EDUSCOPE

Empowering the students at I.O.Me 001 to develop digital microscopes targeting low-resource secondary schools in Kenya

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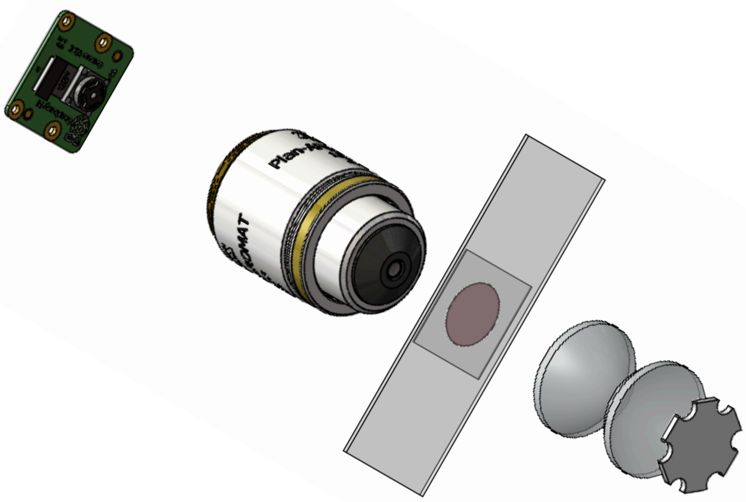
Abstract

This research, part of the Master Integrated Product Design Engineering at Delft University of Technology, is a collaboration between Red Cross Kenya, TUDelft, INSPiRED, the MakerSpaces of I.O.Me 254 and its participating students.

Originating in the 2021 Advanced Embodiment Design course at TUDelft, the Eduscope project aims to improve microscopy accessibility in Sub-Saharan African countries. Leveraging accessible manufacturing technologies, such as 3D printing, and collaborating with local MakerSpaces, it empowers communities by giving them control over the project and enables the fabrication of low-cost digital microscopes.

The Eduscope project has focused on real-world testing at I.O.Me 254, serving as a crucial testing ground and incubator. This research builds on this collaboration, starting with an in-depth exploration of Eduscope V2 and the MakerSpace at I.O.Me 001 in Mombasa, Kenya. Three categories, featural, structural & sourcing improvements, were identified, but more essential four missing pieces between the I.O.Me 001 students and the projects' success were unveiled. Continuing on the four missing pieces, Understanding, Curiosity, Trial & Error and Independence the research goal of "Empowering the students at I.O.Me 001 to develop digital microscopes targeting low-resource secondary schools in Kenya" was outlined. With this research goal three deliverables have been developed to ensure a holistic approach.

The Eduscope Rig is an essential tool in initial recruitment of the students by fostering curiosity and understanding. Next to the educational function, the Rig functions as an essential design tool by boosting Trial & Error practices and reducing supply chain independencies. The Eduscope STEM project is a series of workshops crucial to bringing the students up to the level where they can make actual improvements to Eduscope products. Lastly, the Eduscope V3 Prototype serves as tangible and visual presentation for the three improvement categories, creating an updated reference point for the students and boosting the development of the Eduscope V3.



Let's magnify knowledge, amplify experience and spark curiosity together!

Acknowledgements

During my journey through this graduation project, I have received invaluable support, and I would like to express my gratitude to everyone who has contributed to its success.

During my three-week field research in Mombasa, I.O.Me 001 provided a nurturing environment. Derrick, Nassor, Umi, and Mike ensured my safety and fostered a positive working atmosphere. I extend my heartfelt thanks to the technical students who participated in the Eduscope project at IOMe001 for warmly welcoming me and generously sharing their motivation and knowledge. Additionally, I am grateful to Fast Funding and Delft Global Initiative for their support, which made the field research possible.

My supervisor team has been exceptionally supportive, engaging in fruitful conversations, guiding me in project reflections, and helping me establish a coherent project structure. I am deeply thankful to Prof. Jan-Carel Diehl and MSc. Stefan Persaud for their consistent encouragement and guidance throughout this process.

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Executive Summary

The Eduscope project addresses educational and healthcare challenges in underserved regions like Kenya, offering a digital microscope manufactured using off-the-shelf components and accessible technologies like 3D printing. Unlike other digital microscope projects focused on low-cost diagnostic devices, the Eduscope prioritizes boosting local medical professionals by targeting microscopy education in low-resource secondary schools.

Originating in 2021 as a case study at TUDelft IDE, the Eduscope initiative has broad potential impact. This research, however, maintains a focused approach on the MakerSpaces of I.O.Me 254 to ensure real-world testing and refinement.

This master thesis follows the four stages of the double diamond method. In the Discover phase, a field research at the MakerSpace I.O.Me 001 in Mombasa, Kenya, was conducted to examine the previous Eduscope Prototype (V2) and the participating students. While these students, primarily from the Technical University of Mombasa, displayed potential for the Eduscope development, the project had yet to realize their full potential. Issues included a lack of foundational ‘understanding’ in microscopy, limited ‘curiosity’ sparked among students, challenges in facilitating ‘trial-and-error’ practices and a lack of ‘independency’ due to complexities in the Eduscope V2 design. Parallel to these four missing pieces the Eduscope V2 design analysis uncovered three main categories for improvements, featural, structural and sourcing improvements.

In mitigating the four missing pieces and in boosting the development of an improved Eduscope Version this master thesis outlines three deliverables. The Eduscope Rig deliverable has been extensively used in this master thesis to shape the first workshop for Eduscope STEM project deliverable, but also has been used as a design tool to compare and validate the choices for the improvements incorporated in the Eduscope V3 Prototype deliverable. All three deliverables hold a promising future in the further development of the Eduscope. While the first workshop of the STEM project concluded successfully, completing the full series of 15 workshops is essential to ensure the Eduscope's success and rapid deployment to low-resource secondary schools in Kenya.

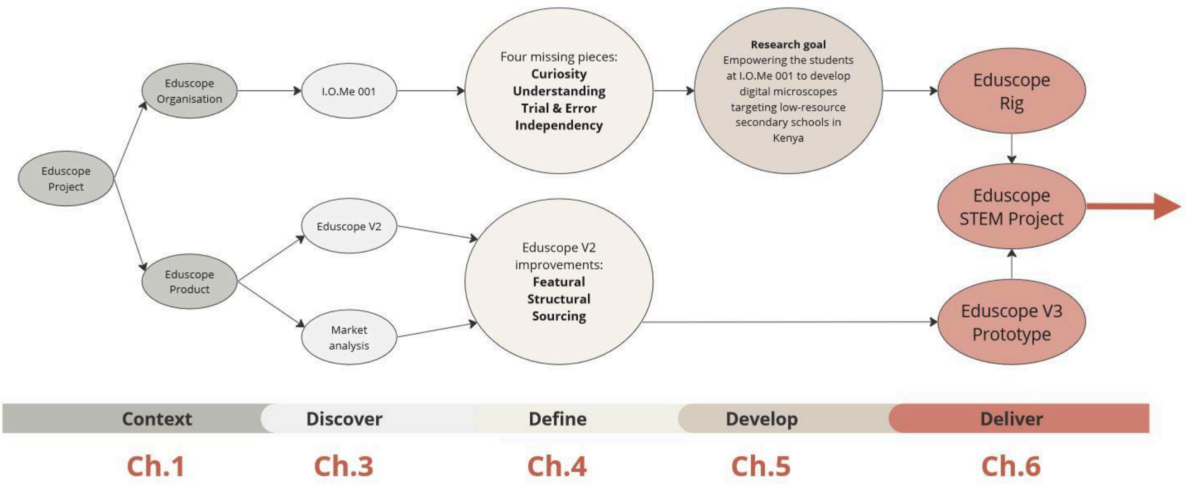
Project Methodology

This section details the methodology applied in this master thesis, employing the Double Diamond design approach, a framework renowned for its effectiveness in structured problem-solving.

The Double Diamond comprises four fundamental phases: Discover, Define, Develop, and Deliver. These phases entail both divergent and convergent thinking, allowing for:

Discover: exploration of diverse areas (Diverging)
Define: identification of specific problem areas (Converging)
Develop: development of potential solutions (Diverging)
Deliver: refinement of the final concept (Converging)

Throughout this interconnected design process, the Double Diamond structure has served as a guiding framework. The visual below presents a representation of this Double Diamond overlaying the design process timeline, facilitating a comprehensive understanding of the research journey and report structure.



1. Context

This chapter explains the relevant context of the Eduscope project. It introduces the project, its products and its stakeholders.

1.1 Project Introduction

The Eduscope project commenced in 2021 at TUDelft as part of the INSPiRED program, where two teams of master IPD students embarked on a semester-long endeavor to produce a functional Eduscope prototype. Their primary aim was to enhance access to microscopy education in high schools across Sub-Saharan African countries, with a specific focus on collaboration and fabrication at the MakerSpace of I.O.Me 254 in Lamu. Following their research, two prototypes, V1A & V1B, were developed, as depicted in Figure 1.1. Subsequently, four students behind the Eduscope V1A continued refining the prototypes, leading to the emergence of the latest iteration, V2, in January 2022.

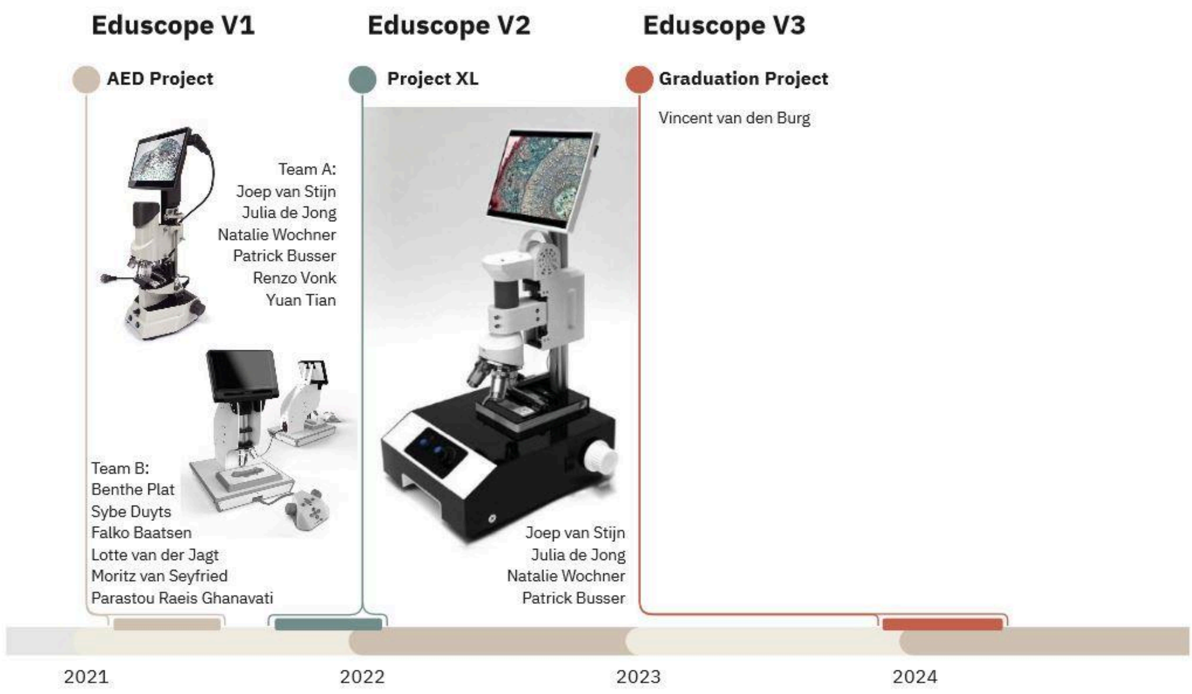


Figure 1.1 The Eduscope timeline

This master thesis builds upon their findings and proposes further steps for advancing the Eduscope project. The primary objective of the Eduscope is to cultivate a passion for science among secondary school students in low-resource Kenyan communities and nurture local medical professionals to enhance healthcare and promote independence. This is achieved through the creation of an affordable and customizable digital microscope. The proposed Eduscopes therefore use off-the-shelf components and the manufacturing technologies available at the MakerSpace in Lamu. With the digital imaging and connection to a display the microscopy education at low-resource secondary schools is made more cost-efficient as it enables many students to see the live preview simultaneously.

As of 2023, I.O.Me 254 has launched its second MakerSpace in Mombasa, called I.O.Me 001. The timeline of I.O.Me 254 has been included in Figure 1.2. This location has been the target of this master thesis as this master thesis immediately kicked off with a three-week field research at I.O.Me 001 to analyze the Eduscope V2, the context of I.O.Me 001 and the participating students at I.O.Me 001.

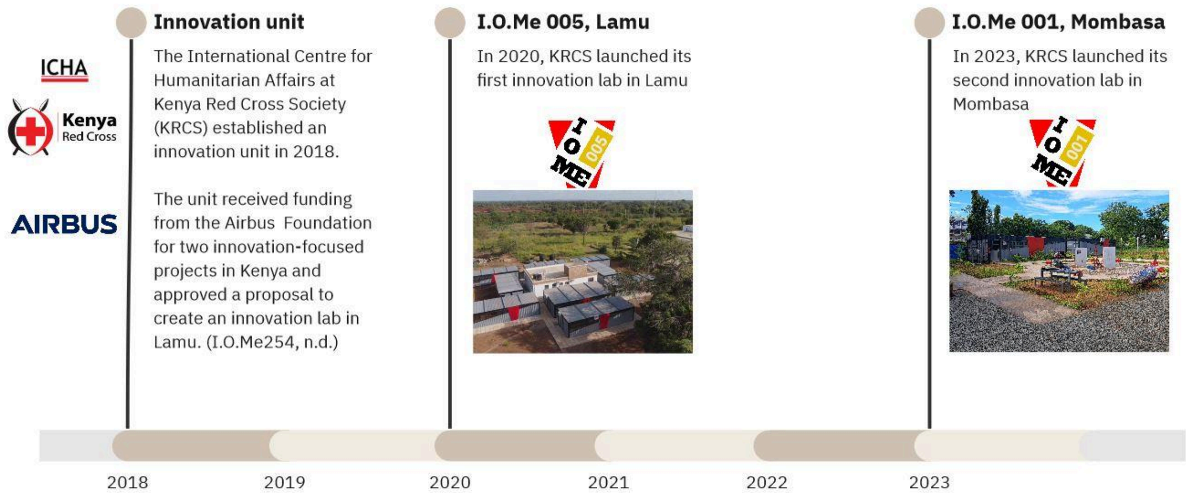


Figure 1.2 I.O.Me 254 timeline

1.2 Stakeholders

This chapter acknowledges the importance of stakeholders in the design process. Figure 1.3 shows the stakeholder map, which visualizes the interplay between the organizations and the people involved. On the subsequent page, the different parties are further described.

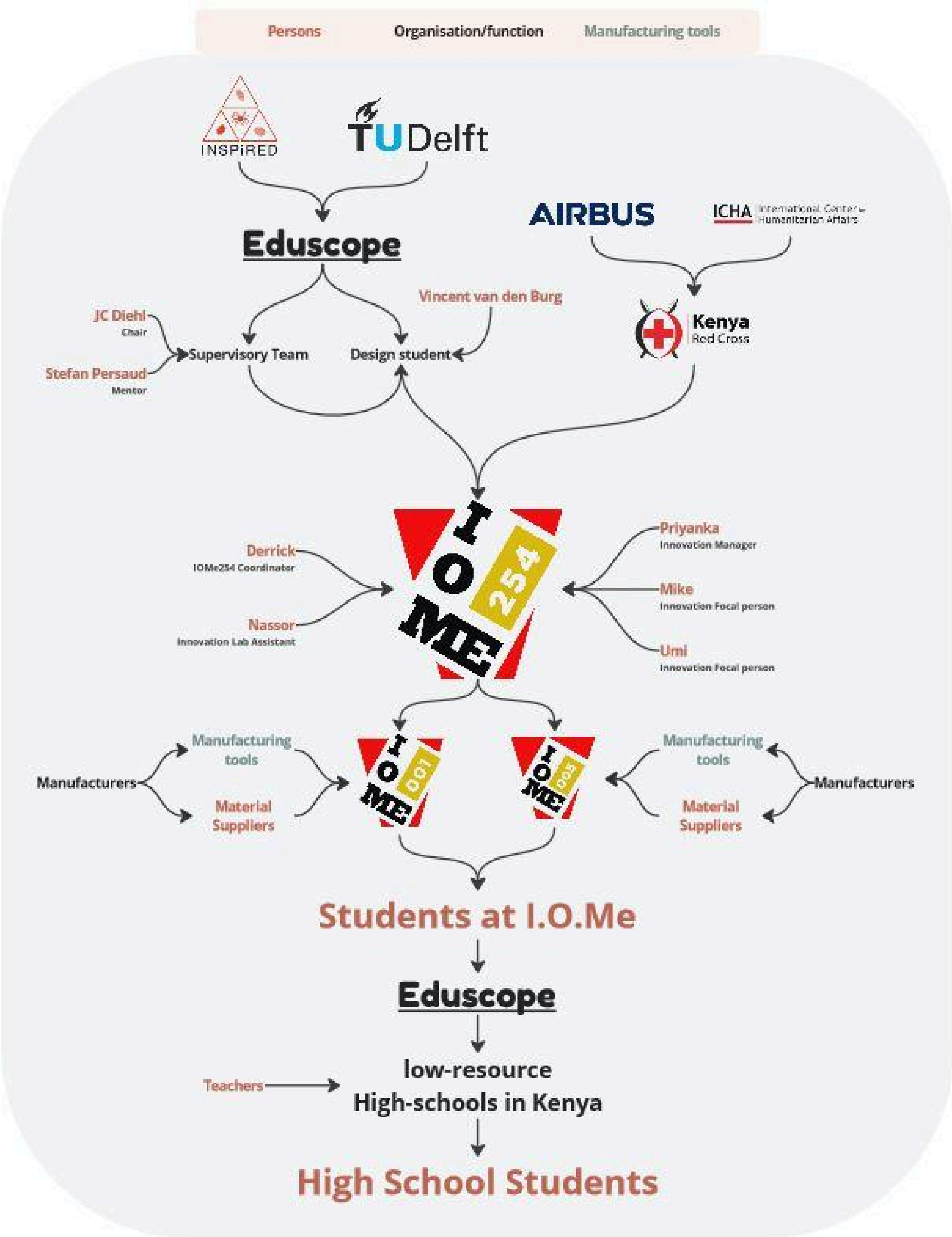


Figure 1.3 Eduscope Stakeholder map

INSPiRED is a research project for the development and validation of inclusive, smart, easy-to-use, cost-effective and efficient optical devices for the diagnosis of poverty-related parasitic diseases in Nigeria and Gabon (INSPiRED, n.d.).

INSPiRED is a collaboration between:
- Leiden University Medical Center (LUMC),
- Delft University of Technology (TU Delft),
- University of Ibadan in Nigeria,
- University of Lagos in Nigeria
- CERMEL in Gabon.

INSPiRED offers valuable experts, resources and inspiration for the Eduscope project. Although the Eduscope microscope is not focussed on diagnostics but on microscopy education it is in line with the vision of improving health care in similar areas, tackling the same Sustainable Development Goals.

Kenya Red Cross society

The Kenya Red Cross Society (KRCS) is a humanitarian organization dedicated to alleviating human suffering and promoting resilience in Kenya. Founded in 1965, KRCS operates nationwide, providing a wide range of services including disaster response, healthcare, blood donation services, community health and emergency preparedness & response training (Kenya Red Cross, n.d.). The organization works closely with communities, government agencies and other humanitarian partners to deliver timely and effective assistance to those in need.

KRCS is part of the International Red Cross and Red Crescent Movement, adhering to its fundamental principles of humanity, impartiality, neutrality, independence, voluntary service, unity and universality. Through its various programs and initiatives, KRCS strives to build a more resilient and compassionate society in Kenya. Notably, the MakerSpaces of I.O.Me 254 represent an example of these supported initiatives, providing local communities with access to technology and resources for innovation and development.

I.O.Me 254 serves as a nurturing hub for turning ideas into reality. The focal point lies in fostering innovations and ideas tailored for humanitarian interventions (I.O.Me254, n.d.). For this I.O.Me 254 offers multiple free services:

1. Digital Manufacturing, varied fabrication techniques for efficient, flexible product creation
2. STEM, students collaborate on projects, nurturing creativity and innovation
3. Training, diverse training workshops, from digital literacy to design thinking
4. Incubation, supporting startups and small businesses with commercial projects.
5. Innovation, collaboration hub for partners across sectors.
6. WSEI, empowering Kenyan women entrepreneurs with training, coaching and connections.

I.O.Me 254 operates through two MakerSpace locations, one in Lamu (I.O.Me 005) and one in Mombasa (I.O.Me 001). These MakerSpaces are innovative environments, constructed from repurposed shipping containers, offering the necessary infrastructure for innovation and development. Equipped with fabrication tools such as 3D printers and laser cutters, both locations facilitate rapid prototyping, custom fabrication and small-batch production.

The terms "MakerSpaces" and "fablabs" are often used interchangeably to describe similar collaborative environments and facilities. Both MakerSpaces and fablabs provide access to advanced manufacturing tools & equipment, foster creativity & innovation and promote collaborative projects & learning opportunities. While there may be slight differences in the specific equipment or focus areas between MakerSpaces and fablabs, the overarching concept of providing a space for making, tinkering and learning remains consistent. Therefore, it is common for these terms to be used simultaneously or interchangeably to refer to community-driven spaces where individuals can engage in hands-on activities and creative exploration.

Student at I.O.Me 001
The students who participated in the Eduscope project during this master thesis at I.O.Me 001 came from diverse academic backgrounds at the Technical University of Mombasa, including engineering, biology, physics, and computer science. These students represented various academic levels, spanning multiple years of study. Consequently, their participation showcased a broad spectrum of background knowledge and individual goals.

2. Foundational Knowledge

This chapter covers the topics which are fundamental to the understanding of the project and design choices.

2.1 Microscopy

Microscopy is the science of viewing objects too small to be seen by the naked eye. Figure 2.1 shows different objects, their size and which instrument is needed to be able to see it.

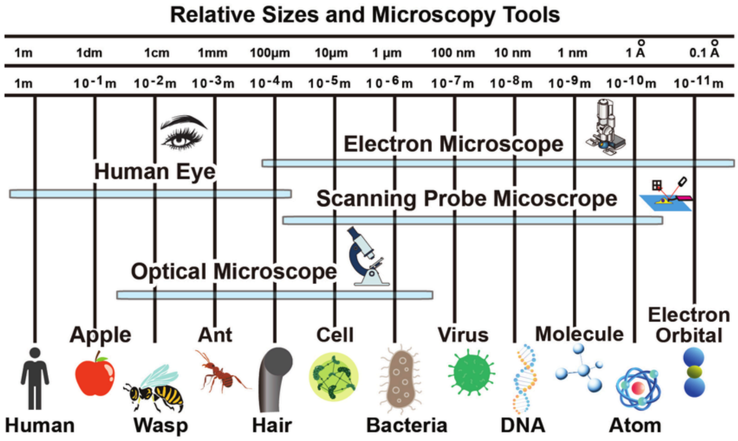


Figure 2.1 Microscopes overview (Review: Advanced Atomic Force Microscopy Modes for Biomedical Research, n.d.)

Optical microscopes use visible light and lenses to magnify objects. While Electron microscopes use beams of electrons to magnify objects and Scanning probe microscopes use a physical probe that scans the objects. While the electron- and scanning probe microscope can zoom in further they do lack the color. Next to that, the electron- and scanning probe microscope are industrial machines targeted at enterprises. An optical microscope is in comparison very simple and can be even found as children's toys.

Figure 2.2 shows the shape of a simple optical microscope and Figure 2.3 shows how the objective and the eyepiece work together in magnifying the image of an object. “A microscope's total magnification is a combination of the eyepiece and the objective lens. For example, a microscope with a 10x eyepiece and a 40x objective has 400x magnification. There are, however, a few limits to the amount of total magnification that can be reached before empty magnification comes into play. Empty magnification occurs when the image continues to be enlarged, but no additional detail is resolved. This is often the case when higher magnification eyepieces are used.” (MicroscopeWorld, n.d.).

Figure 2.2 Simple microscope (Tapui, n.d.)

Figure 2.3 A simplified microscope design (Edmund Optics, n.d.)

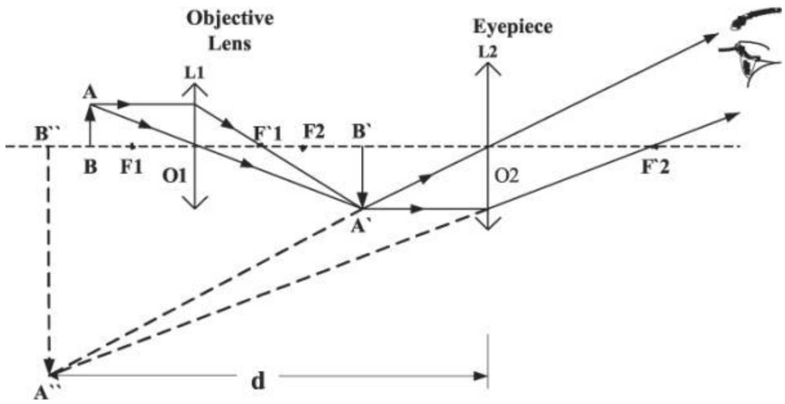


Figure 2.4 The optical principle of microscope imaging (Chen, Zheng & Liu, 2011)

Figure 2.4 shows a more detailed overview of the magnification principle used in optical microscopes. These optical microscopes have different magnification powers for objectives and eyepieces. The common magnification power of objectives are 4x, 10x, 20x, 40x 60x & 100x and for eyepieces 5x, 10x, 25x. In high school education most of the time the following configuration is used: 4x, 10x & 40x objective and 10x eyepiece (AmScope, 2022).

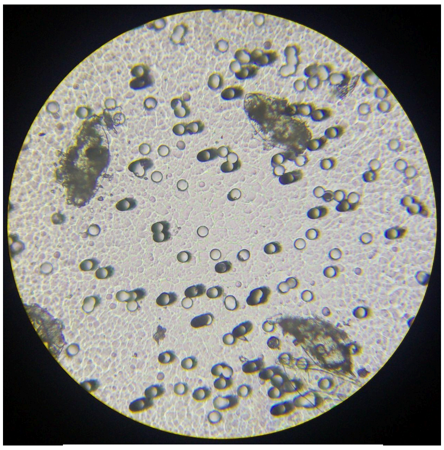


Figure 2.5 Schistosomiasis

Optical microscopes are commonly used in laboratory and educational settings to study the structure and function of cells, microorganisms and materials. In laboratories for example diseases are detected by examining blood/urine samples. Figure 2.5 shows the detection of schistosomiasis using a 40x objective and a 10x Eyepiece.

Unfortunately when magnifying an image using light the resulting image is prone to distortions just like the sunlight can be distorted by passing through rain droplets causing a rainbow. The optical microscopy is victim to distortions like spherical aberration, astigmatic aberrations, field curvature, and chromatic aberration. The rainbow is an example of chromatic aberration and Figure 2.6 shows how this aberration is tackled with the use of an Achromatic Lens.

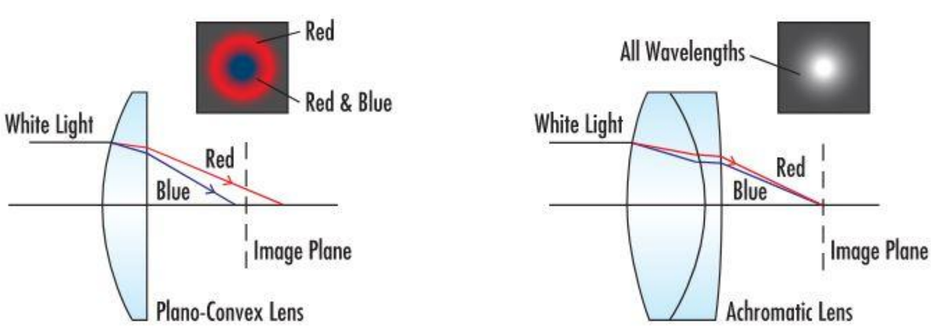


Figure 2.6 Chromatic Aberrations (Edmund Optics, n.d.)

2.2 Microscope classification

While various types of microscopes exist, optical microscopes remain one of the most common and versatile tools used in scientific research and education. Among optical microscopes, there are different categories catering to diverse needs and budgets. This chapter sheds light on these categories.

The components of a traditional microscope, often used in high school education, is depicted in Figure 2.7.

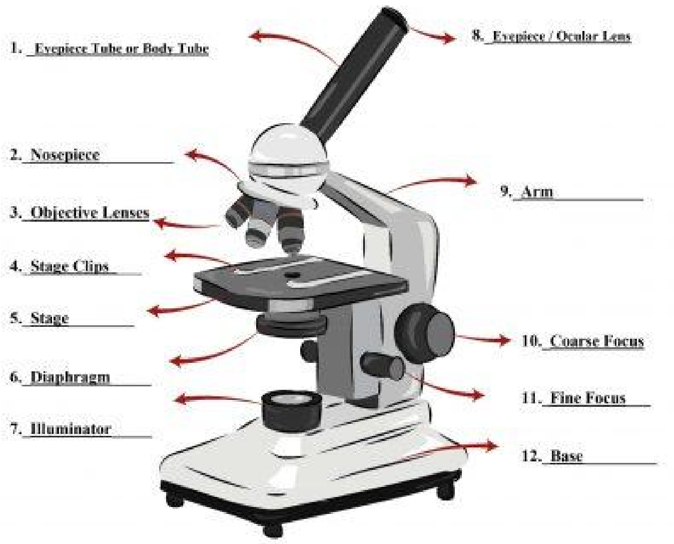


Figure 2.7 Parts of a Microscope (SmartSchoolSystems, n.d.)

An optical microscope, like the one above, that utilizes an eyepiece next to the objective lens is called a compound microscope. The objective and the eyepiece work together to magnify an image visible to the observer.

The optical microscopes can be categorized on their price range from:

1. Kids toys: Using low-quality materials to stimulate the first steps in the world of microscopy, starting at only 10 euro.
2. Student Microscopes: Affordable and simple microscopes designed for educational purposes, suitable for basic observation and learning. Starting at 50 euro.
3. Laboratory Microscopes: Mid-range microscopes offering enhanced features and specifications, commonly used in high schools and laboratory settings for research and analysis. Starting at 300 euro.
4. Research-grade Microscopes: High-end microscopes equipped with advanced optics, imaging capabilities, and accessories, ideal for demanding research applications and professional use. Starting at 2000 euro

Next to that, the optical microscopes can also be categorized based on their configuration, with two main types being monocular and binocular microscopes. The first features a single eyepiece for viewing and the other incorporates a second eyepiece. The binocular configuration offers the specimen to be viewed in stereo vision and is commonly used in laboratory and research environments. Viewing through a binocular microscope requires more training as the eyepieces need to be positioned correctly and the eyes need to be trained for this stereo vision. On the other hand, looking through a monocular microscope for a prolonged time often results in the user suffering from eye strain and fatigue. Therefore, AmScope (2022) recommends monocular microscopes to be used in classrooms & laboratories and Binocular microscopes to be used by scientists taking part in long observation periods.

Furthermore, optical microscopes employ various illumination techniques to enhance contrast and visibility of specimens:

- Bright Field Illumination: Standard illumination method where the specimen is illuminated from below, producing a bright image on a white background.
- Dark Field Illumination: Utilizes oblique or off-axis lighting to create contrast by illuminating the specimen from the side, particularly useful for observing unstained or translucent specimens.
- Fluorescence Illumination: Excites fluorescent molecules within the specimen using specific wavelengths of light, enabling visualization of specific structures or molecules with high sensitivity and contrast.

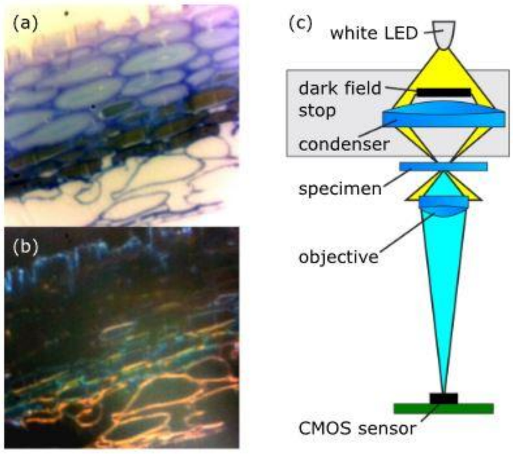


Figure 2.8 Dark field example (Sharkey, Foo, Kabla, Baumberg, & Bowman, 2016)

Figure 2.8 shows the comparison between Bright field illumination (a), Dark Field Illumination (b) and the dark field stop in (c) leading to the darkened background.

Lastly, optical microscopes may incorporate additional digital features and techniques to enhance functionality and usability.

- Digital microscopy: Utilizing a camera sensor to digitize the resulting magnified image, useful for sharing and storing your images. More on this in chapter 3.5.
- Autofocusing: Automated focusing mechanism that maintains sharp focus on the specimen, particularly useful for time-lapse imaging and prolonged observation.
- Auto Slide Scanning: Automated scanning of microscope slides to capture multiple images or create panoramic views, enabling efficient analysis of large sample areas.

In conclusion, optical microscopes offer a diverse array of configurations, illumination techniques, and additional features to accommodate various applications and user requirements. Understanding these classifications and techniques is essential for selecting the most suitable microscope for specific research, educational or professional needs.

With this introduction to the microscope classification, the standard microscope depicted in Figure 2.2 can now be understood as a monocular compound light field student/laboratory microscope.

2.3 Digital microscopy

Digital microscopy offers several advantages over traditional microscopy, especially in the context of low-resource secondary schools in Kenya. For example, as illustrated in Figure 2.9, by making microscopy digital more students can look through the microscope at once and utilize gamification to spark interest and engagement in scientific exploration.

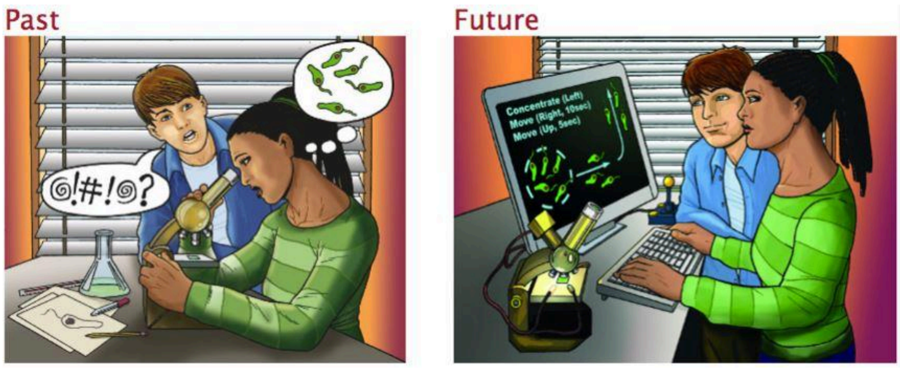


Figure 2.9 Digitized microscopy (Instructables, 2018)

This chapter sums up the key points of digital microscopy in the use case of rural secondary schools in Kenya, starting with the **benefits** it can offer:

1. **Increased Access**: With digital microscopy, multiple students can simultaneously view the specimen on a screen rather than waiting for their turn to look through a single microscope eyepiece. This not only enhances the learning experience by allowing for more interactive and collaborative exploration but also reduces the time needed for each student to complete practical exercises.
2. **Cost Efficiency**: While the initial investment in digital microscopy equipment may be higher due to the inclusion of electronic components such as cameras and display screens, the long-term cost savings are significant. Rather than purchasing multiple traditional microscopes to accommodate a class of students, a single digital microscope can serve the same purpose. This reduces the overall expenditure on microscopy equipment, making it a more cost-effective solution in the long run.
3. **Maintenance and Durability**: Rather than managing multiple microscopes, the maintenance of just one microscope suffices. The adoption of a digital microscope, which requires no more maintenance than a traditional microscope, enhances the longevity of microscopy classes. This is particularly crucial in Kenya, where coastal regions experience elevated temperatures, dust and humidity necessitating careful upkeep of equipment.
4. **Integration with Technology**: Digital microscopy integrates seamlessly with other educational technologies, allowing for innovative teaching methods and interactive learning experiences. Students can capture images and videos of microscopic specimens for further analysis and discussion, enhancing their understanding of complex biological concepts. Additionally, digital microscopy facilitates remote learning opportunities, enabling students in rural areas to access high-quality educational resources beyond the confines of the classroom.
5. **Resource Sharing**: In regions where resources are scarce, digital microscopy offers the potential for resource sharing among schools. Through digital platforms and

online resources, schools can collaborate and share educational materials, including digital microscopy images and videos, thereby maximizing the utility of existing equipment and minimizing duplication of resources. Next to that, the sharing of the digital microscope itself is also more convenient compared to transporting multiple traditional microscopes between schools.

On the other hand, there are **challenges** attached to the use of digital microscopes compared to traditional microscopes:

1. **Initial investment**: One digital microscope tends to be more expensive upfront compared to one traditional microscope due to the additional components such as cameras and an imaging processor.
2. **Complexity**: Digital microscopes may have a steeper learning curve compared to traditional microscopes, especially for users who are unfamiliar with digital imaging technology.
3. **Dependence on Technology**: Digital microscopes rely on electronic components, which may be prone to malfunctions or technical issues, leading to potential downtime and disruption of microscopy activities.
4. **Image Quality**: While digital microscopes offer the convenience of digital imaging and image capture, they may not always provide the same level of image clarity and resolution as traditional optical microscopes.
5. **Power Requirements**: Digital microscopes require more power sources to operate electronic components such as cameras, making them less suitable for fieldwork or environments with limited access to electricity.

Embracing digital microscopy offers rural high schools in Kenya the opportunity to significantly enhance the quality of science education. However, in designing such digital microscopes, efforts should be made to mitigate the challenges they may present.

2.4 Kenya

Kenya, located in East Africa, is known for its rich ethnic diversity, thriving economy, and stunning landscapes. Spanning a total area of 582,650km², Kenya is home to an estimated population of 47,564,296 million people. (Ochola, Karanja, Elliott, 2021). With over 40 different indigenous groups, including the Kikuyu, Luo, Luhya and Maasai, Kenya is a melting pot of diverse cultures (Mwakikagile, 2007).

Economically, Kenya is one of the leading economies in East Africa. However, challenges such as high unemployment and a significant informal economy persist. Income inequality is stark, with prosperity concentrated in urban areas like Nairobi, leaving many rural areas grappling with poverty and inadequate access to basic services (Kenya National Bureau of Statistics 2020). Despite improvements in health outcomes, the country still faces challenges with infectious diseases due to factors like poor leadership, corruption, inadequate healthcare workforce and weak public health policies (Ochola, Karanja, Elliott, 2021). These disparities manifest in distinct challenges and lifestyle preferences unique to each setting. To address the scarcity of educational resources and inadequate infrastructure, initiatives like Eduscope specifically target rural areas, aiming to bridge the educational divide and empower marginalized communities.

Agriculture is the primary economic activity in Kenya, but practices such as irrigation and fishing pose risks for the spread of Neglected Tropical Diseases (NTDs) such as schistosomiasis (Ochola, Karanja, Elliott, 2021). In fact, Kenya faces challenges with 18 out of the 20 NTDs listed by the World Health Organization suspected, confirmed or endemic to the country (Ministry of Health, 2022). These neglected tropical diseases (NTDs) are diseases of poverty that inflict severe human suffering and place a heavy toll on the social and economic fabric of over 1 billion individuals globally. These diseases primarily afflict vulnerable and marginalized populations in tropical and subtropical regions. (World Health Organisation, 2020)

Other similar digital microscope projects to the Eduscope, like the Schistoscope (Braakman, 2021), have a direct focus on these NTDs by automating NTD diagnostics. Figure 2.10 shows the resulting image of the Auto Slide Scanning technique used on a sample with Schistosomiasis.

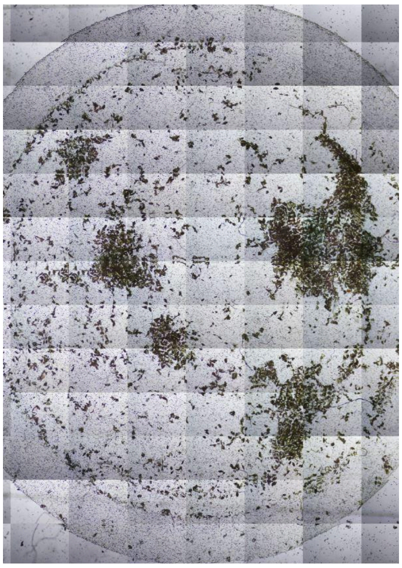


Figure 2.10 Auto Slide Scanning Schistosomiasis (Braakman, 2021)

3. Discover

This chapter sheds light on the previous Eduscope Versions and other digital microscopes. It starts by exploring the strengths and weaknesses of the Eduscope prototypes, the Schistoscope and the OpenFlexure microscope. The inclusion of the Schistoscope and OpenFlexure microscope stems from their focus on increasing accessibility to microscopy by leveraging simple manufacturing technologies, aligning closely with the ethos of the Eduscope project.

The "Strengths and Weaknesses" methodology used provides a framework for evaluating the performance and capabilities of each microscope in a simplistic and visual manner. This enables a comprehensive yet rich overview of insights into the design and functionality of digital microscopes.

Secondly, this chapter conducts a market analysis, mapping various digital microscopes based on their price and functionality within the educational domain. This comparative analysis offers valuable perspectives on the landscape of available options, guiding the understanding of and exploring the unique features and value propositions of each microscope.

Finally, this chapter shares the story and findings from my field research conducted in the beginning of the projectspan, where I collaborated closely with the technical students at I.O.Me 001 in Mombasa. This immersive experience provided firsthand insights into the practical applications and challenges of developing digital microscopes in a MakerSpace setting in Kenya.

The next chapter converges the findings from this Discover phase into the most critical insights for the continuation of the Eduscope project.

3.1 Eduscope V1A & V1B

The initial Eduscope prototypes both feature a Nosepiece with three objectives connected to a Raspberry Pi HQ Camera. Both versions have motorized the translation of this optics assembly. V1A employs a gantry plate mechanism with a leadscrew and stepper motor (Plat et al, 2021), while V1B utilizes a pre-built drivetrain from AliExpress (Busser et all, 2021). For the fixed vertical axis the V1A uses a 4020 frame while the V1B uses acrylic sheeting.

V1A adopts a traditional manual stage, more resembling analogue microscopy, while V1B employs a motorized stage further digitizing the microscope. Both versions utilize a Raspberry Pi for user interface and image processing, an Arduino UNO for motor control, and integrate a screen for direct digital interaction. The strengths and weaknesses of these microscopes are depicted in Figure 3.1 and 3.2 on the next page.

