identified were sorted by severity and categorized into Learning, Content, Presentation and Interactivity related issues (Table 7). Design ideas were generated to overcome most of the identified problem areas (Table 7). Some of the design ideas for high and medium severity issues were implemented in the follow-up design iteration (refer Fig. 45 and Fig. 47).

I have also summarized the identified issues and their respective remedial design ideas using the Extended User Experience Model (Joshi & Medh, 2006) for e-learning products (refer Appendix II). The structure helps understand issues in each category against its place in the Garrett's model of user experience.

Learning Related Issues

In the prototype evaluated, the audio instructions (as per the script on page 52) play over the related interactive screens. Since this audio is the only component that delivers direct information and is not supported by an additional information delivery mechanism (such as text or visuals) mishearing and misinterpretation are likely. All learning beyond the audio instructions was designed to be purely experiential via explorations. Hence, to provide additional guidance I added animated visuals to these audio clips. The related interactive screen would come after this animated audio-visual.

For example, an introductory video "Manav Netra" was made for introducing the role and the overall functioning of the human eye (refer Fig. 45). This would play before the "Manav Netra" interactive screen. The student can return to this video as and when required.

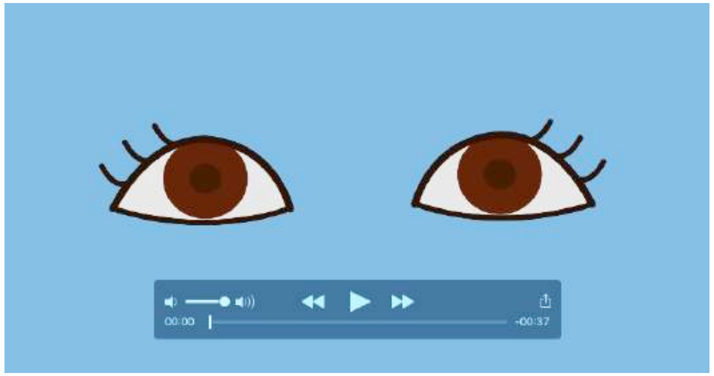


Fig. 45: Inserted instructive audio-visuals before the interactive screens (https://youtu.be/xYaZgTKvKZE)

Additionally, it was discovered that a process to bookmark content, and to ask doubts is needed. Since these are scope level issues, they have been set aside for future re-designs.

Content Related Issues

While the students explored the application, I observed simulation errors for specific use-cases (such as those mentioned in Table 6). These errors can largely be resolved by code tweaking.

The first example is illustrative of how exploratory learning can broaden our learning and understanding. In this specific case, the student was exploring '*nikat-drishti dosh'* or 'Myopia'. This visual defect is often memorized as "the defect where the image forms in front of the retina". The simulation depicted it as shown in Fig. 46. In Fig. 46 (a), the eye is looking at a blackboard far away. The image forms in front of the retina (as expected) and this cause the view (as shown in the 1st person view) to be blurred. However, while looking at a notebook close-by, the image is sharp and should have formed on the retina. This is wrongly depicted in the ray diagram in Fig. 46 (b), which could lead to misconceptions.

Table 6: Content related simulation errors

Findings	**Design Ideas**
Light doesn't focus on retina in defected eye even when they are looking at a focused location	Edit code & highlight in audio-visual
The light rays should go through the pupil, and not over the iris	Correct via code
The horizon doesn't remain horizontal	Coding issue (fix rotX to 0)

(a) (b)

Fig. 46: Snapshot of prototype while student explored 'Myopia' –
(a) While looking at far away objects, and (b) while looking at close by objects

During testing, two additional topics were identified that would make this learning more relevant – 'Why do we have two eyes?' and 'Keeping your eyes healthy'. Content for these topics need to be created and hence, this has been set aside for future re-designs.

Presentation Related Issues

Humanizing

The prototype application lacked humans. They were missing in the scene and the first person's eyeball lacked a housing face because of which it floated in mid-air. Adding humans (refer Fig. 47) makes the scenes real, which helps students relate easily with the scenario (not however, that this is may add to distractions, and needs to be tested with). Adding a face to the 1st person also helps in identifying the eyeball.

