Industrial Design
Project III

Low Cost Portable Digital Microscope for children

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IDC School of Design
Indian Institute of Technology, Bombay

Approval sheet

Industrial design Project III

The project titled “Low Cost Portable Digital Microscope for children” by Apurba Mondal, is approved for the partial fulfillment of the requirement for the degree of “Master of Design” in Industrial Design.

Project Guide

Chairperson

Internal Examiner

External Examiner

Declaration

The content produced in the project report is an original piece of work and takes due acknowledgement of referred content, wherever applicable. The thoughts
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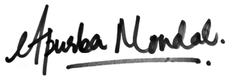
M.Des Industrial Design
2017 - 2019



Date: 13th June, 2019

Place: IDC, IIT Powai, Mumbai, Maharashtra.

Acknowledgment

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I would like to thank Prof. Ambarish Kunwar of Department of Biosciences, IIT Bombay. I would like to give special thanks to Ms. Saumya Yadav working with Prof. Kunwar, for her enthusiasm, Knowledge and insights on working with microscopes.

Special gratitude to my parents, cousins, classmates and friends for their support and feedback throughout the period of the project and helping me gain a holistic understanding of Design.

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Abstract

The aim of the project is to design and test a portable and affordable digital microscope for school students which connects to screen based devices. It is focused on being an easy to operate device and is economic to be a personal device for learning. It would provide an opportunity for students to look at what the naked eye can not see and hone their curiosity. As a mandatory device provided by the institute for academics would aid them and also could be gifted to those who don't have a microscope in their curriculum yet.

Various concepts of operation, slide (Onion peel cell) and non-slide(eg. Butterfly) samples insertion, navigation, zoom and focus controls were compared. Playfulness of the device is a key focus and an important feature which has been introduced is invertibility. This has benefits when a live sample needs to be viewed in a petri dish. The camera lens instead of being above the sample is below it and the tissues, cells etc. deposit at the bottom and is clearer to view. The device can be simply inverted and kept to be used like this. This has major applications in higher studies in biological sciences.

User feedback based on the prototypes aided in improving the design further. A minimal instruction sheet on how to operate, understand scale marking of sample viewed and preparation of slides are designed to create an easier experience.

Contents

1. Introduction

Microscopes have been a part of biological, medical discoveries since the 17th century ever since the revolutionary Antonie van Leeuwenhoek invented the glass lens which was capable of seeing living microbes present in pond water. This sparked more biologists to observe, document new microorganisms, predict their behaviour and prevent diseases. This curiosity to see beyond our naked eyes starts from an early age and having an affordable and portable device for their personal use will help them nurture their interest towards the field of sciences.
After a brief market study, it was realised that there is a niche in the market for the need of such children friendly devices as opposed the scientific ones in the labs. To make it as easy as possible, the parts were stripped down to the necessities: Focus, zoom and slide placement.

The school student gets to share devices in the lab which are expensive and hence the student does not get to play around with it. For school students of 11th standard and college, the device could aid them in academic learning.

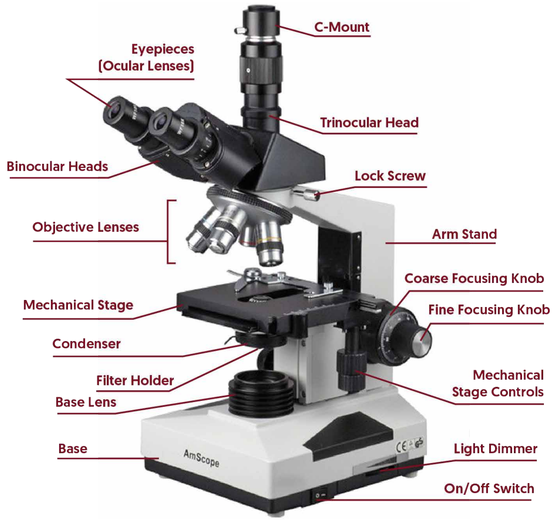


Fig 1: Compound Microscope

2. Research

2. Research

2.1
Visit to Professor Ambarish Kunwar, Biosciences Department , IIT Bombay.

Professor and his team have developed a rig for a digital microscope in their lab which is used for reasearch work and provides magnification of upto 400X. From the discussion, several needs were pointed out such as the need of personal microscopes which can document work for the students and researches working in the labs. The setup is a simple one where parts of a webcam are used. The CMOS Image sensor, compund lenses and USB cable are used which are fixed and the distance between the sample and the lens are controlled by moving an acrylice stage on which the sample is kept. Light source is an LED USB light.

Current Parts:

1. Acrylics stand
2. LED light source
3. Webcam with Lens inverted
4. Slides and cover slip
5. Screws to hold acrylic slide platform up
6. USB cables to power up LED and Provide Live feed on LCD Screen, Smartphone, Computer.

Key points of the meeting:

1. Need for the current setup to be convertible to a Inverted Microscope
2. For Lab research purpose to observe mitosis and meiosis of cells
3. For the product to be school student friendly
4. Have finer adjustment of stage movement in the Z-axis

Fig 2: Onion stem cell

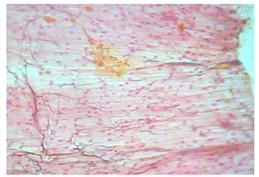


Fig 3: Onion stem cell

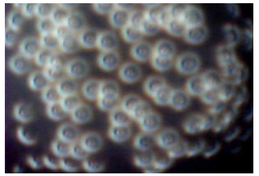


Fig 4: Onion stem cell

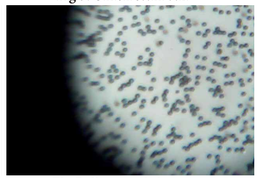


Fig 5: Gram staining

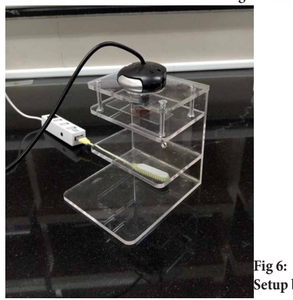


Fig 6:
Setup by Proff. Kunwar

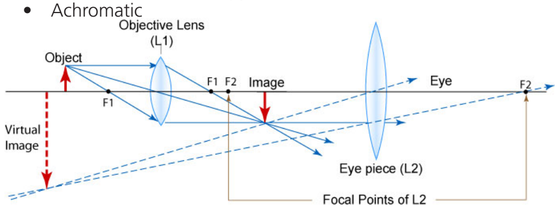
2.2
Optics in Microscope

The fuction of the lens is to converge or diverge the light ray and create real or virtual image. Every lens has a focal length of both it's surfaces and using the property of the lens, they are arranged to get the optimum magnification, chromatic abberation and image quality in microscopes. **Eyepiece** and **Objective** lens are the two primary lenses used. Their arrangement have three variables where one or more can be controlled to achieve magnification and focus.

- Tube Length (L)
- Focal Length of eyepiece (Fe)
- Focal length of objective lens (Fo)
- Formula for total Magnification:
- = Mo . Me
- = (-L/Fo).(25/Fe)
- Mo: Linear Magnification, Me: Angular Magnification

The digital microscopes do not have a viewing eyepeice but instead an image sensor which can be seen live on a screen. The lower end microscopes only zoom the images, not magnify. The higher ended microscopes have a high magnification range and lower distortion. These have multiple purposes in research:

- Supports Oil immersion
- UV Confocal Microscopy
- Achromatic



2.3
Basic Parts of Optical / Compound Microscope

Revolving Nosepiece or Turret: This is the part that holds two or more objective lenses and can be rotated to easily change power (magnification).