Figure 3.1 Eduscope V1A

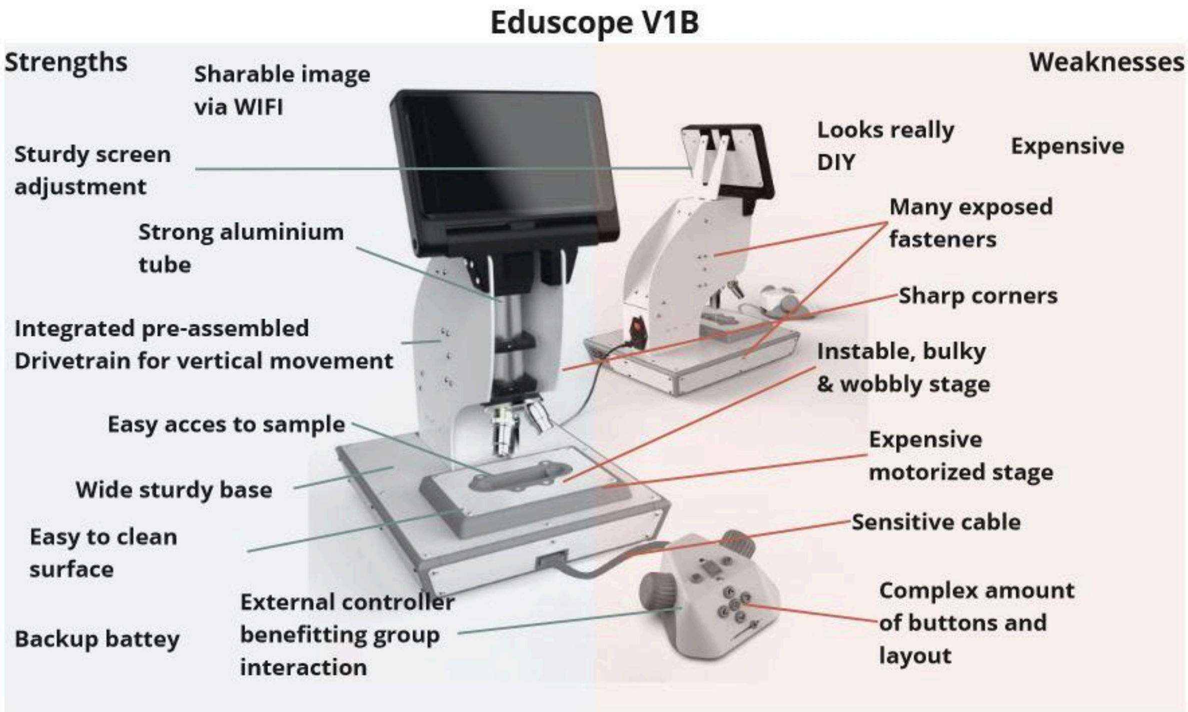


Figure 3.2 Eduscope V1B

3.2 Eduscope V2

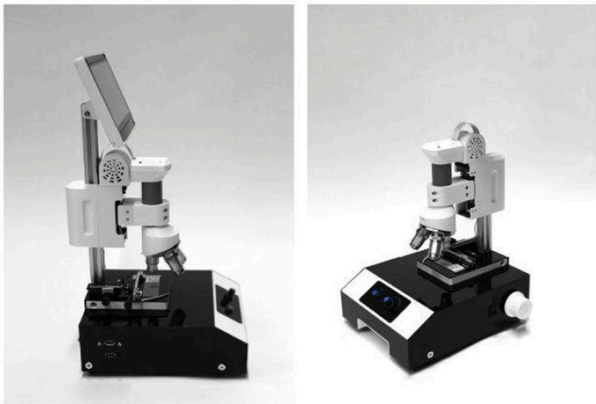


Figure 3.3 Eduscope configurations (Busser et al, 2022)

The second version of the Eduscope combines some aspects of the previous versions. The V2 uses the pre-build drivetrain to move up and down the optics assembly consisting of the Nosepiece with three objectives on one side and the HQ camera on the other side. The drivetrain has been fixed to a 2020 profile which also connects to a 7 inch display on top. This vertical axis mounts to the base structure which covers the electronics and an accu in a boxy shape. Just like the V1A the microscope makes use of a knob on the side to actuate the vertical movement. The V2 uses a manual stage for horizontal movement and a lighttower unit underneath for converging the lightsource onto the specimen. This lightsource is controlled via a potentiometer on the front which is located next to a button for capturing the magnified image of the specimen. The V2 utilizes a Raspberry Pi for the user interface and image processing and an Arduino UNO for the motor control (Busser et al, 2022). The Eduscope has two configurations one being with the integration of the screen and the other one without as shown in Figure 3.3.

The Eduscope V2 has been thoroughly analyzed during the Field Research at I.O.Me 001 in the beginning of the project. The documentation on flaws, construction difficulties and opportunities are attached to the Appendix B. The Strengths and Weaknesses visual depicted below summarizes these findings.

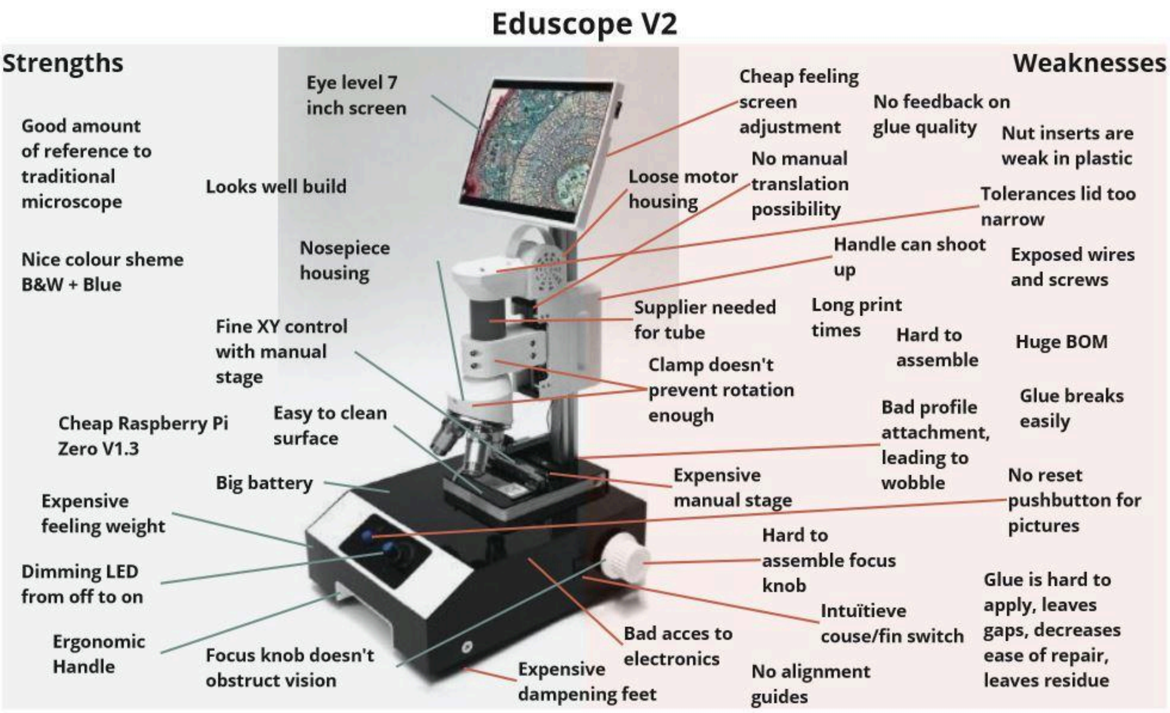


Figure 3.4 Eduscope V2

3.2 Schistoscope analysis

The Eduscope project has drawn inspiration from the Schistoscope project since its outset. While the Eduscope started in 2021 the Schistoscope started in 2019, but just like the Eduscope it started as a case for the Advanced Embodiment Design course in the master of Integrated Product Design at the TUDelft and is part of the INSPIRED Project. In the Figure below the timeline of the Schistoscope and its versions has been visualized.

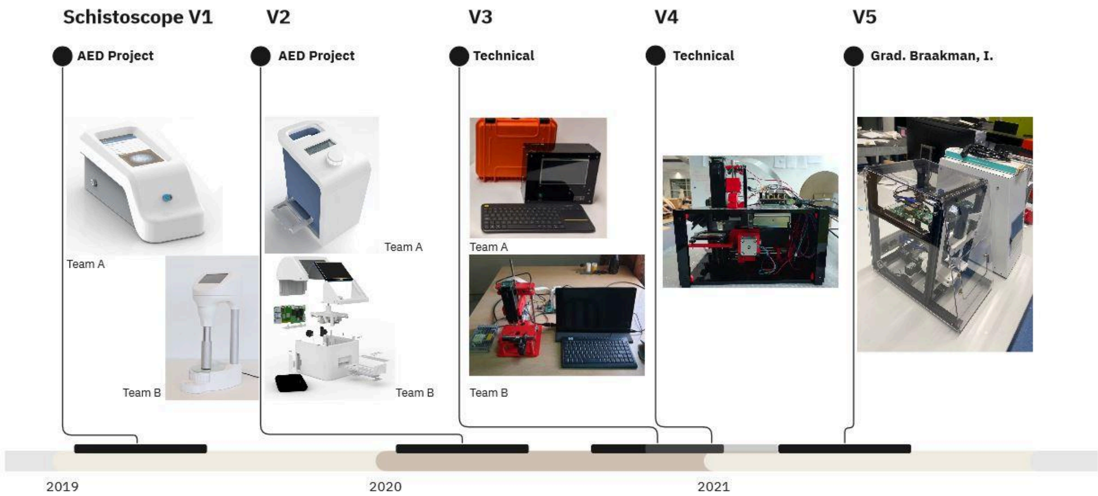


Figure 3.5 Schistoscope timeline

The Schistoscope uses motorized translations and machine learning to detect Schistosomiasis, a neglected tropical disease, in urine samples without the need for medical professionals. It takes pictures of the urine sample using a 4x objective lens and the Raspberry Pi High-Quality camera. Motorized translations are facilitated by three drivetrains, similar to those used in V1B and V2. Controlled automatically, the Schistoscope stitches magnified images together creating a whole slide analysis within 20 minutes (Braakman, 2021). The Figure below shows the Strengths and Weakness of the Schistoscope V5.

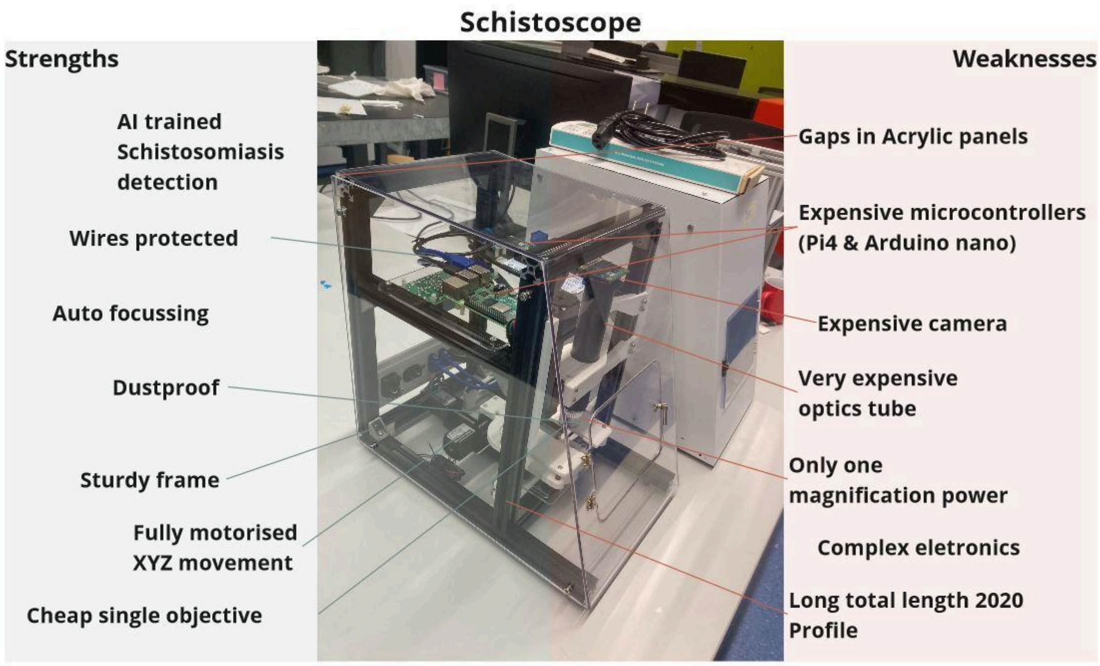


Figure 3.6 Schistoscope

3.3 OpenFlexure microscope analysis

The OpenFlexure microscope is an open-source, 3D-printed, and fully-automated laboratory microscope, with motorized sample positioning and focus control. This digital microscope has been already produced over a hundred times in Tanzania and Kenya for educational, scientific, and clinical applications (Collins et al., 2019) proving its functionality. Interestingly, this microscope uses plastic flexures for both the horizontal and vertical translation, meaning its motion is free from friction and vibration. Next to that, the inclusion of a plano convex lens in the optics tube has resulted in its small form factor.

The microscope has multiple configurations (Figure 3.7). One (left) configuration uses a 4x objective, a plano convex lens and a Raspberry Pi Camera Module v2. The second configuration is an innovative cheap solution to microscopy. “To create a microscope the wide angle lens is reversed and separated from the camera.” (Bowman & Stirling, n.d.). Another interesting aspect of this microscope is the inclusion of ridges in the optics tube to reduce internal reflections of the magnified image. The strengths and weaknesses of the OpenFlexure microscope are illustrated in Figure 3.8.

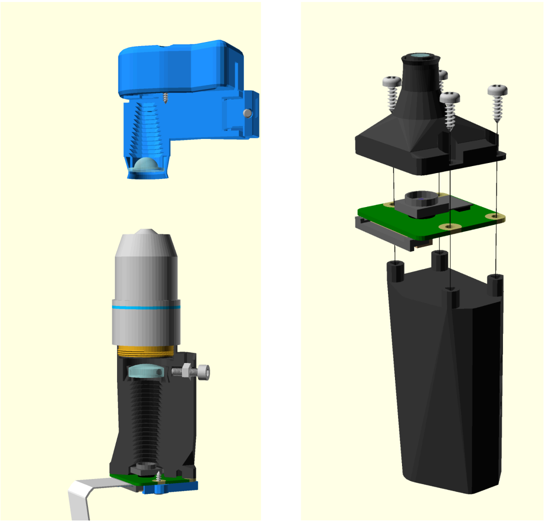


Figure 3.7 OpenFlexure configurations (Bowman & Stirling, n.d.)

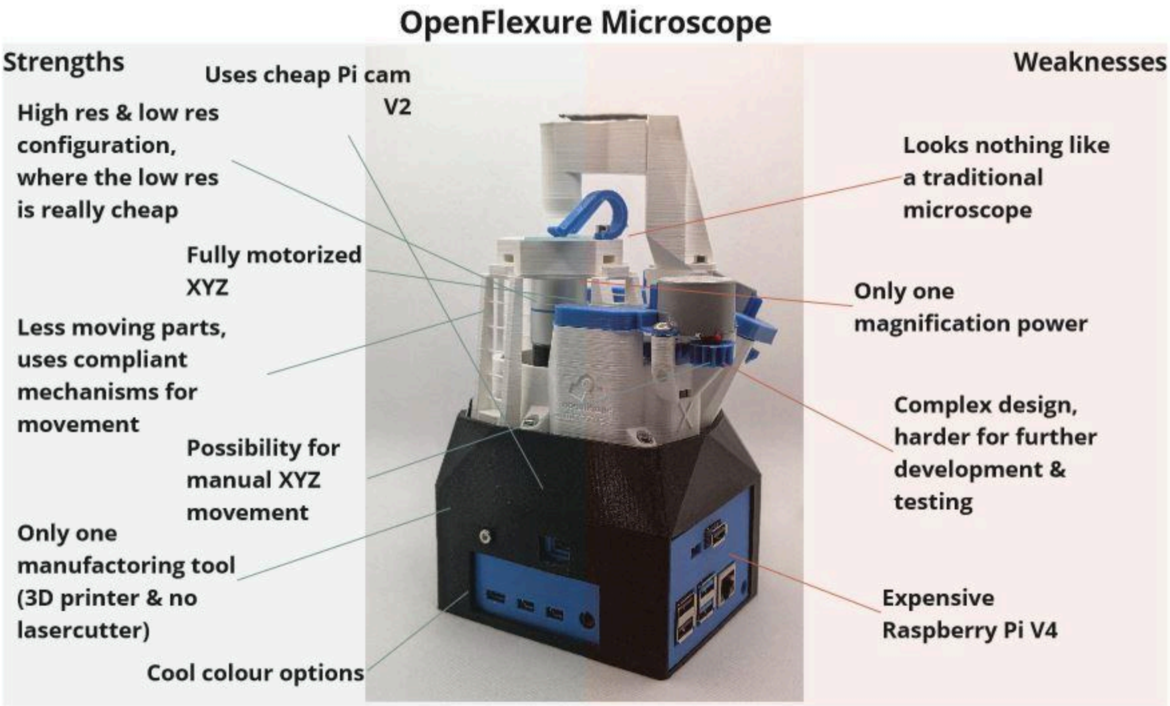


Figure 3.8 OpenFlexure

3.4 Market analysis

This section provides a comprehensive market analysis of digital microscopes, mapping them based on their usability in secondary school microscopy education in Kenya and their price range. The microscopes selected for analysis range from budget-friendly options below 100 euros to mid-range options around 800 euros, aligning with the affordability requirement of the Eduscope project. Excluding more expensive models ensures a focus on accessible alternatives for educational settings. The prices in the market analysis are estimates given by the reports in which these microscopes are found. It should be noted that because of material availability, price fluctuations, order quantity and location these prices differ.

Microscope grading is established through assumptions derived from an analysis of the materials and techniques employed for translation, embodiment and the user interaction. The functionality and performance axis aligns with the specific use case of the Eduscope project, prioritizing its practicality within rural secondary school settings in Kenya rather than emphasizing on functionality and performance in medical diagnostics.

By plotting these microscopes on an axis of usability versus price, intriguing alternatives to the latest Eduscope prototype are uncovered. What stands out are the differences in feature sets, like the motorized versus manual movements, the integrated versus external display connections and the viewing capabilities of analogue & digital versus digital only. As can be depicted from the market analysis the Eduscope V2 has a favorable position compared to the Eduscope V1s and the Schistoscope both in price and usability. The OpenFlexure while being less expensive scores lower on the usability scale because of its unfamiliar microscopy use and limitations in viewing capabilities.

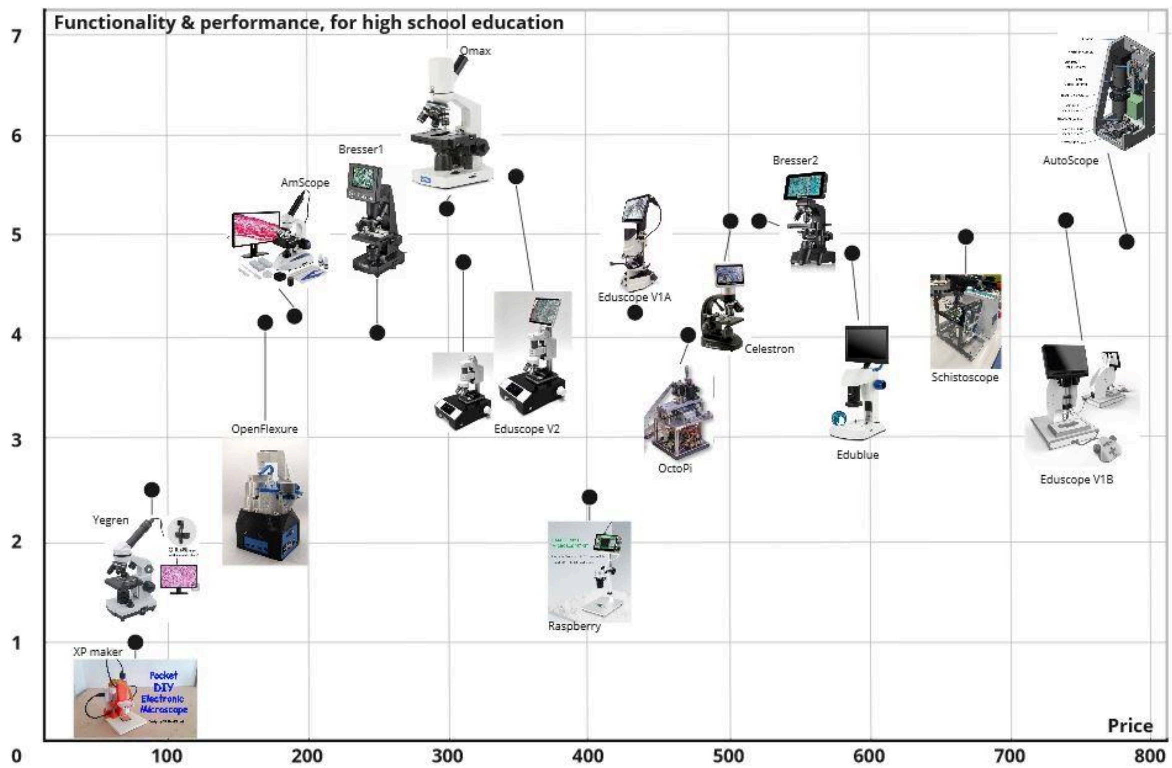


Figure 3.9 Market Analysis

One standout competitor identified through this market analysis is the Omax microscope. Offering both digital and analogue viewing capabilities, it enhances usability in high school microscopy education.

Figure 3.10 Eduscope V2 vs Omax MD810

3.5 I.O.Me 001 Analysis

During the initial three weeks of this research project, I conducted field research in Mombasa, Kenya, at the Makerspace I.O.Me 001. This involved close collaboration with the Makerspace employees and technical students who utilized the facility. Together, we thoroughly analyzed the Eduscope V2, initially exploring a pre-built version before constructing one ourselves. Throughout this period, we encountered numerous construction challenges, offering valuable insights into the project. We often had to employ creative solutions for missing pieces or tools and deepened our understanding of mechanics, electronics, and coding through trial and error. This section focuses on the fundamental role played by these ambitious Kenyan technical students in advancing and implementing the Eduscope project. A total of 14 students participated in this collaborative effort over the three-week period, all hailing from various disciplines at the Technical University of Mombasa. Despite differences in prior knowledge related to the Eduscope's disciplines, their enthusiasm and ability to quickly grasp concepts showcased their technical aptitude. Nevertheless, this section highlights the missing pieces between their science enthusiasm and their role in the Eduscope Project.

During the co-working sessions, I struggled to get everyone actively engaged in the assembly process. Also, it was tough to spark curiosity among all students, which made it difficult for some to grasp the Eduscope and start thinking creatively about the design. It felt the co-session was missing an interactive part in which the students could show their enthusiasm and expertise in tackling technical challenges. To illustrate my point, I use the exaggerated statement that the co-session felt more like a training for an assembly team rather than a workshop for a design team. So instead of asking to construct something following a manual the first practical sessions should involve tackling technical questions. Such questions will encourage problem-solving and critical thinking towards the Eduscope.

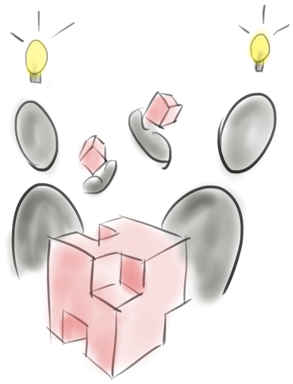


Figure 3.11 Curiosity

In Mombasa and upon returning to the Netherlands, I encountered significant challenges in reconstructing the Eduscope due to the unavailability of components listed in the Bill of Materials (BOM). Many of the third-party Eduscope parts, primarily sourced from Aliexpress, were not accessible. This underscored the critical need for the Eduscope project to 1. minimize its supply chain, 2. enhance the reliability of its suppliers and 3. reduce dependence on specific vendors. The technical students in Mombasa should be empowered with the redesign of the Eduscope. Moreover, the process of comparing and validating alternatives, when they are forced to switch to other suppliers, should be simplified and made time efficient. Currently, the Eduscope does not offer the flexibility to easily design for these and switch with these alternatives.

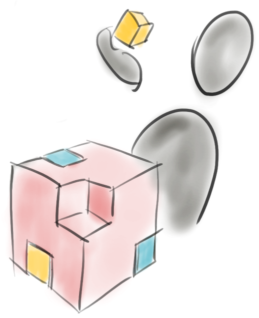


Figure 3.12 Independency

As non-optics students, I and the students found it challenging to fully understand the optics decisions detailed in reports such as the Eduscope, Schistoscope, and OpenFlexure. Additionally, it became apparent that the Eduscope remained somewhat abstract, both for technical students in Mombasa and myself. We encountered difficulties in understanding the microscope's components and how they collectively functioned. This lack of understanding highlighted a crucial gap: the Eduscope does not let the technical students explore the components and their interplay in a practical and engaging manner. By incorporating interactive elements that encourage hands-on interaction with the components, such as playful experimentation or tangible demonstrations, students can better grasp the microscope’s complexities. This approach encourages further research into the functioning and optimization of the Eduscope.

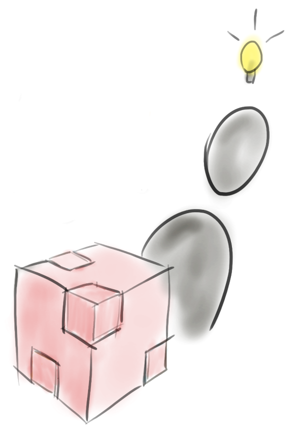


Figure 3.13 Understanding

In a discussion with Florian Bociort, an assistant professor at the TUDelft specialized in optics, the significance of practical experimentation over strict adherence to theoretical concepts was emphasized. Bociort highlighted that the theoretical calculations are too complex and too difficult to apply for this project. The applications used for these calculations take a long time to learn, which is a struggle in a young evolving team. Moreover, these calculations often rely on idealized materials, which may not accurately reflect the characteristics of components, especially those sourced from platforms like Aliexpress. Additionally, the challenge of determining these parameters alongside the unreliability of components also leads to the added complexity. All of the factors emphasize the importance of trial and error in the Eduscope, where hands-on experimentation allows for a better understanding of how different components interact and perform. Consequently, there is a need for a more flexible configuration for the Eduscope, enabling an iterative approach to product development aimed at optimizing performance.

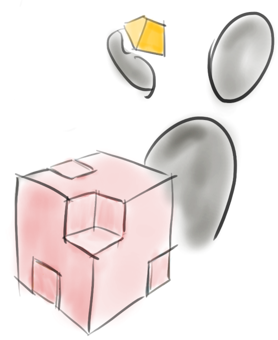
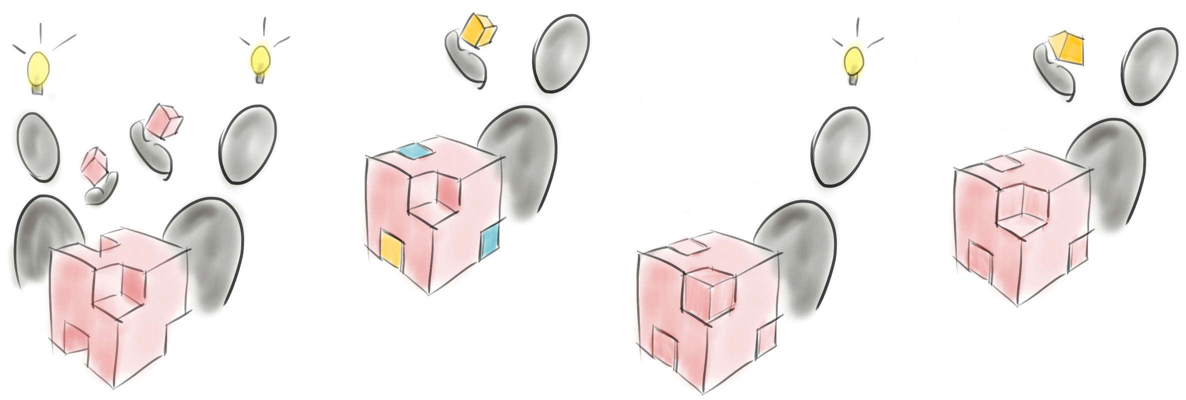


Figure 3.14 Trial & Error



4. Define

With converging the findings from the discover phase this chapter delves in on the necessity of a strategic shift in approach of the Eduscope project. Through the evaluation and analysis discussed in the previous chapter, this chapter consolidates these findings to explain why simply refining the existing Eduscope Version 2 will not be adequate. Instead the focus needs to be shifted to empowering technical students at I.O.Me to develop digital microscopes themselves. With this a research goal has been defined and this chapter concludes with mapping the challenges and listing the Requirements for this research goal. The next chapter, ideates on techniques and tools to shape this empowerment.

4.1 Converging the findings

The discover phase is categorized here in three sections, with the first one focussing on clarifying why the Eduscope project focuses on Microscopy Education. The second translates the findings from handling the Eduscope V2 and analyzing similar microscopes into the most interesting improvements. The last section, focusses on the findings from working closely together with the I.O.Me students and translating these findings into project opportunities overlooked by the previous Eduscope versions.

4.1.1 Clarifying the overarching projectgoal

As discussed in the introduction and previous Eduscope Documentation the Eduscope project focuses on improving healthcare in Kenya by increasing accessibility to microscopy in secondary school education. In the discover phase of the project multiple digital microscopes were analyzed, but not all of them had the same target group. Two distinct digital microscope functions were identified. One is the use of digital microscopy in the medical field and the other is using digital microscopy in the educational field.

Within the medical field, the digital aspect of the microscope functions as a diagnostic tool, aiding in the automated analysis of biological samples for the detection and identification of diseases. This function significantly enhances the efficiency and accuracy of disease diagnosis, particularly in resource-constrained settings where access to trained medical professionals may be limited. With digital imaging, results can be easily tracked and shared, improving both time-efficiency and accuracy. On top of that, additional digital features can be integrated. Adding motors to the axis enables autofocusing and enables the automation of stitching images together. Additionally, the incorporation of machine learning allows for the automatic detection of diseases. The Schistoscope is a perfect example of a medical digital microscope that leverages these additional digital features to create expert-independent, affordable and reliable diagnosis of schistosomiasis.

Although these medical digital microscopes offer expert-independent diagnoses it can not replace local medical expertise. Local medical professionals are indispensable in Kenya's healthcare system due to their intimate knowledge of the local context, including regional health concerns, cultural practices and patient histories. They play a vital role in translating diagnoses into effective prevention and treatment strategies tailored to the specific needs of their communities. Moreover, their ability to adapt and respond to unforeseen situations is critical in the resilience of the healthcare system. In situations where digital systems may be unavailable or malfunctioning, local medical professionals can step in to provide manual diagnosis and treatment, preventing disruptions in healthcare delivery.

The Eduscope project acknowledges the necessity of local medical professionals and therefore focuses on educating the next generation of local medical professionals by focussing on expanding access to microscopy education at rural secondary schools. In this educational field the digital microscope serves as an educational tool, facilitating interactive learning experiences in microscopy. The digital imaging microscopy education allows multiple students to engage simultaneously with specimens displayed on a screen rather than waiting for a turn to view through a single microscope eyepiece, increasing the cost-effectiveness of the microscope. Other benefits and challenges regarding the digital aspect of microscopy in the educational field were already thoroughly explored in chapter 2.6.

Summarized, two separate paths in improving healthcare in Kenya via digital microscopes are identified. One, like the Schistoscope, focuses on creating low-cost automatic sample analysis. The other, like the Eduscope, focuses on creating low-cost microscopy education. Both are needed to create a long-lasting positive improvement on the health care in Kenya, but the Eduscope microscope should strike a balance between features and cost with a core focus of creating low-cost microscopy education accessible to low-resource rural secondary (high) schools in Kenya.

4.1.2 Continuation on the Eduscope V2

The Eduscope V2 represents a breakthrough in digital microscopy for educational purposes. Manufacturable by the innovative I.O.Me Makerspaces, it seamlessly combines functionality with affordability and accessibility. The Eduscope V2 stands out for its advanced digital imaging and onboard computing features, adding a layer of interactivity and engagement to the educational experience, making the Eduscope V2 a versatile tool for modern classrooms. Featuring a Nosepiece with three commonly used objectives (4x, 10x, and 40x), it caters specifically to secondary (high) school educational needs.

Moreover, its precise motor control enables both fine and coarse focusing modes, mimicking traditional microscope functionalities. The modular display design ensures adaptability to various user preferences and requirements. Remarkably, all these advanced features come at an attractive price point of approximately 250 euros (36,000 KSH).

Although the Eduscope V2 is remarkable, during the V2- and market analysis many design opportunities were found. These opportunities, found in the discover phase, are further defined into the three categories of: feature improvements, structural improvements and sourcing improvements.

1. Feature improvements

One notable observation is the presence of creeping featurism in the Eduscope V2. While it offers advanced features like motor control and a built-in battery, these additions have resulted in a complex Bill of Materials (BOM) and increased dependency on specific suppliers.

Next to that, the integration of motor control, battery, and buttons has led to intricate electronics wiring, complicating assembly processes and increasing construction time and errors. This wiring complexity also hampers fault detection and repair capabilities, limiting the Eduscope's robustness and maintainability. Additionally, the current design lacks a scalable framework for future development, hindering its adaptability and evolution over time.

It is crucial for the Eduscope to strike a balance between added features and sourcing, construction and development constraints to ensure its sustainability and continued improvement.

Interestingly, both the Schistoscope and Openflexure microscope lack physical controls for motor movements, camera adjustments and illumination control. However, digitizing the physical interactions also poses a challenge as it can constrain hands-on learning experiences.

An alternative model, the Omax MD810, offers an intriguing approach by prioritizing simplicity and versatility. Unlike the Eduscope V2, the Omax MD810 features manual translation for both horizontal and vertical movement, resembling traditional microscopy methods. While it integrates a digital camera, it foregoes control buttons in favor of computer-based interface control via USB connectivity. Most notably, the Omax microscope provides both analog and digital viewing options, enriching the educational experience by offering students exposure to both traditional and digital microscopy techniques. This dual viewing option not only broadens students' understanding but also enhances the resilience of microscopy education by mitigating disruptions in situations where the digital system malfunctions.

The Omax microscope does have two notable disadvantages. First of all, the Omax microscope is not manufacturable at Makerspaces like I.O.Me as it uses uniquely machined and injection molded parts. Next to that, the Omax microscope's camera is of low quality, only 1.3mp, and relies on a connection with a computer to work while the V2 is a standalone device.

Summarizing, the current version of the Eduscope should be redesigned with an eye on keeping the BOM simplistic and the microscope resilient to changes. Next to that, the microscope should enable analogue viewing capabilities and manual translation in the situation the digital system, i.e. the camera and/or the motors, malfunctions.

2. Structural improvements

The current design of the Eduscope V2 faces several structural challenges that hinder its stability and durability.

First of all, the acrylic housing used in its construction proved to be unreliable due to difficulties in gluing and subpar material quality. Both part splitting, glue residues and surface cracks were found during the V2 analysis. Interestingly, the Eduscope V1s and the Schistoscope use less gluing of acrylic sheeting by screwing the acrylic sheeting flush to the components, the frame or the printed parts. With this the Eduscope V1s and the Schistoscope both achieve higher structural integrity of the acrylic sheeting.

Secondly, the mounting of the vertical axis and component positioning on this vertical axis proved to be unstable. During the analysis it was found that the vertical axis could not support the weight and therefore tilt forward. From the analysis, two vertical axis opportunities prevailed: 1. improving the vertical axis mounting to the base frame, 2. reducing the momentum created by the components on the vertical axis.

Within the second opportunity, alternatives were explored. For instance, the V1A model utilizes a gantry plate on a 2040 vertical frame, while the V1B employs acrylic sheeting as a structural frame. Next to that, examining other microscopes such as the Schistoscope reveals robust structural integrity achieved through a box frame constructed from the 2020s and 2040s. Additionally, the OpenFlexure microscope presents innovative solutions to reducing the undesirable momentum as it uses an additional lens to shorten the optics tube and thereby shortening the vertical axis.

Summarizing, the structural embodiment of the Eduscope V2 has multiple areas on which it can improve. First of all, it should improve on the construction techniques and eliminate the difficulties and unreliability of the glue. Secondly, it should have more structural framing behind its surfacing material. Lastly, it should increase the stability of the vertical axis by leveraging more fixation to the base and/or by decreasing the momentum force of the components by reducing, lowering and/or centering the mass on the vertical axis.

3. Sourcing improvements

Analyzing the sourcing strategy of the Eduscope V2 uncovers several areas for improvement aimed at optimizing procurement processes, reducing costs, and enhancing component reliability.

Firstly, the sourcing of the condenser lens from Thorlabs, while offering reliability, presents a significant cost challenge. Exploring alternative suppliers or materials could potentially mitigate expenses without compromising on quality. Moreover, the utilization of expensive dampening feet in the V2 design suggests an opportunity to investigate cost-effective alternatives readily available in the market. By leveraging cheaper alternatives without compromising functionality, overall production costs could be substantially reduced.

Secondly, the discovery of rust on the manual stage, acquired within the last three years, raises concerns regarding the longevity and reliability of that component in the context of Kenya. This emphasizes the need for more stringent sourcing practices to ensure the durability of critical parts. Next to that, the manual stage priced at ~15 euro (~2200 khs) also raises cost considerations and alternatives for the manual stage should be explored.

Furthermore, issues encountered with HQ cameras, also purchased within the last three years. The presence of dots on the IR filter obstructed the visibility of the specimen significantly in 3 out of the 6 HQ cameras present during the field research. This underscores the importance of sourcing more durable and easily maintainable camera components. This highlights the necessity of prioritizing component quality and longevity in the sourcing process. Next to that, the HQ camera priced at 60 euro (8700 ksh) also raises cost considerations and alternatives for the HQ camera, like the Raspberry Pi V2 camera in the OpenFlexure microscope, should be explored.

Summarizing, the sourcing strategy for the Eduscope V2 reveals areas for enhancement in cost reduction and component reliability. Firstly, alternatives should be explored for the Thorlabs condenser lenses and the expensive dampening feet. Secondly, for the manual stage exploration is necessary to find cost advantage and/or with higher durability alternatives. Lastly, the Pi HQ camera should be compared to the Pi V2 camera as it could improve durability and save a significant amount of money.

Redesign analogy

Through the combination of the feature, structural and sourcing enhancements a fitting analogy emerged:

"I envision the Eduscope to embody the simplicity, robustness, accessibility, and repairability of the Tuk Tuks found throughout Mombasa."

4.1.3 Strategic shift to empowerment

The Eduscope project focuses on developing low-cost digital microscopes for low resource secondary (high) schools in Sub-Saharan Countries. From the outset of the project fablabs have been acknowledged as outstanding manufacturing and development plants to enable local manufacturability. Together with the fostering of science education and local medical professionals using these fablabs further fosters the local independence, economy and science endeavors. Next to that, another benefit of using local technicians is that they are best equipped with understanding the requirements and wishes of their local communities and cultures. During the Eduscope V2 development the focus has narrowed to a specific fablab to enable a real world test scenario, which would ignite the field tests and production of the Eduscope. The chosen fablab of I.O.Me 254 in Lamu, Kenya, has proven its enthusiastic collaboration and shows much potential in putting this project to the market.

Unfortunately, the Eduscope V2 has shown many challenges which were necessary to tackle before starting the production engines. For these challenges three promising improvements categories have been identified, namely the feature, structural and sourcing improvements. While these improvements could have translated into the next prototype a more important aspect of this project has been identified during the field research of this research. While the technical students at I.O.Me would be able to assemble a microscope using the construction manual, curiosity, understanding, independency and trial & error were missing to enable further developments and make the Eduscope resilient to any changes given by the unreliable nature of marketplace suppliers, such as Aliexpress.

Instead of focussing on producing yet another Eduscope prototype this research therefore focuses on empowering the technical students at I.O.Me to develop digital microscopes themselves. Empowering the technical students at I.O.Me with the Eduscope project serves as a solution to the missing pieces of curiosity, independence, understanding and trial & error identified during the field research.

Firstly, the initial struggle to engage all students during assembly sessions indicates a need for a more stimulating approach. By shifting focus from mere assembly instructions to interactive sessions, that encourages exploration and questioning, sparks curiosity and prompts students to think creatively about design challenges. Empowered with curiosity, these students are more likely to remain involved over the long term and are better positioned to explore novel applications of the Eduscope products, providing valuable feedback for improvements.

Secondly, the challenges faced in sourcing components underscore the importance of minimizing the supply chain and reducing dependence on specific vendors. By involving students in the redesign process and simplifying the comparison and validation of alternative components, they become empowered to navigate supply chain challenges autonomously.

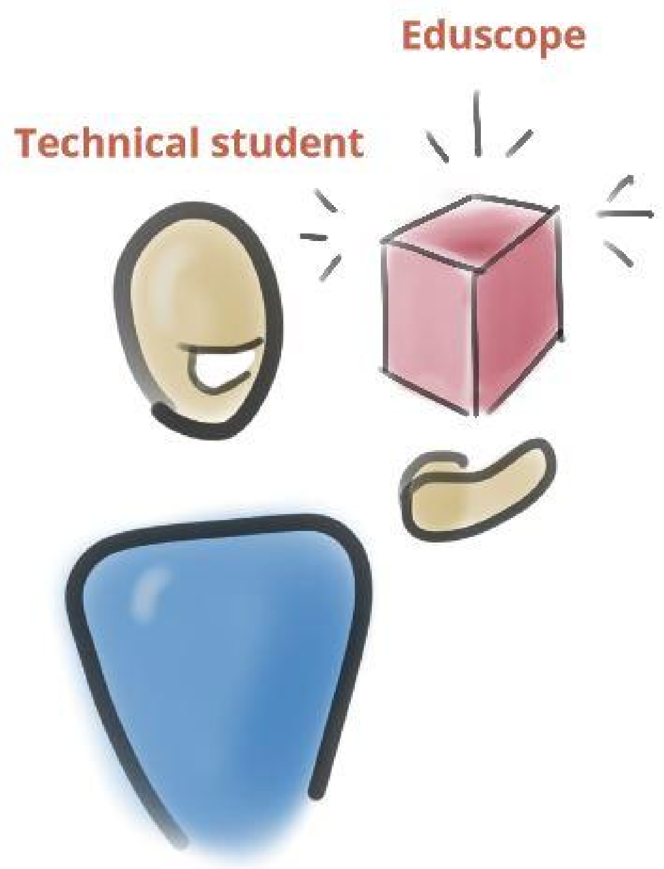
Thirdly, the lack of understanding of the microscope's components and their collective functioning highlighted a crucial gap in the project. Practical experimentation and hands-on interaction with the components empower the students with a deeper understanding of the technology. This understanding is vital for fostering a culture of innovation and continuous improvement within the project.

Fourthly, facilitating a culture of trial and error empowers the students with practical experience and use critical thinking skills. By providing students to interact directly with components and compare their performances, the Eduscope project promotes a more iterative and flexible approach to product development.

4.2 Goal Definition

Following the conclusion and explanation in the previous chapter this research continues on the following research goal:

“Empowering the students at I.O.Me 001 to develop digital microscopes targeting low-resource secondary schools in Kenya”



5. Develop

This chapter explores the possible directions in which the technical students at I.O.Me 001 can be empowered to develop digital microscopes targeting low-resource secondary (high) schools in Kenya. These directions were found using the mindmap methodology in combination with fast sketching. From this Mind Map the directions are further explained. One of these directions, an optics rig, is selected as the best direction. From that direction two additional directions, a STEM project and a V3 Prototype, have been combined with the optics rig. This chapter concludes with exploring the design evolution of the Rig and Prototype

5.1 Ideation, Empowerment of Technical Students at I.O.Me 001

The mindmap combination with fast sketching for finding the different directions is illustrated in Figure 5.1. The different directions are further described here.