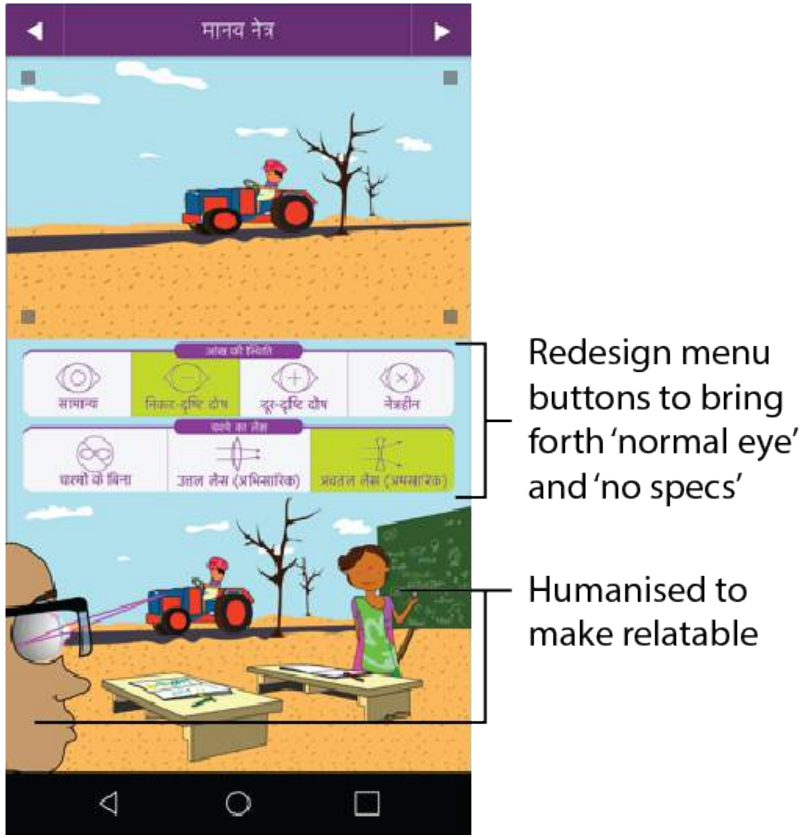


Fig. 47: New design indicating applied design ideas

Visibility & Highlighting

Since students are expected to construct knowledge for themselves by using the interactive screens to explore a concept, all interactive components of the screen were explicitly marked out using contrasting outlines and a hand indicator to show “click here” (as shown in Fig. 48). In-spite of these markers, the students did not easily identify that these were interactive elements. However, they did observe motion in the first person view quickly and it turned out to be a clear indicator of interactivity. Hence, I suggest use of micro-animations for showing possible gestures and interactions. For example: a tapping hand rather than the icon for the tap gesture.

Fig. 48: Prototype screens with markers for interactive components

Narration

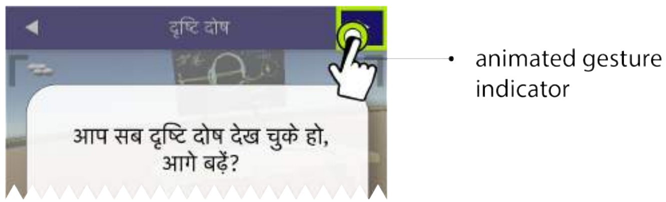
The narrator’s tone may also be thought of as too formal at times, and will need re-scripting with research on local word usage, or by using the local language.

Interactivity Related Issues

Navigation

4/6 students did not intuitively understand how to go to the next page. The correct way of doing so was by clicking the arrow on the right side top corner (refer Fig. 48). They could, also, often not estimate when they have completed all the functions/ tasks of one section and would ask for approval to move to the next section. Intuitively they would either tap on the right bottom corner, or swipe right. Since, the swipe motion would interfere with the drag interactions of the core interactive, we cannot use the swipe gesture for inter-section navigation.

Hence, I propose to introduce an end of section notification. Here, the move back/next button gets highlighted when all combinations of the settings have been tried or when a student aggressively swipes right/left (sample shown below). This would also function as a training aid to the navigational functions of the application.



Audio Instructions

While the audio plays, students stop all activity to listen. Hence, when the interactive page is first displayed, students do not try to touch and manipulate the screen components. Also, when testing in context, a need to be able to control the playback (change speed, move back and forth, play and pause) became evident. These issues are overcome by introducing the separate audio-visual instructions with media controls, as discussed under learning related issues.