Objective Lens are a series of plano convex and convex lenses that capture the light from the sample and slightly with every lens, converges the rays to fall on the eyepiece. Higher ended lenses can reduce chromatic and achromatic abberations, focal depth and higher magnification range.

A steady **light source** used in place of a mirror. If your microscope has a mirror, it is used to reflect light from an external light source up through the bottom of the stage.

Condensors concentrate the light rays onto the sample.

Coarse and Fine adjustment **knobs** move the sample away or closer to the objective lens.

Terms:

- **Numerical Aperture(NA)**: The resolution of an optical microscope is defined as the shortest distance between two points on a specimen that can still be distinguished by the observer or camera system as separate entities. Clarity of one particle from other.

- **Working Distance**: The distance at which the image is viewed the sharpest. Higher NA means that less working distance.

2.4
Market Study

Fig6.

NHBS Children's Microscope kit
Magnification: 140X
Resolution: 2 Micron
Price: 500

Fig7.

Levenhuk LabZZ M101
kids Microscope
Magnification: 40X, 100X, 400X
Price: 2,800

Fig8.

iTikes Microscope
2-in-1 play Standalone microscope with real lens App-based play unlocks more learning with interactive 3D images, illustrations and animations
Real working microscope with 3 focus adjustments - 100x, 200x & 300x

Fig9.

NHBS Microscope kit
Magnification: 150x
The set also includes two prepared slides, six blank slides, petri dish with magnifier, specimen vials, tweezers, pipette and spare bulb. This set is designed for children of eight years and up.

Fig10.

Plugable 800x Inverted Digital USB Microscope
Magnification: 800x
Price: 6,400

The products in the market have a range of features. Majority of the devices purchased are for lab purposes which range from 40,00 Rupees to more than 2 Lakh. Cost of the product mainly is higher due to better lens quality and features, finer focus adjustment and condenser control. But there are ranges of products which targets a wider audience such as bead based
Foldoscope, scientific style microscopes and phone camera bead lens attachments. The Foldoscope is based on the Leeuwenhoek microscope and uses glass bead which provides good magnification but there is high spherical aberration. But these do not cater to the younger audience due to them being difficult to control and use for school experiments. There is a need of a product in the market for bridging this gap of need and affordability.

Fig11.

Carson MicroBrite Plus Power LED Lighted Pocket Microscope

Magnification: 60x-120x
Price: 950

Fig12.

Portable USB Digital 8-LED Mini Microscope

Endoscope Camera Magnifier
Magnification: 20x-800x

Fig13.

Microspin 2 MP digital USB microscope

Upto 600X Magnification
Price: 6,000 INR

Fig14.

Celestron Amoeba Dual purpose Digital Microscope

10x, 60x and 200x magnification
1.3 MP digital camera
Top and bottom LED illumination
82 mm (3.2") diameter stage
Coarse focus with dual knobs
Plug-and-play
Accessories Included: 8 prepared slides, 4 blank slides, tweezers, needle probe, eyedropper, ULead photo capture software for Windows

Fig15.

Foldoscope
An affordable paper microscope which uses borosillicate spherical glass lens.
Magnification: 140x - 200x
Price: 340 INR

Fig16.

Nurugo Micro
Magnifcation: 400x
Price: 17,000 INR

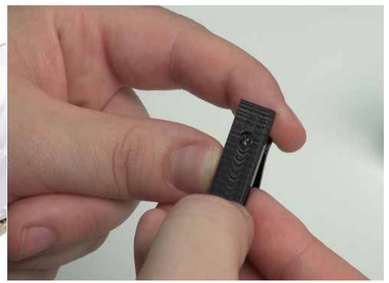


Fig17.

Fig18.

Omano OM118-M3 Monocular

Student Compound Microscope
Magnification: 40X-400X
Price: 9,000

Fig19.

Phase Contrast Inverted Microscope

With 5MP Camera - MWC-IN400TA-5M
Magnification: 40X-900X

Fig20.

IQCrew 40X-200X Science Discovery Series Inverted Microscope

Fig21.

The Motic BA210 biological microscope

For clinical, University or Institutional uses
Magnification: 40x, 100, 400xr, 1000xr oil immersion.
Price: 90,000 INR

2.5
Market Study Observations

Popular microscopes in the market were compiled and plotted taking into Cost (X-Axis) and Magnification(Y-Axis) in to consideration and marking each of them on their user group where the categories were:

School Children
Undergraduate students
Professors and Researchers
Pathologists and Hematologists

- Non Portability is an issue in microscopes of all ranges.
- A low cost alternative with high magnification is lacking in the market for students.
- High magnification microscopes are expensive as the quality of lenses is high which can reduce optical aberrations.
- A wide scope of improvemnt in Product interface and usability.

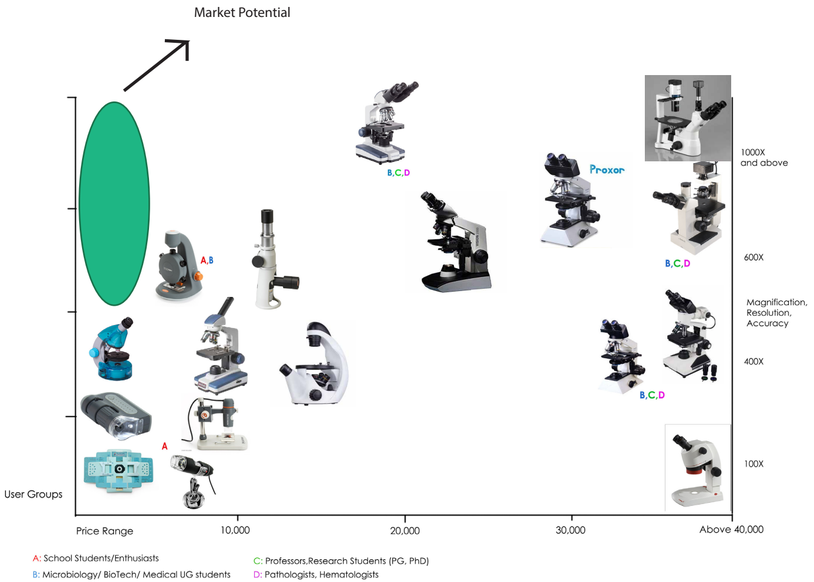


Fig22. Market analysis

2.6
Types of Microscopes

- Stereoscopes
- Compound
- Dark field: A light object is seen on a dark background.
- Electron Microscope
- Raman Microscope
- Digital Holographic Microscope

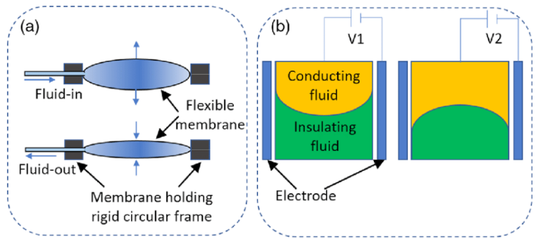


Fig23. Mechanically and Electronicallty controlled fluid lenses.

New Technology

Today, objectives are designed with the assistance of Computer-Aided-Design (CAD) systems using advanced rare-element glass formulations of uniform composition and quality having highly specific refractive indices. The enhanced performance that is demonstrated using these advanced techniques has allowed manufacturers to produce objectives that are very low in dispersion and corrected for most of the common optical artifacts such as coma, astigmatism, geometrical distortion, field curvature, spherical and chromatic aberration. Not only are microscope objectives now corrected for more aberrations over wider fields, but image flare has been dramatically reduced with a substantial increase in light transmission, yielding images that are remarkably bright, sharp, and crisp.