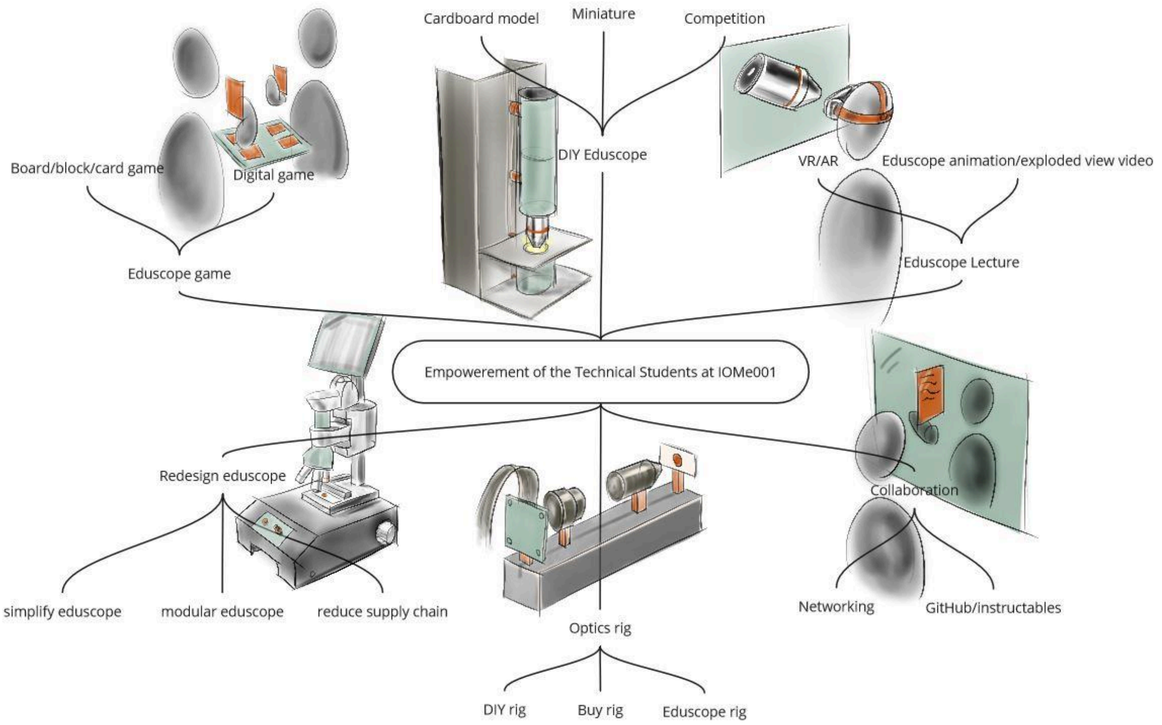
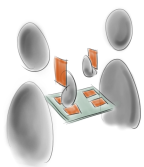
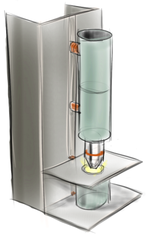


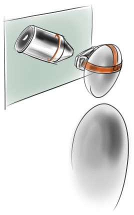
Figure 5.1 Empowerment ideation



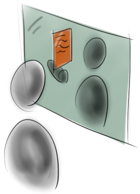
Eduscope Game
By transforming the complex Eduscope concepts into game mechanics, students are more likely to grasp technical aspects effectively while enjoying the learning process. Moreover, the collaborative nature of the game encourages teamwork and problem-solving skills, promoting peer-to-peer knowledge sharing and collaboration. Additionally, gamification provides a structured approach to learning, offering clear objectives and rewards, which can enhance student engagement and persistence in mastering the subject matter.



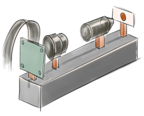
DIY Eduscope
By engaging students in hands-on craftsmanship, they cultivate a sense of ownership and pride in the project. Through crafting a 1-to-1 or miniature model of their envisioned Eduscope using materials like cardboard or other craft tools, students unleash their creativity. This tactile experience fosters a deeper understanding of the Eduscope’s design and functionality. Moreover, by actively participating in the creation process, students are more likely to remain invested and motivated in the project.



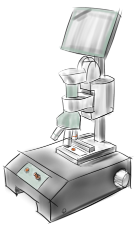
Eduscope Lecture
By leveraging the latest interactive and visually-rich educational experiences the Eduscope is intricately explained to the technical students. Utilizing sophisticated visualizations, students are guided through the design and functionality of the Eduscope in an immersive manner. These visualizations not only simplify complex concepts but also spark curiosity and deepen understanding.



Collaboration
By fostering open collaboration with individuals and organizations, students gain access to a wealth of knowledge and resources, enriching their understanding and guiding their development efforts. This open network ensures that students are less reliant on single project owners or knowledge holders, promoting independence and encouraging a culture of shared learning and innovation.



Optics Rig
By shaping a platform on which the optical elements can be moved and swapped the students are encouraged to learn the intricate concepts of optics and digital imaging in a playful and interactive manner. Next to shaping their understanding, such a platform functions as a sophisticated design tool on which the students can easily realize their ideas and compare the results fostering the design practices of trial & error, A/B testing and fast prototyping.



Redesign Eduscope
Through a modular design approach, the Eduscope is transformed into a more adaptable and versatile microscope, allowing components to be easily interchanged and upgraded. This modular framework not only simplifies the redesign process but also fosters a culture of experimentation and iteration, enabling students to explore different configurations and optimize performance through trial and error. Additionally, by streamlining the Bill of Materials and reducing dependencies on specific suppliers, students gain greater autonomy in sourcing components.

The different design directions are compared in reaching the research goal of "Empowering the students at I.O.Me001 to develop digital microscopes targeting low-resource secondary schools in Kenya". For this the Datum Method, as described in the Delft Design Guide (2016), has been used as it enables a visually comprehensive comparison between the ideas in reaching the goal. For this comparison, the goal has been divided back into the four missing pieces identified in chapter 3.5. The resulting comparison is visualized in Figure 5.2.

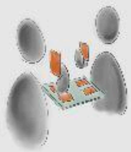
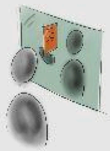
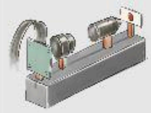
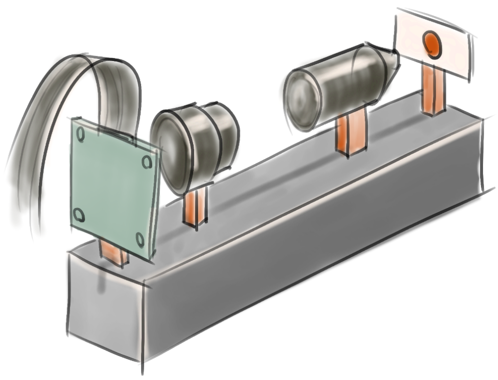
						
Curiosity	3	3	2	1	2	0
Independency	0	2	0	2	3	3
Understanding	2	3	3	2	3	2
Trial & Error	0	2	0	1	3	3
Total Score	5	10	5	6	**11**	8

Figure 5.2 Datum Method

Based on the Datum Method, the decision was made to develop an optics rig for the Eduscope project. This idea is further elaborated on in the subsequent section.

5.2 An optics rig



The optics rig idea of creating a platform facilitates hands-on learning and design experimentation, enhancing students' understanding and fosters innovation in the Eduscope development. The platform accommodates for easy element fixation on the same optical plane, aligning the different elements. The fixation leaves a freedom of movement across the length of the platform. This allows for the elements to slide away from and towards each other, unleashing the opportunity to understand the distances between the elements.
While the elements can be easily swapped and slide along the length the elements can also be fastened on the platform leaving no freedom of movement enabling great conditions for comparing different elements to each other, for example the Raspberry Pi HQ camera can be easily compared to the Raspberry Pi V2.1 camera.

5.3 A STEM project

An optics rig is a significant step towards empowering the students, yet further guidance is essential to propel them towards developing the next iteration of the Eduscope and bringing the Eduscope to production. While the rig facilitates initial engagement, sparking curiosity and creating understanding, the rig does offer little guidance in how further development should take shape. The rig does function as a design tool fostering independence and trial and error as well, but these design practices will not be activated directly after the initial engagement (see Figure 5.3). If these practises are only possible after further reading, the students will lose interest as acquiring that knowledge should be as interactive and hands-on as acquiring the initial understanding of optics and the Eduscope via the optics rig.

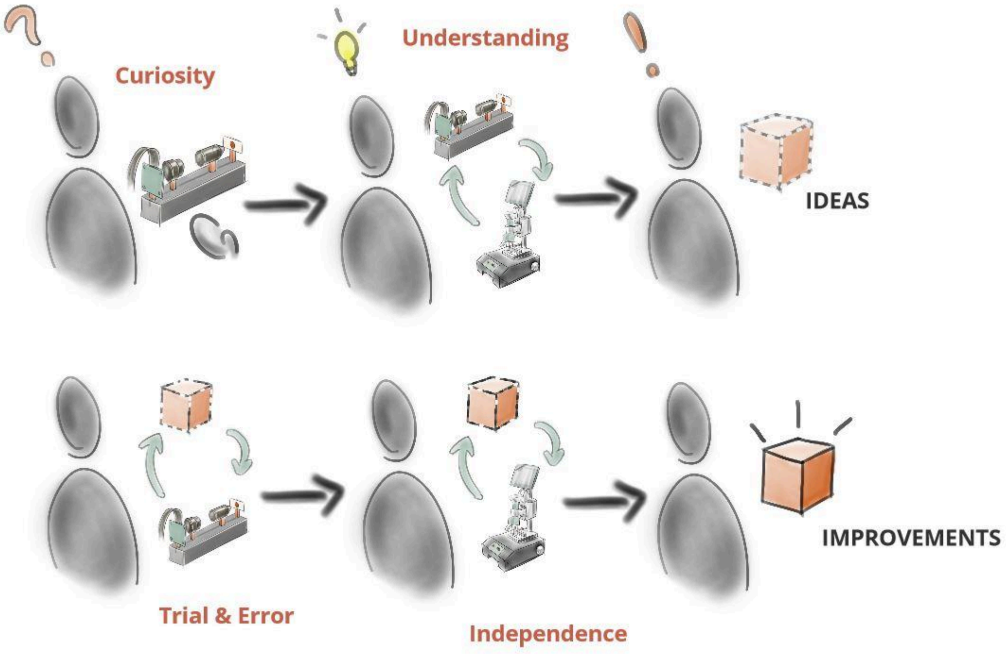


Figure 5.3 A STEM Project

Without the knowledge of ideation methodologies (e.g. Delft Design Guide (2016) methods like fast sketching, brainstorming and scamper) and engineering practises (e.g. SolidWorks, 3D printing and fast prototyping) the task of further development would not be in in reach for the technical students. As Lev Vygotsky (1978) describes it best, there is a space between what a student is capable of doing unsupported and what a student cannot do even with support. This space is where the student is able to perform, but only with support from someone with more knowledge or expertise.

A STEM project will offer the students a whole series of workshops which chronologically bring the students up to the level in which they are familiar not only with the optics and digital imaging but also familiar with design engineering practices focussed on the further development of the Eduscope device. Next to that, the social aspect of team building inherent in a STEM project encourages students to invest themselves fully in the project, forging strong bonds with their peers and inspiring a collective commitment to see the project through to its conclusion.

The optics rig serves as an ideal first workshop in the STEM project, offering a hands-on introduction to the principles of optics and digital imaging. Therefore, this research focuses on shaping this first workshop to effectively capture the students' interest and motivation.

Through careful planning and design, the optics rig workshop aims to create a stimulating learning environment that encourages active participation and inquiry. By providing clear instructions, demonstrations, and hands-on activities, the workshop empowers students to experiment with different optical configurations, fostering a deeper understanding of optical principles and their applications in microscopy.

However, due to time constraints, this research may only be able to provide recommendations for subsequent workshops in the STEM project. While the optics rig workshop lays a solid foundation, the following workshops will build upon this knowledge and delve into more advanced topics such as design engineering practices, digital imaging techniques and project management. These recommendations will guide the development of future workshops, ensuring that they align with the overall objectives of the STEM project and provide meaningful learning experiences for the students.

How the STEM project and in particular the optics rig workshop has taken shape will be further explained in chapter 6.2

5.4 A V3 Prototype

As illustrated within Figure 5.3, the optics rig and STEM project together will foster further development of the latest Eduscope version. However, this research has identified numerous enhancements for the Eduscope V2, the focus shift to the optics rig and STEM project hinder the translation of these enhancements into the next version of the Eduscope. Yet, it's crucial to visually represent these improvements. Without such representation, students may default to the Eduscope V2 as the baseline in their understanding and further development, hindering the adoption of the envisioned improvements. By translating the feature, structural and sourcing improvements, described in chapter 4.1.2, into a Prototype of the Eduscope V3 offers the technical students with an updated reference point, accelerating the fusion of insights from this research and further development. The Eduscope V3 Prototype therefore serves as a catalyst for further refinement and innovation, ultimately driving the Eduscope project towards its first launch of the Eduscope at low-resource secondary (high) schools in Kenya. How the Eduscope V3 Prototype has taken shape will be presented in chapter 6.3.

5.5 Design evolution Optics Rig

For the creation of the optics rig research has been conducted to explore various structural configurations. The most insightful configurations are illustrated in Appendix C. One of these configurations is illustrated in Figure 5.4. From this selection a categorization was found which separates the configurations based on their structural sliding rail. This categorization is visualized in Figure 5.5.

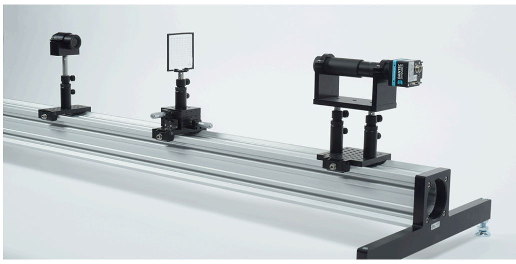


Figure 5.4 Square Optical Rig (Light Optical Bench - (SIPO-001)

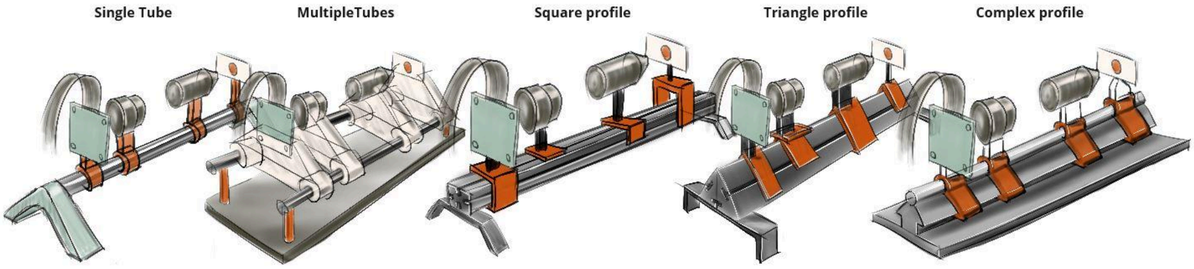


Figure 5.5 Rig structure categories

The single tube configuration was rejected due to concerns about the rotation of optical elements around its structure, which could compromise imaging quality. Although cost-effective, implementing rotation restrictions, such as using a 'D' shaped tube, would incur additional expenses or labor. Similarly, the complex profile option was deemed impractical due to its rarity and associated high costs.

While the multiple tubes configuration seemed promising, it was prone to friction issues as the tubes were spaced apart. Although linear bearings could address this, their cost-effectiveness was questionable, especially considering the need for two bearings per element.

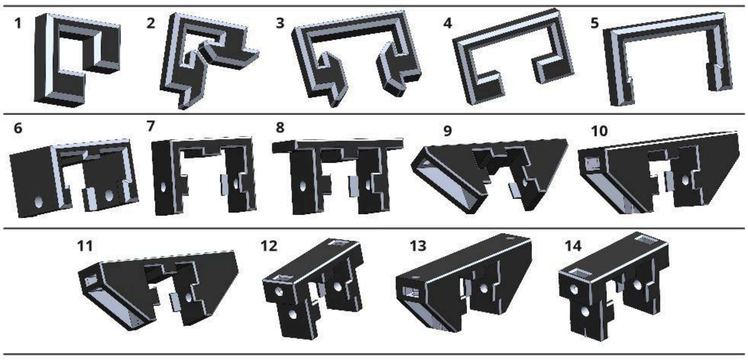
Alternatively, the square and triangle profiles could be achieved using the readily available 2020 profile, utilized in the Eduscope V2 and the Schistoscope V5. Widely used in DIY projects and domestic manufacturing, the 2020 profile offers affordability and accessibility. Its prevalence in these and other open-source projects provides ample examples for connection methods, making it a suitable choice for the rig structure of this project.

Figure 5.6 2020 Profile (123-3D.nl, n.d.)

The iterative design process, which transforms this simple 2020 profile into a sophisticated optics apparatus, is visually depicted on the subsequent pages. Chapter 6 will unveil the result of this evolution with the presentation of the “Eduscope Rig”.

After selecting the 2020 profile, the focus shifted to determining the structural and sliding attachment. Simple tests were conducted using SolidWorks and 3D printing.

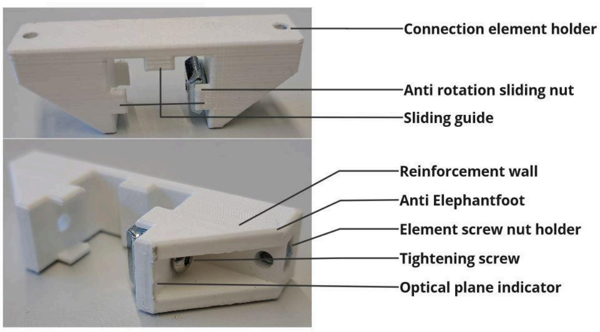
SolidWorks was chosen as the CAD program due to its availability at I.O.Me 001. These tests incorporated a draft on both sides to prevent an "elephant's foot," which leads to a wider first layer and inaccuracies (Avery, 2023).



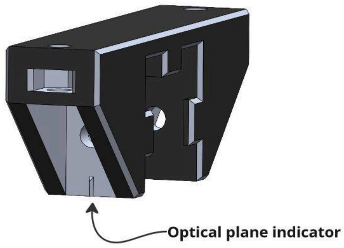
From the initial tests, depicted as the first five models in Figure above, the fourth and fifth tests were combined into a 6th model. This iteration accommodated the length of the m3 sliding nut, chosen for its common use as a fastener on 2020 profiles. Keeping the ElementHolder separate from the 2020Slider offered several advantages:

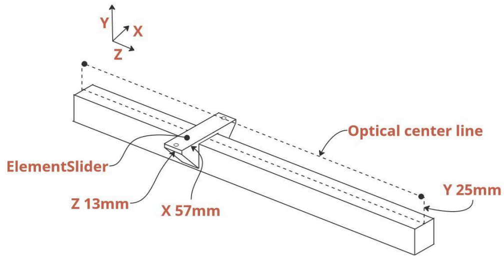
1. Simplified design of the ElementHolders, reducing complexity and design time.
2. Optimized orientation for 3D printing of both the 2020Slider and ElementHolder, enhancing strength and reducing the need for support material.
3. Repurposability of the 2020Sliders for other ElementHolders, decreasing printing time and material costs.
4. Ability to switch elements while maintaining the position of the 2020Slider, enhancing accuracy in comparisons.
5. Increased resilience to changes in the 2020 profiles, such as supplier variations or replacement with different structures, as not all 2020 profiles are identical.

The Figure above illustrates the fine-tuning of the 2020Slider to facilitate easy fixation of necessary optics elements and provide flexibility and accuracy in element positioning along the length of the 2020 profile. The chosen 2020Slider, number 13, can be easily affixed to the structure using a single screw and sliding nut. Additionally, the ElementHolders can be mounted on top using two press-fitted m3 nuts. These selections were made based on the common availability of m3 nuts and screws, which are also required for the m3 sliding nuts. The Figure on the left summarizes these features.

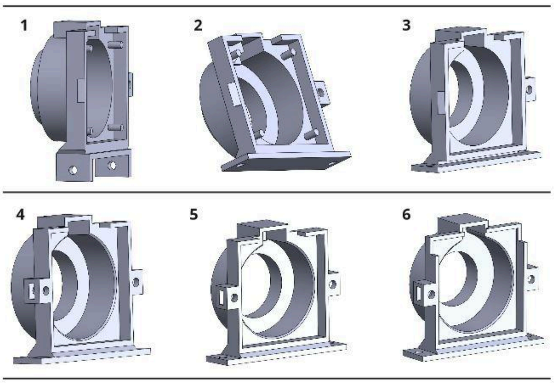


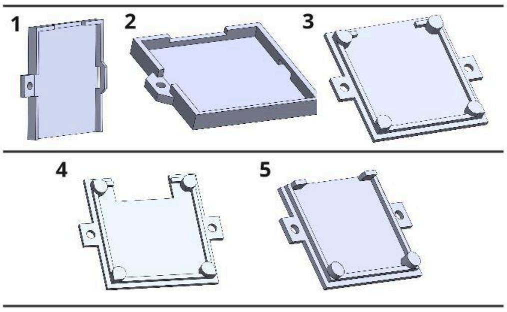
The 2020Sliders have an indicator in the middle of the slider (see the Figure on the left) to facilitate accurately measuring the distance between the optical planes of the elements. The Figure on the right outlines the main characteristics of the 2020Slider.





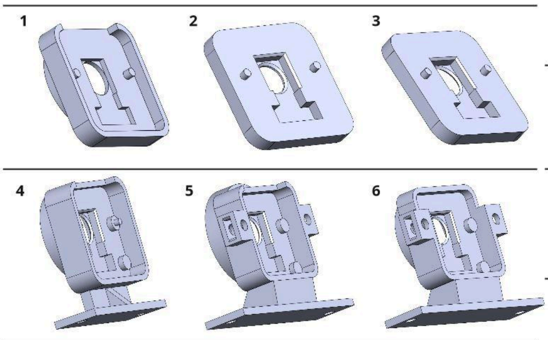
The ElementHolders fixate the elements' optical center above the optical plane indicator and on the optical center line as depicted in Figure on the top right. The design of each ElementHolders is visually presented on the following pages. Each ElementHolder uses a tight simplistic housing of the element while keeping fasteners to a minimum.

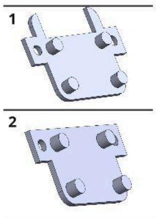


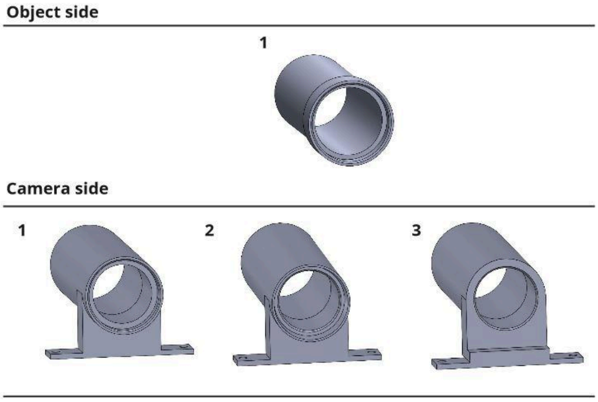


The first ElementHolder shown (above) is the HQCamHolder, which houses the Raspberry Pi High Quality Camera via tight tolerances around its m12 lens mount, thereby ensuring the cam is properly centered. The holder is accommodated by a lid which closes the housing and further fixates the camera in position.

The second, is the V2CamHolder, which houses the Raspberry Pi Camera Module 2. It uses similar techniques to the HQCamHolder as it also uses a tight fit but now around the lens of the camera.

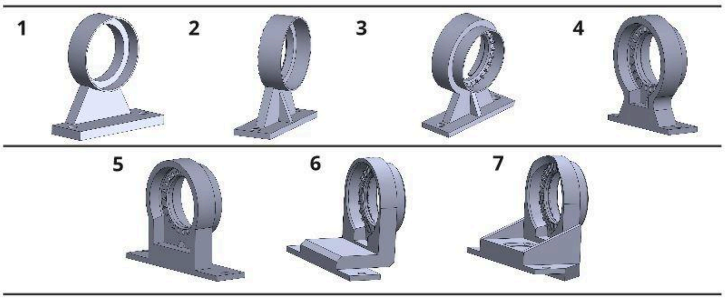


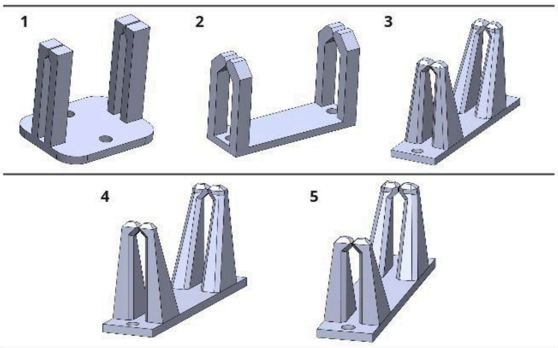




The left visual shows the design evolution of the extendable optics tube. The extension of the tube is facilitated by two tubes sliding over each other and accommodates for flexible component positioning on the 2020 profile. While the object side connects to the NosepieceHolder, the camera side needs to have a 2020Slider connection for stability and the facilitation of an Eyepiece.

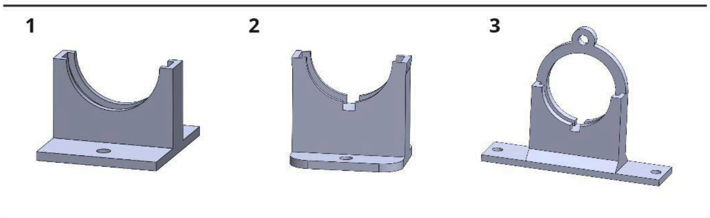
The visual on the right, shows the design evolution of the NosepieceHolder. The nosepiece with its objectives are quite heavy given the necessity for structural walls on the side of the NosepieceHolder.

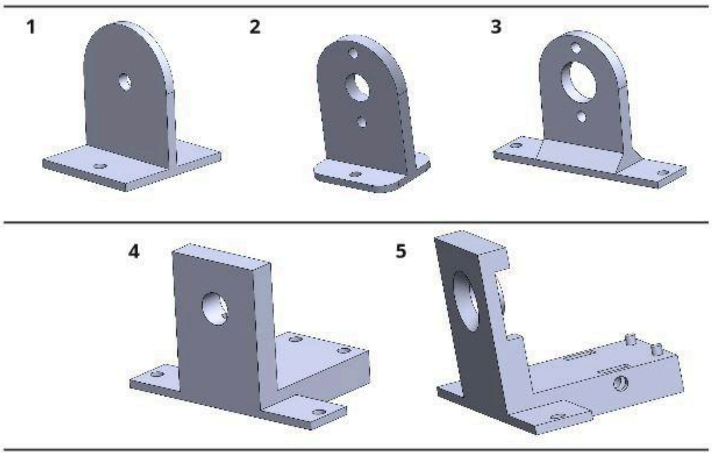


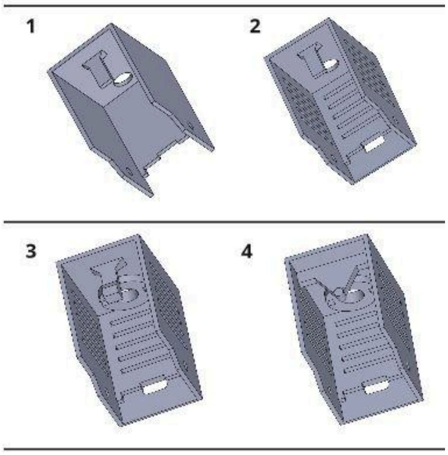


The SlideHolder on the left, holds the slide without the nosepiece slamming its objectives against the arms of the slide holder.

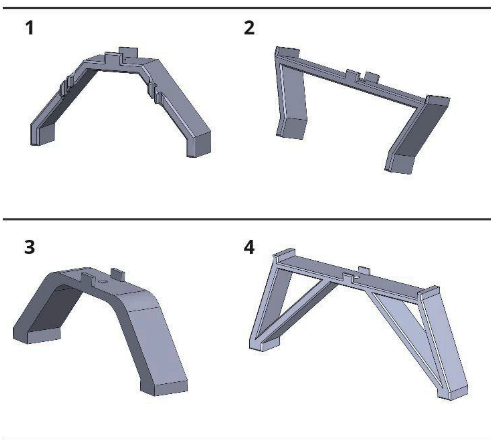
The LensHolder on the right, holds the lens and accommodates a screw and nut on the top to fixate the lens in place. While the Eduscope V2 uses expensive convex lenses sourced from Thorlabs the decision was made to source cheaper acrylic lenses from Aliexpress as those lenses were expected, by a professor Florian Bociort, to be enough for the purpose of this digital camera.





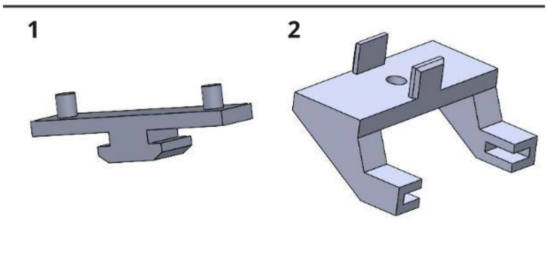


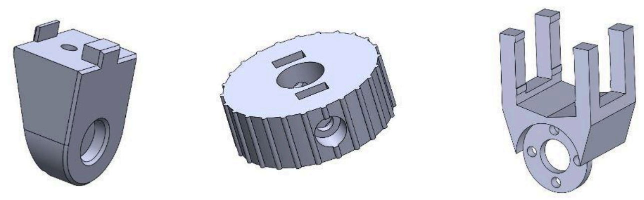
The LED holders above show its transformation from just fixating the LED module to housing the LED dimming circuit. The LED module in the first models was not correctly aligned because of play and this resulted in a huge impact on the background illumination. Therefore, the LED module uses the press fitt to ensure its alignment. Next to that, the LED holder has some natural ventilation holes to help with cooling, as it was noted that the LED could get very hot on its maximum rated power. The natural ventilation is an overkill for the actual LED circuitry as it powers the LED at a maximum of 80%, but could still prolong life.

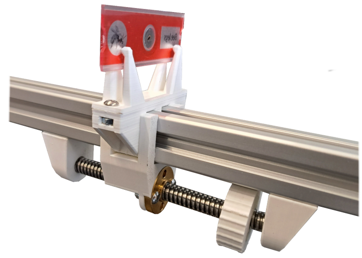


The Stands on the left are designed such that they don't flex too much while keeping print time to a minimum. The Stands accommodate anti slips on their feet to give a robust experience to the user. Next to that, the Stands accommodate a place for the 500 mm ruler to rest on. The 500 mm ruler has been chosen to help the technical students keep track of the distances between the elements.

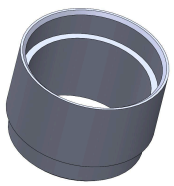
The pi holder on the right, has transitioned from a press fit into a clamp for improved (dis)assembly and because the Pi transitioned from positioning on top of the 2020 profile to the bottom. For the last the Pi had to face its circuitry to the 2020 profile leading to its elevated design.



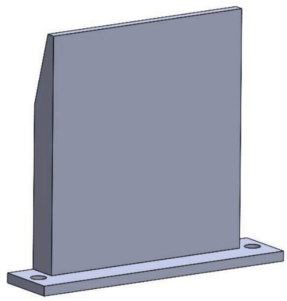




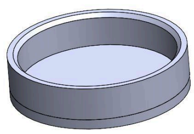
While hand positioning sufficed for most elements, it proved cumbersome and time-consuming for the SlideHolder. This manual adjustment required precision and steady hands, resulting in difficulties with focusing. To streamline this process without the complexity of a drivetrain, a leadscrew was introduced. Positioned at the bottom of the rig, the leadscrew is paired with a MoverHolder, MoverWheel and MoverSlider (see Figure above), facilitating precise movement of the Element Slider via rotation of the leadscrew.



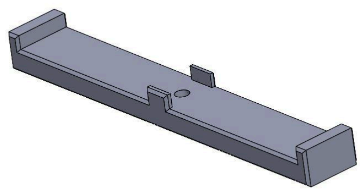
The purpose of the camera extension, on the left, is to facilitate the connection between the camera and the optics tube. The "Tube cam side" is positioned above its optical reference point, as is the camera sensor's optical reference point. Therefore, the camera extension becomes necessary to eliminate unwanted light. The camera holder itself could also be extended removing the need for this extension, but this would lead to a larger minimum distance from the tube or eyepiece and therefore would decrease the rig's configuration flexibility.



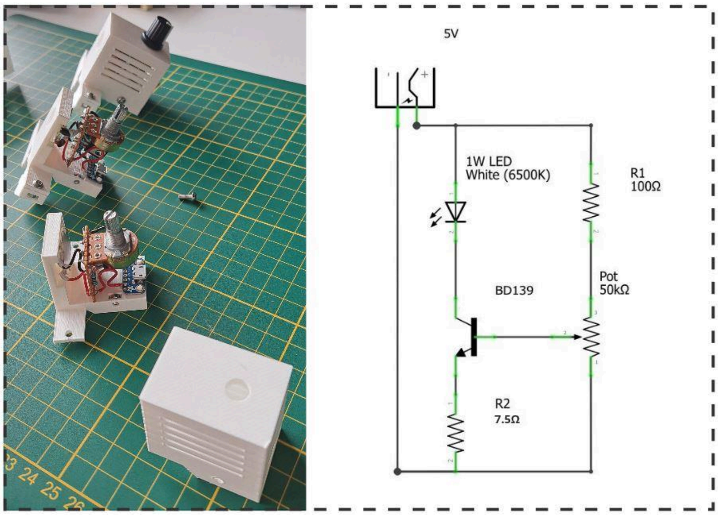
The ProjectionScreen (right) is an additional element, contributing to the understanding of optics by the students as the image is projected on a white surface.

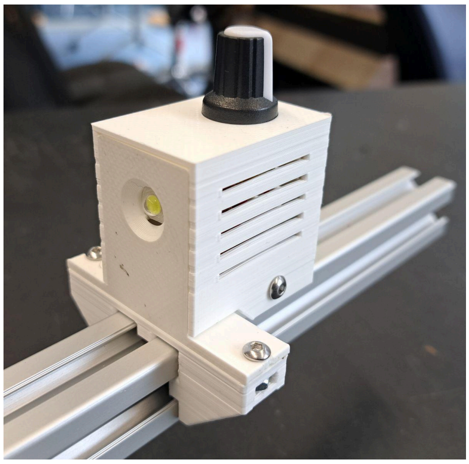


The Lenscap on the left functions as protection of the lens from dust and other environmental factors.



The MidRuler on the right functions as an extra holder for the 500 mm ruler to reduce the arching of the ruler due to gravitational forces. With this MidRuler smaller rulers are also accommodated.



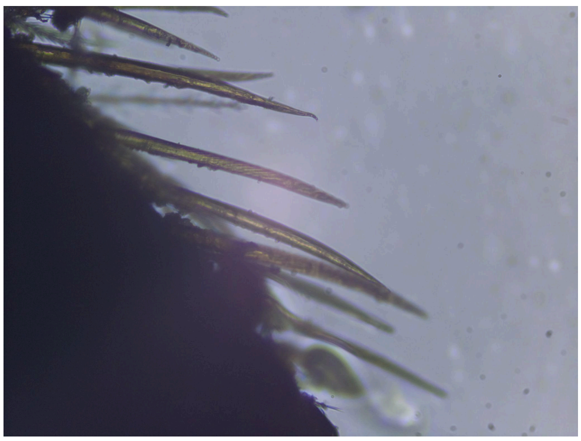


The LED in series with a current limiting resistor, used in the Eduscope V2, provided with unsatisfactory results. The LEDs appeared to die fast and the dimming of the LED didn't go smoothly from dimmed to bright. Using a potentiometer and basic Pulse Width Modulation code, more control could be taken over the dimming curve. However, by using two resistors and an NPN transistor a simple and inexpensive LED dimmer has been created (see visual above). This setup removes the dependence on microcontrollers and their booting time, coding, data wires and computing power.

For the Eduscope Rig a specific python has been developed. This python code opens a camera preview under specific camera parameters to ensure a consistent testing environment, improving the quality of the comparison tests. Unlike the Eduscope V2 which hosts a button for capturing images the interface with the Eduscope Rig is more flexible, the usb interface of the Eduscope Rig is used to connect computer peripherals, enabling the students to quickly change the python scripts to their specific needs.

For the Eduscope Rig the following camara parameters were carefully selected:

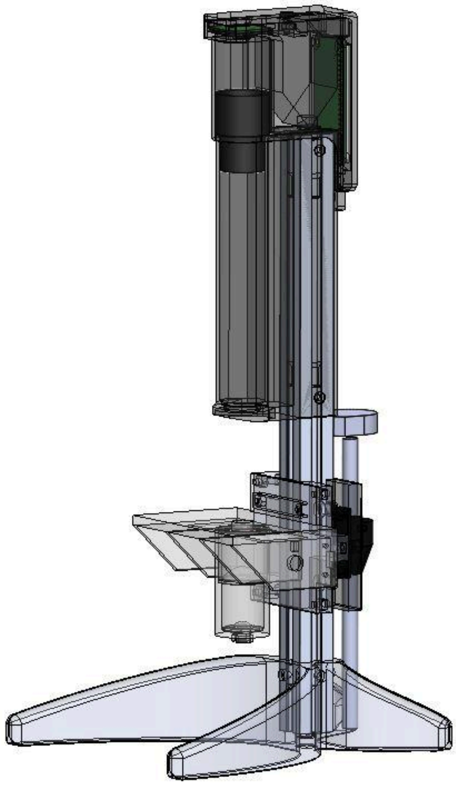
rpicam-hello --shutter 200000 --analoggain 3 --framerate 8 --awb indoor -t 0 --brightness 0.4 --sharpness 0



While these values are selected carefully, fine tuning these parameters could further improve image quality and reliability. As light from the environment does influence the image a different environment could result in different optimum values.

5.6 Design evolution V3 Prototype

Integrating the Feature improvements
The creeping featurism of the Eduscope V2 has been mitigated by removing elements such as the motor and the accu. With the removal of the motor many parts became absolute, like the Motorcontroller, Arduino Nano, Buck converter, Custom PCB, spring etc.. The removal of the motor resulted in the base of the Eduscope V2 to become quite empty and together with the removal of the accu much weight has been removed.



The optional Power Bank in combination with the Eduscope V3 Prototype gives a better functionality as compared to the integrated accu of the Eduscope V2 as it is easily used for other purposes or replaced.

The simplification of the components and wiring improves the Eduscope V3 prototype in its ease of understanding, assembly, maintenance, repairability, dependencies and upgradability/further development.

Next to that, while the motor control offered a course and fine control mimicking the course and fine knob on the traditional microscope it also showed its weaknesses in unreliability and dependence on the working wiring system. The replacement by a leadscrew of a pitch of 2 mm and manual wheel ensured to give enough fine control for the microscopy classes at secondary (high) school in low-resource Kenya.

While many features have been stripped, one feature has been added to improve the secondary (high) school microscopy class and that is the integration of a removable camera and an eyepiece. This allowed for both digital and analogue viewing capabilities, mitigating the disruptions in microscopy classes and improving the students' understanding of microscopy.

Integrating the structural improvements
By replacing the motor with a leadscrew and by repositioning the translation on the optics tube to the stage, the optical center line was moved closer to the vertical 2020 profile, thereby mitigating momentum forces.

Because of the BOM reduction and much weight and momentum forces have been eliminated the base is designed as a 3D printed foot instead of the box in the Eduscope V2, which was made out of 2020 profiles and acrylic paneling. By making this decision, the number of 2020 profiles is significantly reduced. Next to that, the necessity for acrylic has been removed, which in turn removed the necessity for laser cutting and gluing, improving the construction and reducing dependencies.

Integrating the sourcing improvements

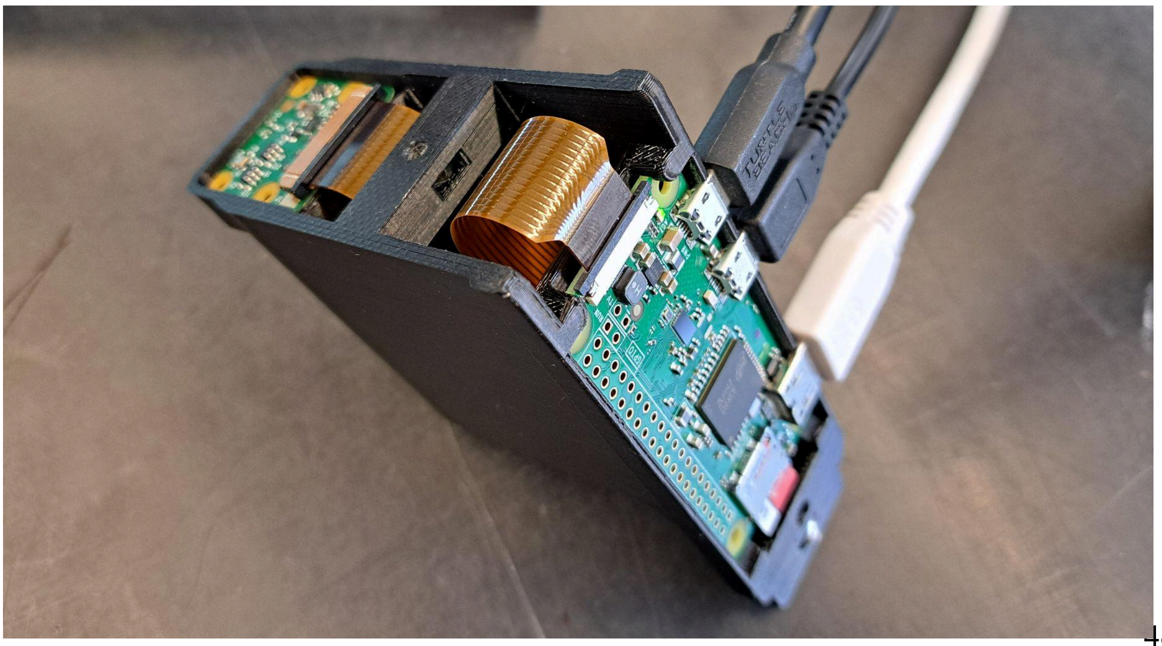
Expensive components of the Eduscope V2 have been replaced by cheaper alternatives without compromising on quality.

From the tests conducted on the Eduscope Rig, it was concluded the cheap acrylic plano-convex lenses performed similar to the expensive plano-convex lenses sourced from Thorlabs. On top of that, where the Eduscope V2 used two lenses, one for collecting the light source and the other for condensing the light source, the Eduscope V3 Prototype uses only one as that was shown to be sufficient enough. Next to that, the Raspberry Pi Camera Module 2 (with 10x eyepiece) has been compared to the Raspberry Pi High Quality Camera using the Eduscope Rig and the results, visible in chapter 7.1.2, show the Camera Module 2 is very sufficient for its application in the microscopy education. The decision to use this Module 2 for the V3 Prototype enabled the dual viewing capability, but also saved ~30 euro. With this decision, the problems with the presence of dots on the IR filter used in the HQ-cam is also removed.