Also, in noisy areas and to keep hands free for exploration, a suggestion to plug in earphones would be made at the beginning.

Manipulate-able Parameters

The menu options in the prototype (as shown in Fig. 48) has these options:

Eye defect:
- ○ Myopia
- ○ Hyperopia

Lens in spectacles:
- ○ Concave
- ○ Convex

By design, keeping both options inactive under either title was supposed to indicate absence of either any defect, or the spectacles. However, this was not understood. Hence, the options of the “Normal Eye”, and “No Spectacles” were introduced in the menu re-design (refer Fig. 47).

Table 7: Issues categorized and severity identified. Design ideas generated to solve for each issue.

A3 TABLE STUCK HERE

(Included separately in DVD in case of soft copy)

S – Sangriya village; M – Mori Joshiyan village

Chapter 10: Results

Of the 6 students interviewed, 1 student (M2) already understood the content well, and confidently answered most questions. Of the other 5, 4 students comfortably used the application as reference to confirm/ change their answers to the applicative questions asked after the think-aloud tests.

Value added through relevance

Multiple students mentioned how they had never thought of the chapter as something they could use in real life. Many had not fully comprehended that the corrective lenses being spoken about in the textbooks referred to spectacles.

Students interacted with the content in a very personal way. It was interesting how they pointed out the absence of humans. A student, who was blind in one eye, discussed how the first person PoV section in the application would be different for him. Another student, who didn't wear spectacles in-spite of having an eye defect, exclaimed that she would go get herself some spectacles! She hadn't realized that not wearing spectacles would make her eyes worse. These reactions indicate internalization and self-reflection – an integral part of experiential learning.

Compared to textbooks

After using the application and the applicative quiz, I asked the students what they like about the product, and how does it fare when compared to their textbooks.

The textbooks provide clear definitions. Due to small screen real estate, the images on the screen were smaller, and needed zooming. In textbooks, all the content is available in one place – text besides an optically zoom-able image, and cross-referencing – flipping through pages, is easier.

The mobile application is more engaging. Animations, micro-interactions, colours etc. captures attention for much longer. The dynamicity helped them learn by instantly checking their understanding against the visualizations, and preventing misconceptions.

The interactive tool, hence, helped them view the topic as more than just theory. It delivers the theory to the student nevertheless, by integrating it with relatable applications and practice.

Scope for future work

The design ideas identified must be implemented in a working prototype, and tested with a large sample of students against a control group.

Multiple scenarios must be developed to able to test effectiveness of content relevance. It must also be analyzed if making content fun and interactive hampers learning goals by acting as an agent of distraction.

Creating interactive content using the application-first approach for other topics, would allow testing of replicability and validity of this approach.

Caution

Mobile phones are also a means of distraction (especially due to social media applications) and are therefore considered as a negative influence on student studies. Mobile education evangelists should be cognizant of the same.

Appendix I – Content Analysis – 'Lenses in the Human Eye'

Digital version available here – https://docs.google.com/spreadsheets/d/1Yml3pZlRHka1gkfoAJXp1p9A7QaquDx5dOFwPkHyC5w

Source 1: Rajasthan Board Std. X Science Textbook

Content	**Data-Type**	**Alt Data-Type**	**Teaching Method**	**Notes**
Human eye uses light to allow us to see surrounding objects				
Human eye has a lens	Fact		Reflection using questions	
Human eye is an important sensory organ	Fact		Mentioned as a fact	
It is impossible to recognise colours without using eyes	Meta-Cognitive		Showcase utility/ importance	
Human eye is like a camera - Parts of the human eye (nomenclature, description)	Fact		Labelled image + written description	
The eyeball has ~2.3cm diameter	Fact		Mentioned as a fact	
Lens forms an image on a light sensitive screen - retina; Light enters through the cornea, most refraction happens here; Crystalline lens makes small adjustments to focus light from objects at varied distances; Pupil controls the amount of light that enters the eye;	Process	Fact	Detailed step-by-step textual description of process; includes introduction of nomenclature of parts, their descrition and function	