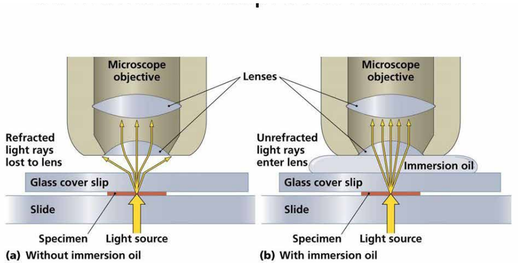


Fig24. Oil immersion lenses have better image cotrast as more light enters.

2.7
Inverted Microscopy

The objective lens in a compound microscope is placed above the slide and there is very less space between the two for the contents of the slide to be manipulated. In inverted Microscope, the lens is at the bottom and the light sources is on top and there is room for working. Used in Living specimens metallurgy, cell culture and for viewing aquatic specimens.

Advantages over compound microscope:

- Living specimens can be manipulated
- Ability to maintain a more natural environment for the specimen, thus, extending its life
- This is an excellent microscope for metallurgical samples, and for the observation of living specimens or tissues.
- Therefore, the process of cell division can be examined which is not the case using a conventional compound microscope.
- Gives a better picture as the tissues settle at the bottom of the dish
- Water doesn't splash on to the lens while handling the specimen

Disadvantages:

- Cost.
- There are fewer manufacturers and the engineering to manufacture the microscope.This means there are fewer used microscopes of this type on the market, and less competitive pricing.
- All microscopes have a limited working distance for focusing on the specimen.
- When using the inverted type, this difficulty is compounded by the reality of looking up through containers of various optical quality and thickness.
- You may look through plastic, which has a much different optical correction than the thin glass slip on a standard slide.

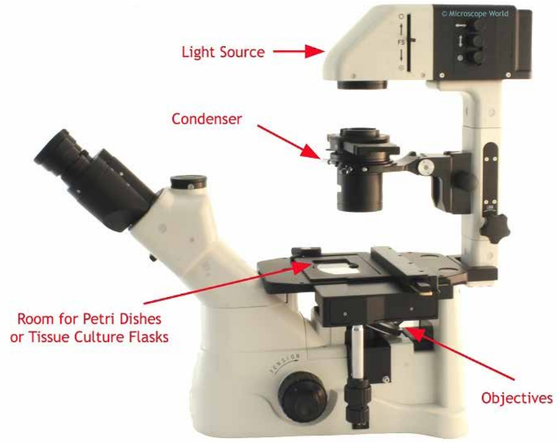


Fig25. Standard inverted microscope

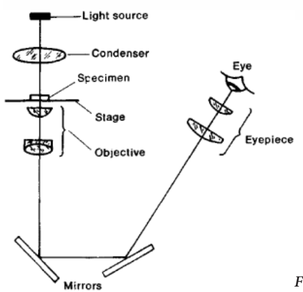


Fig26. Inverted Microscope Optics

2.8
Academic Curriculum

According to the 10th grade CBSE board curriculumn, biology sample preparation mainly encompasses: Stomatal Peeling, Onion peeled plasma, cheek cells. Rest of the samples are permannet slides which only the student has to observe under the microscope.

In 11th and 12th grade,Starch granules in potato, Onion root tip to see mitosis and meiosis, Spirogyra (taking water samples from stagnant sources) sampes are prepared by the students.
5 stages of Binary fission in Amoeba, Budding in Yeast, Animal Tissues, Pollen Germination are only observed, not made.

White and Red blood cells can be observed with proper dying and diluting of the blood sample.

What else can be viewed?

- Pond water has a host oforganisms: Paramecium, Euglena, Cocci, Spirilla, vorticella
- Insect wings: Butterflies, spiders, ants, moths
- Bird Feathers
- Roots and stem cross sections
- Fungi and Molds
- Fabrics and Paper textures
- Bacterias: Typhoid, Malaria
- Urine specimens, dental plaque
- Food items: Yogurt, Wine, Beer(Fermented beverages)

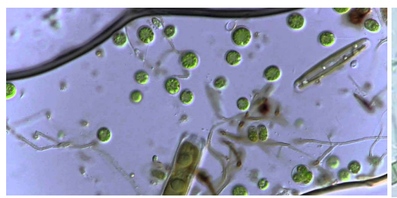


Fig 27: Pond Scum

Fig 28: Bacteria and Blue-green algae

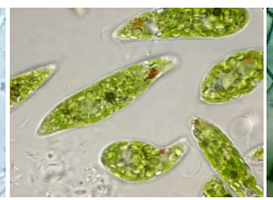


Fig 29: Euglena

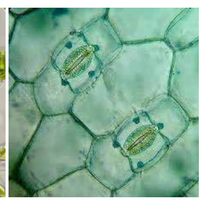


Fig 30: Stained Stomatal Cells

3. Design Brief and Design Objective

3. Design Objective & Design Brief

To create a simple and playful digital microscope for learning purposes.

To design a low cost and Portable Digital Microscope using CMOS Image sensor for fun learning which streams live feed on screens such as smartphones, LCD monitors/ Laptops.

Must Haves:
User Friendly Interfaces and control
Easy focus adjustment and zoom
Slide Placement and Adjustment
Frugal Design

May Haves
Playful Design
Storage space for keeping slide preperation items
Invertible Microscope

Fig 31. Internal Electronics

Functional Requirements

Magnification upto 600X with 0.5 micron resolution
Stage movement in Z axis till 5 cm
Resolution of 100 micrometer
Lightweight: Less than 500 gm
Operates on low power: USB cable
Portable: Can be carried in pockets, bags
Engages the user (Playful)
Robust: Can survive wear and tear
Easy to clean and maintain

User Groups

Secondary, Higher secondary School Students (Age: 10 - 17 years)
UG Biosciences and Medical students (Age: 18 - 25 years)

Problem Identification and **Design Directions**

Function Structure

Focus control: Primary Importance and therefore needs to be easy to control with fine turning control.

Zoom Control: Secondary importance, Coarse turning
Viewing non slide samples such as insects, flowers etc.

Cable Management: Cord is wound onto the device or seperately attached to a port.

Slide adjustment
Slide insertion
Sample manipulation in inverted mode

Light intensity adjustment
Certain samples are viewed better with higher direct light intensities or with diffused lighting.
Battery for the light source can be rechargable or changeable depending on the cost limits and overall weight of the device.

Portability
Light weight and frugal. Does not break easily.
Compactness: Low volume can fit into bags and is yet safe.
Carried as a set with storage space for other tools like dyes, dropper, tweezer, filter paper, glycerin, water etc.

Invertibility
- Less effort to transform into invertible format.
- Stable to hold a petri dish.
- Enough space to keep a dish and manipulate/move contents.

4. User Interviews

Location: Biosciences Research Lab, IIT Bombay
Name: Saumya Yadav
Age: 24
Qualification: M.Tech Biosciences
Information Provided:

- Upto 9 micron of wheat grains viewed
- 0.5 micron beads is the maximum particle visible
- Topography view is better
- Lens and CCD distance of the webcam is fixed
- Typhoid, Malaria bacteria also has been viewed
- Non pathogenic strain of bacteria should not be given to view to school students
- Images observed are blurry but magnified
- Finer adjustment is needed

Types of Microscope used:
Webcam based
Zeiss

Location: Kendriya Vidyalaya School, IIT Bombay
Name: Ms. Selvam
Age: 52
Occupation: Biology Teacher
Information provided:

- Types of samples viewed by students of 8th-12th grade.
- Some samples difficult to view because of low contrast
- All areas of an uneven sample surface are hard to view in clear focus.
- Students follow only what they're told.