Furthermore, the manual stage has been replaced by stageclips. This decision was based on experimentation with the movement of the slide by hand and from that experimentation it was concluded that the positioning on the XY-axis can be done by fingers directly, without it being too cumbersome. This decision saved ~15 euro on the total costs and also reduced areas for rust to occur.

Lastly, one component has increased in price. Instead of the Raspberry Pi zero v1.3 the Eduscope V3 Prototype makes use of the Raspberry Pi zero 2w. While this only added ~3 euros to the overall costs it improved booting time and frame rates significantly. Next to that, the wireless connectivity makes this board a future proof.

In the picture below the modular digital camera is depicted. More visuals on the design are presented in chapter 7.3



6. Deliver

This chapter continues on the selected idea directions from the previous chapter. While the preceding chapter delved into the conceptualization of ideas and some design evolutions regarding the Eduscope Rig, this chapter unveils the resulting deliverables. Firstly, the Eduscope Rig is presented, which functions as a crucial educational and design tool for the technical students at I.O.Me 001. Secondly, the Eduscope STEM project is outlined, with a primary focus on the first workshop where the Eduscope Rig plays a central role for creating curiosity and understanding. Lastly, the Eduscope V3 Prototype is presented, which functions as a crucial reference point for the technical students to continue on the technical insights found throughout this master thesis.

6.1 The Eduscope Rig

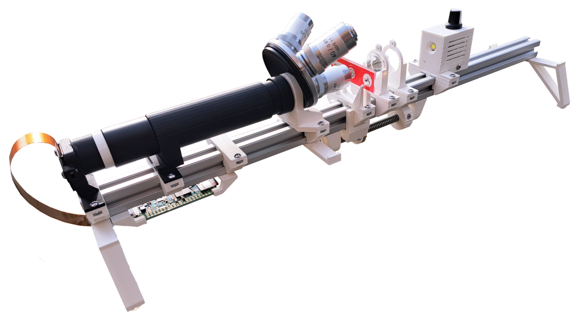
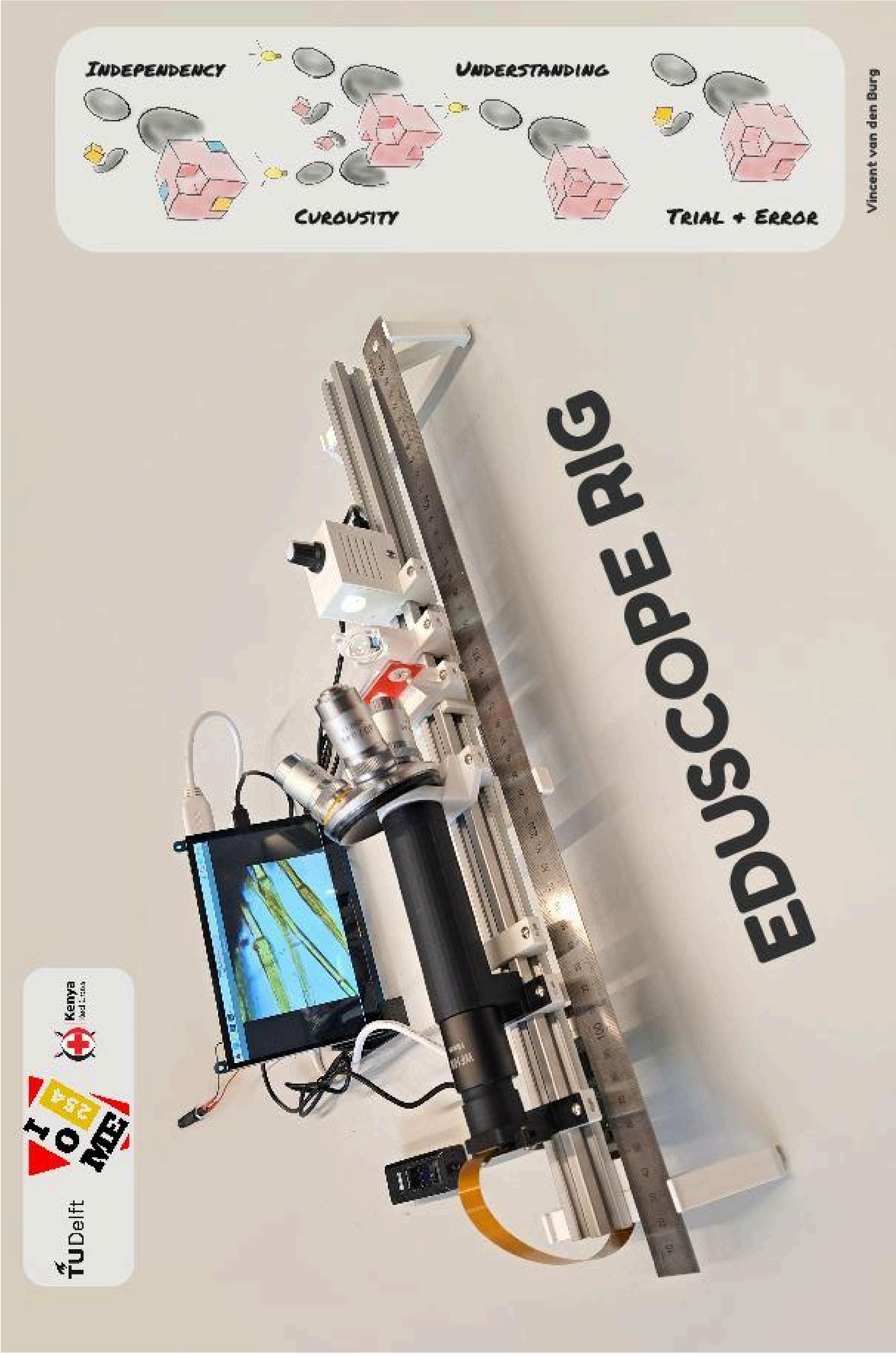


Figure 6.1 The Eduscope Rig

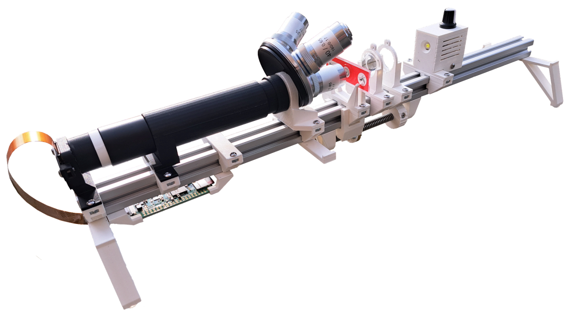
The Eduscope Rig (Figure 6.1) is a simplistic structure on which optical components can be aligned to understand their individual, group and holistic functionality. With the Eduscope Rig students explore different optical configurations, test rapid prototypes, and refine their designs based on feedback and outcomes. This iterative approach allows students to learn from their mistakes, refine their problem-solving strategies and develop a deeper understanding of microscopy, optics and the design principles at play. By fostering a hands-on, experiential learning environment, the optics rig empowers students to actively participate in the development process of the Eduscope, sparking innovation and driving continuous improvement.

Atop the widely used 2020 profile, the rig facilitates the movement of 3D printed blocks, known as 2020Sliders, along its length. These sliders play a critical role in the functionality of the Eduscope Rig by enabling the mounting and alignment of optical elements. These elements, ranging from light sources to magnifying lenses to imaging sensors, form the backbone of the digital microscope. To enhance its functionality and stability, the slot on the underside of the 2020 profile is used for securing stands, holders for the imaging processor (Raspberry Pi Zero) and fixtures for a leadscrew. With a focus on a simplistic Bill of Materials the Rig makes use of only one type of screw for fastening the components to the 2020 profile and to each other. While the 2020Sliders can be easily and accurately positioned using the accommodated ruler, the leadscrew enhances the positional accuracy of the 2020Slider holding the observed object as positioning these with hand is too difficult.

While the rig offers numerous configurations due to its modular design, it can effortlessly replicate the optical setup of previous Eduscope iterations. Consequently, the Rig functions as a standalone digital microscope, a professional comparison test setup, an educational tool and a platform for engineering practices. On the next page a visual overview of the Eduscope Rig is depicted.


INDEPENDENCY
CUROUSITY
UNDERSTANDING
TRIAL + ERROR
Vincent van den Burg
EDUSCOPE RIG
TUDelft
Kenya

In the subsequent section, the function of the Eduscope Rig is projected back on the research goal and its foundational elements, the four missing pieces identified in chapter 4.1.3.



“Empowering the students at I.O.Me001 to develop digital microscopes targeting low-resource secondary schools in Kenya”

By offering hands-on exploration with the digital microscope components, fostering curiosity, the rig plays a vital role in enhancing students' understanding of optics, microscopy and design principles. Additionally, its ability to enable trial & error and foster independence in sourcing components contributes to the students' capacity for innovation and adaptability. As a result the Eduscope Rig empowers the students at I.O.Me 001 to develop digital microscopes for low-resource high schools in Kenya.

1. Sparking Curiosity
Through the rig, students can visually and tangibly perceive the components comprising the rig and the Eduscope. This hands-on insight into the microscope's structure stimulates students to experiment with various configurations and components stimulating their curiosity and creative thinking. This curiosity can lead to more innovative solutions for improving the Eduscope and related projects, like the Schistoscope.

2. Understanding Optics
Because the rig doesn't have a housing, students can easily distinguish between the different components. Moreover, by using the 2020 profile and detachable components, students can configure the rig in multiple ways. This allows them to see what each component does individually, in relation with other components and as a whole. This interactive exploration helps them to understand the fundamental basics of optics and microscopy.

3. Enabling Trial & Error
The rig enables students to easily develop and test new components on the rig to investigate whether they could indeed enhance the effectiveness of the microscope. By allowing students to experiment with new components in a controlled environment, the rig facilitates innovation and iteration. Students can quickly prototype and assess the performance of their ideas without the need for expensive or complex equipment.

4. Fostering Independency
The rig enables students to use fast prototyping methods to easily switch to another supplier when a previous supplier stops selling the needed optical component. For example, a new convex lens results in a new focal point, resulting in a need to revalidate the performance & distances and to redesign the embodiment. Doing this isolated from the Eduscope improves time efficiency significantly and thus reduces the dependencies on specific suppliers.

6.1.2 Eduscope Rig technical overview + Results

This section unveils the technical intricacies of the Eduscope Rig, offering a comprehensive overview of its construction and associated costs. The construction manual for the Eduscope Rig, containing these and many more details, is attached in Appendix A.
The first overview, Figure 6.2, displays the assembled and connected Eduscope Rig configuration, accompanied by its construction costs and time on the right side.

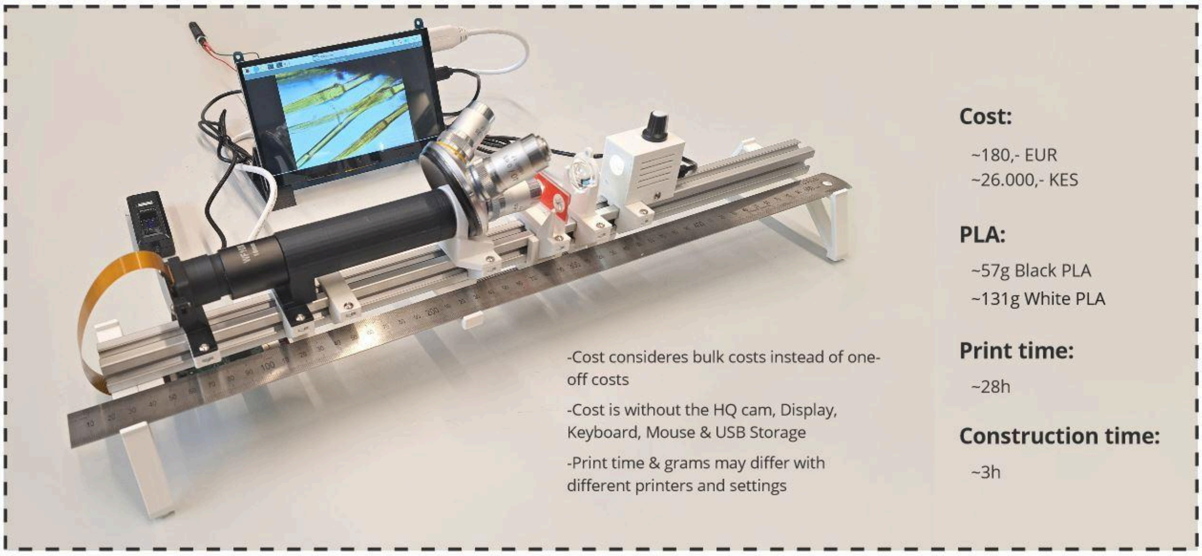


Figure 6.2 The Eduscope Rig construction overview

The second overview, Figure 6.3, highlights the sourced components essential for the digital microscope's functionality. The complete Bill of Materials, available in the manufacturing manual, provides shopping links and additional part details, facilitating easy exploration of alternatives.

This condensed overview highlights the primary expenses, excluding peripheral items such as cables, chargers, rulers, and anti-slip dots, which are readily interchangeable or commonly available. From the total cost, 180eu (26000KSh), 144eu (2100KSh) is shown in this overview.

Figure 6.3 The Eduscope Rig essential cost overview

The third overview, Figure 6.4, shows all the 3D printed parts. On the fourth overview, Figure 6.5, the Eduscope Rig is visualized with annotations.

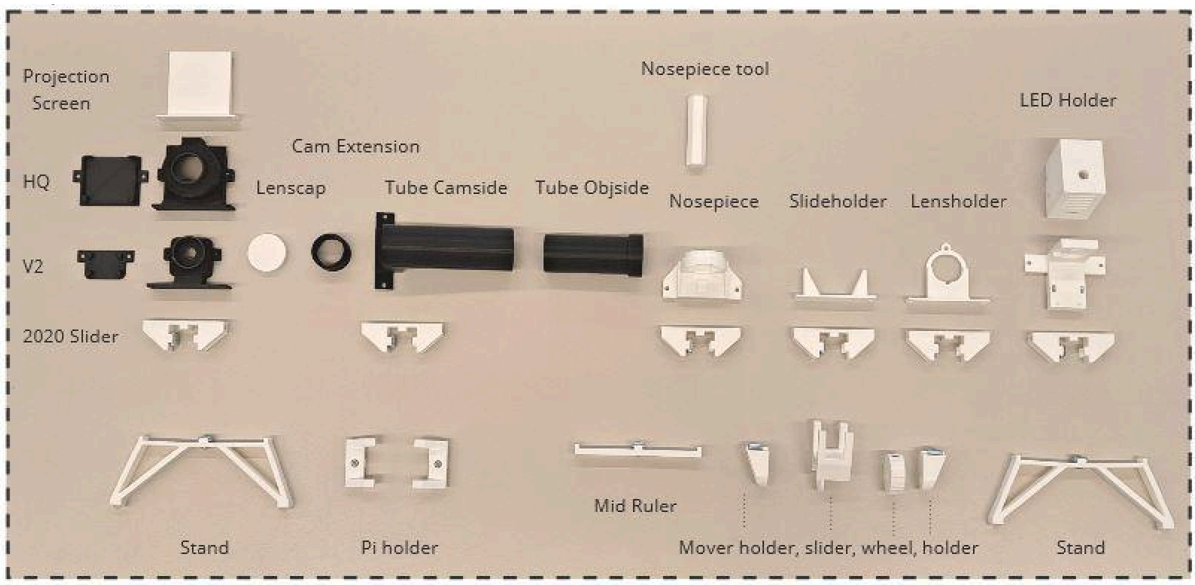


Figure 6.4 The Eduscope Rig 3D prints overview

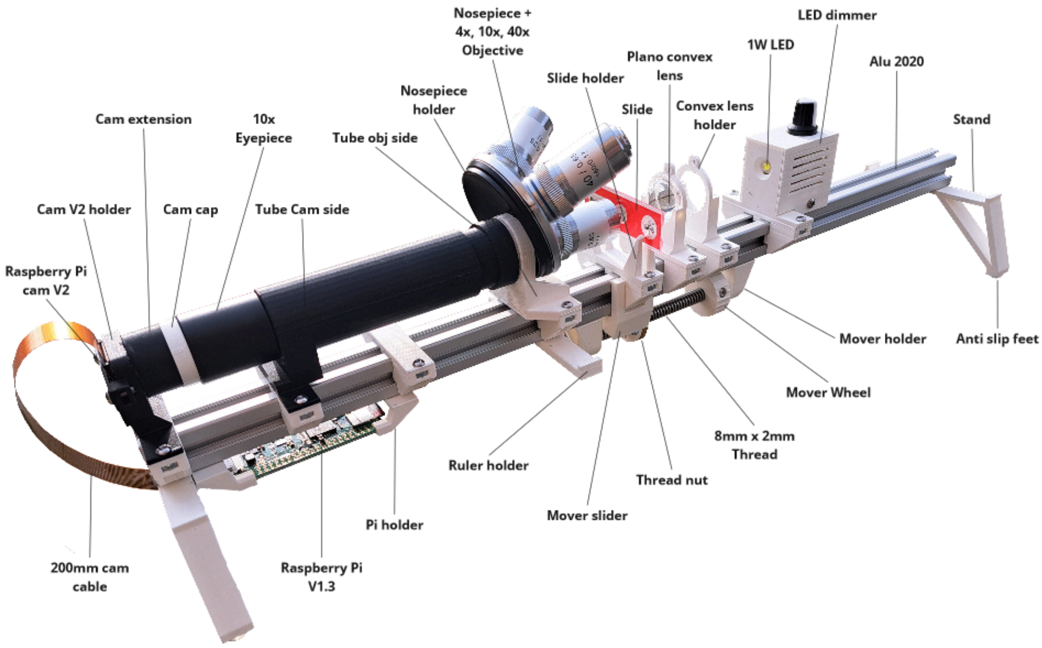
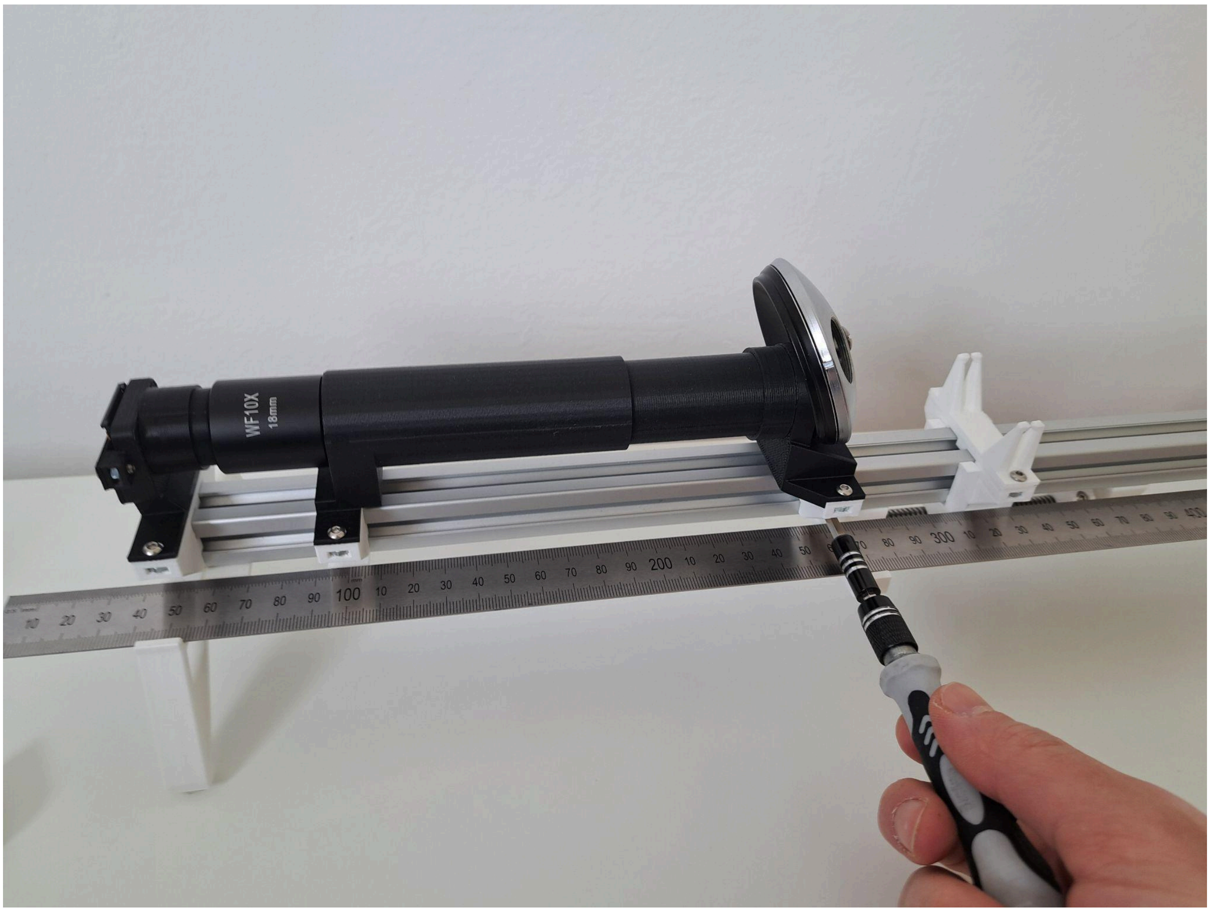
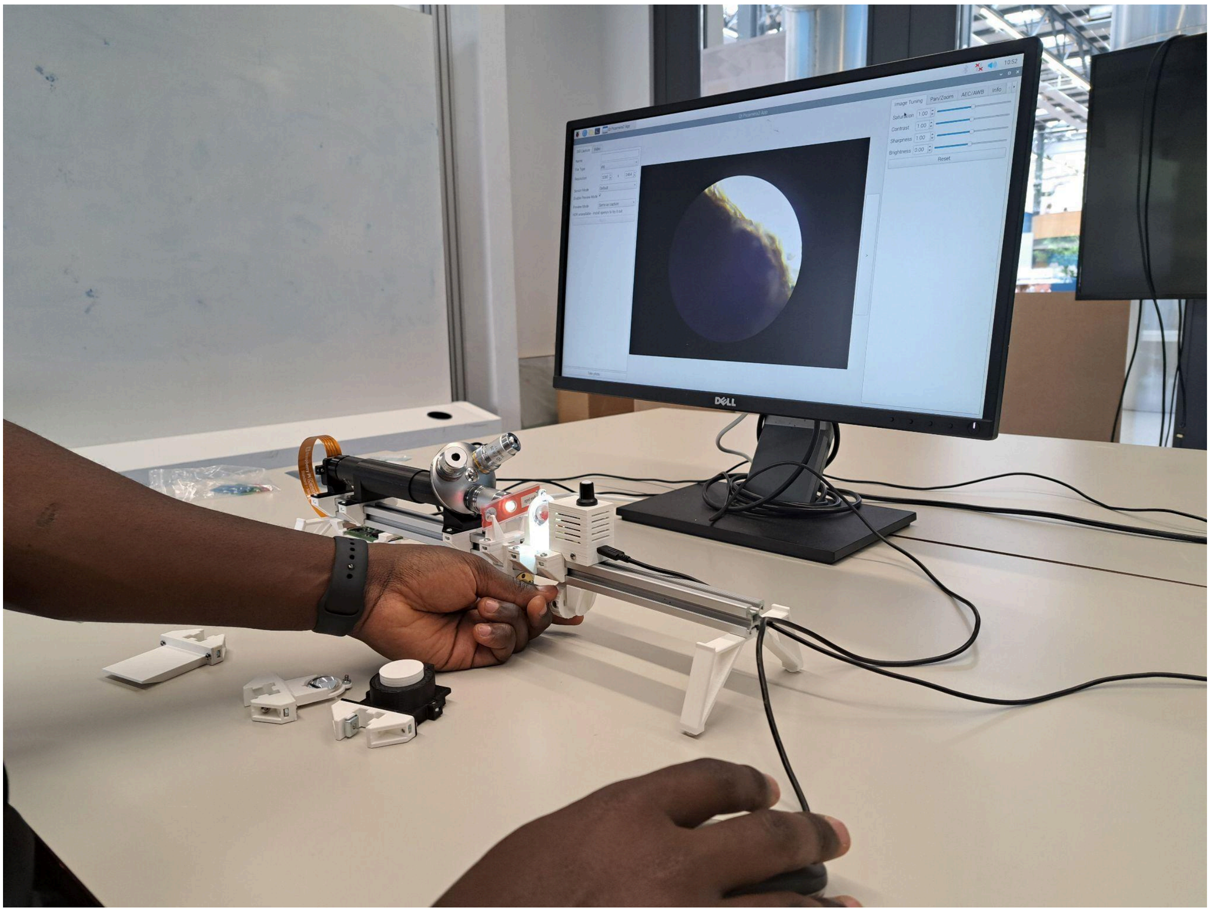
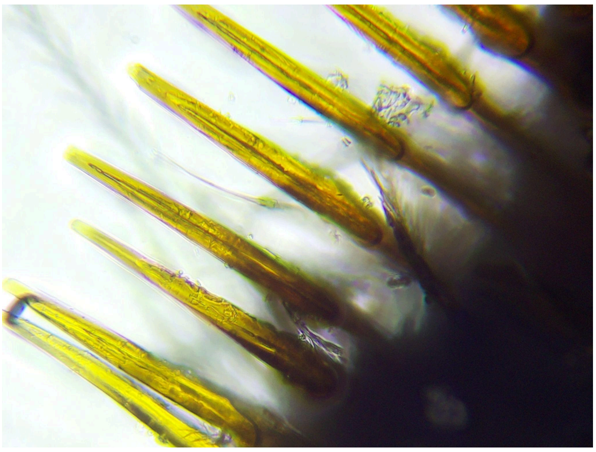
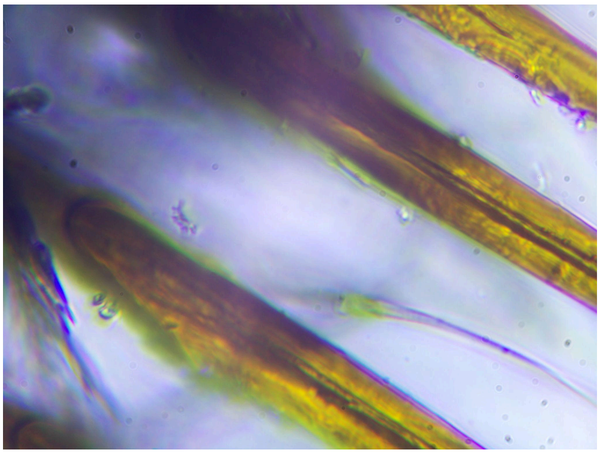


Figure 6.5 The Eduscope Rig annotated

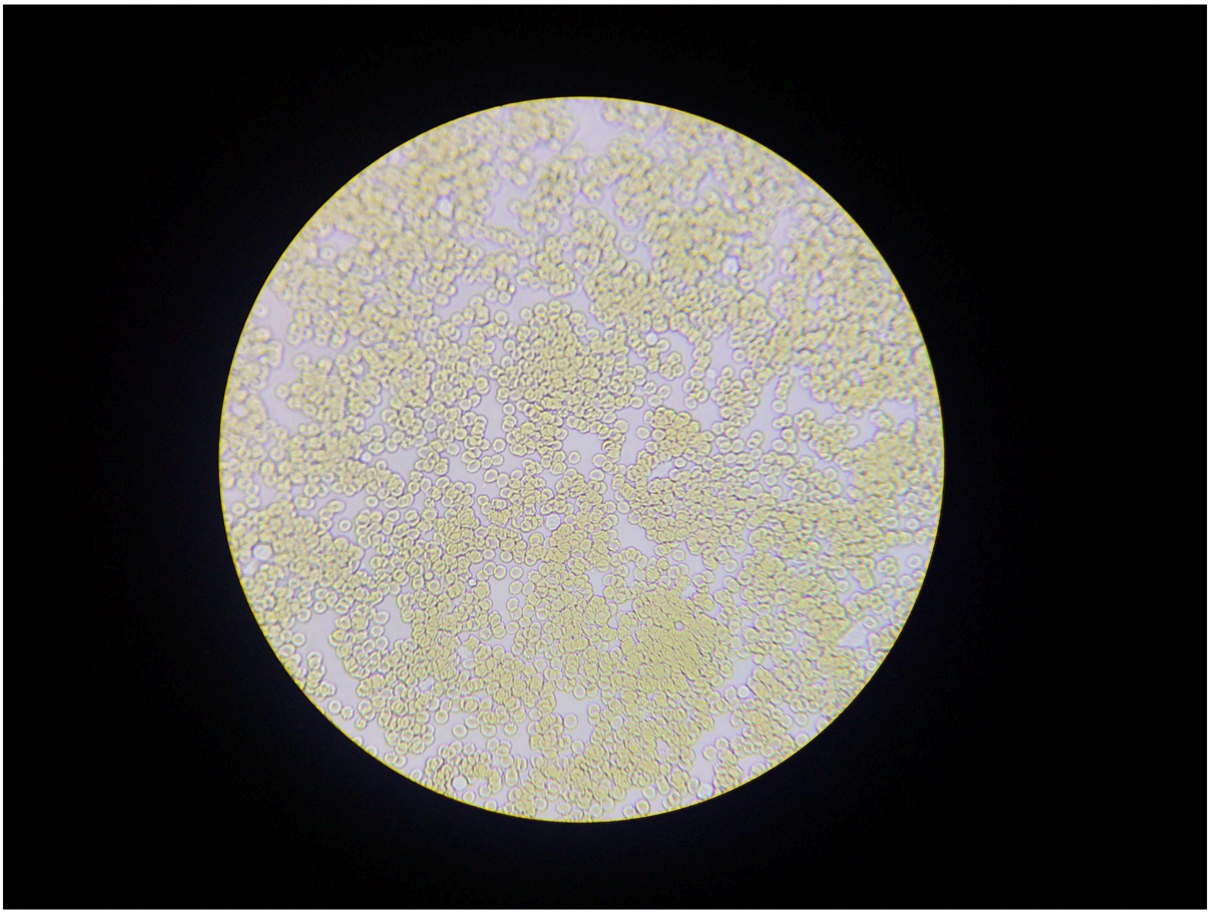

WF10X
18mm


DELL

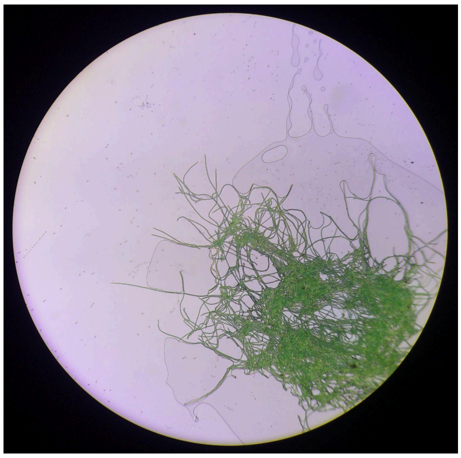
Pictures of hairs on a bee leg:

Left: 40X (objective) + 10X (eyepiece) + digital zoom -> Raspberry Pi Camera Module 2
Right: 40X (objective) -> Raspberry Pi High Quality Camera

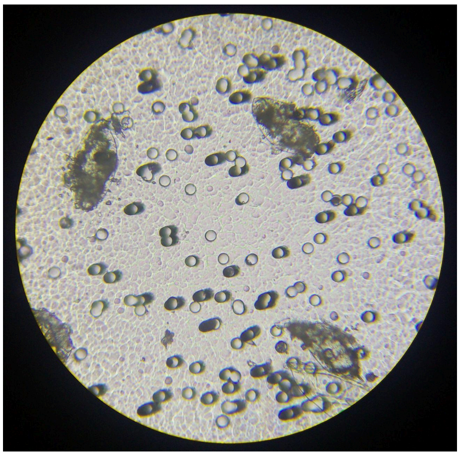
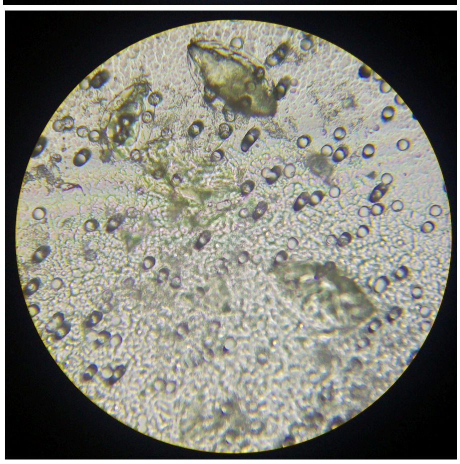


Picture of a blood smear:

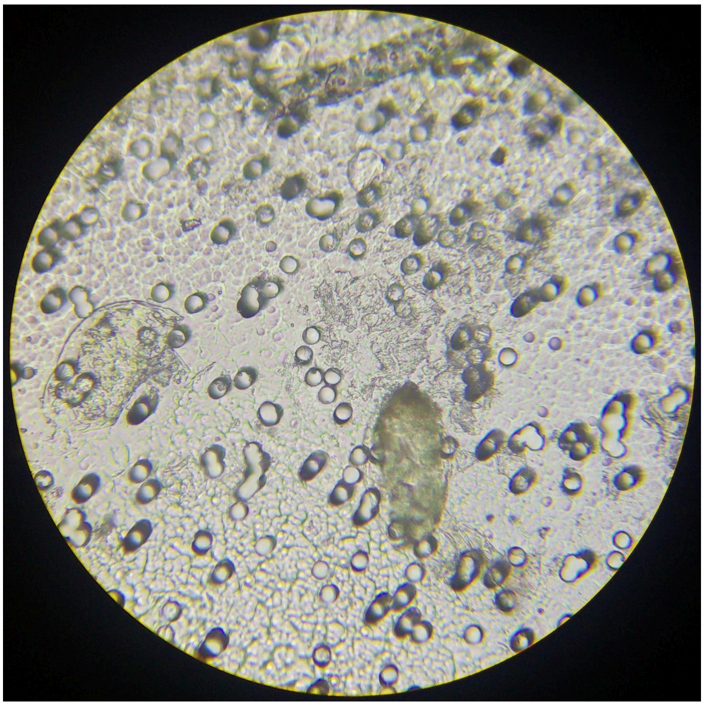
40X (objective) + 10X (eyepiece) -> Raspberry Pi Camera Module 2


Pictures of riverwater. 10X (eyepiece) Top right 4x, right 10x, left 40x

Pictures of Schistosomiasis. 10X (eyepiece) 40x



6.2 The Eduscope STEM Project

The Eduscope STEM project (see Figure 6.6) comprises a series of workshops designed to actively involve students at I.O.Me 001 in the further development of the Eduscope product. Organized into four stages mirroring the double diamond design method, the in total 15 workshops aim to guide the students through the entire design process of the further development of the Eduscope project, which concludes with the students presenting the improved Eduscope.

The STEM project is facilitated by the I.O.Me 001 fablab where a knowledge holder leads the workshops and guides the students through the project. The project is free of charge, but students are expected to commit to the full length of 15 workshops.

The STEM project is focussed on interdisciplinary collaboration by involving students from diverse academic backgrounds, such as engineering, biology, physics and computer science. This interdisciplinary approach boosts both creativity and a more holistic approach to innovation. Next to that, the project challenge is split into smaller challenges for each workshop. In line with the thoughts of Deci & Ryan (1992), by emphasizing on these intermediate results it fosters a sense of accomplishment and intrinsic motivation among the students.

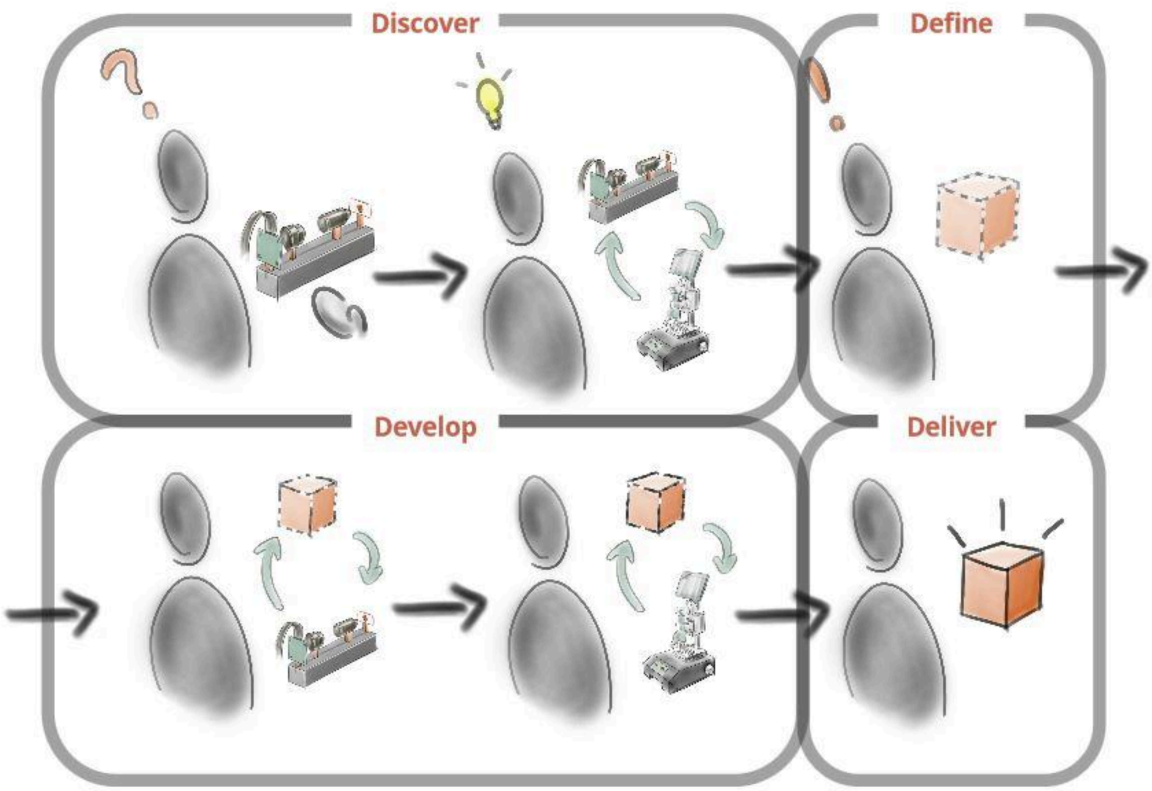
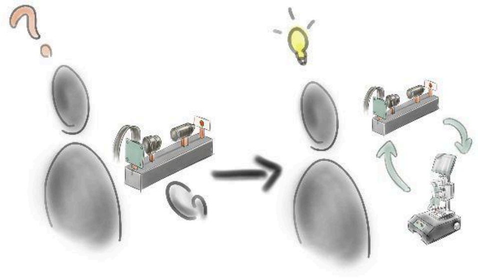


Figure 6.6 The Eduscope STEM Project

Stage 1, Discover



Four workshops are dedicated to sparking curiosity for and understanding of the Eduscope project.

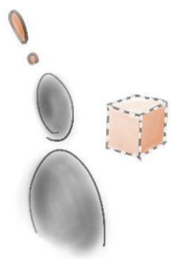
The first workshop, focused on the Eduscope Rig, introduces students to the fundamentals of optics and microscopy through theoretical learning and hands-on exploration.

The second workshop builds on this knowledge, delving deeper into essential optics and microscopy concepts while also providing practical experience in slide preparation and product testing & examination using the Eduscope Rig and the Eduscope V3 Prototype.

The third workshop helps the students better understand the design engineering of the individual components. The students are first enriched and enthused by examining examples of the exercise of "Things Come Apart" Mclellan (2019). Subsequently, they create and photograph a physical exploding view of the Eduscope Rig and the V3 Prototype.

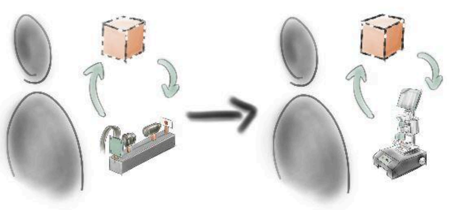
In the fourth workshop, the students deploy methods such as market analysis and SWOT analysis (Delft Design Guide, 2016) to unveil and present the design characteristics of the Eduscope Rig and the V3 Prototype.

Stage 2, Define



In one workshop the students are supported in framing the Eduscope project, using the "List of Requirements" (Delft Design Guide, 2016) students write down their findings from the Discover phase. Subsequently, the students categorize these findings in clear paths for improvements using a method such as 'Analysis of Interconnected Decision Areas' (AIDA) (Roozenburg & Eekels, 1998) or using the three categories of feature, structural & sourcing improvements, thereby clustering the most promising directions.

Stage 3, Develop



Five workshops are dedicated to engaging students in creative brainstorming, idea generation, trial & error and fast prototyping sessions.

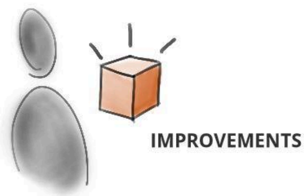
In the first workshop the students use the Brainstorming method (Delft Design Guide, 2016) to start the ideation process without any borders. This session is extended on by using themes from the Circular Design strategy (Products that last, 2014) such as durability, maintenance, repair, adaptability and upgradability. Using the Fast Sketching method the most promising ideas are visually stored for the next workshop.

The second workshop builds on these ideas using the SCAMPER method (Delft Design Guide, 2016) to find interesting modifications on these ideas. This method is then continued on by using How-Tos (Delft Design Guide, 2016) with the focus on making the ideas desirable, viable and feasible. The most promising ideas are selected using methods from the Delft Design Guide (2016) such as the weighted objectives, datum method or the Harris Profile to select the most promising ideas for further development.

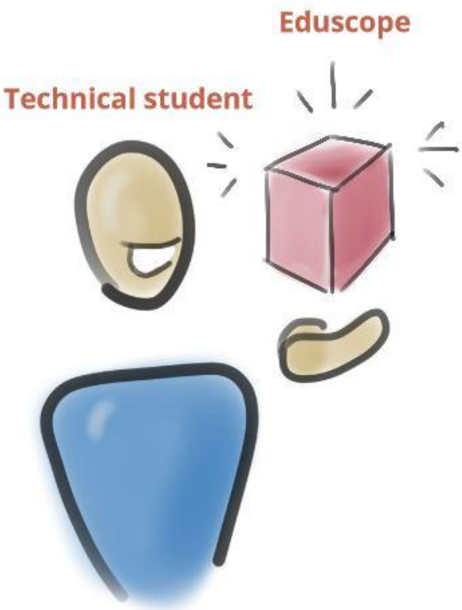
The third to fifth workshop emphasizes design engineering practices, enabling students to prototype their ideas. The third workshop starts with exploring the SolidWorks and 3D printing techniques. In the third workshop the students are immediately challenged with making improved or additional elementholders for the Eduscope Rig. In the fourth and fifth workshop the students are guided in their Rapid Prototyping and A/B testing practices to prototype and evaluate their ideas. For the evaluation of the ideas which affect image quality the structure of the comparison table is advised depicted in Appendix D.

Stage 4, Deliver

In the last stage the students are guided in 5 workshops to independently refine their best prototypes into an improved version of the Eduscope.



In the last two workshops extra emphasis is laid on presentation skills to effectively communicate their improvements. For the fifth workshop the students are enthused to invite friends and family as this workshop, and with it the STEM project, concludes with a presentation from the students on their intensive training and the resulting improved Eduscope.