The lens makes an inverted image of an object on the retina; Light-sensitive cells activate and generate electric signals; Optical nerves take these to the brain; The brain processes these signals to identify the object as is.				
Crystalline lens makes small adjustments to focus light from objects at varied distances	Concept		Mentioned as a fact	
Iris controls size of pupil to control amount of light entering eye, dependant on light intensity	Process		Referring to the student's experience; Textual description of functioning	
Crystalline lens is made of a jelly-like susbstance	Fact		Mentioned as a fact	
Ciliary muscles can (to some extent) change the curvature of the lens	Fact	Concept	Concept mentioned as fact	
Changing curvature of the lens changes its focal distance	Principle		Mentioned as a fact	
Depending on distance of object, the ciliary muscles expand/contract to make the lens thin/fat in turn increasing/decreasing its focal distance (How your eye accomodates)	Process	Concept	Concept taught as a process; Showcasing relationships	
Defining accomodation	Concept		Introduced concept as a fact, followed by description as a process and later summarised into a definition and nomenclature	
Near point (definition) at 25cm, can't see clearly at very nearby distances; Same for far point	Fact		Explained through example activity (bring page close to eye)	
A normal eye can see clearly from 25cm to infinity	Fact		Summarising to applicable useful information	
Cataract - definition, causes and correction method	Fact		Mentioned as a fact	

Why do we have two eyes? Why are they both in the front and not on the sides of the face? viewing area, visibility, detection, stereoscopic view, depth of view	Fact applied		Facts mentioned with alternate examples (of animals and of one-eye view); Also explained through an example activity (close one eye...)	
The gap between two eyes cause a differential image to form. The brain processes this information to estimate depth of object.	Process	Fact	Texttual explaintion accompanied by an example activity (close one eye...)	
Eyes sometime lose their accomodation power, making sight non-distinct/ blurry. Reflective errors make sight blurry.	Fact		Causal example	
There are 3 common refractive errors of the eye - Myopia, Hyperopia, Presbiopia	Fact		Types & nomenclature introduced (also mentioned in english);	
These refractive errors can be corrected by using appropriate spherical lenses	Concept		Mentioned as a fact	
Near sightedness & Far sightedness - Definitions	Fact		Written definition, mentioned as fact	
Near sightedness & Far sightedness - Effect Movement of near & far points	Fact		Labelled image + written description; Explained with a practical example (such a person can't see things kept a few meters away..., such a person has to keep reading material farther away than 25cm to read clearly...); Why this happens is explained later	
Near sightedness & Far sightedness - Cause Eyeball shape & curvature of the lens	Fact	Concept applied	Mentioned as a fact	did not reiterate how curvature effects focus distance
Near sightedness & Far sightedness - Corrections Using concave/ convex lens to diverge/converge incident light onto the retina	Process	Fact	Labelled image + written description; Use of which lens mentioned as fact and corrective power described as a process	no explicit mention of the use of spectacles
Suitable power corrective lens brings back image on the retina	Process		Mentioned as a fact + slight inkling of a process (corrective lens focuses light on retina...);	no explaination of why and how in case

			Explained why the corrective lens focuses light on retina (...provides additional [converging?] power)	of near sightedness
Presbiopia - Definition, Cause (weak muscles & inflexible lens due to old age, lowered accomodation power), Effect (Farthened near-point)	Fact		Mentioned as a fact; Mentioned that this is common with old age, hence providing some utility or learning	incomplete definition
Person can have both near & far sightedness. Such a person needs bi-focal lens	Fact	Concept applied	Mentioned as a fact	
Bifocal lens - Upper part is concave to see far away things clearly, and Bottom part is convex to see nearby things clearly			Description of lens, its parts and positions, and their functionalities	no image used
New corrective methods - contact lenses and surgical interventions	Fact		Mentioned latest developments as interesting facts to know	

End of Chapter Questions	Type
What is accommodation power of the eye?	Define
A nearsighted person cannot see clearly beyond 1.2m, what type of corrective lens should he/she use?	Applicative question for fact based answer
Where does the near point and far point for a normal eye lie?	Factual question
A student sitting in the last bench has difficulty seeing the blackboard. What defect does he have? How can it be corrected?	Applicative (scenario based) question

Source 2: Khan Academy[5]