Type of microscopes used:
Compound Microscope
Price: 2,000
Magnification: 10X - 45X

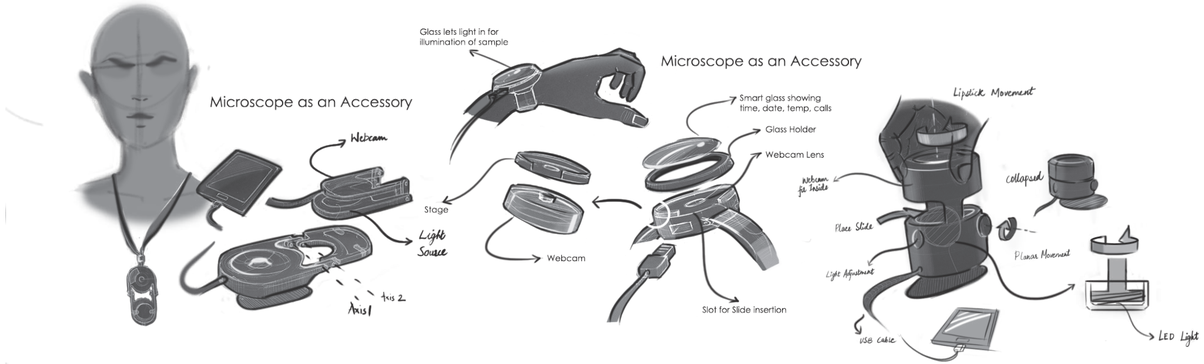
Location: Kendriya Vidyalaya School, IIT Bombay
Name: Aditi Satpute
Age: 16
Occupation: Student
Information provided:

- Would like to spend more time in the classroom viewing the specimens.
- Would like to have a personal device which she can take anywhere.
- Does not want to deal with making slides, using dyes etc.
- Wants to have one at home.

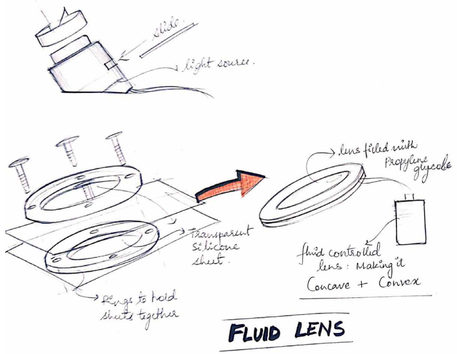
Microscope used:
Compound microscope
Magnification: 40X

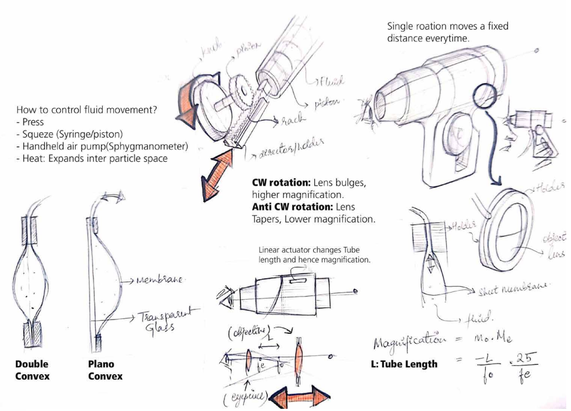
5. Ideations

5. Ideations



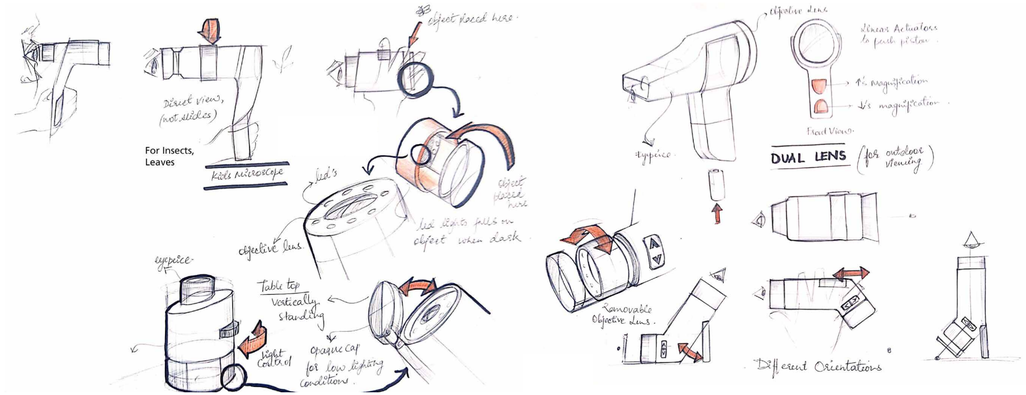
Ideations





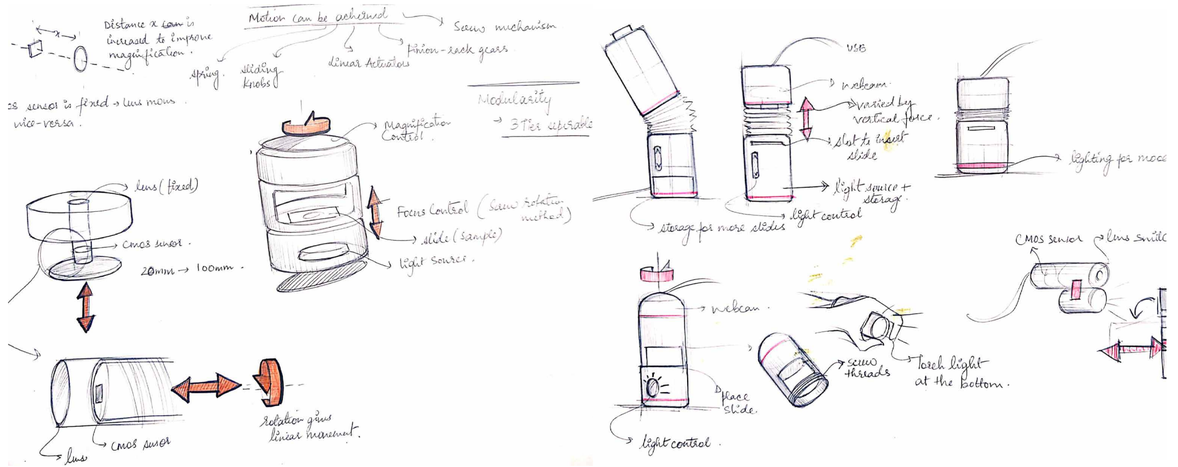
- The idea is to use a rapidly evolving lens type: The fluid Lens.
- There are frugal and high end versions of the same.
- A handheld outdoor microscope.
- Squeeze two mini pumps to let the fluid move and change lens property.

Ideations



A playful outdoor microscope with two lenses (Objective and Eyepeice). Focal adjustment and Tube length (magnification) an be controlled by rotating the tubes.

Ideations



6. What is Playful?

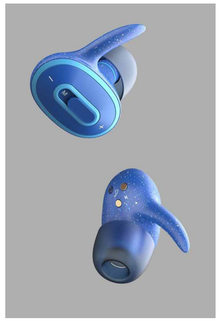
6. What is Playful?

Taking inspiration from the classic panasonic radios and cassette players, a touch of playfulness comes from the colourful control buttons and knobs.
Bright primary colours to give an emotion of energy and liveliess.

These attributes purely being percieved from sensory stimuli.

Other factor that aids in engaging user's interest is having an element of mystery which can be achieved by adding an element of visual / usage complexity.

A more functional product gives the feeling of power when being used and hence seems more appealing.