6.3.1 1st Workshop, The Eduscope Rig workshop

During this master thesis, the first workshop of the STEM project was successfully executed. This workshop's goal was to evoke curiosity and shape understanding of the Eduscope Project and its nuances in optics and microscopy. The workshop's structure consisted of a theoretical introduction, followed by an extensive hands-on exploration of the rig and concluded with extra theory and a peek into the next workshops.

The hands-on exploration of the Eduscope Rig consisted of a series of assignments in which the students were gradually exploring components and their interplay while building the Eduscope Rig. The hands-on exploration concluded with a fully working digital microscope with which the students were able to digitize the magnified image of a microscope slide.

The workshop, spanning 3.5 hours, took place on April 22, 2024. In this workshop I was the knowledge holder leading the workshop from Delft using Teams. Two on-site assistants at I.O.Me 001 supported the workshop execution. The two assistants were given a thorough briefing on the workshop content and structure. Next to that, the assistants unboxed and tested the two Eduscope Rigs, which were sent to I.O.Me 001 from Delft.

On the day of the workshop, the two assistants arranged the initial setup while I commenced the session via Teams. The setup, inclusive of the Teams interface, is depicted in Figure 6.7. Slides from Appendix E were used for both the theory and practical assignments to provide visual support and ensure clarity in hands-on activities.

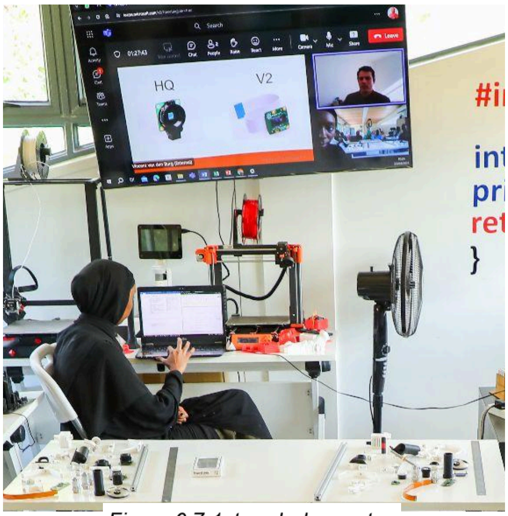


Figure 6.7 1st workshop setup

Theory 1

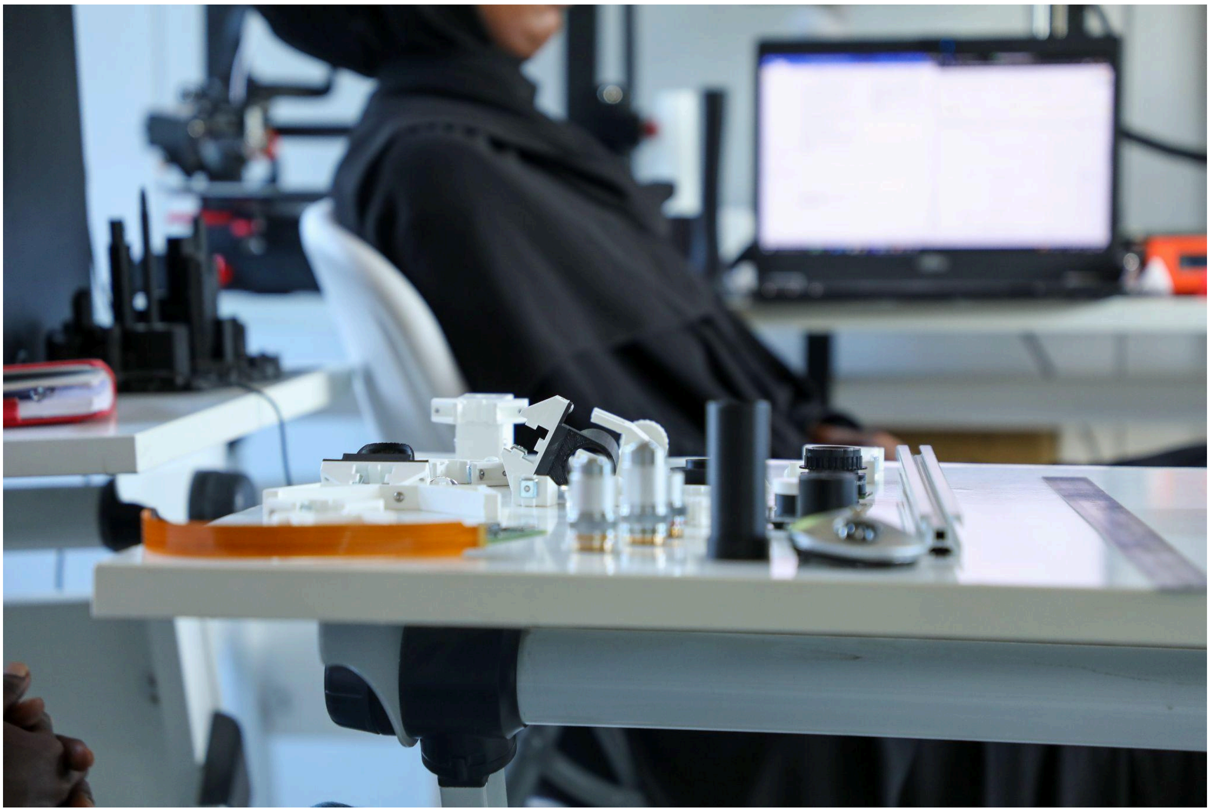
The theoretical segment of the workshop provided students with foundational knowledge in microscopy with a quick focus on optical microscopy. Topics included slide preparation, the functions of microscope elements and applications in neglected tropical diseases. The session concluded with an introduction to the Eduscope Rig and its various components, transitioning seamlessly into a hands-on exploration where students were tasked with identifying and examining each element individually.

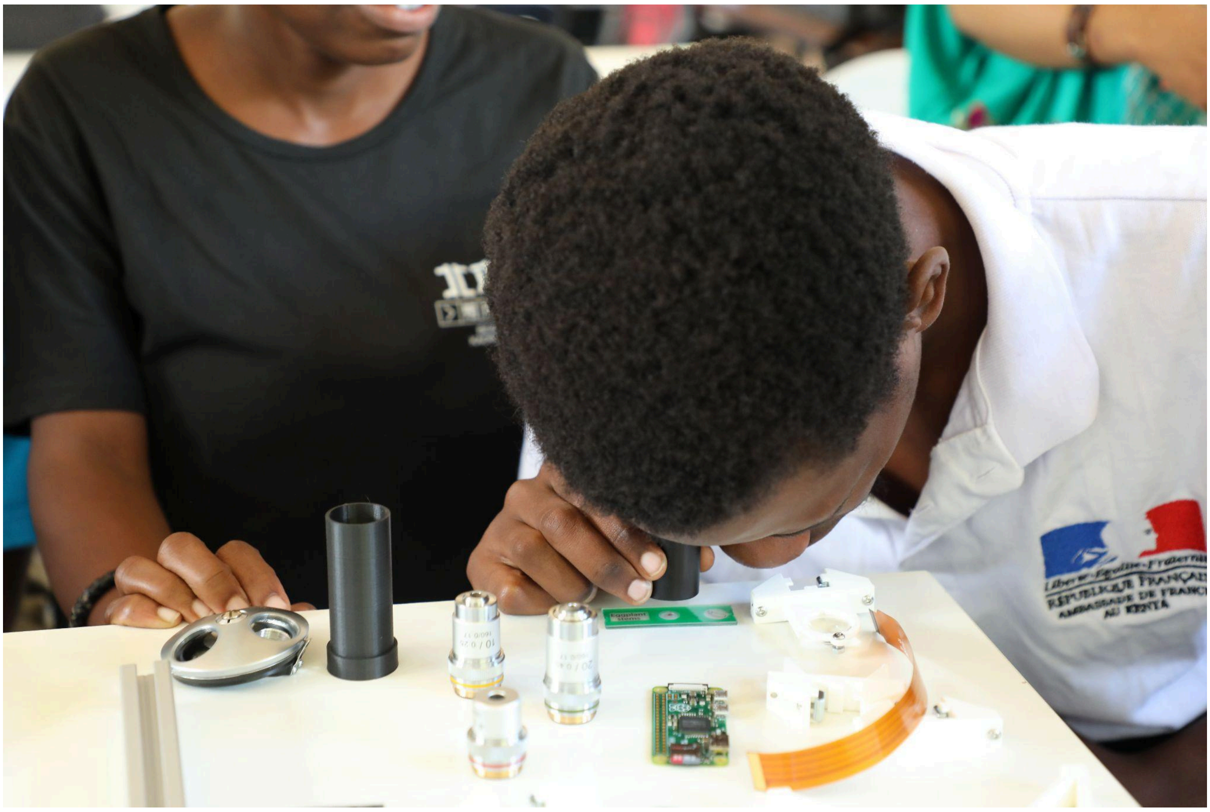
Practica
Continuing on the theory, the eight students were divided over the two Rig setups, 4 per Rig. One of the Rigs used the Raspberry Pi High Quality Camera while the other Rig used the Raspberry Pi Camera Module 2, giving them the chance to compare the camera from the Eduscope V2 against the camera from the OpenFlexure microscope.

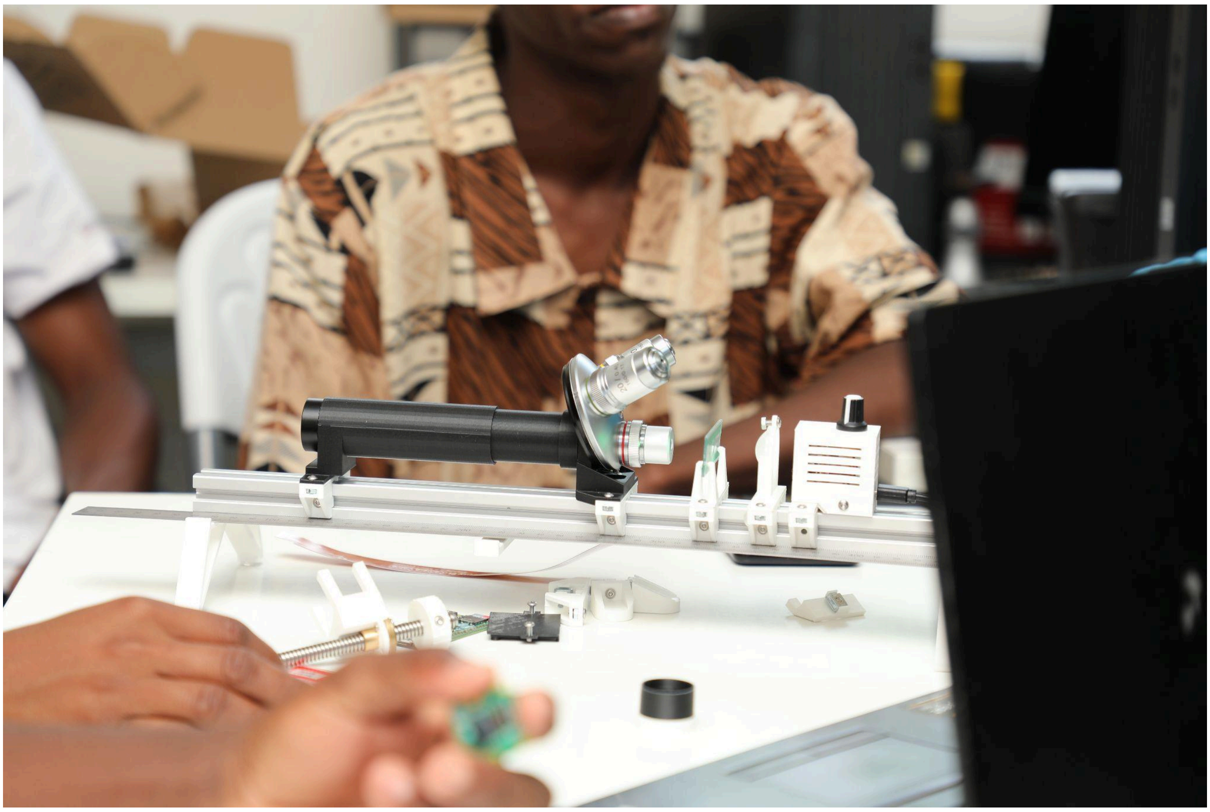
Five hands-on assignments were divided over an estimate of 2 hours. With these assignments the students gradually built the Eduscope Rig with intermediate viewing configurations. These five assignments are depicted in the Eduscope Rig workshop slides, see Appendix E. The following pages share the photographs from the Eduscope Rig workshop's practica.

Theory 2
The concluding theory section functioned as an evaluation session of the Eduscope Rig workshop to repeat and discuss some of the many insights. Additionally, this section gave a sneak peek of the Eduscope V3 Prototype, discussed future Research & Development and explained the design evolution of the Eduscope Rig.

Workshop check-out
A mentimeter has been used as the last activity of the workshop to evaluate what they have learned and the quality of the workshop. The mentimeter results can be found in Appendix F.








Sage


int main ()
printf (”
return 0;
}

6.3 The Eduscope V3 Prototype

The Eduscope V3 Prototype serves as a tangible embodiment of the improvements identified throughout this master thesis, consolidating them into a visual and physical representation. By encapsulating the envisioned enhancements, the Eduscope V3 Prototype prototype provides the I.O.Me 001 students with a clear reference point for the development of the Eduscope V3 and better promotes the trial & error practices while reducing the dependencies on suppliers. Drawing inspiration from the Eduscope Rig, the V3 Prototype maintains a similar structure, ensuring ease of understanding.

With a focus on simplicity and affordability, the V3 Prototype streamlines the Bill of Materials to the bare essentials, stimulating continued accessibility within low-resource environments. Incorporating only the essential features, the V3 Prototype ensures reliable functionality in the microscopy education at low-resource secondary (high) schools in Kenya. Leveraging a modular design approach on top of the versatile 2020 profile it boosts repairability and upgradability, catering to educational needs and resilience of microscopy education. Moreover, its modular design is used in accommodating both analogue and digital viewing configurations fostering a deeper understanding of microscopy and mitigating disruptions in microscopy education.

Similar to the Eduscope Rig, the V3 Prototype emphasizes ease of use and practicality. By translating complex technical concepts into a user-friendly format, it empowers secondary (high) school students to engage actively in the microscopy courses.

In summary, the Eduscope V3 Prototype represents an essential step forward in the evolution of the Eduscope project. With its simplified design, modular flexibility and educational focus, it embodies the core principles of accessibility, affordability and innovation, driving progress towards improving the access to microscopy education at low-resource secondary (high) schools in Kenya.

The next page visualizes the Eduscope V3 Prototype and its benefits. The recommendations for further developments are discussed in the Discussion.

6.3.1 Embodiment of the improvements




6.4 The three deliverables

By combining the Eduscope Rig, the STEM project and the Eduscope V3 Prototype the students at I.O.Me 001 are empowered in the development of digital microscopes for low-resource secondary (high) schools in Kenya.

With the help of a STEM project the interdisciplinary students commit themselves to a journey full of knowledge, hands-on exploration and engineering practices.

The Eduscope Rig is an educational and design tool crucial to this STEM project. The Rig simplifies the complexity of optics, digital imaging and microscopy via hands-on exploration creating both curiosity for and understanding of (digital) microscopy. Further in the series of workshops the Eduscope V3 Prototype is brought to the table. The V3 Prototype functions as a translation of the many insights gathered during this master thesis on the technical improvements of the Eduscope V2. With the introduction of the V3 Prototype the students are given the backbone of the envisioned Eduscope V3. The combination of the Eduscope Rig and the Eduscope V3 Prototype functions as a design tool fostering Trial & Error and Independency, thereby boosting the design process of the Eduscope V3 and beyond.

The Eduscope Rig, Eduscope STEM Project and Eduscope V3 Prototype are well-aligned with the stakeholder I.O.Me 001 in Mombasa for several reasons:

1. **Alignment with Objectives**: I.O.Me 001 aims to foster innovation and development tailored for humanitarian interventions. The Eduscope project, focusing on enhancing science education and healthcare accessibility in underserved regions like Kenya, directly supports this objective.
2. **Utilization of Resources**: I.O.Me 001 provides various services, including digital manufacturing, STEM education, training workshops, incubation support, and collaboration hubs. These resources align perfectly with the needs of the Eduscope project, enabling it to leverage fabrication tools, collaborative spaces and training opportunities to develop and refine its prototypes. The fabrication tools available at I.O.Me 001, such as 3D printers and laser cutters, facilitate rapid prototyping and small-scale manufacturing. This enables the Eduscope project to iterate on its designs efficiently, leading to the development of functional prototypes tailored to local needs and contexts.
3. **Community Engagement**: The Eduscope project engages local students from diverse academic backgrounds. This aligns with I.O.Me 001's mission of fostering creativity and innovation among students, empowering them to contribute meaningfully to local development initiatives.

Overall, the combination of the Eduscope Rig, Eduscope STEM Project, and Eduscope V3 Prototype aligns closely with the mission, objectives and resources available at I.O.Me 001 in Mombasa and the development of the local students


THE EDUSCOPE RIG
DELL
TUDelft
Kenya
Red Cross

Discussion & Recommendations

This chapter is dedicated to discussing the scope of this master thesis, breaking the boundaries that have framed this investigation. The discussion is split into holistic project/research discussions and discussions for each of the three deliverables of this master thesis. With the wealth of insights, each discussion point is concluded in recommendations aimed at propelling the Eduscope project, STEM initiative, Eduscope Rig, and Eduscope V3 (Prototype) towards greater efficacy and impact.

Eduscope Project/research

Mono focus on Kenya

This research initiative has been scoped down to foster real world testing environments. Initially, during the Eduscope V1 study this project started with a focus on the holistic Sub-Saharan African countries. With narrowing down the scope other areas are taken out of consideration. This project however is not bound to the chosen fablab of I.O.Me 254 and Kenya. As elucidated by previous research, such as the Eduscope V1B study by Plat et al. (2021), platforms like Fablabs.io offer a wealth of resources by showcasing various fablabs worldwide. This expansion of perspective underscores the potential for the Eduscope STEM project, along with its Eduscope Rig and V3 (Prototype), to catalyze advancements in science education and microscopy accessibility on a global scale. By concurrently addressing local economic and healthcare needs, this project becomes an attractive candidate for funding, thereby facilitating its implementation in diverse fablabs or organizations eager to host STEM initiatives. While the current focus is on Kenya, it is imperative that the Eduscope project runs in parallel with similar STEM endeavors in other regions, ensuring broader reach and impact across borders.

I.O.Me 254 has served as an invaluable testing ground and incubator for the Eduscope project, providing essential infrastructure, expertise and support. The resources and collaborative environment offered by I.O.Me 254 have been instrumental in refining the project's prototypes and methodologies. Given its central role in the project's development and that the project has not been fully field tested at low-resource secondary (high) schools, it is essential to maintain I.O.Me 254 as a primary testing platform ensuring the continuity of ongoing research, development and testing processes.

However, by embracing an open-source approach, the project can extend its reach beyond I.O.Me 254. By sharing project resources, documentation and methodologies on open-source platforms, such as GitHub, other fablabs and organizations worldwide can access and adapt the project to their local contexts. This decentralized approach empowers diverse communities to bring the project to themselves, fostering innovation and scalability while alleviating the need for researchers to relocate to other fablabs. Thus, while maintaining a primary focus on I.O.Me 254 for now, the project's open-source nature enables broader dissemination and adoption in the future.

Dangers of commercialization

The risk of the Eduscope V3 and subsequent iterations being appropriated by organizations and commercialized poses a significant threat to its core objectives. While commercialization may offer benefits such as lower production costs due to economies of scale, it could stifle innovation and flexibility in addressing the needs of specific low-resource areas. Additionally, handing over the project to commercial entities would undermine its value as a case study for STEM projects, depriving local students of valuable science education and real-world experiences. By placing proprietary restrictions on the project's technology and methodologies, commercial entities may discourage open sharing and collaboration among researchers, educators and developers. This could impede the collective effort to improve and refine the Eduscope, limiting its effectiveness and scalability. Ultimately, commercialization would concentrate resources and knowledge in the hands of a few, limiting opportunities for broader participation and collaboration.

Hence, it is imperative to maintain a strong focus on educating participants in the STEM project. By empowering local technical students with the knowledge and skills to contribute to the development of digital microscopes tailored to their specific low-resource secondary (high) schools, we ensure cultural involvement and pride in the project. This approach fosters a sense of ownership and investment among the community, encouraging active participation and collaboration. Moreover, involving local students in the design and implementation process ensures that the resulting solutions are culturally relevant and responsive to the unique challenges faced by their communities. Ultimately, prioritizing education and local involvement not only enhances the effectiveness and sustainability of the project but also promotes empowerment and self-reliance within the community.

Too much control

While the primary aim of this research is to empower technical students, it is essential to acknowledge the potential drawbacks of granting too much control. Without clear guidance or a structured framework, students may feel overwhelmed and unsure of where to begin, leading to inefficiencies and stagnation in the project's progress. While the Eduscope V3 prototype serves as an additional design step, there is a need for clear targets and priorities to drive the development of the most critical elements forward.

To address this challenge, it is crucial to establish an overarching governing body responsible for overseeing the project and its goals. This body would provide strategic direction, set clear objectives and keep records of progress to ensure alignment with the project's overarching vision. By having a centralized authority decisions can be made efficiently and resources can be allocated effectively. Furthermore, the governing body can play a vital role in facilitating collaboration and coordination among stakeholders, including technical students, researchers, educators and community members. Through regular communication and feedback mechanisms, the governing body can gather insights, identify emerging needs and adapt strategies accordingly to ensure the project's success.

Ultimately, by implementing a governing body, the project can maintain momentum, drive innovation, and ultimately achieve its goal of launching the Eduscope V3 in a timely manner, while empowering students and fostering their development along the way.

To ensure efficiencies and decrease dependencies, it is recommended that the governing body overseeing the project is someone internal to the organization hosting the STEM project. For I.O.Me, this individual could ideally be the Innovation Lab officer/assistant or the lab coordinator. Appointing this internal representative to lead the governing body ensures that the STEM project remains closely aligned with the organization's mission, vision, and values, while also promoting efficiency, accountability, and effectiveness in project implementation and management.

Implication of more stakeholders and master students

This research has primarily focused on engaging stakeholders present at the inception of the project. However, it's essential to acknowledge the potential contributions and benefits that could arise from collaborating with additional organizations. For instance, organizations like ‘Porticus’, with a shared ethos of empowering communities and fostering resilience and ‘ToolsToWork’, dedicated to enhancing education and empowerment in Sub-Saharan cultures, could offer valuable expertise, funding, and partnerships to advance the goals of the Eduscope Project. While such collaborations hold promise for enriching the project, it's crucial to maintain the project's integrity and prevent commercialization.

Given the time constraints limiting the full development of the STEM project, a master student from TUDelft could play a vital role in further shaping this initiative. By focusing on refining the STEM project framework, this student could contribute valuable insights and expertise to enhance its effectiveness and impact without interfering with the shift of ownership to the STEM participants.

Additionally, integrating technical expertise from an Integrated Product Design master student could provide valuable support to the project. IPD students could facilitate the design and development of components in collaboration with students at I.O.Me, but these IPD students should be warned on their interference with the ownership of the STEM participants and a strong focus should remain on creating easily understandable design tools/files for the further development of the STEM participants.

During the field research in Mombasa, a student expressed interest in continuing the research project as their own graduation project. While the criteria for master's theses in Mombasa may differ, exploring the possibility of local students pursuing further development through a master's thesis could be an intriguing avenue to foster continued growth and innovation within the community. This approach not only leverages local expertise and perspectives but also empowers students to take ownership of the project and drive meaningful change within their own context. Also for these master students, the focus should remain on STEM participants to ensure alignment with the project's overarching goals and objectives, fostering collaboration, skill development and meaningful impact within the community.

Eduscope services and logistics

Beyond the development and refinement of the Eduscope product with the STEM project, ensuring its efficient distribution, repair services and ongoing support within the local community poses significant logistical and operational challenges. The moment the first batch of Eduscope products are delivered to those low-resource secondary (high) schools it is crucial to invest in establishing robust supply chains, repair centers, maintenance support and customer service mechanisms to ensure the accessibility and longevity of the Eduscope project.

Addressing this gap requires collaboration with stakeholders who specialize in logistics, distribution and service provision. Local businesses, community organizations or governmental agencies may play a role in establishing and maintaining these essential support systems. By partnering with entities experienced in logistics and service management the Eduscope project can leverage existing infrastructure and expertise to ensure reliable deployment, repair and ongoing support for users.

Additionally, integrating feedback mechanisms and user engagement initiatives into the project's design process can help identify potential challenges early on for further developments of the Eduscope products.

Research quality

This master thesis encompasses a broad design scope, which has necessitated making decisions with limited insights from literature, field exploration, and idea validation. Consequently, certain decisions, such as opting for the Raspberry Pi Camera Module 2 over the Raspberry Pi High-Quality Camera for the Eduscope V3 Prototype, were made swiftly and may require further exploration. However, it's important to highlight that the choice of the Camera Module 2 offers advantages beyond just image quality versus cost, as it enables the Eduscope to support dual viewing capabilities.

Parts and mechanisms requiring deeper research include the leadscrew bearing, leadscrew mechanism, stage clips, and the gantry plate with its wheels. Additionally, it's crucial to acknowledge that this research was conducted by a student who was initially unfamiliar with the local context. His cultural perspective and geographical location may have influenced the desirability, usability, feasibility and viability of the project deliverables. Therefore, ongoing exploration and adaptation are essential to ensure the project's relevance and effectiveness within the target community.

Eduscope STEM Project

First workshop

The initial workshop received positive feedback from the participants, who rated it highly in terms of educational value and enjoyment. However, it was observed that the workshop may have been too densely packed with content. This highlights the need for further research to achieve a better balance of workshop components. For instance, this research might reveal the need for an additional workshop during the discover phase of the STEM project.

Setup

During the initial workshop, the setup involved placing two Rigs on one large table. However, this arrangement limited the ability of the four students assigned to each Rig to freely move around it. As a consequence, there were instances where participants struggled to access the Rig, impeding their hands-on exploration. To address this issue in future workshops, it is recommended to configure the setups in a way that maximizes participant interaction with the equipment. This could involve arranging the tables to allow for easier access and movement around the Rigs, ensuring that each participant has ample opportunity to engage with the setup.

Furthermore, concerning the setup, incorporating a calibration slide could enhance the understanding of magnification levels by providing a convenient reference point for determining the degree of zoom, but it also can be effectively used as slide for comparing image results when conducting comparison tests with the Eduscope Rig or Eduscope V3 (Prototype).

Part fragility

During the workshops, it's important to highlight the fragility of the camera cable connectors, as one of them broke during the first workshop. While this type of breakage appears to be common, as evidenced by discussions on online forums, repairing the cable connector can significantly disrupt the workshop activities. Therefore, participants should be reminded to handle the connectors with care to minimize the risk of damage and potential interruptions to the workshop.

Workshops

The workshop recommendations provided in this report are drawn from personal experiences and estimated time frames. However, it's important to note that the length and structure of the workshop series may vary based on organizational factors or participants' learning pace. Therefore, adjustments to the duration and content of the workshops may be necessary to better suit the needs and constraints of the participants and organizers.

Eduscope Rig + V3 (Prototype)

Frame

The utilization of the 2020 profile structure in both the Eduscope Rig and V3 Prototype brings numerous advantages owing to its widespread availability. However, despite the prevalence of this profile, not all 2020 profiles are created equal. While the outer 20mm by 20mm should be the same among all 2020 profiles the dimensions of their channels can differ.

Although sliding nuts are generally designed to be compatible across different 2020 profiles, there remains a possibility that they may not fit seamlessly with one another. In such cases, one of the components needs to be replaced. However, a different 2020 profile can also necessitate modifications to the design of both the Rig and the V3 Prototype.

To mitigate these dependencies, the design of the Eduscope Rig has been adapted to separate the 2020Slider from the ElementHolders, reducing the need for extensive redesign of the ElementHolders. Next to that, in both the parts for the Rig and the V3 Prototype, simple guiding walls are employed to interlock with the 2020 profile. While this design allows for relatively easy adjustments within the SolidWorks files, any necessary redesigns will inevitably entail an iterative process to achieve optimal tolerances.

To minimize the risk of compatibility issues, it is advisable to conduct thorough tolerance checks before purchasing 2020 profiles in bulk. By verifying the compatibility of these profiles beforehand, potential disruptions to the assembly process can be mitigated, ensuring smoother and more efficient project execution.

Raspberry Pi Housing

The Pi Housing on the Rig is designed with simplicity in mind, facilitating short printing times and allowing for flexibility in further development. However, this design choice leaves the Pi exposed and vulnerable to environmental factors and users handling, increasing the risk of damaging the Pi.

Moreover, the Pi is housed between two clamps, which presents a challenge during mounting or dismounting. There is a risk of the Pi slipping away and falling, potentially causing damage upon impact. Unfortunately, incidents like this have occurred during the course of the project, resulting in damage to the Pi's SD card. This highlights the need for further research to improve the housing design, aiming to enhance the protection of the Pi while still considering factors such as print time and flexibility.

In the V3 Prototype, the housing of the Raspberry Pi offers improved protection compared to the Rig. However, it's worth noting that this housing is not waterproof or dustproof. Additionally, there's a concern regarding the limited airflow provided to the Raspberry Pi within this housing.

While addressing environmental protection and airflow could enhance the durability and performance of the Raspberry Pi, it's important to prioritize tasks based on critical needs. As of now, the Raspberry Pi has not demonstrated any malfunctions within this housing, suggesting that immediate attention may not be necessary. Nevertheless, further research could be beneficial for future iterations of the prototype.

Nosepiece

This research promptly selected a Nosepiece with three objectives, a configuration traditionally associated with microscopy education. This choice is well-suited for providing students with an interactive learning experience, showcasing the importance of magnification in examining specimens. However, it's worth exploring alternative options. One consideration is whether the nosepiece could be substituted with a 3D-printed version or a user-friendly objective replacement system. These alternatives may offer cost savings and reduce reliance on suppliers, while still achieving the desired educational outcomes.

Additionally, an investigation into using fewer objectives could be beneficial. While the traditional setup includes three objectives, simplifying the configuration to one or two objectives may streamline the design and reduce complexity. This could potentially lower production costs and make the Eduscope more accessible to schools with limited resources. Thus, exploring these alternatives could lead to a more flexible and cost-effective solution for the Eduscope project. An idea worth mentioning is designing a Eduscope V3 version where the objective is replaced by a RMS adapter with only one objective, this would reduce the cost of the whole Eduscope V3 from ~180 eur to ~135 euro.

Z-axis translation

The Eduscope Rig encountered challenges with the Mover due to play and friction introduced by the fixation holders for the leadscrew and the momentum on the 2020Slider with the SlideHolder. This resulted in significant backlash in the Mover and an unsatisfactory user experience. In contrast, the Eduscope V3 Prototype addressed these issues by incorporating a bearing and a gantry plate, effectively mitigating these struggles. While the gantry plate may not be suitable for the Rig's functionality, replacing the Leadscrew Holders with those used in the V3 Prototype, which utilize a bearing, shows promise in enhancing the Rig's functionality.

The decision to opt for a 2mm pitch leadscrew over an 8mm pitch for the leadscrew proved advantageous for achieving accurate slide positioning. However, it's worth noting that traditional microscopes employ a sophisticated rack and pinion system with a gearbox to enable smooth operation, offering both coarse and fine adjustments. Although replicating such a system involves complex geometry and machinery, it may present superior performance compared to the Leadscrew used in this research. Further exploration into this sophisticated system and its application in locally manufacturable digital microscopes is warranted.

Regarding manual translation, it remains unclear if it is superior to the drivetrains utilized in the Eduscope V2 and the Schistoscope. While manual translation offers advantages in terms of sourcing, complexity and cost, drivetrains may offer benefits for integrating digital systems, such as gamification. However, the manual translation remains far less complex and less dependent on suppliers/energy and other components.

While the innovative translations offered by the OpenFlexure microscope are intriguing, their implications for Eduscope prototypes have yet to be explored. Leveraging these flexures could potentially enhance reliability and reduce Bill of Materials complexity, further advancing the Eduscope project.

XY-axis translation

For the Eduscope Rig, simplicity was prioritized in the design of the SlideHolder, as slide analysis was not the primary focus. However, this simplicity led to an unintended consequence: freedom of movement for the slide, resulting in tilting back and forth. In contrast, the Eduscope V3 Prototype addresses this issue by utilizing a horizontal stage on which the slide lays flat, effectively mitigating tilting. While replicating this positioning in the Rig may not be feasible, further research could explore alternative techniques, such as incorporating additional clamp positions, to address the tilting issue.

Lighttower

Due to cost considerations, the glass plano-convex lenses utilized in the Eduscope V2 have been substituted with acrylic plano-convex lenses. However, further research is needed to assess the potential yellowing effect of polymer lenses and evaluate their longevity. Nevertheless, leveraging the repairability features of both the Rig and V3 Prototype, the acrylic lenses can be readily replaced if necessary.

Cable management

The Eduscope Rig serves participants requiring its flexibility and is situated in a horizontal position, which mitigates the risk of tipping over in response to sudden pulling forces on the cables. However, the Eduscope V3 Prototype adopts a vertical orientation, necessitating further investigation into potential strategies for preventing accidental tipping due to cable tension. One straightforward approach worth exploring involves integrating cable holders onto the base or frame to redistribute and lower the point of force exertion in case of sudden pulls. This proactive measure can enhance the stability and safety of the Eduscope V3 Prototype, ensuring uninterrupted usage and minimizing the risk of damage.

Python script

The Eduscope Rig is not dependent on one python script and can easily switch between scripts made by STEM students and scripts sourced from the internet, like the auto_full script by Raspberry Pi Foundation. However, the Eduscope V3 should have a reliable script tailored to the needs of the secondary (high) school education system. The development of this script has been out of scope for this master thesis, but strong recommendations are given to integrating this development by giving ambitious STEM participants the opportunity to run the code development parallel to or outside of the STEM project.

The flexibility of the Eduscope Rig extends to its software compatibility, allowing seamless integration with various Python scripts developed by both STEM students and external sources such as the app-full.py script provided by the Raspberry Pi Foundation. However, as the project evolves to the Eduscope V3, there arises a need for a dedicated and reliable script tailored specifically to the requirements of secondary (high) school education systems.

While the development of such a script falls outside the scope of this master thesis, it is crucial to prioritize its integration during the Eduscope development. To achieve this, strong recommendations are made to involve ambitious STEM participants with python coding knowledge in the development process. By providing these participants with the opportunity to contribute to the code development either within or alongside the STEM project, the project can ensure the script meets the educational objectives and technical specifications required for effective classroom use.

PLA Filament and reflections

During this master thesis, experiments were conducted to assess the reflection levels of different filament types and tube designs for the Eduscope. Specifically, comparisons were made between white, black and matte black filaments, as well as between smooth and ridged tubes. The findings revealed that the matte black filament with ridges performed best in terms of minimizing reflections. The Eduscope V3 Prototype utilizes a matte black PLA tube without ridges. While it does yield clear image results, further investigation into integrating ridges into the tube design can be conducted. For reference one can look at the ridge design utilized in the OpenFlexure microscope. Additionally, it is advisable to compare the matte black PLA tube with a black PLA tube for image results to determine if the difference in performance is significant. This could result in more supplier flexibility and cost benefits.

Hygienic surface quality

The Eduscope Rig + V3 Prototype predominantly utilizes FDM printing with PLA for parts that come into contact with users. However, one drawback of FDM printing is the porous surfaces it produces, which can harbor bacteria and other microorganisms. Traditional cleaning methods, such as using ethanol wipes, may not effectively eliminate bacteria within the porous structure. Therefore, further research is needed to explore methods for preventing bacterial adhesion to these surfaces.

There are several techniques that can be employed to enhance the resistance of 3D prints to bacterial accumulation:

1. Sanding: Smoothing the surface of 3D prints through sanding can reduce porosity and make it less hospitable for bacterial growth.
2. Redesign: Modifying the design of parts to minimize surface corners or stringing can decrease areas where bacteria can adhere.
3. Dip coating: Applying a food-grade epoxy or polyurethane resin coating can create a smoother surface that is less prone to bacterial buildup.
4. Electroplating: Coating parts with metal using an electric current can provide a protective layer against bacterial adherence. However, additional steps may be necessary to render plastic prints conductive.
5. Chemical smoothing: Treating prints with solvents like acetone, d-Limonene, or ethyl acetate can dissolve surface imperfections and create a smoother finish.
6. Filament selection: Opting for food-grade filament, such as ceramic filament, may offer better resistance to bacterial growth.

Although other techniques like SLA and SLS printing can yield smoother surfaces, they are not currently available at I.O.Me 001 and involve higher material costs compared to FDM filament. Alternatively, using a laser cutter or CNC machine to fabricate parts from more hygienic materials like metal or acrylic could provide a viable solution. However, these manufacturing techniques also increase the product’s dependencies.

Diffuser

While the imaging results produced by the Eduscope V3 Prototype meet the requirements for secondary (high) school education systems, there is potential to enhance the quality of the background by incorporating a white polypropylene sheet as a diffuser. However, further research is necessary to evaluate the extent of quality improvements against the additional dependency introduced by this modification.

Sourcing cheap versus reliable

It's worth mentioning that AliExpress operates more like a shopping marketplace than a reliable supplier, such as Thorlabs. While opting for cheaper options might seem appealing, there are some downsides to consider. These include the risk of getting products of varying quality, longer shipment times and the chance of shopping links vanishing. So, finding the right balance between saving money and ensuring reliability is essential. That means doing thorough research and checking out different suppliers to make sure they meet the quality standards needed for the Eduscope project. At present, I haven't identified any parts for the Eduscope Rig or Eduscope V3 Prototype that require sourcing from different suppliers than the ones currently recommended.