Content	**Data-Type**	**Alt Data-Type**	**Teaching Method**
Power of lens - comparative example with two lenses with different focal legth	Concept	Principle	Small focal length means powerful lens Hence Power = 1/f [1/m = Diopter]
Spherical Aberation	Concept		Lenses cant focus all rays to one point, they stray a little
Always talk about "thin lenses" only	Principle		thin lenses have less aberration
[reason for above] sin(theta)=theta	Principle	Fact	Just making people accept it as a general concept in physics
Different shape would be needed for low aberration (non-spherical)	Principle		Not elaborated, like what that shape would be
Chromatic Aberration - Issue with different colours of light	Meta-Cognitive		Just definition
Chromatic Aberration - Different colours have different refractive index (blue more, red less)	Fact		Just stated.
Parts of the eye - Cornea, Lens, Cilliary muscles, retina	Fact		Diagramatically shown
Function of the different parts	Fact	Process	The functionalities are explained, also explaining the image formation in the process
Formation of a sharp image on retina	Process	Fact	Real image, inverted, flip in brain. Fact stated that for image to be sharp, need to focus on retina
Far sightedness	Concept	Process	If ciliary muscles cannot make lens convex enough when object is closer. Then what happens

[5] www.khanacademy.org/video/diopters-aberration-and-the-human-eye
Part of the Geometric Optics lesson. This video lecture covers power of a lens, and properties of real lenses.

Correction lens to be added			Convex because it will create a virtual image of object farther away from real position helping eye ofucs it
Near Sightedness	Concept	Process	
Correction lens to be added			Concave since it will create a virtual image nearer to the eye
Near Sightedness - diverging lens, far - converging	Principle		Concluded as the takeaway

Source 3: Amrita Create[6]

Content	**Data-Type**	**Alt Data-Type**	**Teaching Method**	**Notes**
Lenses are optical devices that transmit and defract light	Fact		Diverging and converging lens images with rays (3D)	
Eyes also contain lenses, eyes help us see	Fact		Just stated, then followed by 3D breakup	
Parts of eyes, their function - Cornea, Iris, Pupil, Concave lens, cilliary muscles	Fact		3D view, plus cross section	
Transparent structure Cornea helps collect and focus light inside	Fact			
Iris contains small opening called Pupil, expands/contracts to change amount of light entering	Fact			
Lens - Colourless, transparent, crystalline	Fact	Process	animation with narration	

[6] www.youtube.com/watch?v=U_wTfpYK_ms
An animated video using 3D graphics which covers: parts of the human eye, how they function, common refractive defects & their corrections

Cilliary muscles - hold the lens in place, adjust focal length by changing curvature	Fact	Process	animation with narration	
For distant objects - muscles relax, lens thins, focal length increase	Process		animation with narration	
Nearby Objects - muscles contract, lens thickens, focal length decreases	Process		animation with narration	
Power of accomodation of eye - defined as the ablity to adjust focal length	Fact		stated	
Eye lens forms inverted real image	Principle		Since its just stated.	
Retina - light strikes retina and is converted to electical signals	Fact			
Signals go to brain, it converts them to images	Fact			
Near Point or Least Distance of Distinct Vision - Defn (normal eye - 25cm)	Principle		animation	
Far Point - Defn (from 25cm to infinity)	Principle			
Refractive defects- cause blurred vision, lack of accomodation	Principle		animation	
Four defects - Myopia, hypermetropia, astigmatism, presbyopia	Fact			
Hypermetropia - far sightedness, near objects are blurred	Fact		animation showing 1st Person PoV	
What happens? - image behind retina	Principle		image with ray diagram	
Reason - increase in lens focal length OR reduction in length of eyeball	Principle		animation showing change in curvature shifting the image formed	ERROR - animation shows lens thickening.
Correction - convex lens of suitable focal length	Principle		animation - indicates effect of power of lens as well by adjusting lens to get image on retina	
Myopia - near sightedness, far objects unclear	Fact		animation showing 1st Person PoV	

What happens? - image in front of retina	Principle	Fact	image with ray diagram	
Reason - increase in curvature of lens, or increased length of eyeball	Principle		animation showing change in curvature shifting the image formed	ERROR - animation shows thinning lens
Correction - concave lens	Principle		animation - indicates effect of power of lens as well by adjusting lens to get image on retina	
Presbyopia Defn - Old people, near objects blurred	Fact		animation shows man turning old	
What happens? - near point shifts farther	Principle	Fact	animation showing shifting of near point using line overlays over scenario's image	
Reason - weakening of cilliary muscles or decreased lens flexibility	Principle	Fact	animation showing ciliary muscles becoming weak (wrong location of muscles); Animation shows position of image formation (even though not accompanied by narration)	ERROR: wrong labelling for cilliary muscles
Correction - convex lens of suitable focal length	Principle		Animation (same as far-sightedness)	
Dual defect - both near and far objects unclear	Fact			
Correction - bifocal lens with upper part concave, lower part convex	Principle		Animation showing lens and effect of lens	ERROR : bifocal lens shown is wrong (4:00)
Astigmatism - image focused in horizontal plane, but not vertical	Fact			
Reason - irregular curvature of cornea or lens	Fact			NOTE : Calling astigmatism "facts" since hard to follow
Correction - "Glasses with cylindrical lens"?	Fact			
SUMMARISES with definitions!!!			Repeating previously shown animations with voice over summaries	