Energetic
Playful
Minimal

7. Concept Generation

Concept 1

The concept was based on the initial ideation of having a rotating body which would also be the main controls for Zoom and Focus. It was further detailed out to incorporate invertible microscopy by providing space between the sample stage and the light source.

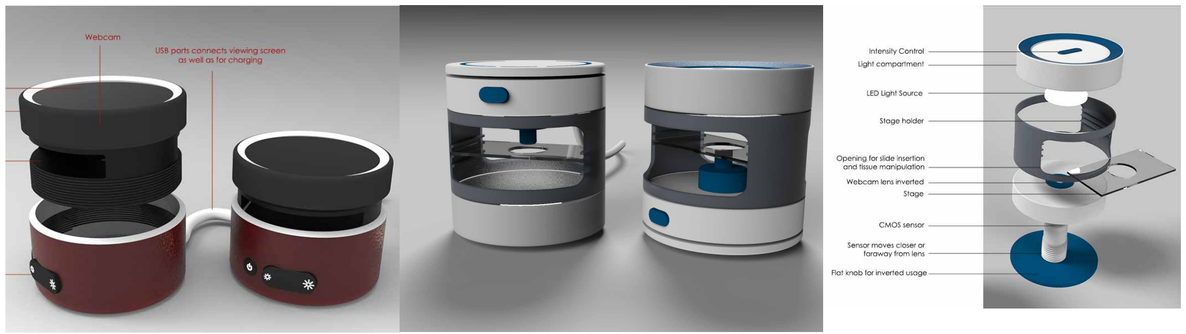


fig 32. Digital Model

Concept 2

The concept was further developed to control D1 and D2 more precisely and the parts were kept simple to complement the user's need for an intuitive device and is also playful.

fig 33. Digital Model

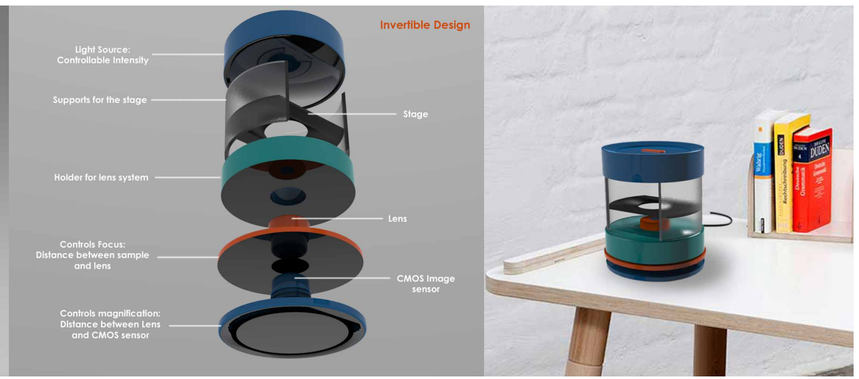


fig 34. Exploded view

Concept 2

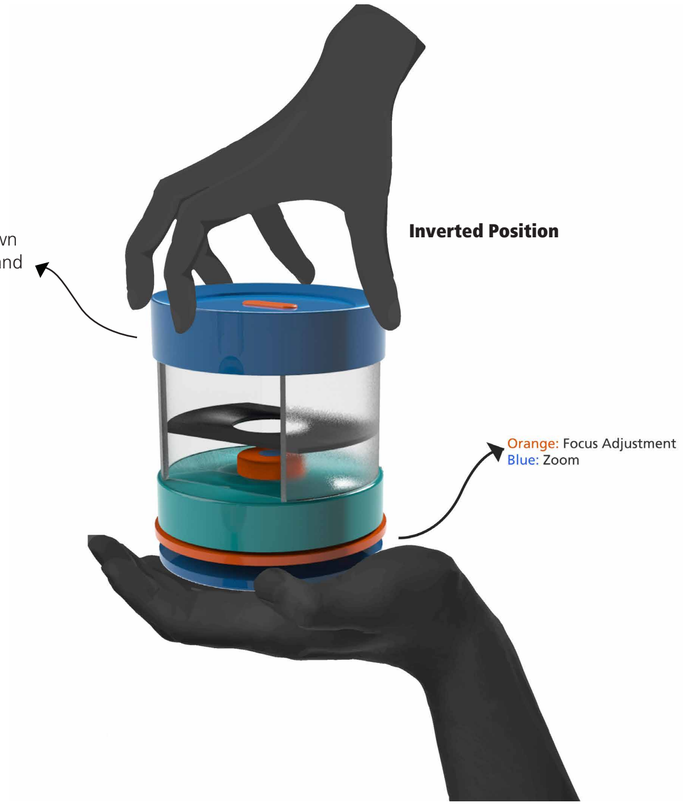
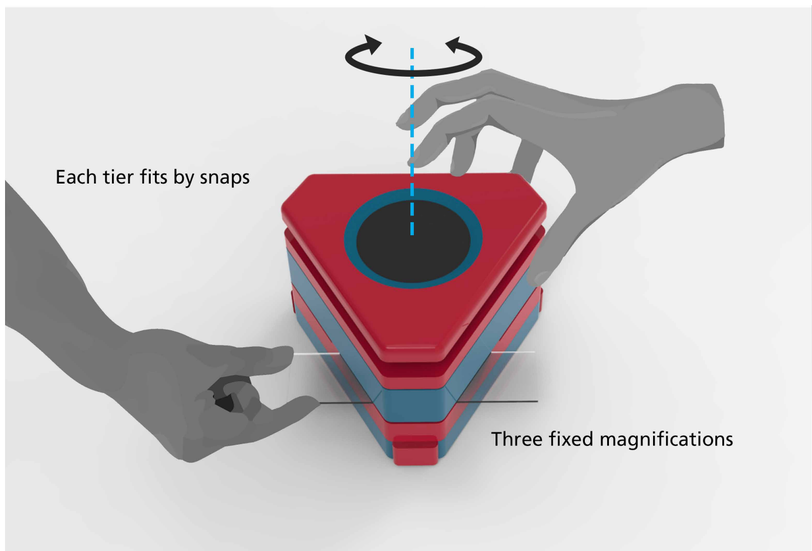


fig 35. Digital Model

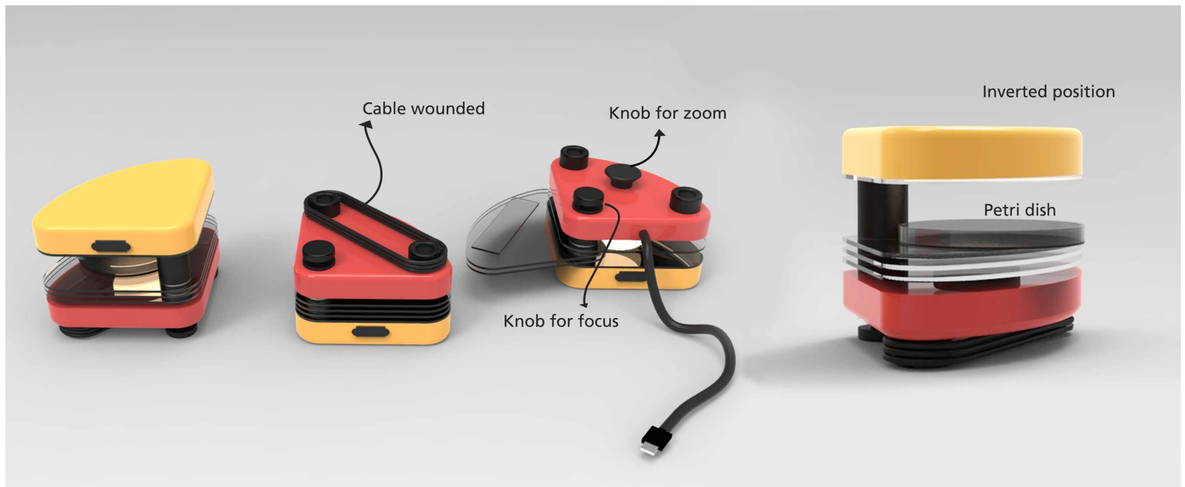
Concept 3

To remove complexity of adjusting focus and zoom, both are fixed. The cable can be wound around the gap provided. Replacable battery.
Each of the 4 units are free to move and gives a playful element.