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Rig structure ideation (Appendix C)

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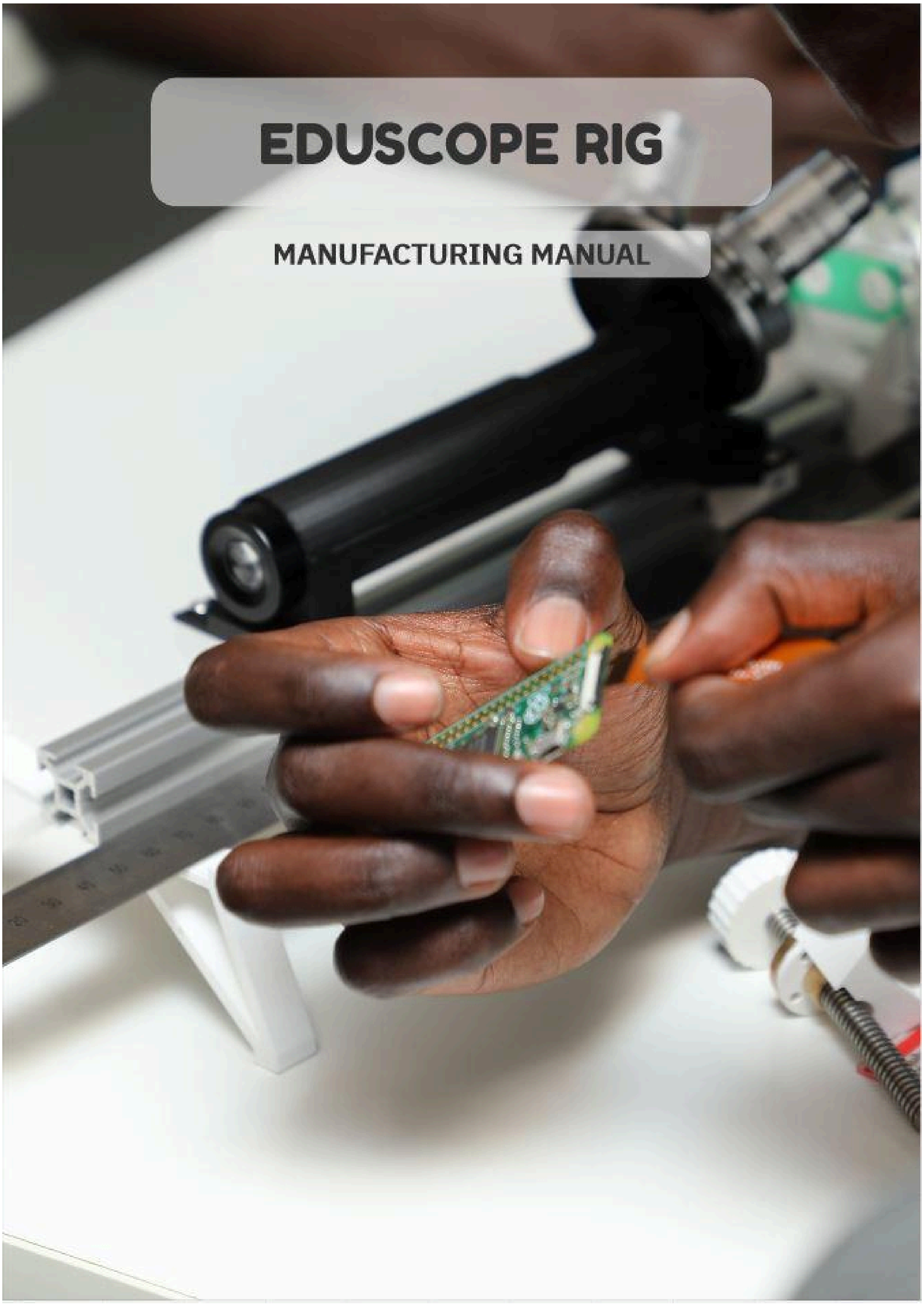
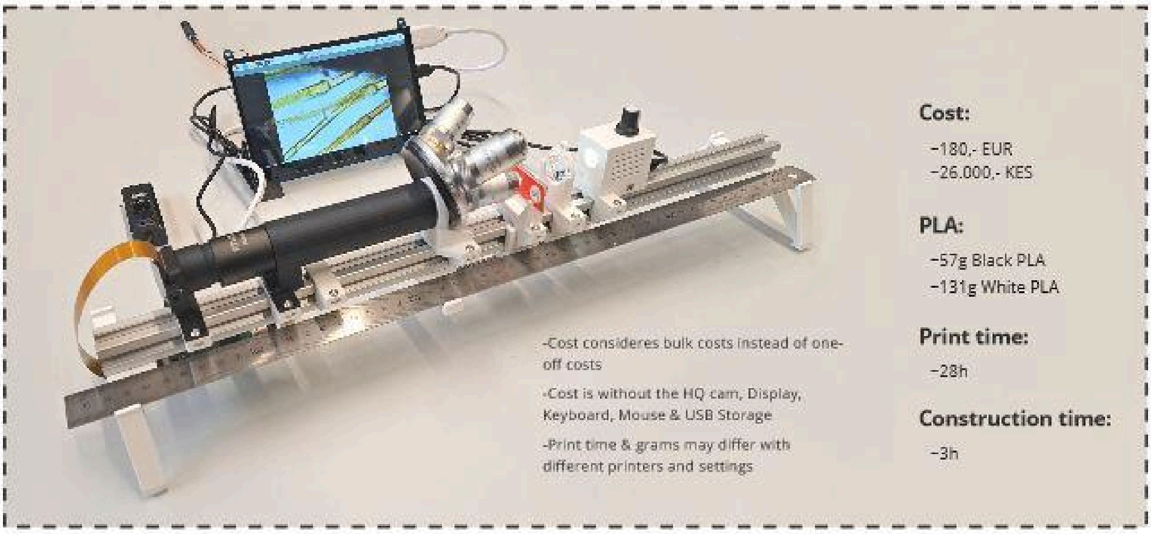
Appendix

A. Eduscope Rig Manufacturing Manual

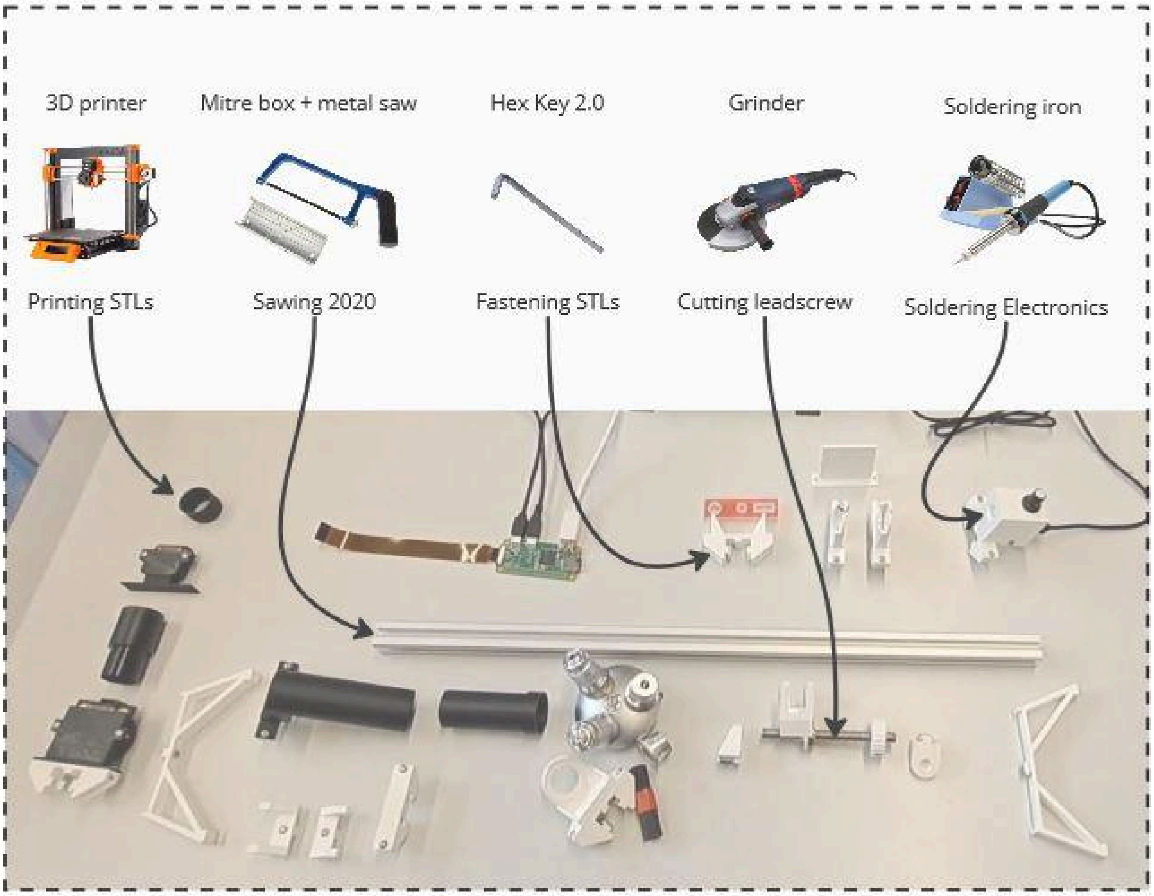


EDUSCOPE RIG | Overview

Construction overview

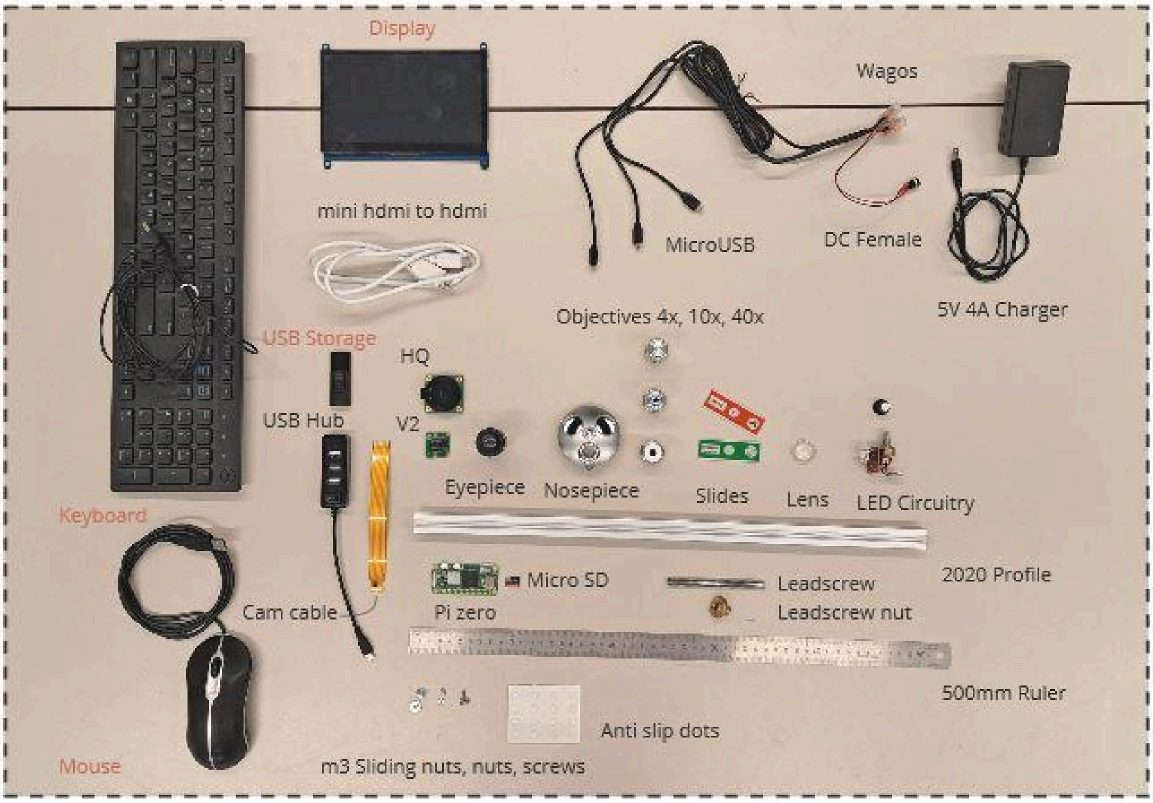


Construction tools overview



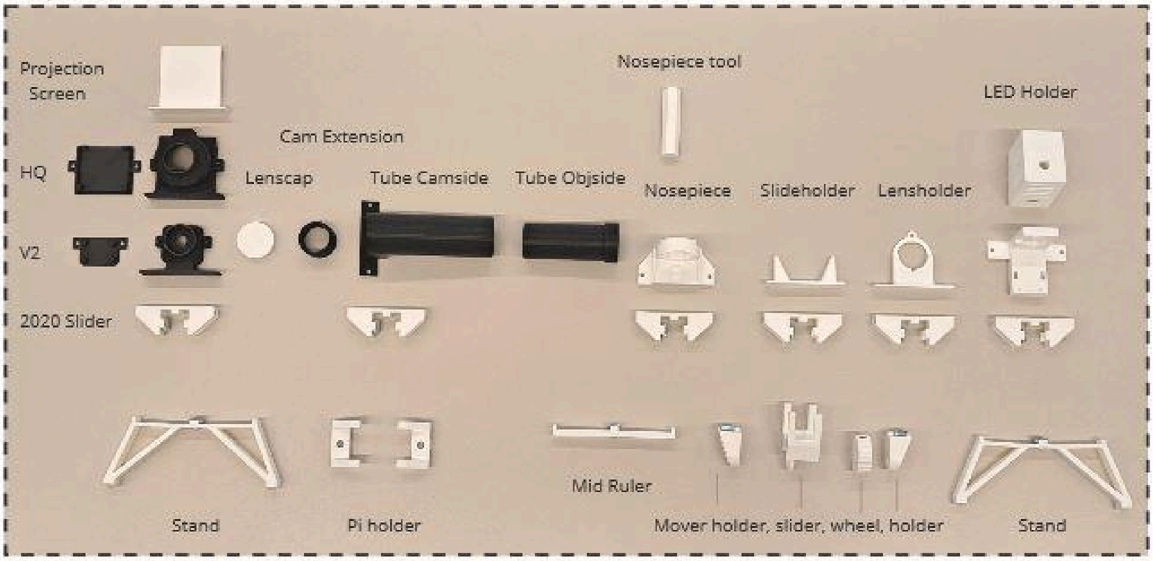
EDUSCOPE RIG | Components

Off-the-Shelf components overview



* Red components are not included in the BOM as these components are considered to be already present

3D prints overview

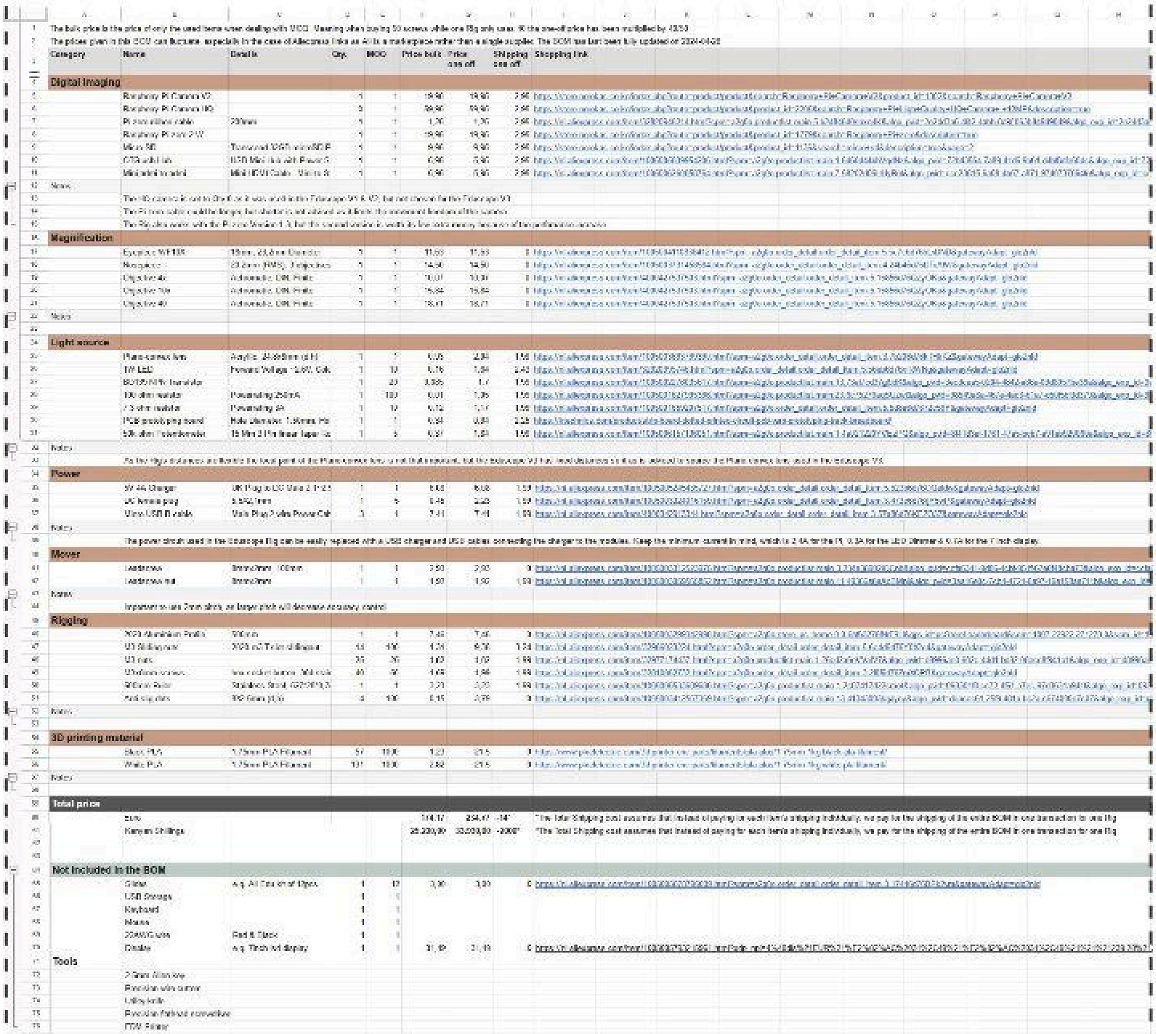


Essential costs overview

This condensed overview highlights the primary expenses, excluding peripheral items such as cables, chargers, rulers, and anti-slip dots, which are readily interchangeable or commonly available. From the total cost, 180eu (26000KSh), 144eu (2100KSh) is shown in this overview.

Bill of Materials

Below is a screenshot of the Bill of Materials (BOM) from an Excel file. Due to formatting limitations, not all information may be accurately depicted. To access the complete and accurate BOM, please use the QR code provided.

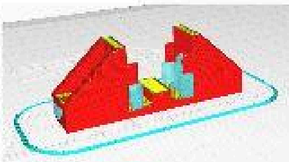


The bulk price is the price of only the used items when dealing with MOQ. [illegible]
The prices given in this BOM can fluctuate, especially in the case of Aliexpress links as Ali is a marketplace rather than a single supplier. The BOM has last been fully updated on [illegible]

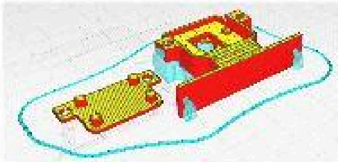
Category	Name	Details	Qty.	MOQ	Price bulk	Price one off	Shipping one off	Shopping link
Digital Imaging								
	Raspberry Pi Camera V2		1	1	19,90	19,90	2,96	[illegible]
	Raspberry Pi Camera HQ		1	1	59,90	59,90	2,96	[illegible]
	Pi zero ribbon cable	200mm	1	1	1,76	1,76	2,96	[illegible]
	Raspberry Pi zero 2 W		1	1	19,90	19,90	2,96	[illegible]
	Micro SD	[illegible]	1	1	9,90	9,90	2,96	[illegible]
	OTG with hub	USB Mini Hub with Power S	1	1	6,90	5,90	2,96	[illegible]
	Mini hdmi to hdmi	Mini HDMI Cable - Male to [illegible]	1	1	6,90	5,90	2,96	[illegible]
Notes								
	[illegible]							
	[illegible]							
	[illegible]							
Magnification								
	Eyepiece WF10X	18mm, 23,2mm Diameter	1	1	11,93	11,93	0	[illegible]
	Nosepiece	23,2mm (RMS), 3 objectives	1	1	14,90	14,90	0	[illegible]
	Objective 4x	Achromatic, DIN, Finite	1	1	10,07	10,00	0	[illegible]
	Objective 10x	Achromatic, DIN, Finite	1	1	15,84	15,84	0	[illegible]
	Objective 40	Achromatic, DIN, Finite	1	1	18,71	18,71	0	[illegible]
Notes								
Light source								
	Plano-convex lens	Acrylic, [illegible]	1	1	0,05	2,04	1,56	[illegible]
	1W LED	Forward Voltage [illegible]	1	10	0,18	1,84	2,43	[illegible]
	BD139 NPN transistor		1	20	0,085	1,7	1,56	[illegible]
	100 ohm resistor	Powerrating 250mA	1	100	0,01	1,36	1,56	[illegible]
	7,5 ohm resistor	Powerrating 3A	1	10	0,12	1,17	1,56	[illegible]
	PCB prototyping board	Hole Diameter: 1,0mm, [illegible]	1	1	0,34	0,34	2,25	[illegible]
	50k ohm Potentiometer	15 Mm 3 Pin linear taper [illegible]	1	5	0,37	1,84	1,56	[illegible]
Notes								
	[illegible]							
Power								
	5V 4A Charger	UK Plug to DC Male [illegible]	1	1	6,08	6,08	1,57	[illegible]
	DC female plug	5.5X2.1mm	1	5	0,45	2,25	1,57	[illegible]
	Micro USB B cable	Male Plug 2 wire Power Cab[illegible]	3	1	7,41	7,41	1,99	[illegible]
Notes								
	The power circuit used in the Eduscope Rig can be easily replaced with a USB charger and USB cables connecting the charger to the modules. [illegible]							
Mover								
	Leadscrew	8mm/2mm, 100mm	1	1	2,90	2,90	0	[illegible]
	Leadscrew nut	8mm/2mm	1	1	1,90	1,90	1,99	[illegible]
Notes								
	Important to use 2mm pitch, as larger pitch will decrease accuracy control							
Rigging								
	2020 Aluminium Profile	500mm	1	1	7,46	7,46	0	[illegible]
	M3 Sliding nut	2020 m3 T-slot sliding nut	13	100	1,24	9,36	1,24	[illegible]
	M3 nuts		26	26	1,69	1,69	1,99	[illegible]
	M3x[illegible]mm screws	[illegible]	40	50	1,69	1,96	1,99	[illegible]
	300mm Ruler	Stainless Steel, [illegible]	1	1	3,21	3,20	1,99	[illegible]
	Anti slip dots	[illegible]	4	100	0,15	3,79	0	[illegible]
Notes								
3D printing material								
	Black PLA	1.75mm PLA Filament	57	1000	1,23	21,5	0	[illegible]
	White PLA	1.75mm PLA Filament	131	1000	2,82	21,5	0	[illegible]
Notes								
Total price								
	Euro				174,17	254,77	-14*	*The Total Shipping cost assumes that instead of paying for each item's shipping individually, we pay for the shipping of the entire BOM in one transaction for one Rig
	Kenyan Shillings				25.220,00	33.000,00	-2000*	*The Total Shipping cost assumes that instead of paying for each item's shipping individually, we pay for the shipping of the entire BOM in one transaction for one Rig
Not Included in the BOM								
	Slides	e.g. All Stock of 12pcs	1	12	3,30	3,30	0	[illegible]
	USB Storage		1	1				
	Keyboard		1	1				
	Mouse		1	1				
	22AWG wire	Red & Black	1	1				
	Display	e.g. 7inch lcd display	1	1	31,19	31,19	0	[illegible]
Tools								
	2.5mm Allen key							
	Precision wire cutter							
	Utility knife							
	Precision flathead screwdriver							
	FDM Printer							

EDUSCOPE RIG | 3D prints

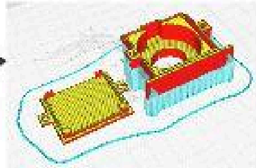
STL settings



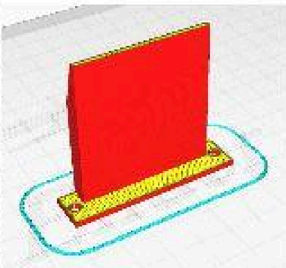
2020 Slider 1h 3m 6g



V2 Cam 1h 36m 9g

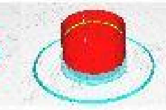


HQ Cam 3h 7m 20g



Projector screen 58m 8g

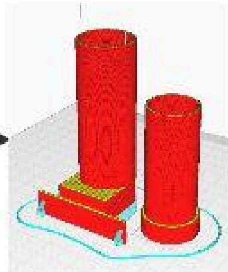
Cam cap 9m 2g



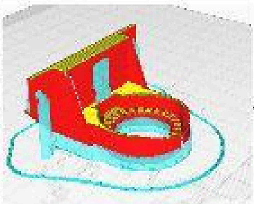
Cam extension 19m 3g

Black PLA

Nosepiece tool 17m 3g

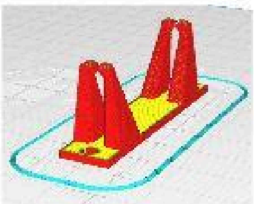


Tube 3h 21m 34g

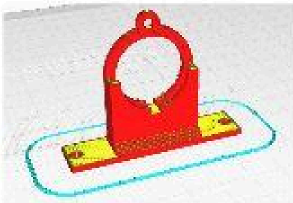


Black PLA

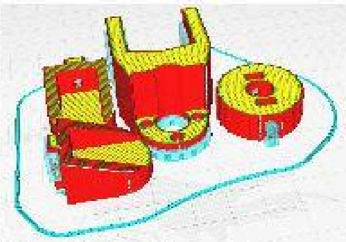
Nosepiece 1h 46m 11g



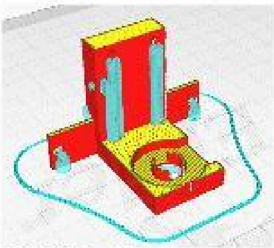
Slide 38m 3g



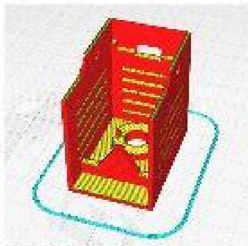
Lens 47m 4g



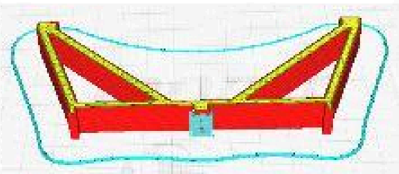
Mover 2h 52m 17g



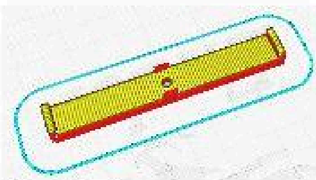
LED 1h 30m 9g



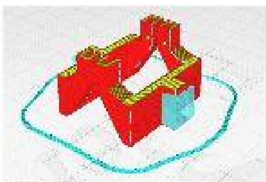
LED Lid 1h 32m 10g



Stand 1h 19m 12g



Ruler 35m 4g



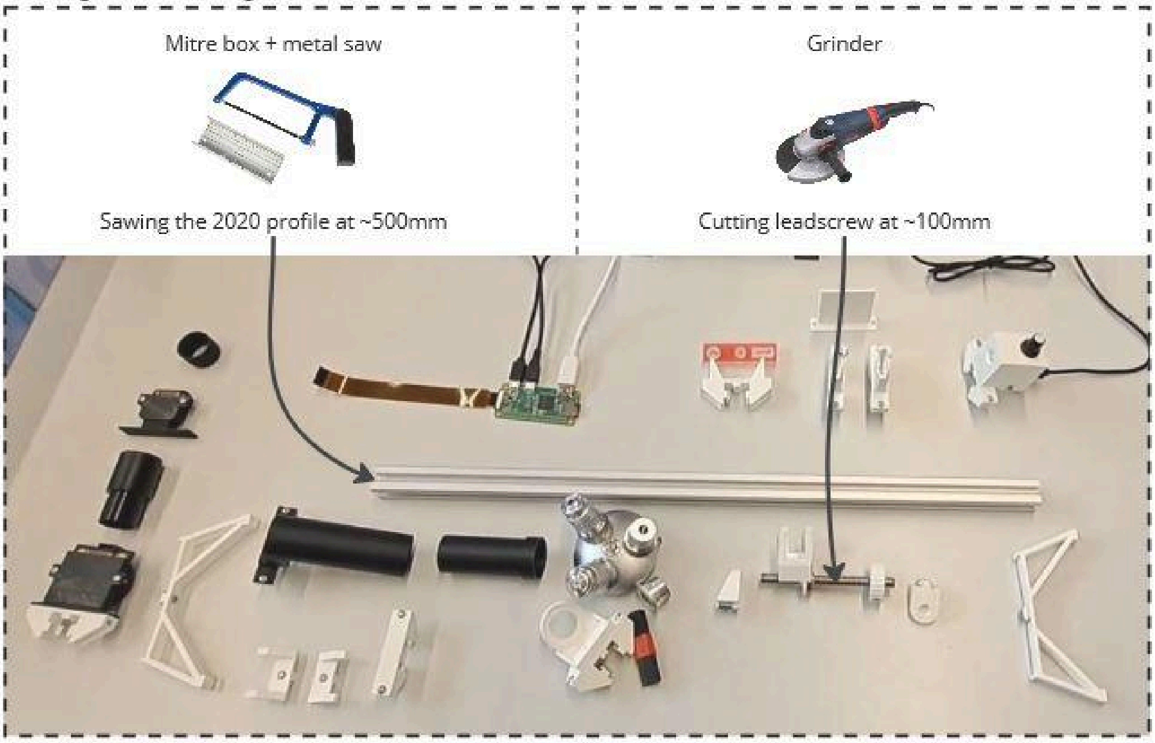
Pi 51m 5g

-The Eduscope Rig uses standard 1.75mm PLA.
-The Tube, Cam extension, Nosepiece and V2/HQ use Black PLA for minimising reflections
-Every part has been printed with 20% infill.

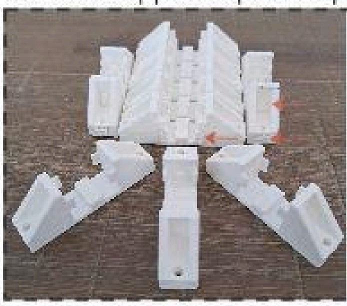
-> Total (excl. HQ cam): 27h 10min, 188grams (~4eu PLA cost) (Including 7x 2020 Sliders)

EDUSCOPE RIG | Assembly preparations

Cutting metal to length

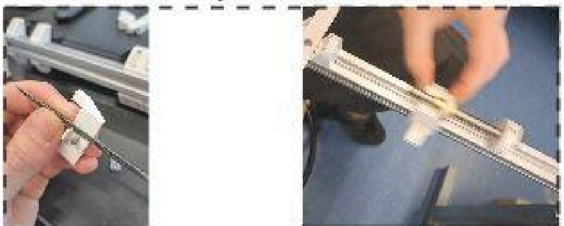


Remove support & print imperfections



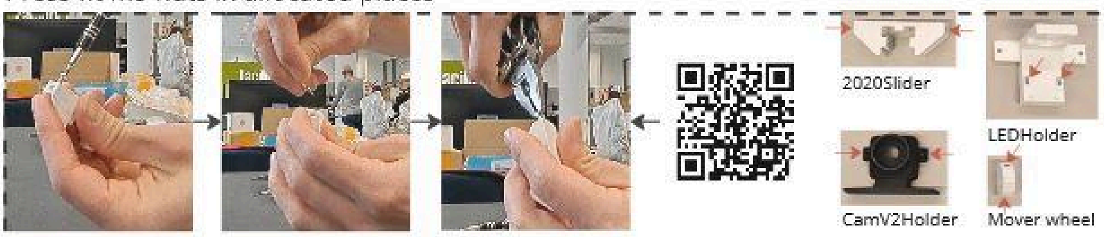
-Remove the support material using e.g. pliers and a small screwdriver
-Remove surface imperfections using e.g. a precision knife

Sand sliders if they don't slide on the 2020



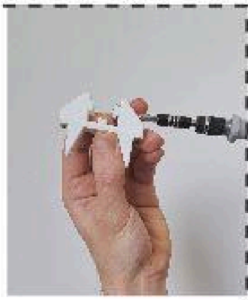
-Check the following parts and sand if necessary:
PiHolders, MidRuler, Stands, MoverSlider, MoverHolder

Press-fit m3 nuts in allocated places



1. Pre-screw the holes and remove any plastic residue to prevent screws from getting stuck in the nuts due to plastic residue
2. Press-fit the m3 nuts in their allocated places:
   - 2 in the each 2020Slider, 2 in the CamHolder, 2 in the LEDHolder and 2 in the moverwheel

Mount the Element Holders & Sliding nuts to the 2020Sliders



-Screw the Element(Holders) on an 2020Slider
-Give each 2020Slider a sliding nut and screw loosely, so it still slides on the 2020Profile. The sliding nuts can be positioned on two sides, make sure you place the nut on the side you are facing to easily loosen/fasten the sliding nut.

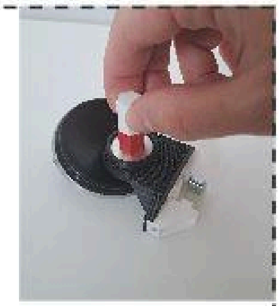
1. V2CamHolder/HQCamHolder
2. ProjectionScreen
3. TubeCamside
4. NosepieceHolder
5. SlideHolder
6. LensHolder
7. LEDHolder

Mount the Sliding nuts to the bottom STLs

-Attach the sliding nuts to the following parts:

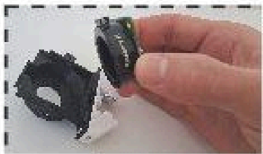
1. Stands
2. PiHolder
3. MidRuler
4. MoverHolder

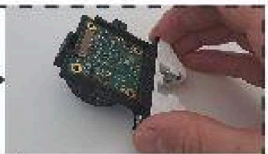
Mount the nosepiece to nosepiece holder



-Press the NosepieceHolder firmly on the Nosepiece, make sure the it's flat against eachother
-Use the ObjectiveTool to fasten the two pieces firmly together

Mount the camera in the CamHolder





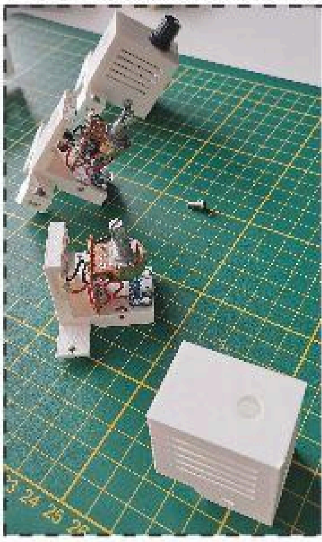
-Hold the printed circuit board at their edges to prevent frying.
-The camera should slide in its position without force.
-Screw the lid in place, holding the camera firm in its position.

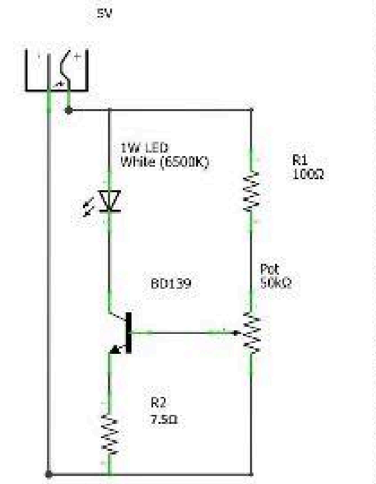
Prepare the Mover assembly

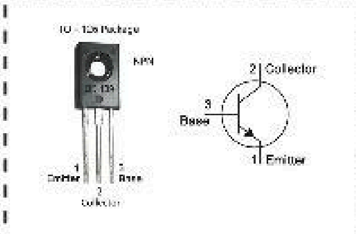
-Attach the Leadscrew nut to the MoverSlider
-Centre the MoverSlider on the leadscrew
-Attach the MoverWheel to the leadscrew as depicted in the figure

EDUSCOPE RIG | LED Circuitry

LED Circuitry components and solder path

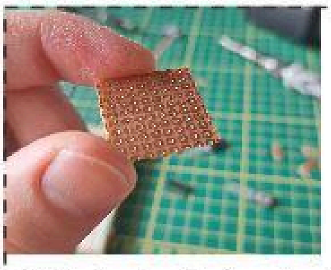


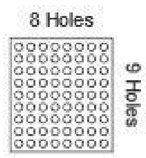




BD139 Transistor Pinout ("Components Info," 2018)

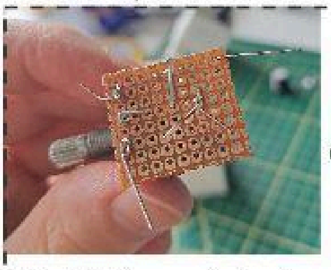
Cut breadboard to size of 8 by 9 holes

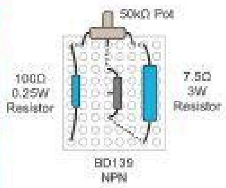




-Cut the breadboard using a sharp knife or precision cutter, making sure you cut along the holes which are outside of the 8x9 array

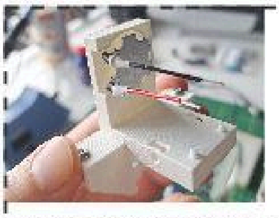
Insert components and bend legs

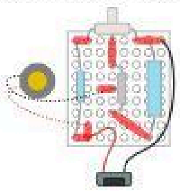




-The dotted lines are the bending paths on the back as depicted in the photograph
-Watch the orientation of the BD139, making sure the "Base" is connected to the middle pin of the Pot (for reference see the photographs below)

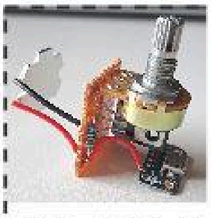
Solder wires & paths

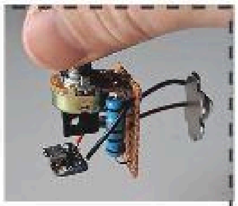




-Cut and strip wires for the LED module and micro USB board, make sure you get the correct length by testing the fit in the LED holder.
-Solder the paths and wires to the breadboard

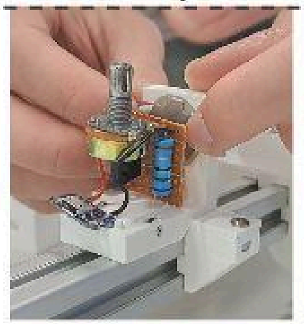
Result & test



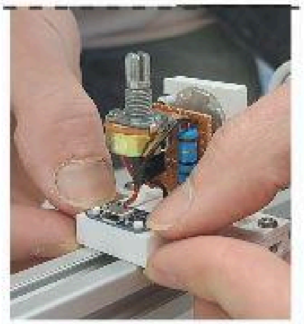


-Test the LED circuitry with 5V and a minimum of 0.2A.
-If the circuitry doesn't work check the solder connections or use a multimeter to detect faulty wiring or components.
-If it does work continue with housing the circuitry as instructed on the next page.

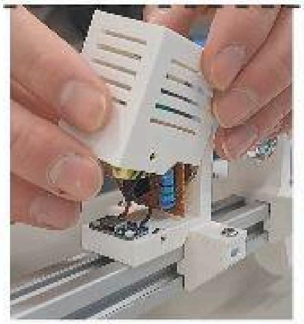
Mounting the LED circuitry to the LED Holder



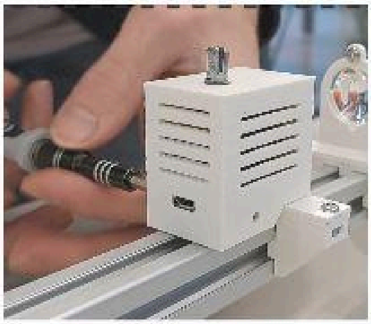
-Align the LED, making sure the wires are installed correctly.
-Press-fit the LED in its place



-Attach the micro USB board to the holder



-Cover the LED circuitry, making sure the LED and USB board stay in their position



-Screw the LED Lid in place, fixating the micro USB board and LED

-Mount the Pot washer and nut to secure the Pot in position

-Attach the Pot knob to the Pot by turning the Pot off and aligning the knob with its arrow to the back

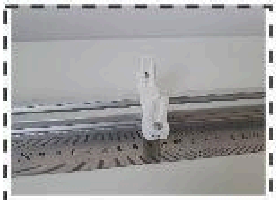
-Attach the micro USB cable for power (5V, min. 0.2A)
-Turn the knob to turn the LED on/off and control the brightness

EDUSCOPE RIG | Assembly

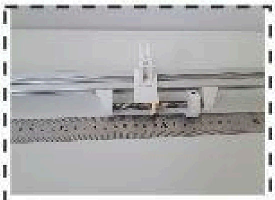
Mount the parts to the 2020 Profile

This section provides recommended distances for optimal performance in design applications, such as component comparisons. It's important to note that sharing this section with new STEM project participants (i.e. exploring the rig without prior knowledge) may not be desirable. In such cases, allowing participants to freely explore the rig fosters curiosity and understanding without the constraints of pre-determined settings. The distances mentioned here are corresponding with the optical plane indicators of the 2020Slider.

Scan the QR code to watch a video demonstrating the assembly process of the Eduscope Rig.



-Slide SlideHolder onto 2020 without fastening



-Position SlideHolder on ~270mm from the left and attach the Mover assembly
-Fasten MoverHolders firmly against the leadscrew

-Fasten MidRuler against the left of the MoverHolder
-Slide Piholders onto 2020
-Fasten Stands at the edges of 2020
-Slide Nosepiece onto 2020 without fastening

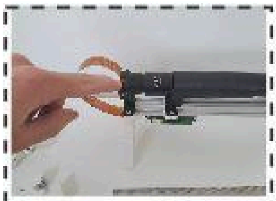
-Attach the TubeObjside to the Nosepiece
-Slide the TubeCamside onto 2020 without fastening

-Place the Eyepiece in the TubeCamside

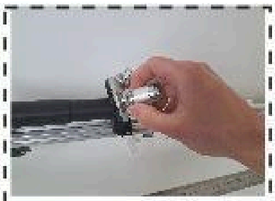
-Attach CamExtension to CamV2
-Slide CamV2 onto 2020

-Fasten CamV2 at the edge and fasten the TubeCamside against it.
-Fasten Nosepiece 160mm away from TubeCamside

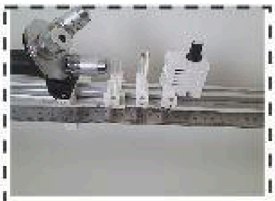
-Attach camcable to the Pi, being careful with the cable clip
-Secure Pi with PiHolders, being careful of not shortcircuiting the pcb



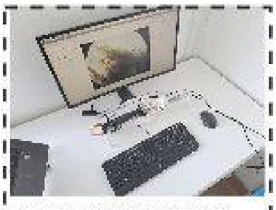
-Attach camcable to CamV2, being careful with the cable clip



-Attach objectives to nosepiece



-Position SlideHolder ~5mm away from the largest magnifying objective
-Fasten the Lens 30mm from the slide and the LED 30mm from the lens



-If the SD card has been configured:
-Connect HDMI cable and computer pheripahls
-Connect power cable to LED and Pi
-Enjoy microscopy

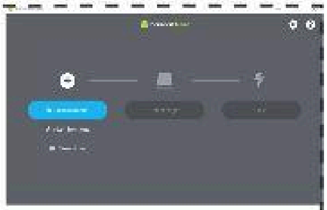
Two options in the Configuration of the Raspberry Pi

The Raspberry Pi Zero uses an SD card to run the Raspberry Pi OS. Through this OS, users can command the Pi to perform various actions using the command terminal or by writing scripts. For instance, within the terminal writing "rpicam-hello" initiates a camera preview. The Eduscope Rig uses a simplistic Python script to activate this camera preview stream with adjusted camera & preview parameters, enhancing its suitability for the Eduscope Rig application.

Copying and pasting this Python script onto another SD card running Raspberry Pi OS is one option. Alternatively, the entire SD card can be duplicated. Cloning the SD card ensures that all required dependencies and libraries are pre-installed to run the script without manual configurations. It's recommended to clone the SD card for reliability and time efficiency. However, given that the rig serves as a development tool, manual configuration of the Raspberry Pi may be preferred to gain more control and understanding of the Eduscope products' digital core.

Cloning the Eduscope Rig's SD card

1. Download & open "BalenaEtcher"
2. Insert the two microSD cards into the pc by means of an USB/SD-adapter
3. Click "Clone drive" and select the source, the microSD card containing the Eduscope Rig Image.
4. Click "Select target" and select the target, the microSD card you want to write to
5. **Double check the correctness of the source and target, switching it around wipes the micro SD card containing the Eduscope Rig image!!**
6. Click "Flash!" and wait until it is done

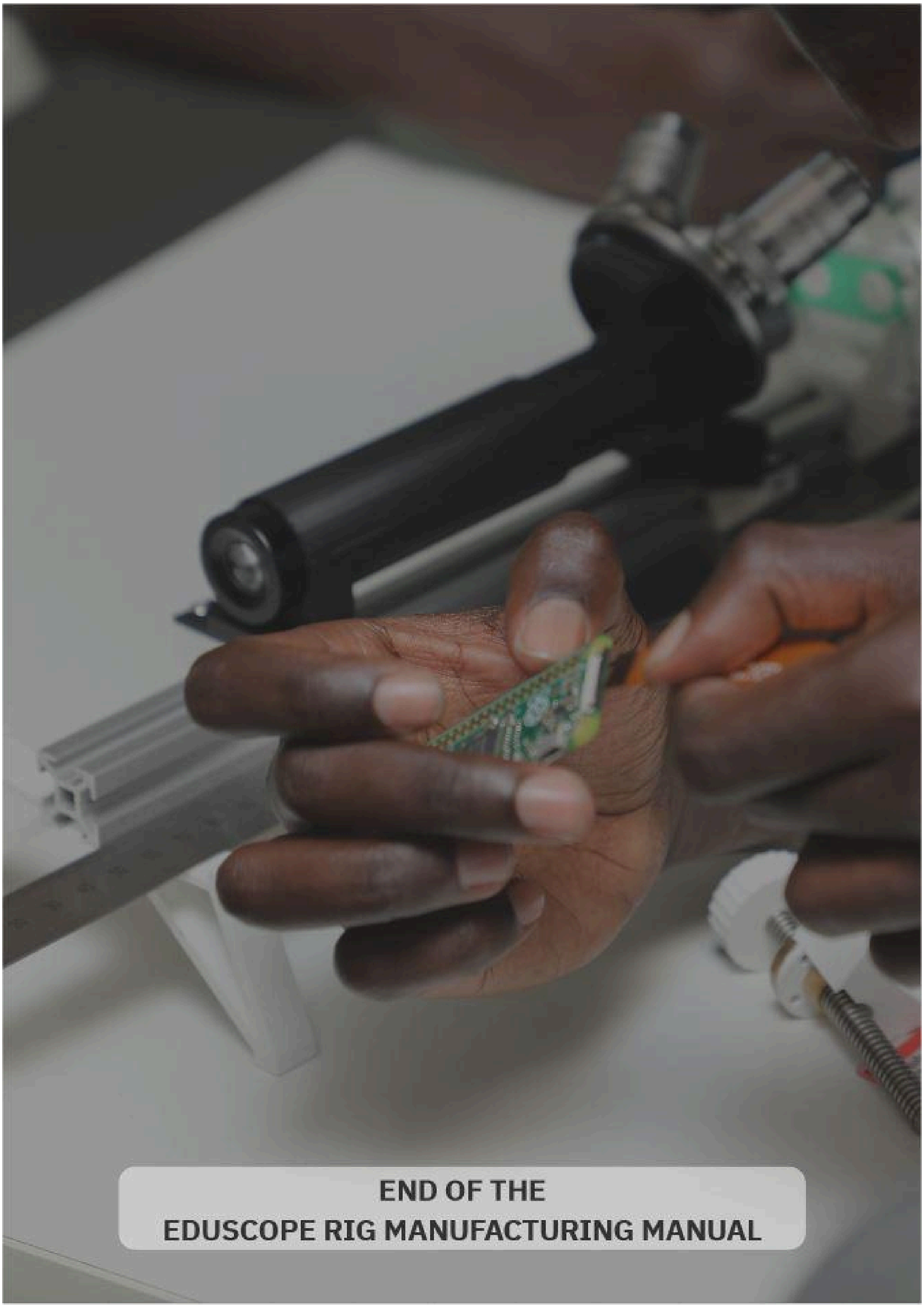


7. Remove the MicroSD card from the pc and insert it in the Raspberry Pi Zero
8. Connect the HDMI & USB-hub to the Pi Zero
9. Connect the power to the Pi zero, this will automatically turn on the Pi Zero
10. When the system has booted, run the "Eduscope.py" which is located on the desktop and select "Execute in Terminal"

Manual configuration

1. Download & open "Raspberry Pi Imager"
2. Insert the microSD card into the pc by means of an USB/SD-adapter
3. Use the window to choose the Raspberry Pi device, OS and Target source (SD card)
4. If asked to apply OS customisation, you can do it now or later when booting the Raspberry Pi device.
5. Start flashing the OS to the microSD card and wait until it is done

6. Remove the MicroSD card from the pc and insert it in the Raspberry Pi Zero
7. Connect the HDMI & USB-hub to the Pi Zero
8. Connect the power to the Pi zero, this will automatically turn on the Pi Zero
9. Run through the configuration of the Raspberry Pi OS
10. Update the Raspberry Pi device by means of the update icon and/or running "sudo apt-get update" & "sudo apt-get upgrade" in the command terminal.
11. Attach USB stick containing the EduscopeRig.py to the USB-hub and copy paste the script to the desktop of the Raspberry Pi
12. Run the EduscopeRig.py and select "Execute in Terminal"
13. Install the required dependencies and libraries if necessary


END OF THE
EDUSCOPE RIG MANUFACTURING MANUAL

B. Eduscope V2 field research analysis

Student Eduscope Workshop

Vincent van den Burg's field research at IOMe001
27-11 –> 1-12

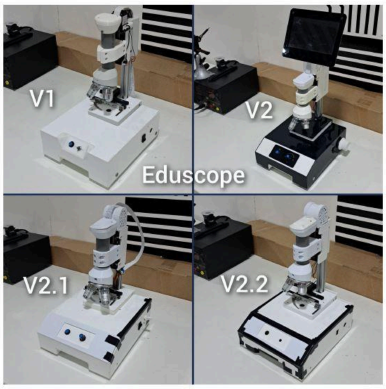
V1 & V2 were the assembled Eduscope versions on location
V2.1 was the to be assembled Eduscope version
V2.2 was the extra to be assembled Eduscope version

On the 13th of December at the moment Vincent left the versions were left with the following annotations.