Source 4: Dron Study[7]

Content	Data-Type	Alt Data-Type	Teaching Method	Notes
Eyeball - if eye is taken out, it looks like a ball (like this images here)	Fact		Image and narration	
Eyes - helps us to see	Fact			
Eyeball - spherical, diameter around 2.3cm	Fact		Exact ho nahi hai, but sphere type ka hi hai	
Parts of eye				
Cornea - Bulging, transparent, convex layer	Fact		Image	
Work of cornea - protection, dust protection	Fact			ERROR, all other things say its a lensish thing
Iris and Pupil : Disc and a hole in it respectively	Fact		Images	
Iris - differently coloured in people, ring shaped	Fact			
Pupil - light comes in through this hole	Fact			
Lens - jelly like material, convex lens	Fact		image	
Suspensory ligament - keeping lens in place	Fact		image	

[7] www.youtube.com/watch?v=EmhHGFLXQXM, https://www.youtube.com/watch?v=U6jcditL7gA, and https://www.youtube.com/watch?v=VwLiZRrorts
A 2-part audio visual that uses screen recording with voiceover in Hinglish.

Ciliary muscles -	Fact		image	
Retina - Screen where light rays meet after coming in from lens	Fact		image	
Optical nerve - from retina to brain (thats all)	Fact		image	
Vitrous humor - liquid filling the rest of the space in eye	Fact		image	
Aqeous humor - between cornea and iris	Fact		image	
Blindspot - where the optical nerve connects to retina	Fact			
Basic Working of Eye	Process			
- lens is converging, real image	Fact		Object - rays - lens - retina. Real image since rays are actually coming to the retina.	
- inverted image	Fact		BECAUSE YOU CAN SEE IN THE PHOTO !	
- optical nerve carries the image	Fact			
- Brain inverts the inverted image	Fact	Principle		
- Pupil : controls the amount of light that enters			Explaination in depth : too much light, too less light, bigger/smaller pupil images	
Video 2 - https://www.youtube.com/watch?v=U6jcditL7gA				
Distant object - parallel rays, convex lens, image on retina	Principle		Citing already known information of convex lenses	
Closer objects - same thing repeat	Principle			
Changing focal length of lens in these two cases	Concept		Using the lens equation - [image distance (v) - constant, hence f is changing]	

Ciliary muscles change this focal length of lens - relaxation and contraction	Concept			
Video 3 - Defects of eye - https://www.youtube.com/watch?v=VwLiZRrorts				
Introduction				
- Myopia : short/near sightedness				Incomplete - Pay wall

Source 5: Aakash iTutor[8]

Content	Data-Type	Alt Data-Type	Teaching Method	Notes
Image formation of object on retina via convex lens in eyeball	Process		Labelled Ray diagram on board	
Convex Lenses for images at different distance for different object distances	Concept	Fact	Concept being used as a fact here	
Image distance fixed in case of an eye (distance to retina)	Fact			
Brain can sense only images formed on retina	Fact		Just stated, out of the blue	
"A part of the eye" must be changing lens curvature	Meta-Cognitive		Logical progression	
"Cerealy" muscles change the curvature of eye lens depending on	Concept	Fact	writing the sentence on the	"They change the