Concept 4

Giving the user freedom to control D1 and D2, Space to prepare slides and the further iteration would be to provide storage space at the bottom to keep fluids, foreceps, dropper and extra slides.The storage would be a detachable element during inverted position and sealed to prevent contents from spilling.



Concept 4 refined

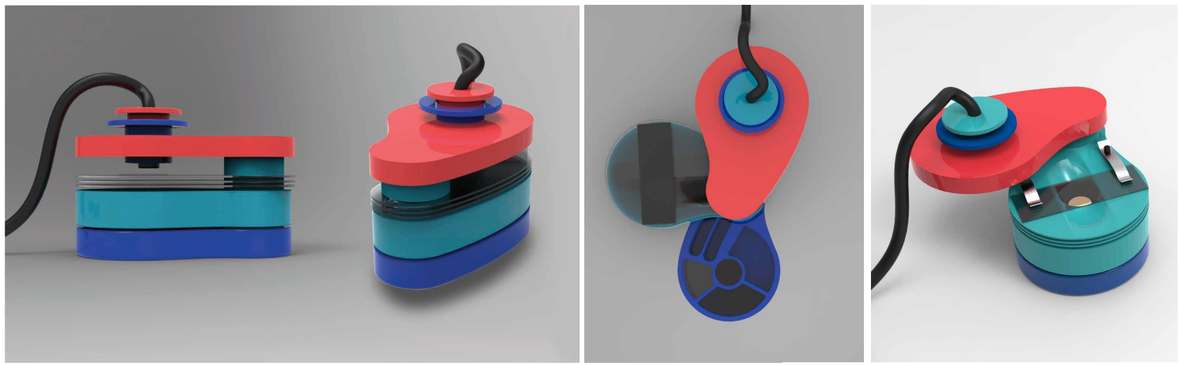


fig 36. Digital Model

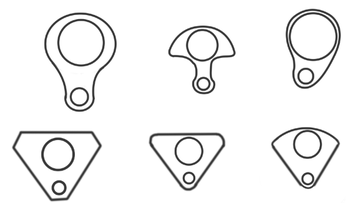


Fig 37: Form Variations

Concept 5

The telescopic design gives an advantage of collapsability and hence compact. Invertible microscopy can be performed bymaking the slide insertion slot longer for the petri dish to be kept and to be manipulated.

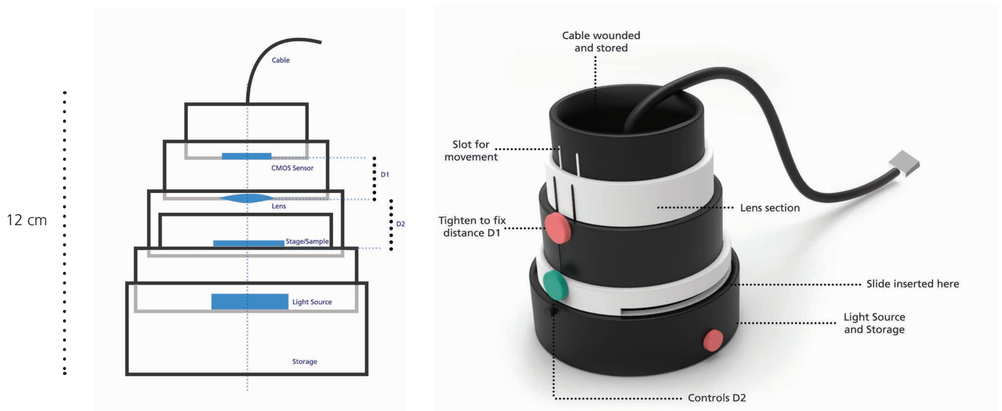


Fig 38: Section view and Dimensions

Mockups and Preliminary Prototyping

fig 38. Mockup models for concepts

The top left three mockup are for an outdoor device.

Observations:
After giving out the mockups for user review, certain usage related issueswere pointed out:
The lens remains exposed when not in use, this will hinder portabaility.
For invertibility, the light source needs to be at the bottom so that the storage module can be rotated to keep the petri dish for live viewing.
The knob for fine focusing needs to be easy to reach and hence needs to be jutting out slightly to be controlled by the thumb.

Concept 4 Mockup
(Role Play Observations)

- On first viewing, it was observed that the bigger radii of the body seems to be the axis.
- The Lens tube remains exposed while not in use. Can be made collapsible.
- The knobs must be more tactile.
- The light source module does not provide any space to keep a petri dish when inverted.
- The stage needs to be thinner.
- Storage space removable to counter weight while being used in invertible mode.
- Can be carried in bags.

Fig 39: Concept 4 thermocol mockup

Concept 3 Prototype
(Evaluation)

Findings:
- While seeing a butterfly wing under the device, it is difficult to focus because of gap.
- Having a fixed height between sample and lens will help in removing focus effort.
- Difficulty navigating a sample as big as a butterfly.
- Volume and weight is slightly bigger than comfort.
- While observing samples(non slides), the surface is not flat. Viewing area goes out of focus.
- Non slide samples are prone to damage due to our fingers. An additional holder to grasp them without stress is needed.
- Need to have distance adjustability between sample and lens.
- Or samples which are not thin/light can't pass through, light must fall onto the surface.

Interventions:
- Having a fixed height stage for each of the 3 lenses and hence the sample will be simply placed there but objects like butterfly wings cannot be viewed.
- Light source will be common with ability to change their intensities.

Conclusions
- Providing fixed distance lenses creates issue of focusing on variety of samples.
- Using 3 different lenses would increase cost and probability of failure.

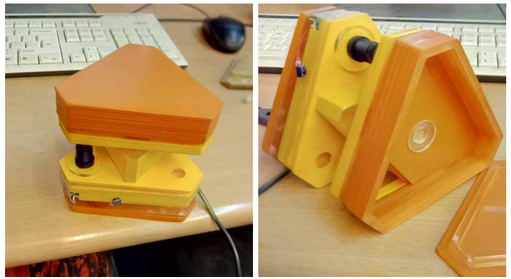


Fig 40: Device cannot be used in invertible mode

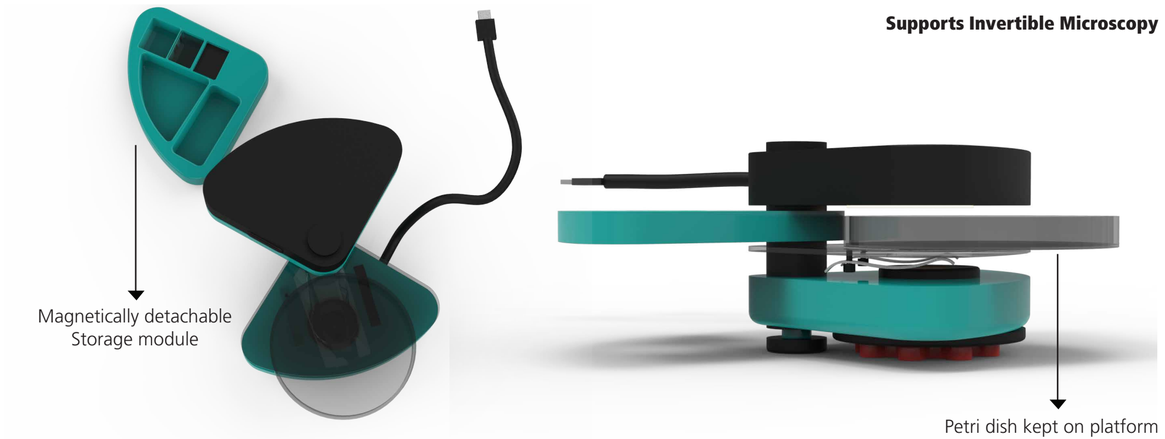
Concept Evaluation
(Self Validation)

Based on the function structure, the factors which are in priority start from the left. Therefore focus and zoom control have highest importance in terms of user need fulfillment.