V1
-No arduino, no pi & no condenser lenses inside (moved to V2/V2.1)

V2
-Camera works, light works
-Lighttower is not aligned with stage. Therefore, the stage is not mounted to the frame. You can manually align the light with the objective lens.
-Motor does not work, I think a more powerful powerbrick would fix this. Recommened specifications: 12V 3A. 2A is the rated capacity of the buck converter with a maximum of 3A using a heatsink. Make sure you attach a heatsink to the first buck converter when using a powerbrick rated above 2A.
-Motor cables are connected to the pcb, watch out for CEMF! Don't turn the motor axis while powered on and only very slowly when powered off.
-Battery is not inside. There needs to be done more research on the electronic diagram, what happends to the output of the buckconverters when the battery is being charged or dicharged. The battery can output 5A, does the buckconverter have a current limiter or does this mean we will destroy the buck converter when the sytems asks for more than 3A.

V2.1
-Camera works, light works
-Motor does not work, I think a more powerful powerbrick would fix this. Recommened specifications: 12V 3A. 2A is the rated capacity of the buck converter with a maximum of 3A using a heatsink. Make sure you attach a heatsink to the first buck converter when using a powerbrick rated above 2A.
-This motor is maybe stuck as turning the axis by hand was also not possible. If a more powerful powerbrick did work on the V2 motor and not on V2.1, replace the motor. First test the motor before mounting it to save time.
-Motor cables are connected to the pcb (I am not sure though), watch out for CEMF! Don't turn the motor axis while powered on and only very slowly when powered off.

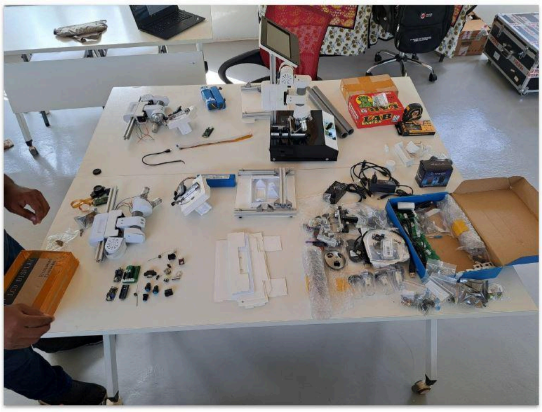


-Battery is not inside. There needs to be done more research on the electronic diagram, what happends to the output of the buckconverters when the battery is being charged or dicharged. The battery can output 5A, does the buckconverter have a current limiter or does this mean we will destroy the buck converter when the sytems asks for more than 3A.

V2.2
-Showmodel
-No electronics inside the base

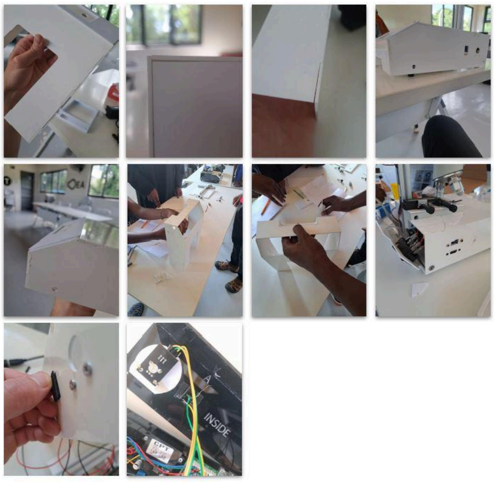
Missing parts, for building the Eduscope V2.1 during the workshop

- Display fastener knob
- Display back panel, Acrylic
- Correct sized DC female plug (did not fit base hole)
- 4-Pin power switch
- Electrical wire (multicolour)
- Heat shrinks
- JST connectors 2-, 3-, 4-pin
- Dupont and JST crimp tool
- Original screws, 2.5mm fasteners
- Spacers for electronics (HDMI connector, PCB's)
- Correct sized Springs (too tight for knob assembly)
- Soldering wire
- Original objective nosepieces (printed part tolerances)
- Tool for screwing the nosepiece to the printed part
- Correct version of printed stage, Light-tower is not aligned with the acrylic plate hole.
- MicroSD card reader
- Wagos
- Electrical tape
- Multimeter
- Clear condenser lenses (instead of foggy ones)
- Right sized aluminium profile, T-slot nuts do not fit



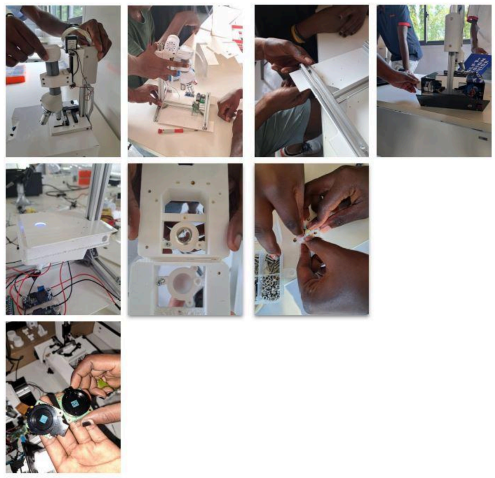
Flaws

- Acrylic base-cover
  - Breaks easily
  - Parts separate easily, glue weakens
  - Glue is hard to apply, leaves gaps, decreases ease of repair, leaves residue (glue, paper etc.) or can even leave marks like fingerprints. The base once was glued to the table leaving a piece of the table on the base
  - Difficult to know how sturdy the glue is or how dry
  - Too thin, giving switches play
  - Tolerances too tight, PCB's don't align with the holes
  - Fingers are not tightly aligned everywhere
  - Hard to slide on the frame, missing guiding rail. Uses a slot connection with the frame which is hard to understand/align
  - 3D printed panel does not perfect fit the acrylic assembly and is hard to glue down



Flaws

- Aluminium frame
    - Vertical profile is wobbly
    - T-slot screwing down is difficult
    - T-slot nuts slide only in from one direction, missing clear instructions how many nuts per T-slot
    - Getting the T-slot nut aligned with the motor assembly is hard when it's in an upright position
    - Aligning H-beam in the middle is done with the eye, missing alignment guides
    - Screen adjustments take a long time and wobbles the vertical axis
- Light tower
    - Manual stage is shifting, as only 1 screw holds it in place, some are screwed with all 3 screws
    - The condenser lens is loose, it moves, and you can even get it out without disassembling, it's only press-fitted
    - The condenser lenses can be placed in upside down
- Camera
    - HQ Camera IR filter has spots which obstruct the view significantly (3 out of 6) and which can be be fully cleaned with blowing, paper or ethanol

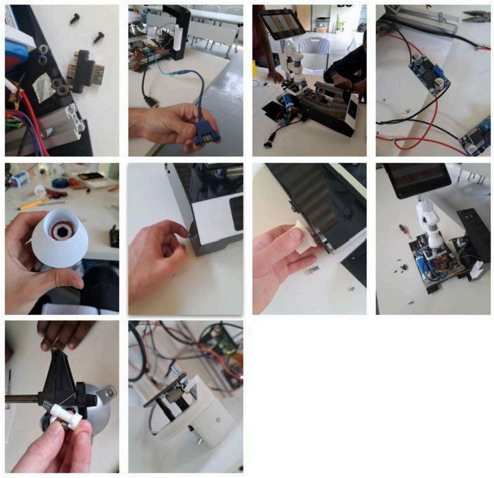


Flaws

- Motor assembly
    - The motor cover is loose, as it's only press-fitted, which also are too tight and too little surface area
    - The handle goes loose easily and then lifting the microscope results in the handle shooting up
    - Cable runners for the cables of the end-switches are too precise
    - End-switches are hard to screw in place
    - The drivetrain can only be dismounted by first dismounting the end switches
    - Wires from motor, camera and end-switches are visible, not tidy and prone to wire break
    - 3D print tolerances on the camera cover connections are too tight
    - Nuts in camera assembly clamp fall out easily, you can't hold them, and they are not rotation fixed.
    - The end-switches are there for the drivetrain ends and not for preventing the objective lens to impact on the slide
    - Drivetrain can not be supported by the threaded inserts, inserts are pulled out
    - Motor Assembly can not be supported by the side screws, plastic splits easily

Flaws

- Fasteners
  - The washers of the HDMI fly everywhere
  - Big crews on the sides of the base cover are ugly
  - There are too many different sized screws
- Electronics
  - Unnecessary bulky cables
  - The electronics are a mess making it hard to understand and hard to remove or attach the base cover. The back cover needs to get off first and some side connections need to get loose.
  - Cable fragility, cables take sharp corners and are clamped in between parts
  - Much has been soldered making troubleshooting and replacing difficult
  - Power Switch-pins too close to bolt from frame
- Fine/coarse switch has no feedback on which setting it is
- The Arduino code needs resetting when shifting between objectives (not verified)
- Rust on the manual stage
- Focus knob was too hard to understand, missing clear explanation
- Focus knob had a loose fit, could easily fall off



What students did different

- Polarity soldering was done wrong on the Power Switch, DC female plug and in between the converters
- Trying to use the smaller springs broke the 3D printed part
- The LED module slided away while screwing it down. The opposite screw holes needs to be crewed down simultaneously as the holes are not fully enclosed
- Glue was spilled on the table multiple times
- First the motor assembly was attached to the verticale profile before attaching the verticale profile to the frame, making it more difficult to screw it down
- The motor cables were connected without running the cables through the motor cap
- The Pi was placed mirrored making the cable connection troublesome
- The 2nd condenser lens, from the light up, was placed upside down

Tops

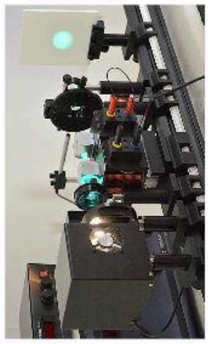
- The Acrylic material looks nice and hygienic/medical
- The Eduscope looks like a traditional microscope
- With the focus knob on the side you don't obstruct your own vision
- The stage with its slide is visible from many corners
- The Eduscope has a nice expensive weight to it, while not being too heavy
- The Eduscope is quite well balanced
- The nosepiece makes it feel real/marketable, instead of fully DIY
- The distance for the condenser lenses can not be done wrong. Same for the objective to camera sensor distance
- The screen's on top is positioned closer to eye level making it easier to see for many students

Opportunities

- Shorten the empty space in front of the stage
- Remove screen from vertical axis, improves stability
- 3D print Manual stage, maybe only using a purchased gear + linear gear
- 3D Print dampening feet to reduce costs
- Provide ceiling on the handle part of the Motor assembly
- Use the aluminium frames without threading & drilling? Would remove machining tools and decrease labour intensity
- Make the embodiment dustproof by using gaskets and only using ventilation holes vertically or face downwards
- Store the Eduscope in a case or with a cover
- Attach acrylic panels by gluing on smaller 3D connectors
- Use smaller battery
- Better weight distribution
- Use only one end-switch as calibration
- Mombasa is near the ocean and the high temp. results in high salinity atmosphere. Therefore, avoid as much metallic parts in the Eduscope
- A big PCB instead of buying converters etc.
- Single objective nosepiece and manually replacing objectives
- Implement a guiding rail for the base-cover (de-)attachment
- Increase dismounting ease of the top-panel of the base-cover, Increasing the access to the internal parts
- Make guiding walls for aligning the LED before screwing it down
- The top cover as a car hood so cables don't break that easily and you know where the hood should go when repairing
- Replace spacers with 3D prints
- Implement those sticky screws for screws which get loose easily, or use lock washers
- Making cable runners for the motor assembly
- Putting the motor upside down, to lower the mass and improve the stability
- Use a continuous potentiometer for the focus knob?
- Finger snaps to hold down the condenser lens
- Finger snaps for the base cover
- Counterbalance the vertical axis by putting weight on the other side, like the motor
- Use of heat shrinks
- Discarding the motor and using a manual vertical translation
- Using a ocular lens to multiply the magnification
- Metaphor, I want the Eduscope to be similar to the level of repairability & accessibility of the Tuk Tuks in Kenya

C. Eduscope Rig Structure Ideation

("Physics Experiment: LEOI-32 Experimental System for Crystal Magneto-Optic Effect," n.d.)



("Faraday Effect Apparatus - Multi Wavelength," n.d.)

("Faraday Effect Polarization With He NE Laser SK058," n.d.)

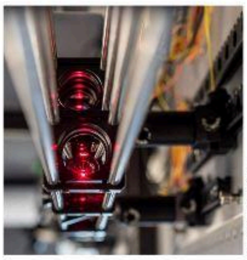
("Michelson-Interferometer - Wellenoptik - Optik - Versuche SEK II + Universität - Physik," n.d.)

("EISCO Basic Optical Bench, 1m Length," n.d.)

("Bench for Optical Systems - Dantec Dynamics," 2023)

("Faraday Effect Apparatus - Liquid Sample," n.d.)

("Light Optical Bench - (SIPO-001)," n.d.)

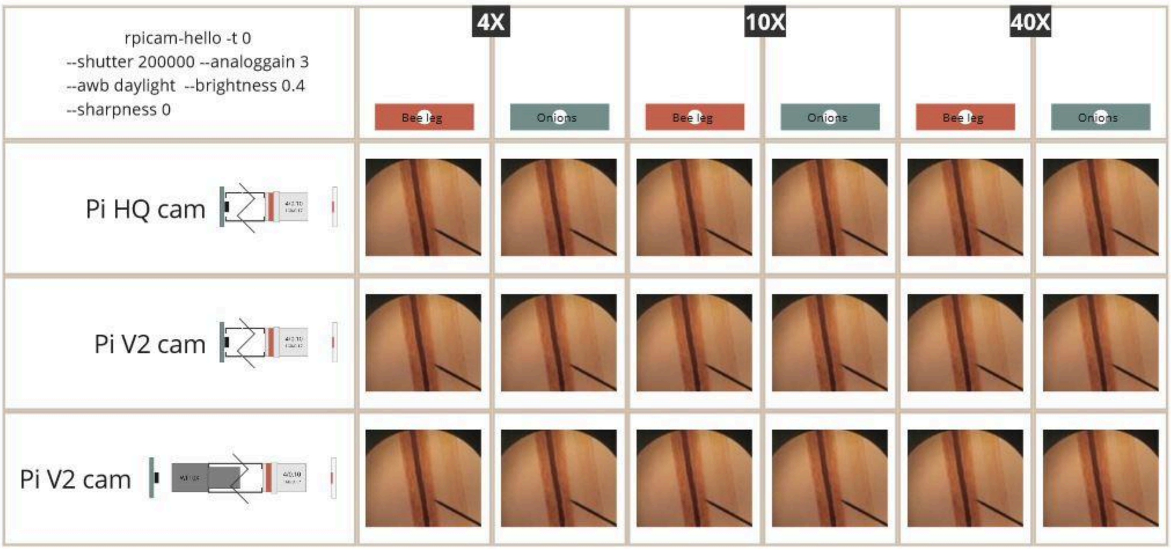


(Martens, 2024)

(BlueTide Web Consulting, n.d.)

(Exo Photography, 2021)

D. Comparison table example



Pot resistance 0 = 100% brightness
Pot resistance 50k = 0% brightness

Eduscope Rig Workshop

a microscopic world

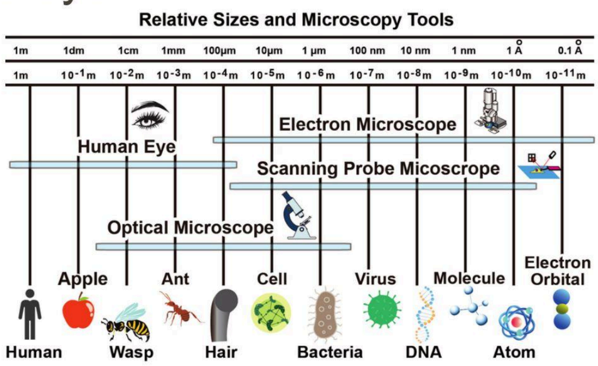
Goals

- Theory on microscopy
- Practica, hands-on, building the Eduscope Rig
- Next steps, making impact on low-resource high schools

Eduscope Lecture

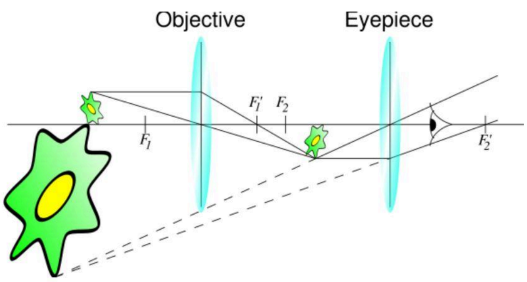
a microscopic world

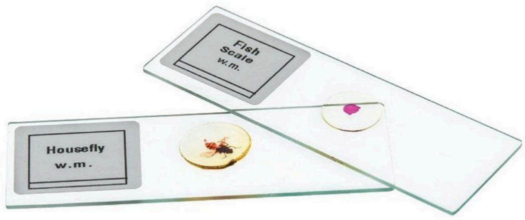
The science of viewing objects too small to be seen by the naked eye.



Source: Xia, Fangzhou & Youcef-Toumi, Kamal. (2022)

Optical microscope





Source: Fresh from the Farm Fungi

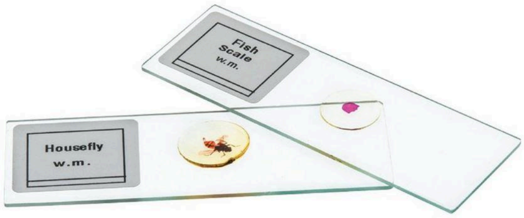
Compound vs. Stereo (optical microscopes)

- A compound microscope is commonly used to view something in detail that you can't see with the naked eye, such as bacteria or cells.
- A stereo microscope is typically used to inspect larger, opaque, and 3D objects, such as small electronic components or stamps.

Source: Fresh from the Farm Fungi

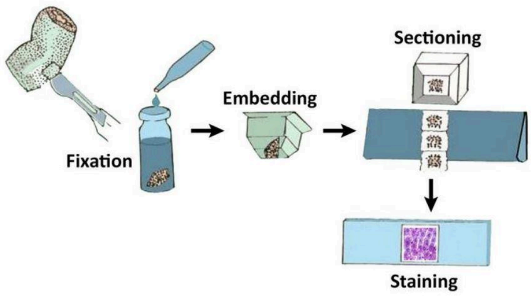
Slide preparations

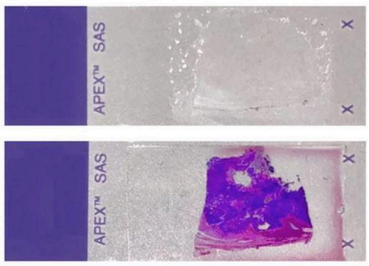
- Dry mount: such as hair or pollen
- Wet mount: often used for viewing cells
- Prepared slides: professionally prepared
- Smears: such as blood samples



Source: allschoolabs, Tom Grill / Getty Images

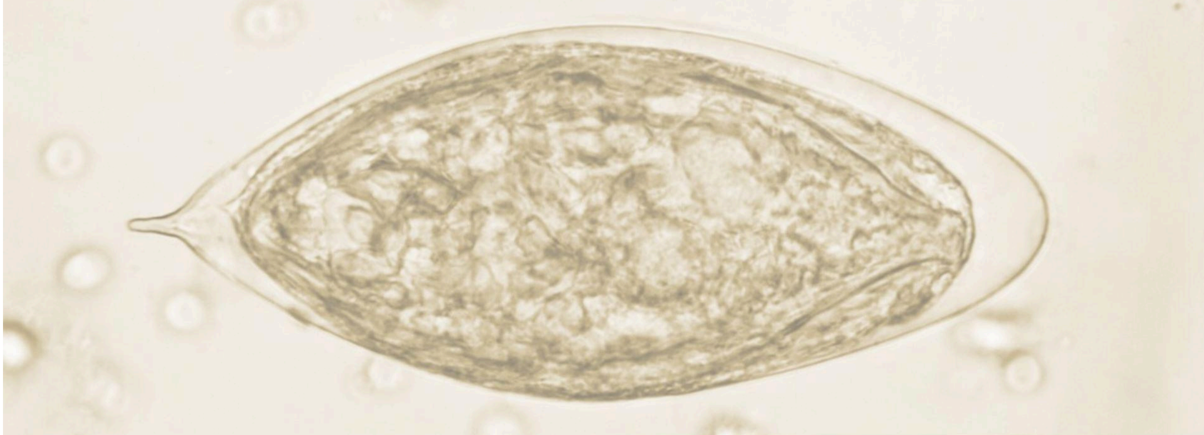
Slide preparation complicated example





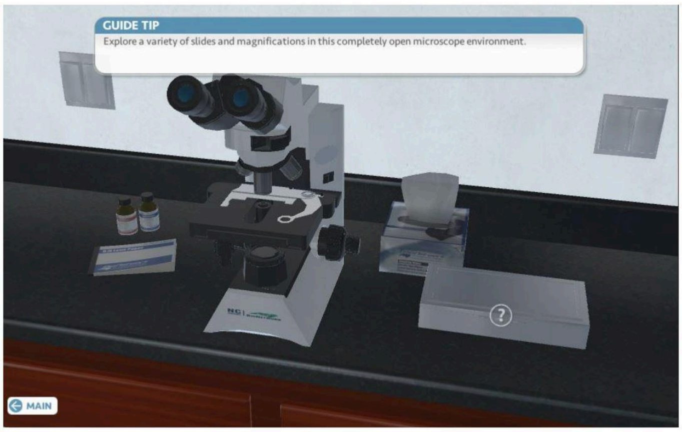
Source: digitalhistology.org

Diagnosing diseases, e.g. Schistosomiasis

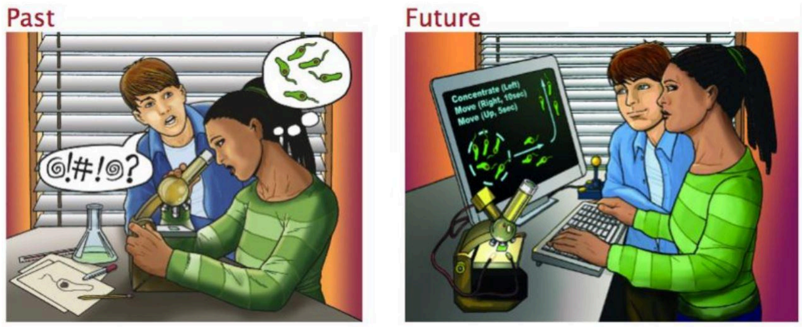


Source: Amboss

Virtual microscope



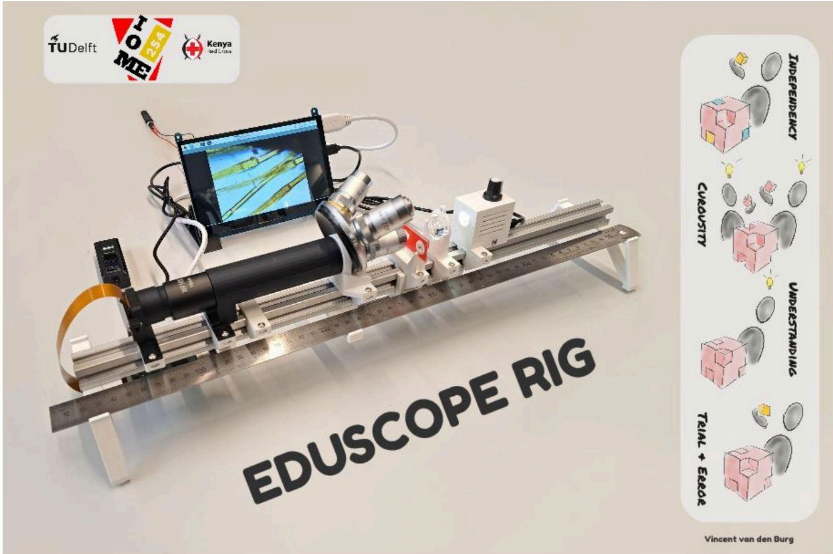
Source: ncbionetwork.org

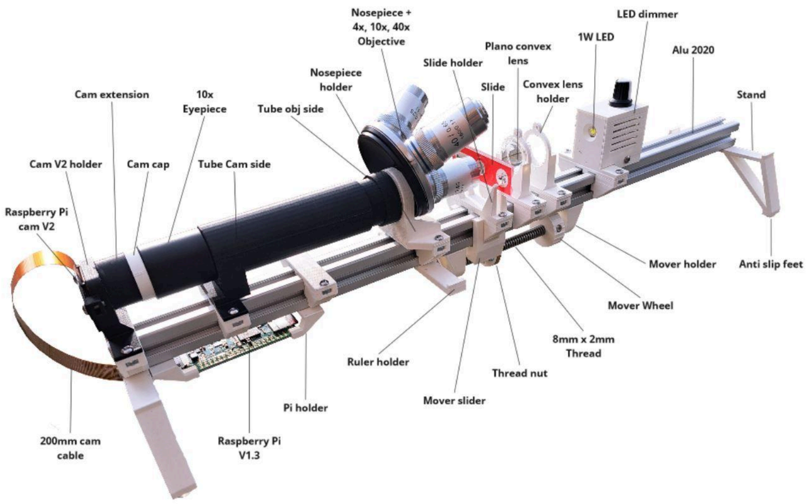


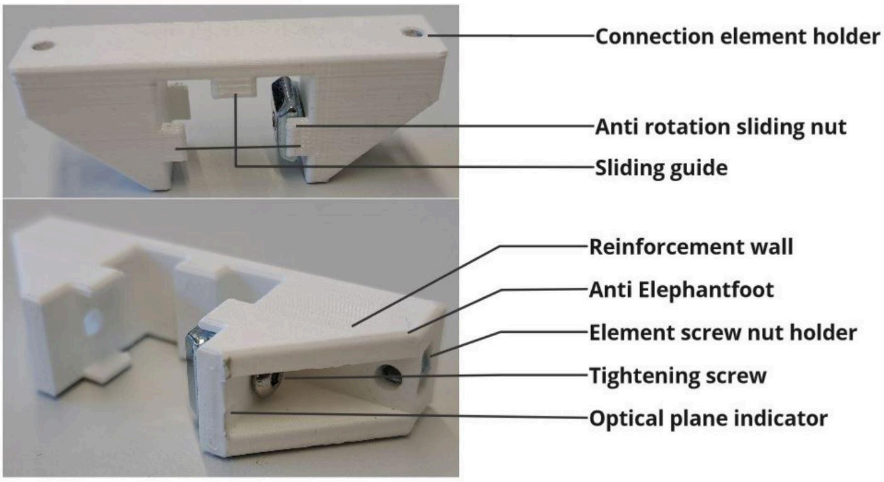
Source: RiksEddy - Picroscope

Eduscope Rig Workshop

a microscopic world

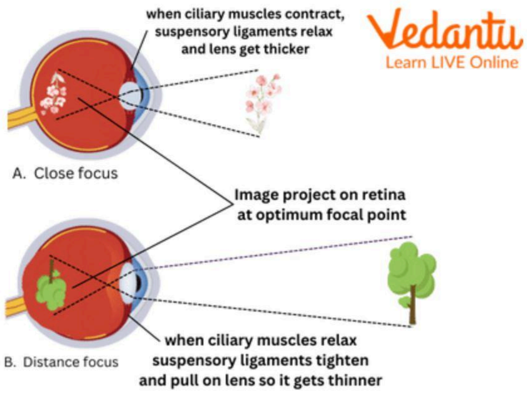

TUDelft
Kenya
EDUSCOPE RIG
Independency
Curiosity
Understanding
Trial + Error
Vincent van den Burg


Nosepiece + 4x, 10x, 40x Objective
LED dimmer
1W LED
Plano convex lens
Alu 2020
Slide holder
Nosepiece holder
Slide
Convex lens holder
Cam extension
10x Eyepiece
Tube obj side
Stand
Cam V2 holder
Cam cap
Tube Cam side
Raspberry Pi cam V2
Mover holder
Anti slip feet
Mover Wheel
8mm x 2mm Thread
Ruler holder
Thread nut
Mover slider
Pi holder
200mm cam cable
Raspberry Pi V1.3



Extra Theory

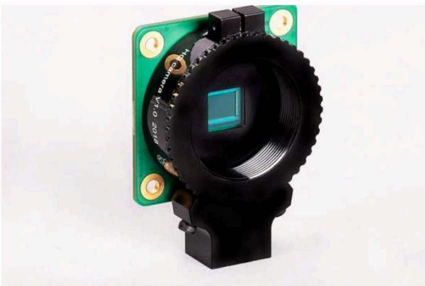
“The human eye has a focal length of about 17-24mm and a maximum pupil diameter of about 8mm” ~ Backcountry Journeys



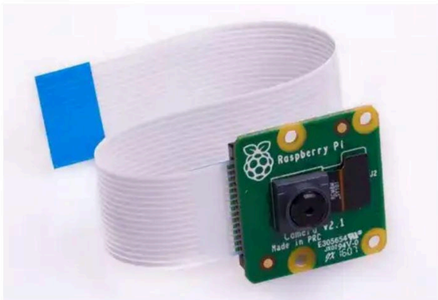
Source: Vedantu

"When you unfocus your eyes while looking at something, you're technically looking away from it, only along the z axis"@Salsicha007 Reddit

HQ



V2



Source: Raspberry Pi

Pratica

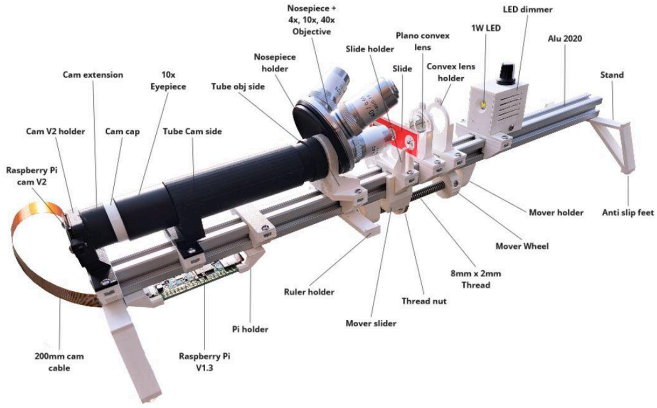
Important

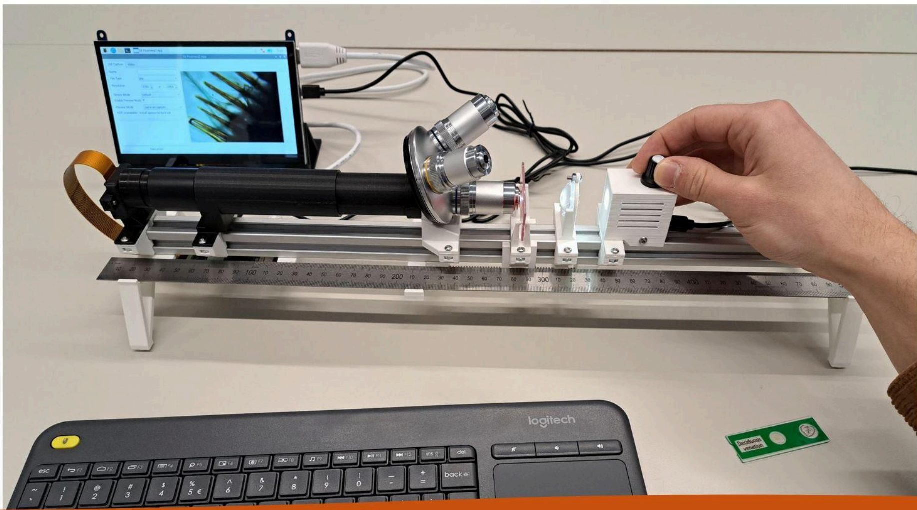
Suppose I try to use an everyday thing, but I can't who is at fault: me or the thing? **We are apt to blame ourselves**, especially if others are able to use it. Suppose the fault really lies in the device, so that lots of people have the same problems. Because everyone perceives the fault to be his or her own, **nobody wants to admit to having trouble. This creates a conspiracy of silence**, where the feelings of guilt and helplessness among people are kept hidden. ~Donald A. Norman

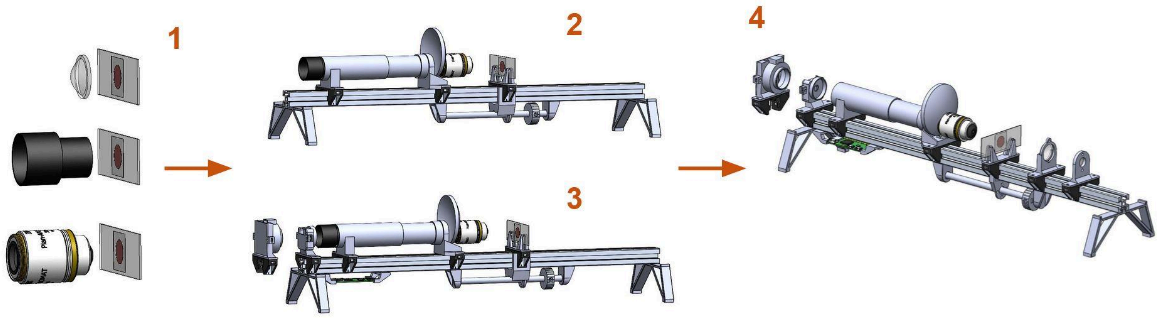
Caution

It is weak plastic. Handle parts with care.

- Don’t tighten the screws too tight
- If something is not moving which it should don't push/pull/bend too hard
- Push/pull at centre of friction, don’t create momentum as it is not needed.
- Watch if the Mover Slider is actually moving



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2
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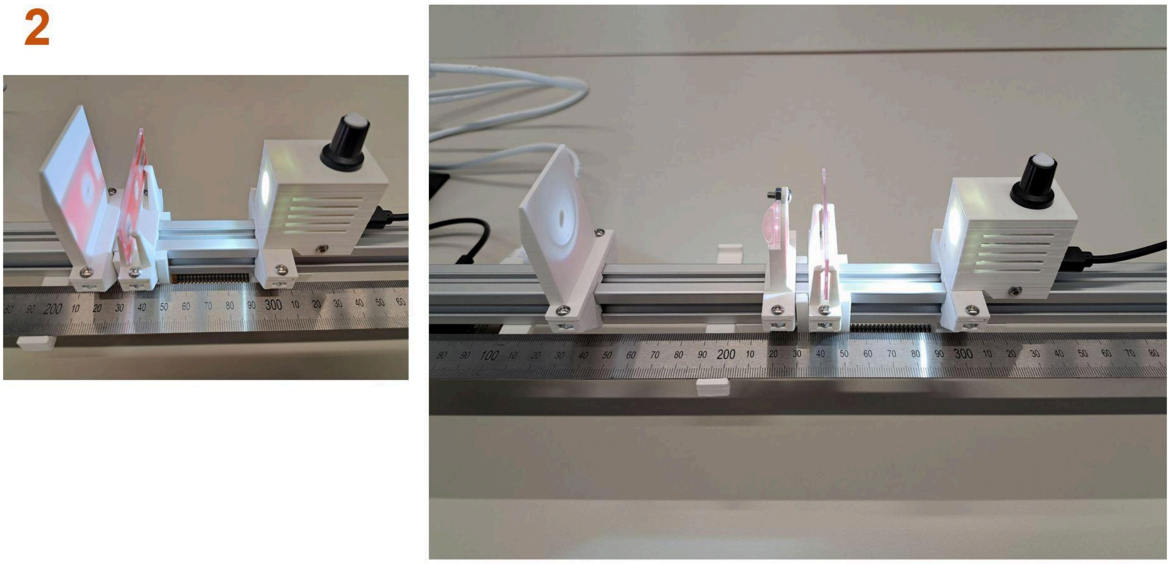
1

2



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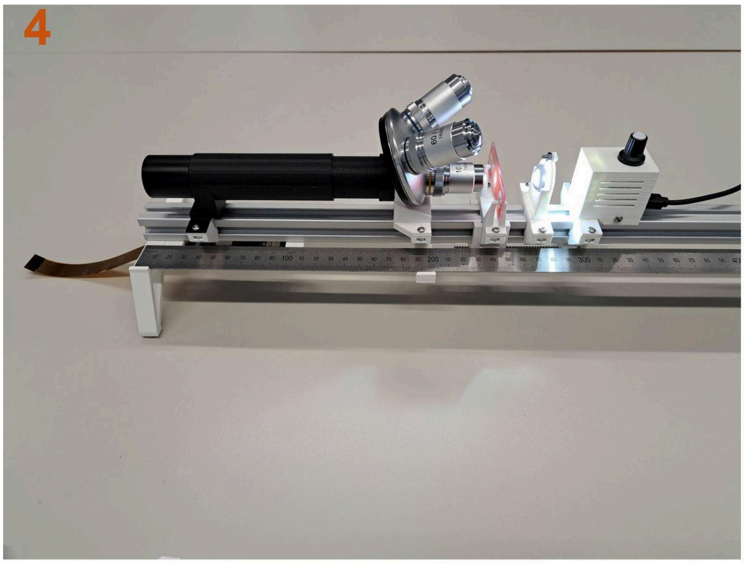
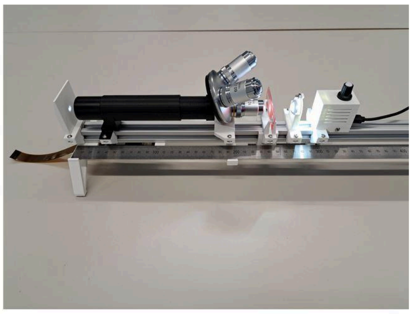
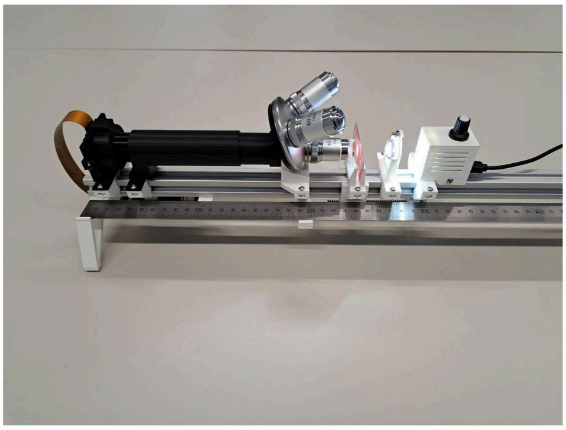
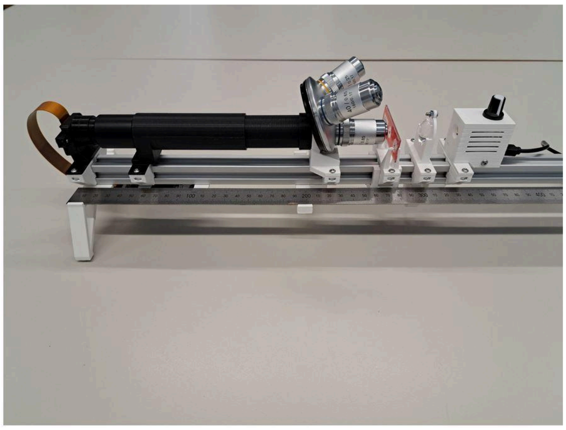
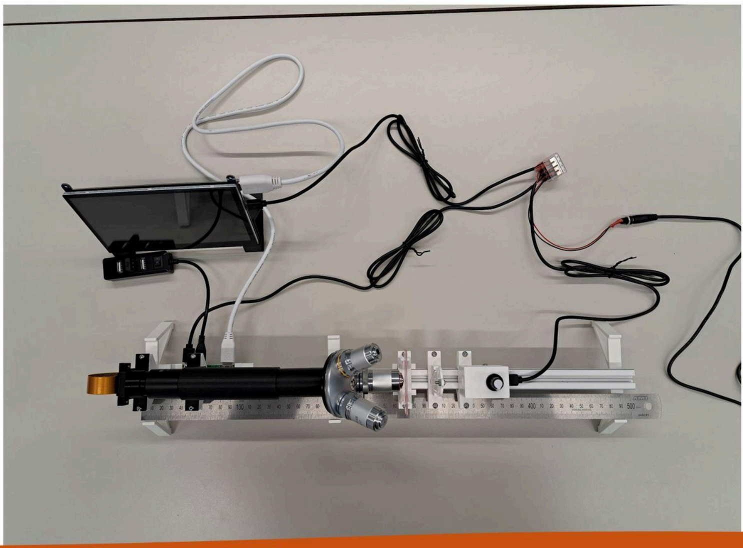




Break (10min)