[8] www.youtube.com/watch?v=7MVN9tQp2Oo and https://www.youtube.com/watch?v=cxPmd5F_46A
Video recording of an instructor using the blackboard to take a class

object distance			board.	curvature by changing its focal length"
Optic nerve has nerve fibres which transmit image information to the brain	Fact		writing the sentence on the board.	
Blindspot - the region on retina where a formed image is not sensed by brain - "Region of zero vision"	Fact		writing the sentence on the board. Pointing at the optic nerve connection	
blindspot is located where the optic nerve leaves the eyeball	Fact		writing on the board	
blindspot region doesnt have rods and cons hence image not sensed	Fact			Rods and cons are just thrown as words out of the blue
Since there is a blindspot there should be a region with sharpest image too!!	Meta-Cognitive		Logical progression according to teacher	[This has zero logic by the way]
Yellow spot - the region most sensetive to light - center of retina	Fact		writing the sentence on board, pointing to the location	
ENDS HERE, teacher wanted to talk about working of "cerealy muscles"				
There are other broken incomplete videos with some parts				
Video 2 - https://www.youtube.com/watch?v=cxPmd5F_46A				
Iris - coloured muscular diaphragm which gives eye its colour	Fact		stated and writing sentence on board	Note : no eye diagram on board at this time
It controls the amount of light entering eye by changing size of pupil	Fact		Sentence on board	Note : no eye diagram on board at this time
Pupil - small black opening in iris	Fact		writing sentence on board	Note : no eye diagram on board at this time
Its black because any light falling on it enters the eye	Concept		writing sentence on board	

Examples of dark room and outdoors, to relate the process of pupil size change	Meta-Cognitive		Explain the phenomenon	
pupil expands in dim light, and contracts in bright light	Fact		eye 2D front view with 2 circles showing iris and pupil	

Appendix II – Issues Summarized

Table 8: Using *the Extended User Experience Model* (Joshi & Medh, 2006) *for e-learning products*

	Learning	***Content***	***Presentation***	***Interactivity***
Surface		Students spend time trying to read content on board and book	Changes on the screen are not very prominent, student's may miss it unless explicitly indicated	Can't identify which components are interactable
			No other humans in the scene to make the scene feel real	Selecting objects is a pain, the screen in not very responsive
			The eyeball is flying in space, difficult to identify	
			The static tutorial marker hand doesn't grab enough attention	
Skeleton	No confirmation if the vision has been corrected		The narrator's tone is formal	Can't find how to go next, no indication for end of module
				Pressing next more than once leads to student's skipping a lessen mid way
				Removal of all defects or lenses (reset) is not intuitive
				The audio instructions need controls

Structure	With no replay-ability and accompanying visuals the audio alone often leads to misconceptions	Expecting definitions or description on clicking of labels (especially in parts of the eye page)		Attempts are made to zoom and pan in the PoV view
		Light doesn't focus on retina in defected eye even when they are looking at a focussed location		Clicks on eye to interact with the the eye
		The horizon doesn't remain horizontal		One needs to continuously tap on the screen to keep it live
		The light rays should go through the pupil, and not over the iris		People stop touching around while audio is playing
				Users try to zoom in all views
Scope	No way to ask doubts	No content about how two eyes work together		
	No way to bookmark/ take notes/ mark as important			
Strategy				Can't use comfortably if hands are busy holding pen or such

Table 9: Design Ideas sorted as per the Extended User Experience Model. Red - High Severity & Orange - Medium Severity

	Learning	***Content***	***Presentation***	***Interactivity***
Surface			Highlight/ Tutorial/ Demo	Highlight/ Tutorial/ Demo
			Add humans to scene	Enlarge hit-area for selectable objects
			Add face to add context	
			Animate - pull attention - make it disappear. Repeat if inaction for 10secs	
Skeleton	Glow, or say hurray!		Rework the script?	Introduce end of module, Pattern Observed: Right bottom for next
				Introduce end of module
				Redesign menu buttons to bring forth normal eye and no spectacles
				Audio-video with controls
Structure	Audio-video with controls	Add definitions on long press especially on the parts of the eye page (other places can have the info icon)		Allow panning PoV area
		Edit code & highlight in audio-visual		Allow change of view by rotating eye
		Coding issue (fix rotX to 0)		Add code to keep screen live
		Correct via code		Start interactivity at the end of audio lessons
				Allow zoom in 3rd person view and ray diagram view, not in 1st person view
Scope	Add to scope	Add to scope? Future lessons		
	Add to scope			
Strategy				Largely a device limitation - prompt to use earphones and attempt to make single handed use friendly

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http://blogs.worldbank.org/edutech/worst-practice

http://www.aupress.ca/books/120155/ebook/99Z_Mohamed_Ally_2009-MobileLearning.pdf