Concept	Focus and Zoom Control	Sample adjustment	Cable management	Invertible	Compact	Final Score
1	6	7	6	8	7	**34**
2	8	6	6	8	7	**35**
3	6	5	7	5	7	**30**
4	9	7	8	8	7	**39**
5	9	6	7	5	8	**35**

8. Final Design & Detailing

8. Final Design and Detailing

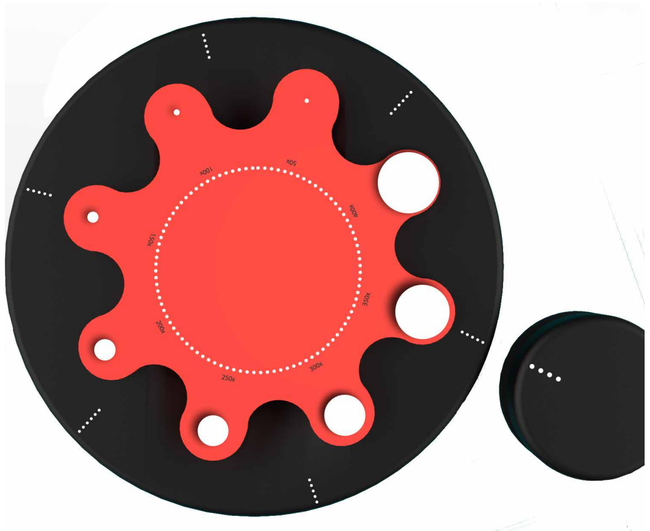


Tissue, cell or water sample can be manipulated and live changes can be viewed which cannot be viewed in temporary or permanent glass slides

Stage is two layered laser cut acrylic sheets with the the slide holders are screwed onto.The holder has a soft spring at the bottom to not hold the slides and insect samples tightly to ease x-y planar movement.

The black knob controls focus and since it being sensitive, is kept bigger. The red knob control zoom which are marked as 50x, 100x, 200x and 400x.

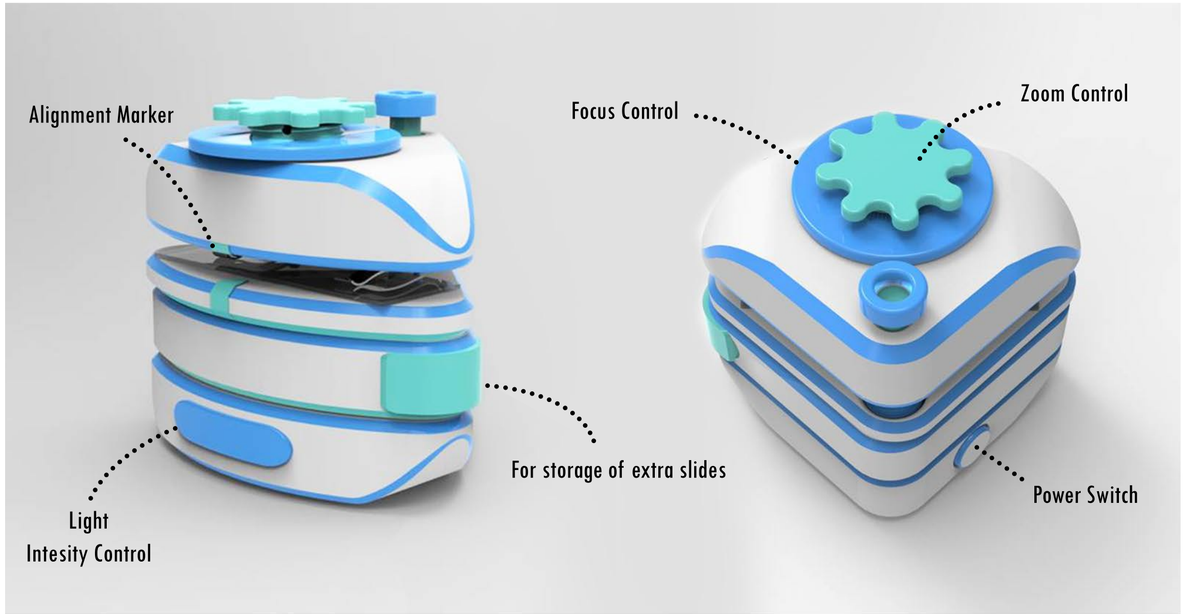
The cable can be wounded around the body of the device or on the knobs.

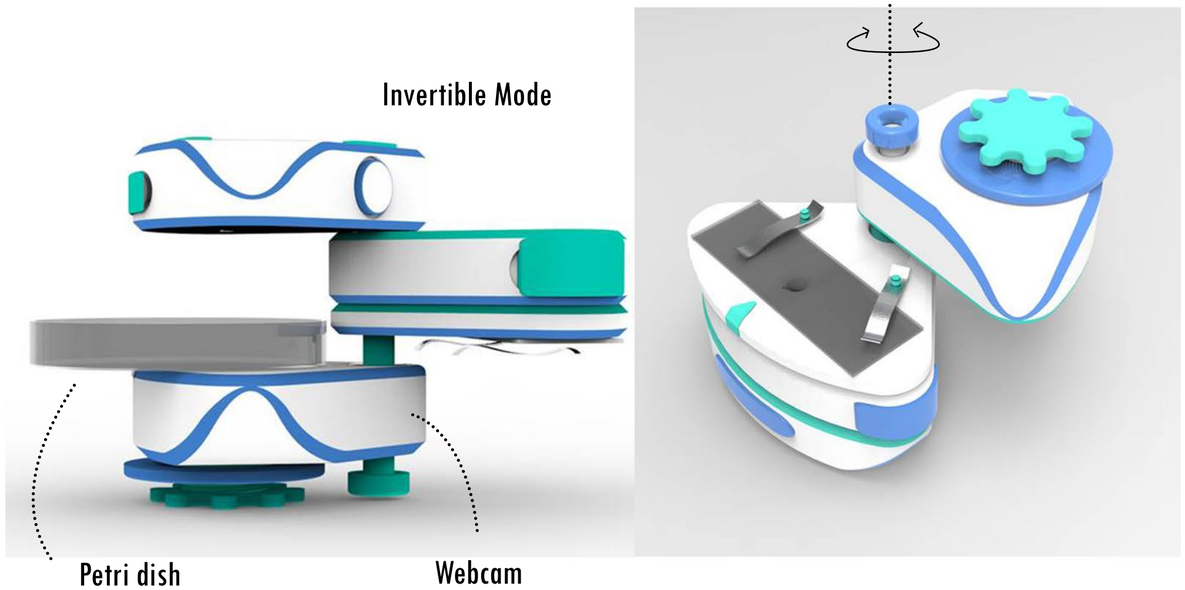


- Red knob markings ranges from 50x to 400x.
- The big black knob below the red one is for fine focus.
- The cap on the axis gives an indication of how much zoomed the device is.

FINAL DESIGN

ITERATION



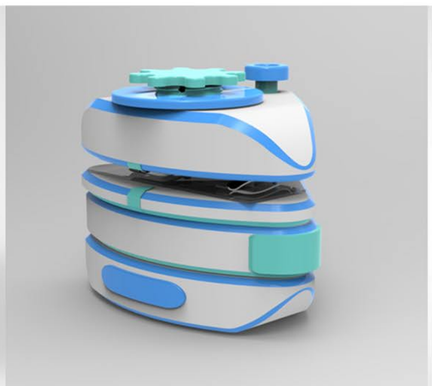


MOOD BOARD

Sporty

Cool

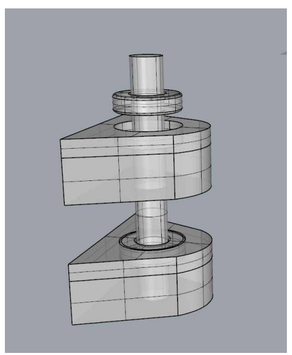
Energetic



Prototyping

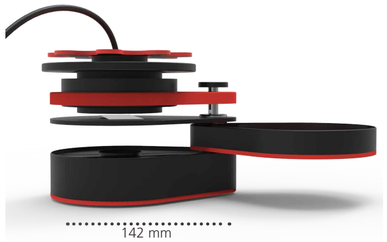
The modules are 3d printed or Laser cut in this case, the stage material is acrylic, and the CMOS sensor and Lenses are pre purchased. Ball bearings hold the modules and Axis rods parallel, one pasted to the inner side and another pasted on the outer as shown in figure. The storage module will have spaces to keep other sample slides, extra and cover slips and dropper.

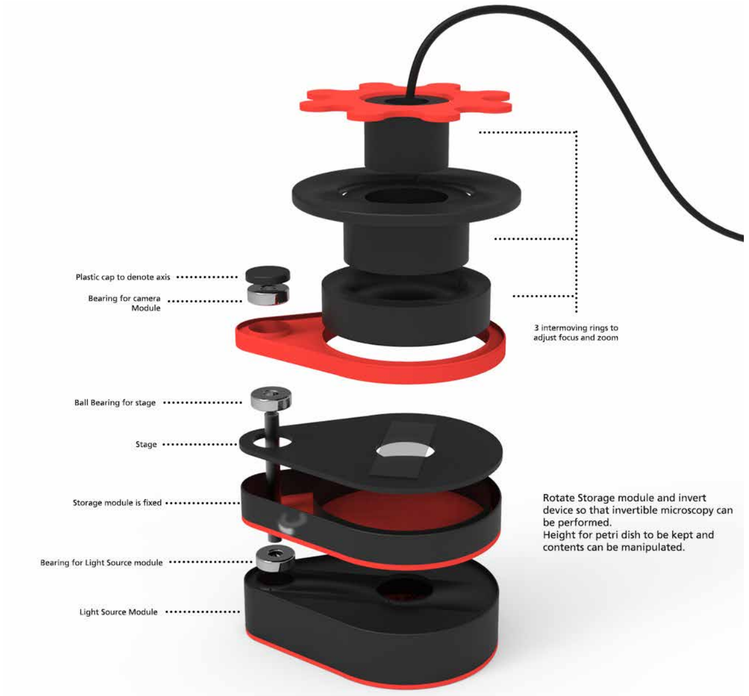
While prototyping, the storage space was initially at the bottom but now the light source module is at the bottom to provide weight and support invertible configuration.



Proof of concept/ prototype model

Prototype visualization





9. Packaging & Branding

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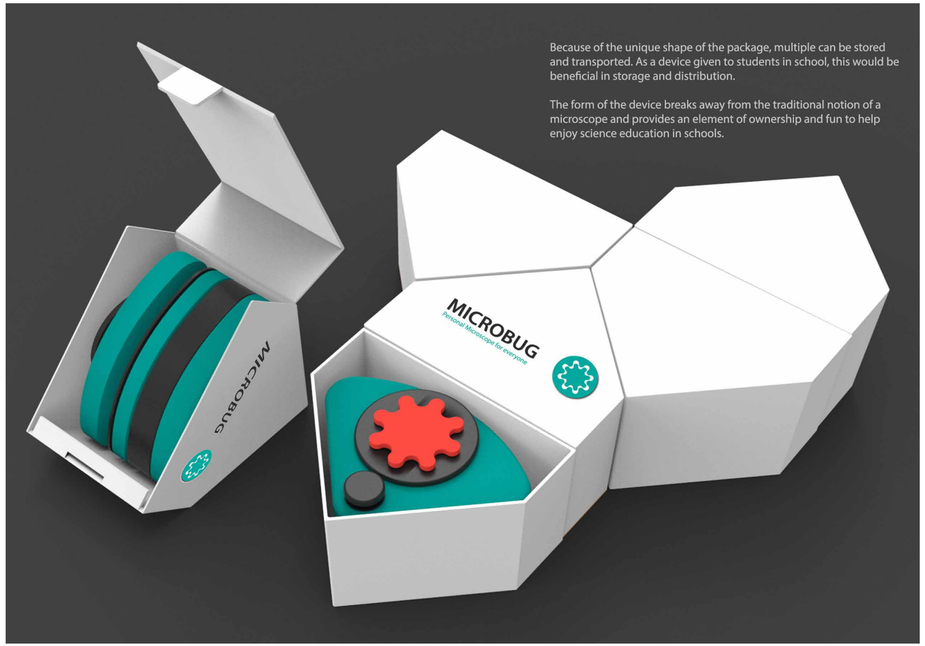
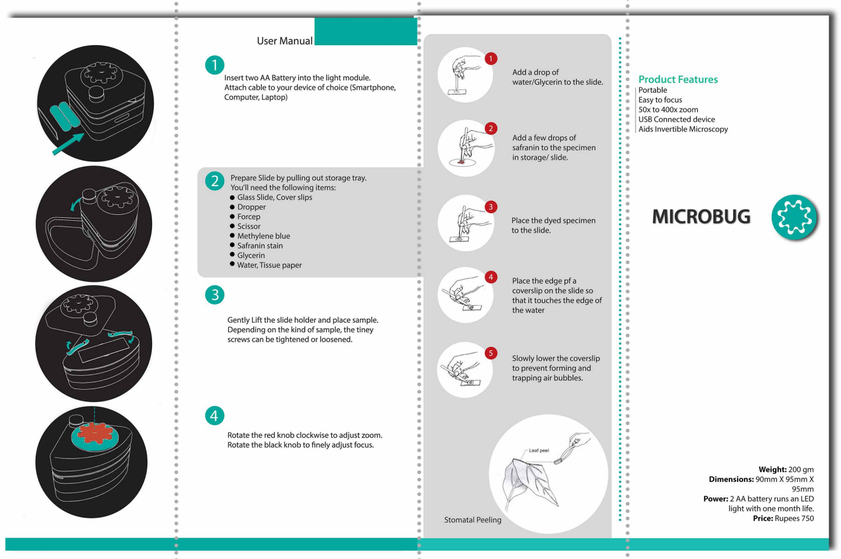


Because of the unique shape of the package, multiple can be stored and transported. As a device given to students in school, this would be beneficial in storage and distribution.

The form of the device breaks away from the traditional notion of a microscope and provides an element of ownership and fun to help enjoy science education in schools.

Instruction manual and Learning kit

Foldable design for easy packaging



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