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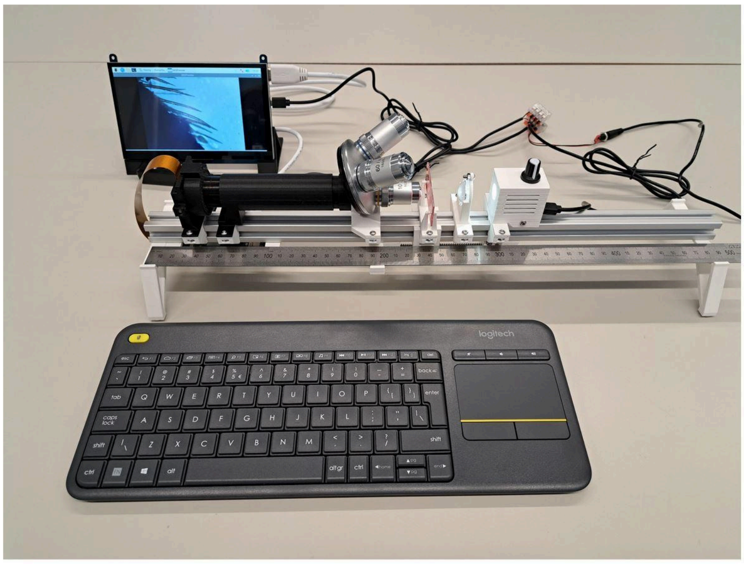
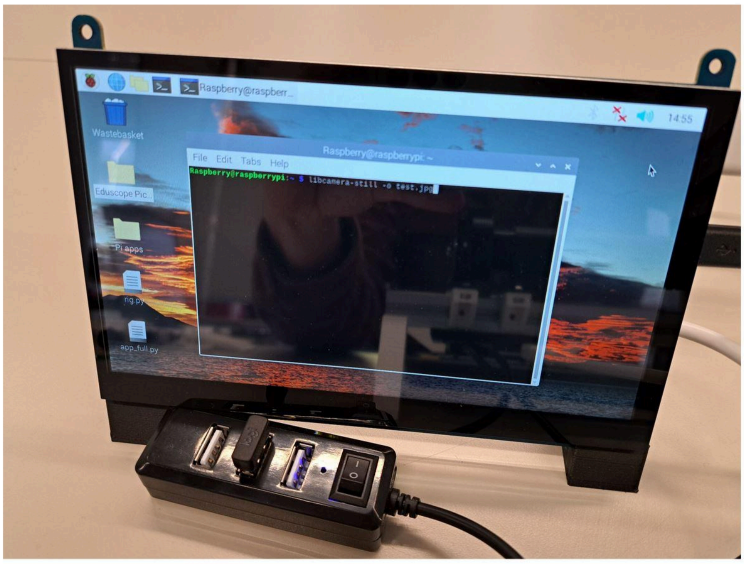
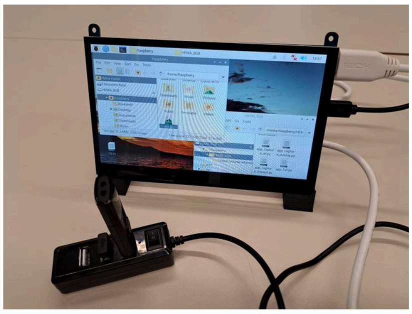
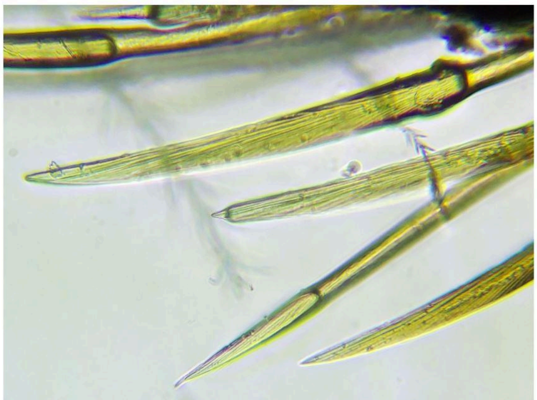
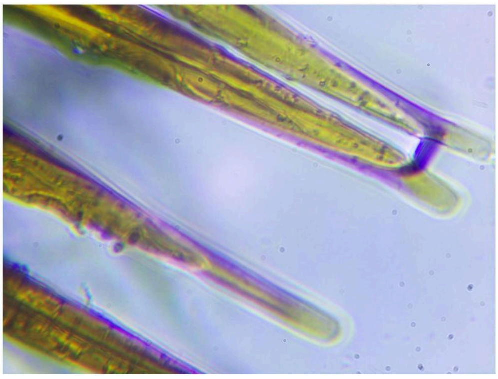
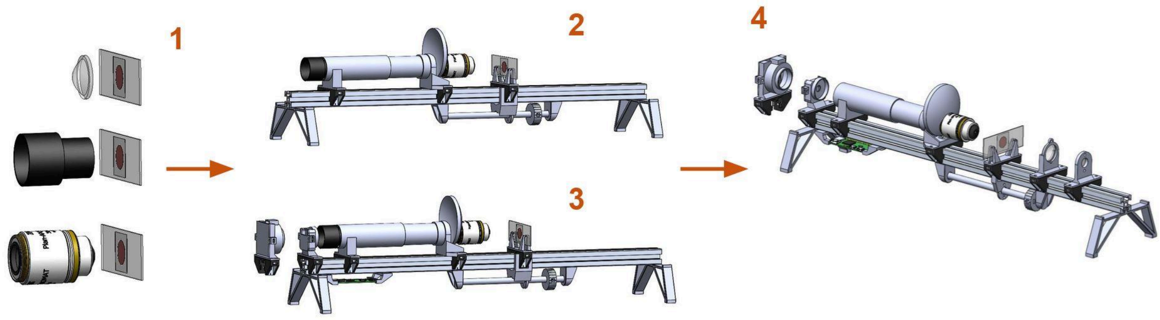



Raspberry@raspberr...
Wastebasket
Eduscope Pic
Pi apps
ng.py
app_full.py
Raspberry@raspberrypi: ~
File Edit Tabs Help
Raspberry@raspberrypi:~ $ libcamera-still -o test.JPG
14:55





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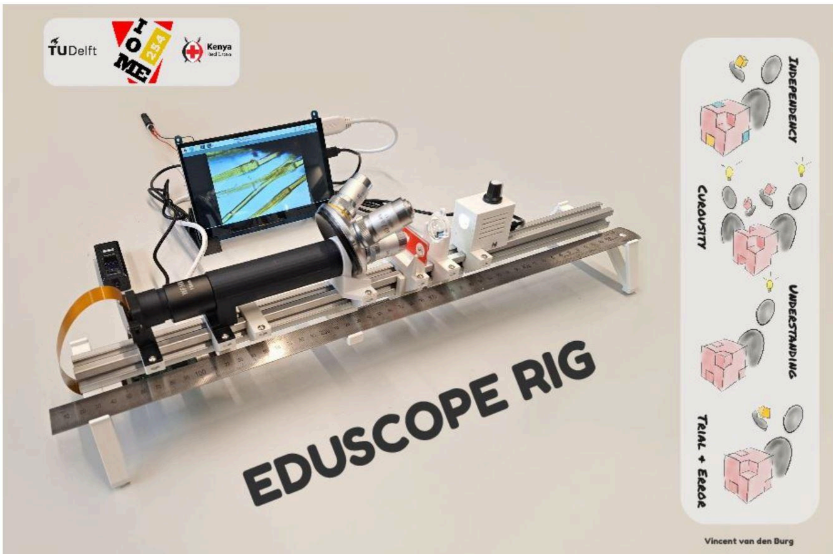
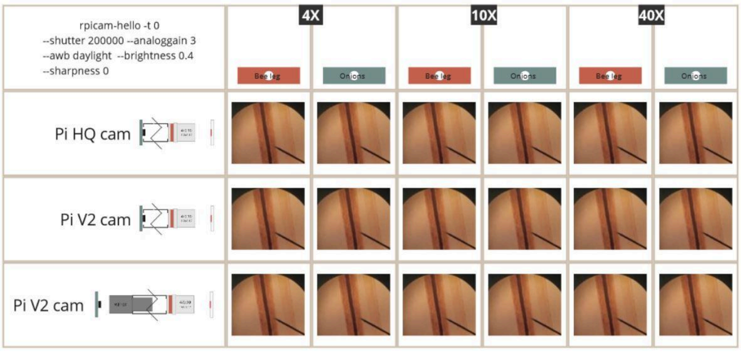

TUDelft
Kenya
EDUSCOPE RIG
INDEPENDENCY
CUROUSITY
UNDERSTANDING
TRIAL + ERROR
Vincent van den Burg

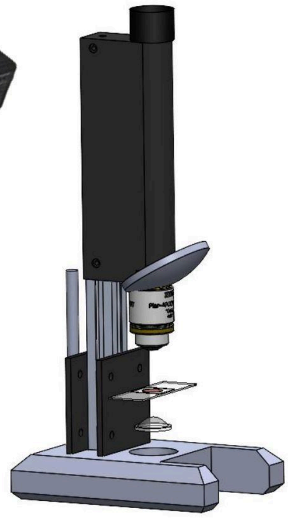
Going forward



Pot resistance 0 = 100% brightness
Pot resistance 50k = 0% brightness

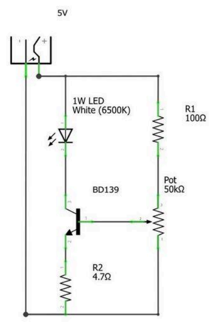
The Eduscope V3

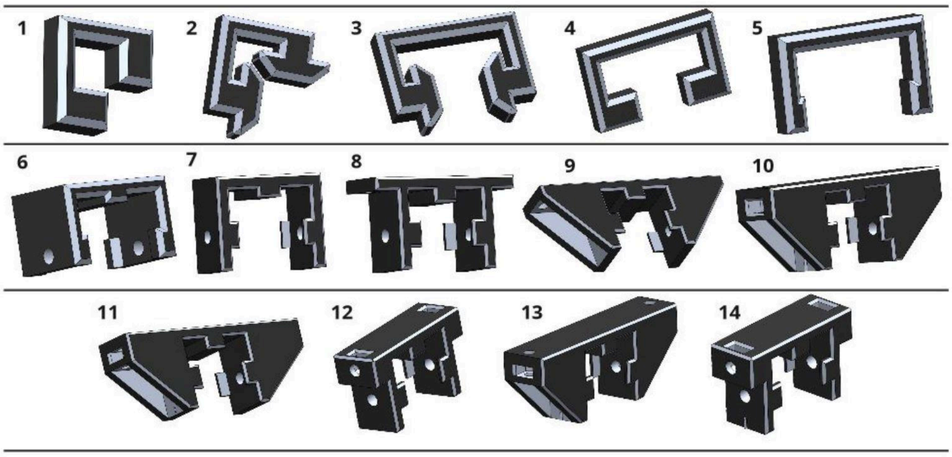
- Digital microscope
- Product of I.O.Me 254



Further R&D

- Python script (rpicam_full.py?)
- Filling in comparison tables
- Optimising element blocks: mover slider, condenser holder etc.
- Missing element blocks: RMS adapter, other cams etc.
- Drivetrain integration vs manual translation
- Optimising LED dimmer electronics, construction efficiency
- Setting up an organisation




1
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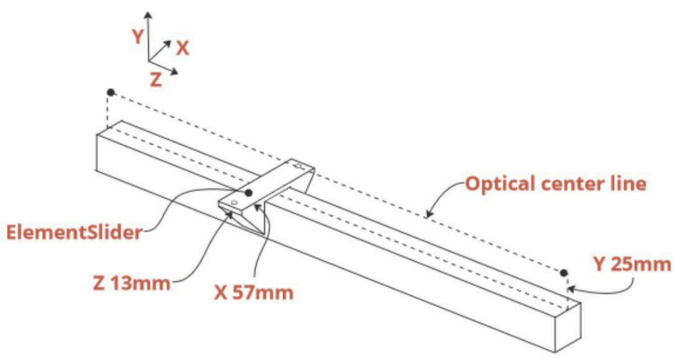
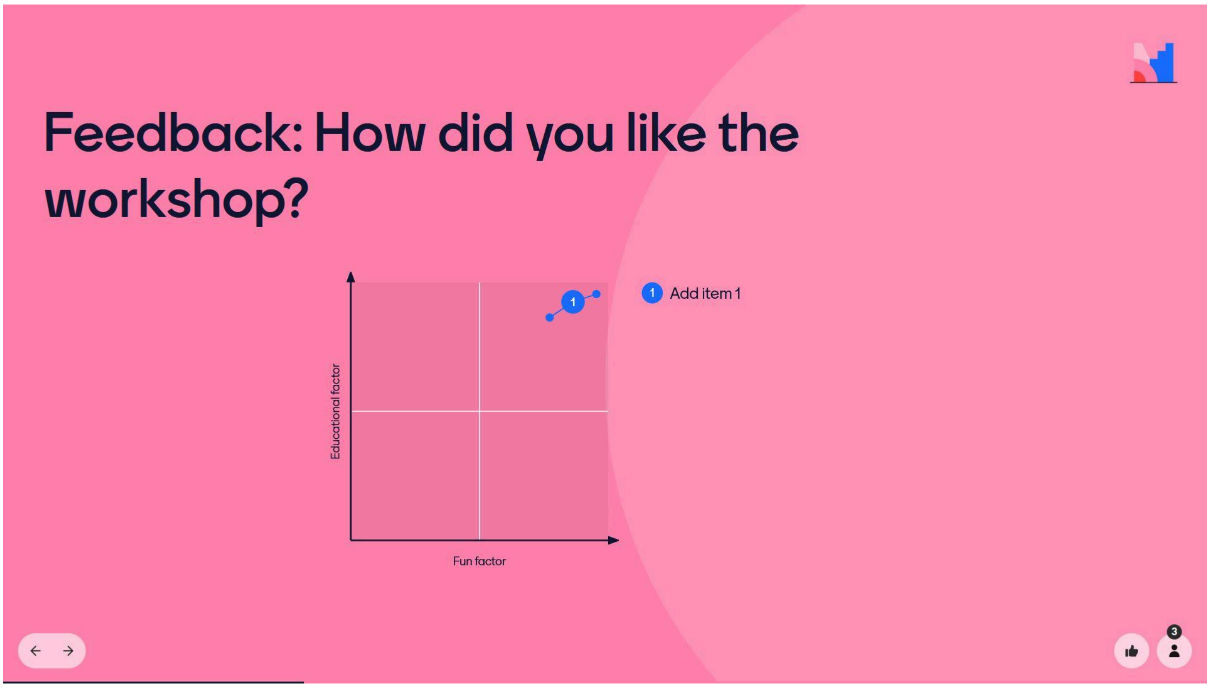
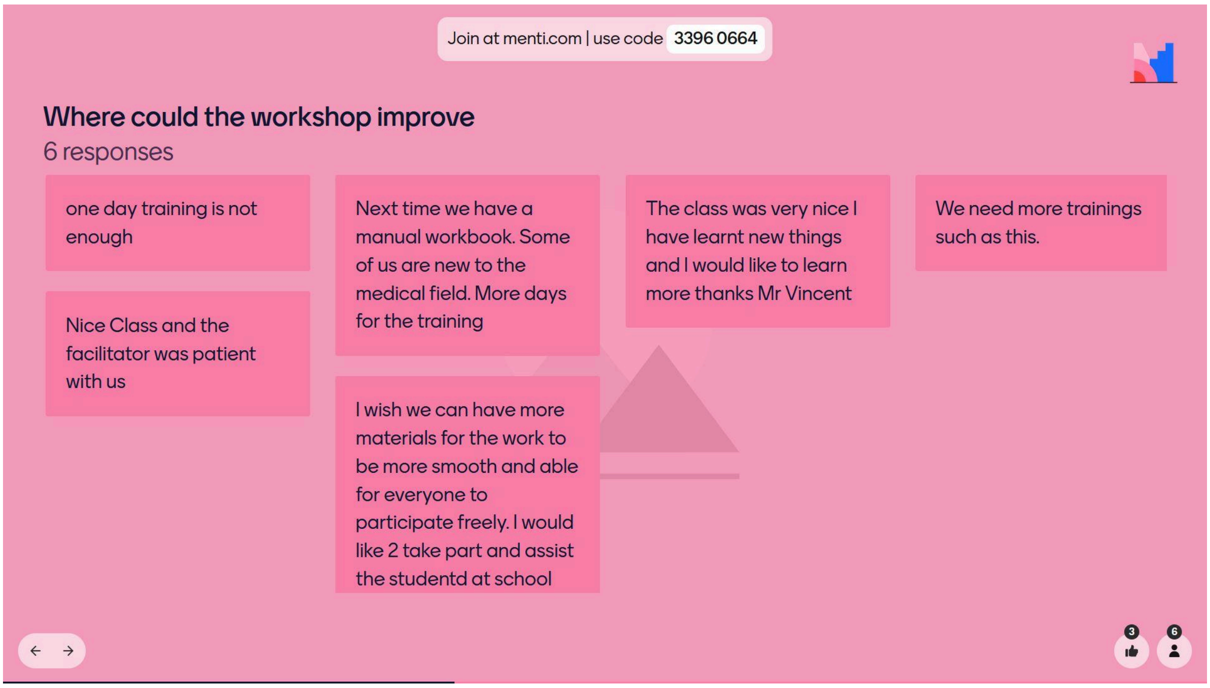
14

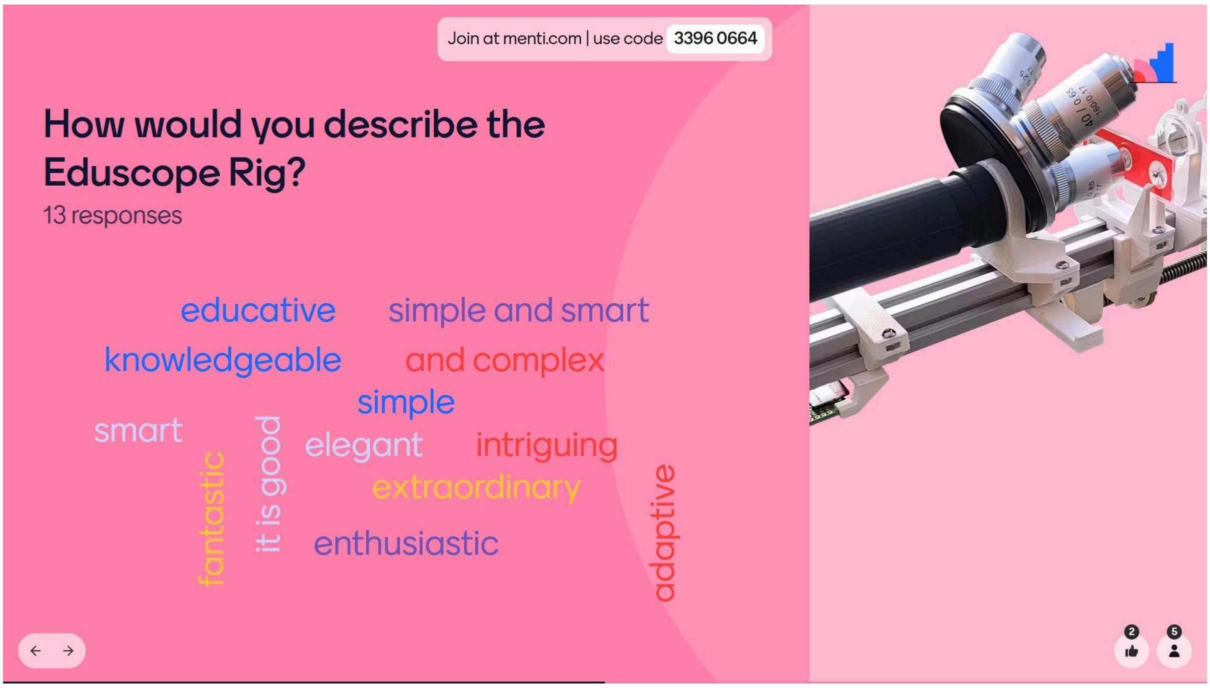
Further R&D


Y
X
Z
Optical center line
ElementSlider
Z 13mm
X 57mm
Y 25mm

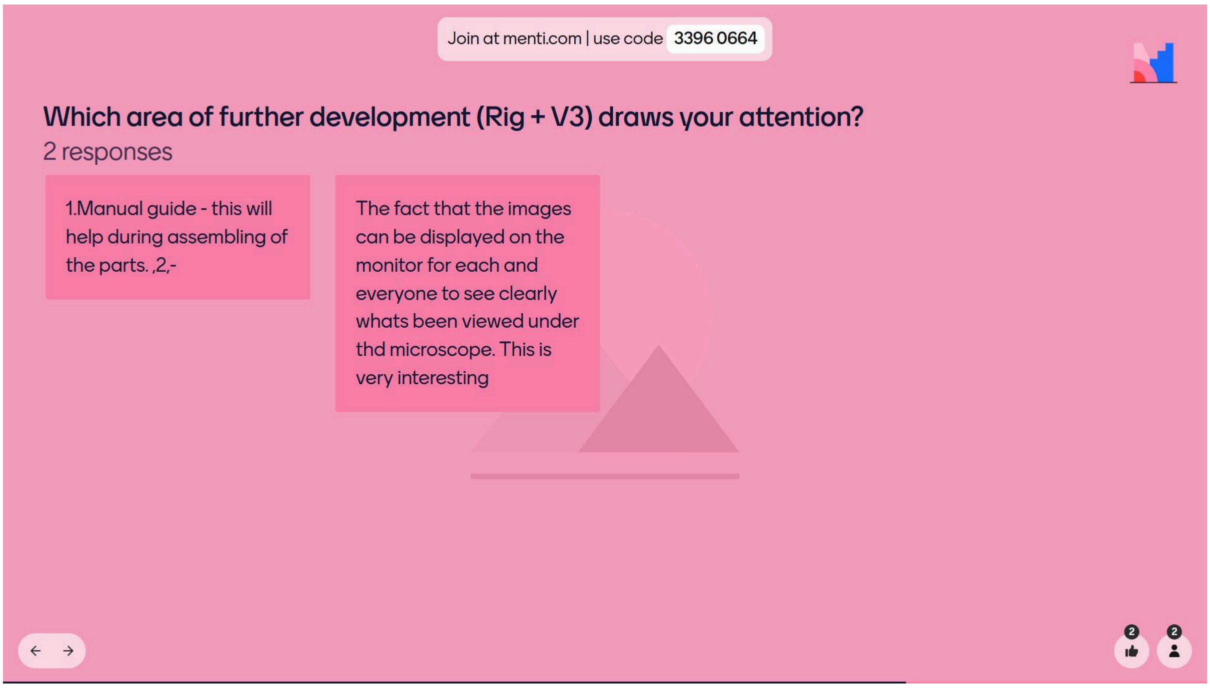
F. Eduscope Rig Workshop Menti Results



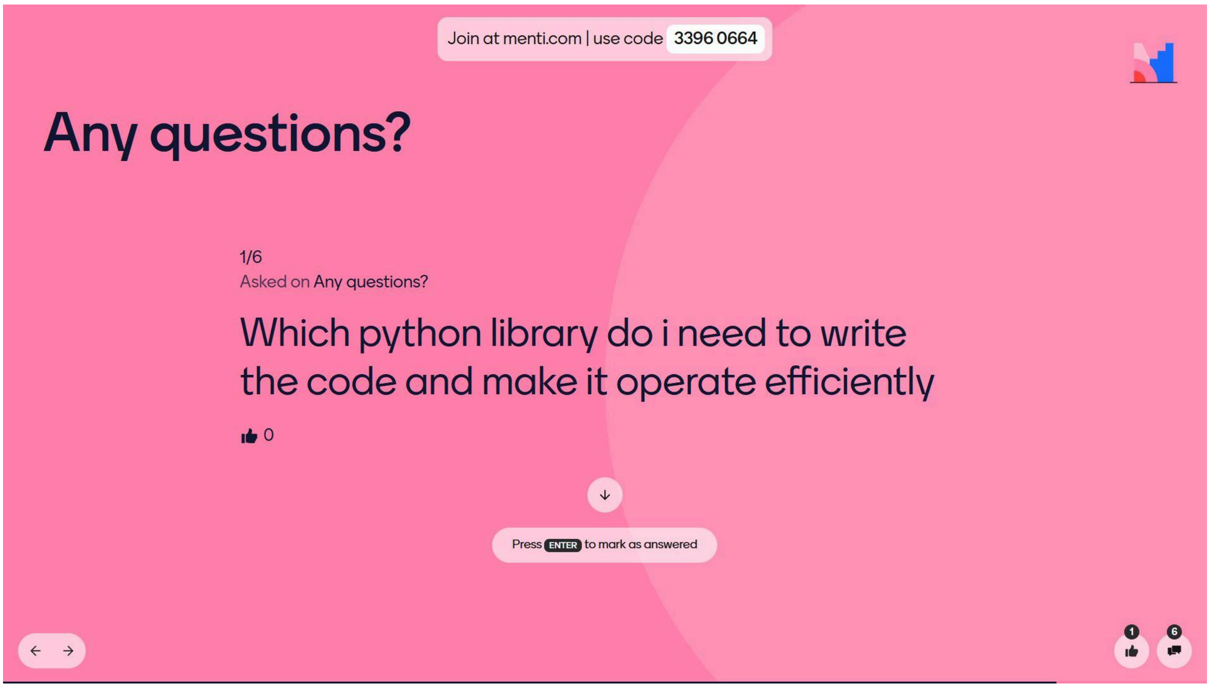



Join at menti.com | use code 3396 0664
How would you describe the Eduscope Rig?
13 responses
educative
simple and smart
knowledgeable
and complex
simple
smart
it is good
elegant
intriguing
fantastic
extraordinary
enthusiastic
adaptive
2
5

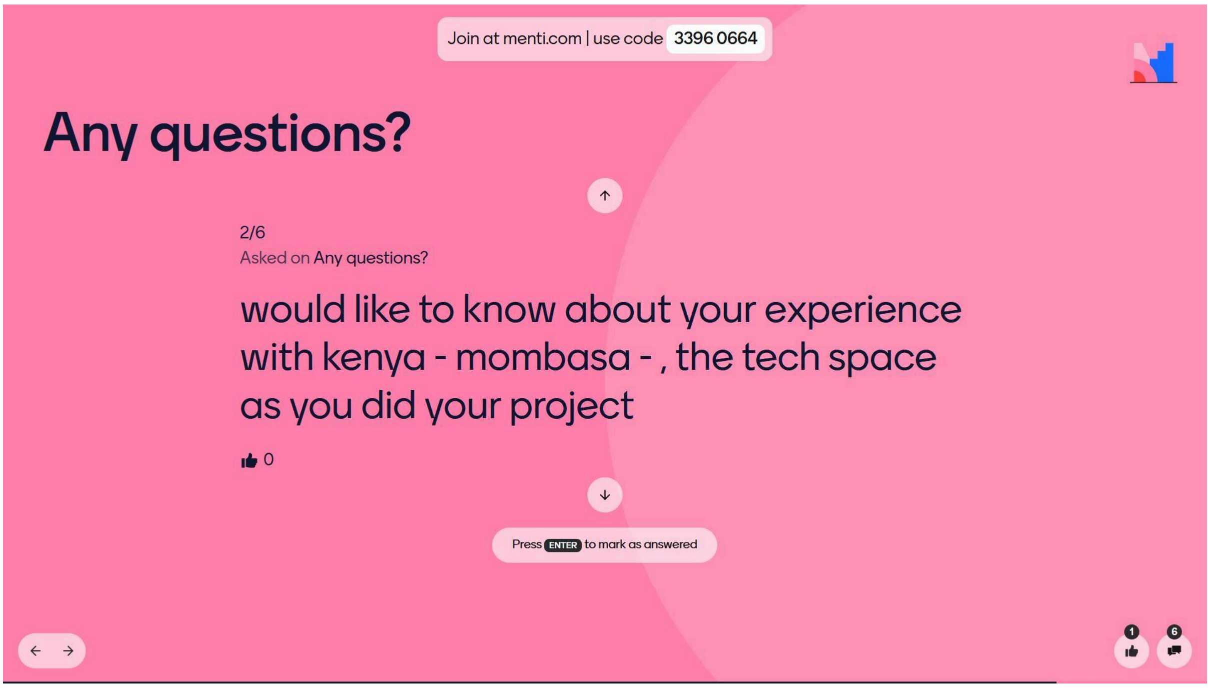

Join at menti.com | use code 3396 0664
Where could the Rig improve
4 responses
Make it a bit more simple so that its shouldnt complicate the students during experiment
Adding AI features. Where else can we use the microscope,considering the fact that mombasa is a historical town.. archeology maybe
I
the mechanical design, of the 3d parts
1
4

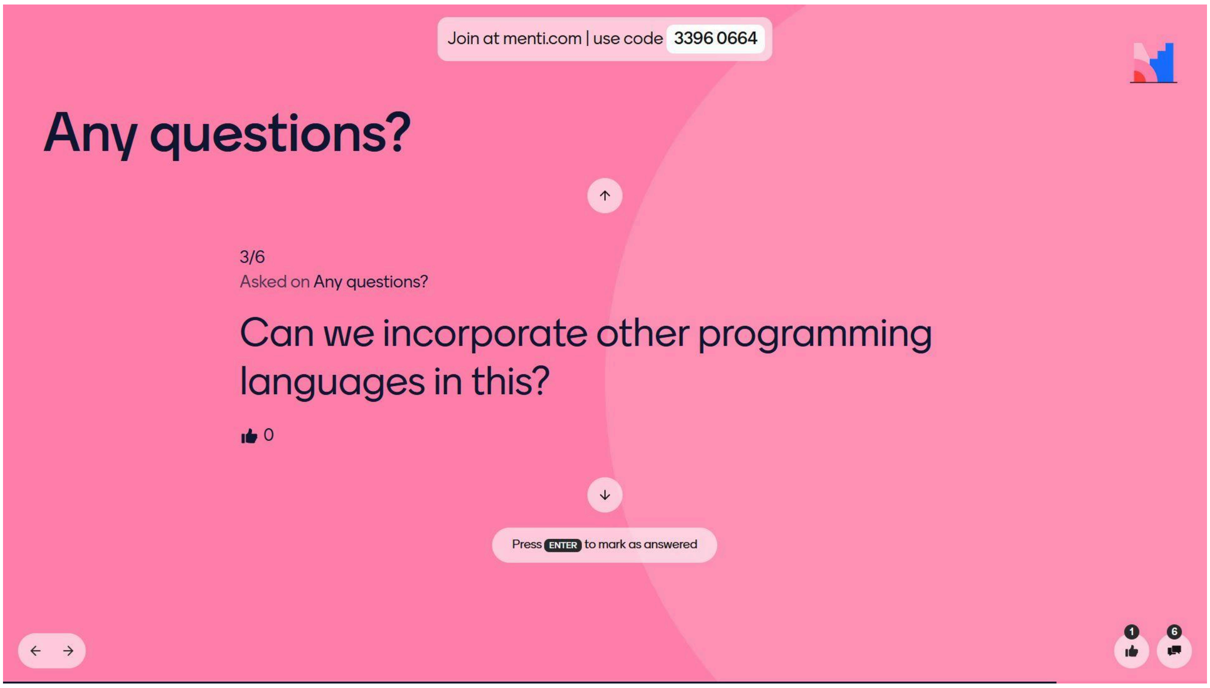


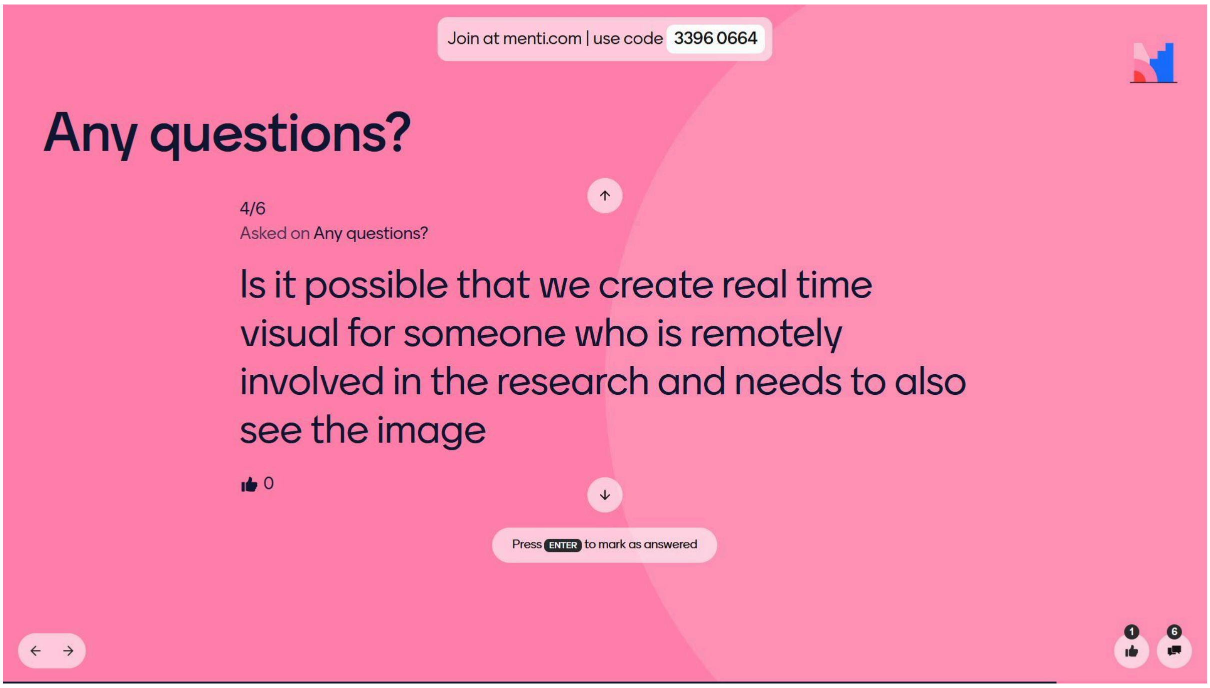
Join at menti.com | use code 3396 0664
Which area of further development (Rig + V3) draws your attention?
2 responses
1.Manual guide - this will help during assembling of the parts. ,2,-
The fact that the images can be displayed on the monitor for each and everyone to see clearly whats been viewed under thd microscope. This is very interesting
2
2

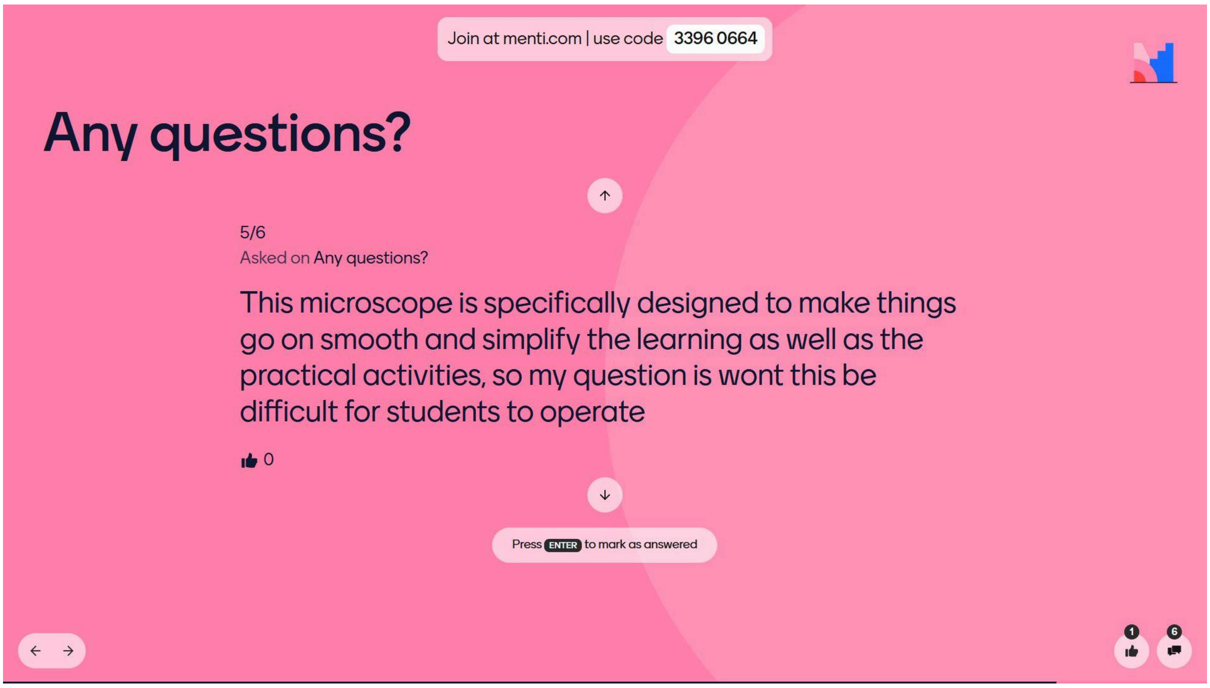


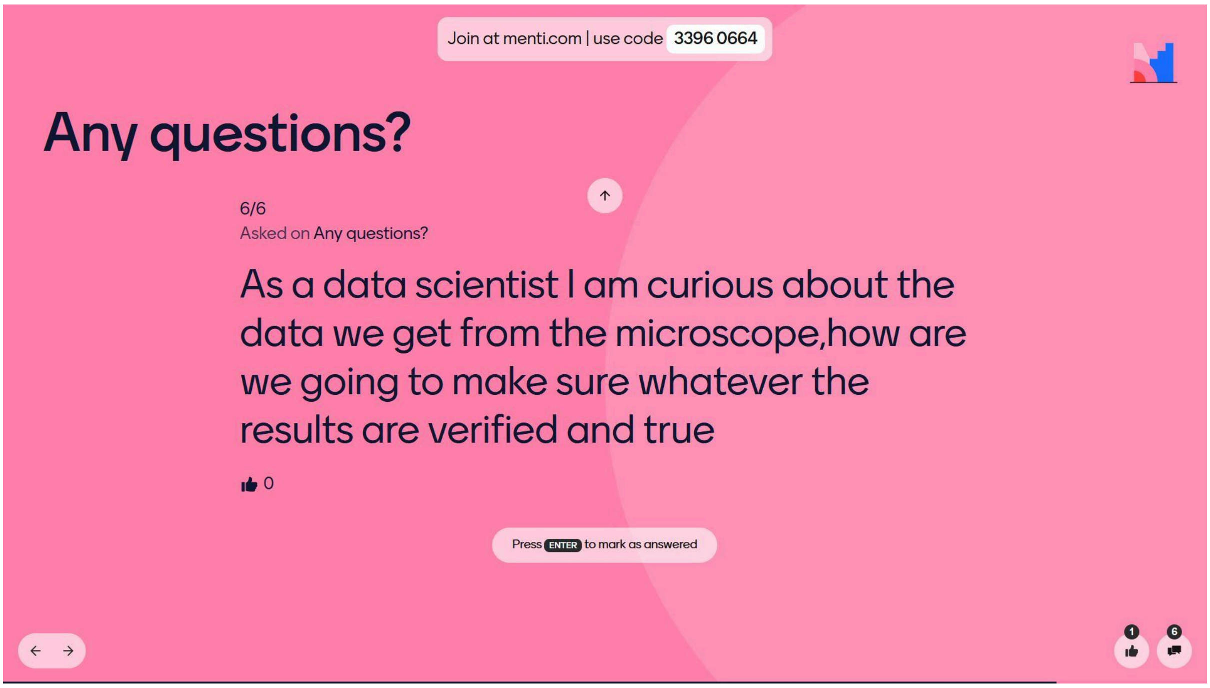
Join at menti.com | use code 3396 0664
Any questions?
1/6
Asked on Any questions?
Which python library do i need to write the code and make it operate efficiently
0
Press ENTER to mark as answered
1
6


Join at menti.com | use code 3396 0664
Any questions?
2/6
Asked on Any questions?
would like to know about your experience with kenya - mombasa - , the tech space as you did your project
0
Press ENTER to mark as answered
1
6


Join at menti.com | use code 3396 0664
Any questions?
3/6
Asked on Any questions?
Can we incorporate other programming languages in this?
0
Press ENTER to mark as answered
1
6


Join at menti.com | use code 3396 0664
Any questions?
4/6
Asked on Any questions?
Is it possible that we create real time visual for someone who is remotely involved in the research and needs to also see the image
0
Press ENTER to mark as answered
1
6


Join at menti.com | use code 3396 0664
Any questions?
5/6
Asked on Any questions?
This microscope is specifically designed to make things go on smooth and simplify the learning as well as the practical activities, so my question is wont this be difficult for students to operate
0
Press ENTER to mark as answered
1
6


Join at menti.com | use code 3396 0664
Any questions?
6/6
Asked on Any questions?
As a data scientist I am curious about the data we get from the microscope,how are we going to make sure whatever the results are verified and true
0
Press ENTER to mark as answered
1
6

G. User feedback Eduscope workshop - Field research - V2 Analysis

Kopiëren

This questionnaire is part of a graduation project by Vincent van den Burg. IOMe254, the Red Cross and the TUDelft are the main stakeholders and the data will not be shared with people outside the scope of the project.

The questionnaire takes approximately 15min.

By participating in this questionnaire I agree that my data will be collected and processed for research puproses only. Next to this, I am aware of this being a voluntary study and I can end the questionnaire at all times.

If you have any questions or remarks about the research, you can always contact us

12 antwoorden

[Age], [Studies], [Study year]. E.g. 26, Product Design, 7th year

12 antwoorden

- 23,medical engineering,4th year.
- 25, Computer Science, 3rd year
- 23, Computer science, 3rd Year
- 20, Computer Science, 3rd
- 20, Computer Science, 3rd year
- 19, Computer Science,3RD Year
- 23, medical engineering, 5th year
- 22, computer science, 3rd year
- 22,Engineering in building technology, done with 3yrs

23, mechanical engineering, 4th year

23 computer programming 3

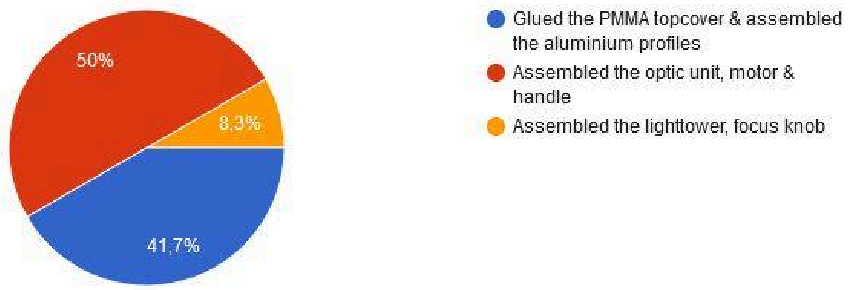
21

Tuesday

On Tuesday, I was mainly in the group which

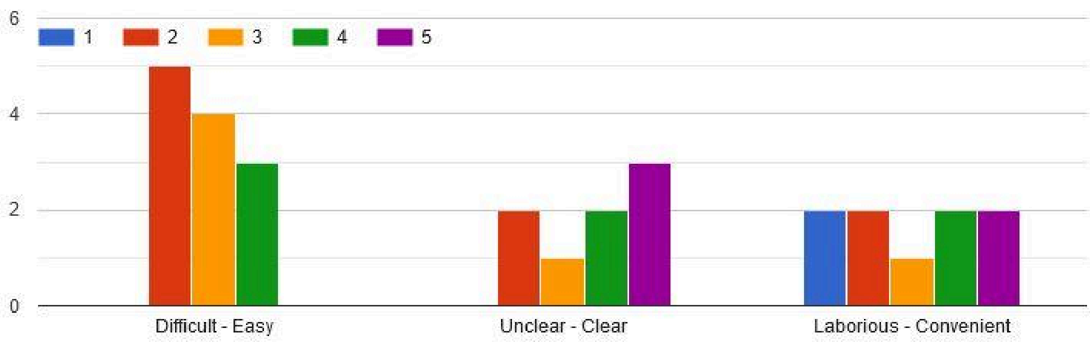
Kopiëren

12 antwoorden



This process on Tuesday was

Kopiëren



The following I would keep as it is (The good)

11 antwoorden

The shape of the top cover

Introduction/ walkthrough of what is required of us.

The use acrylic , makes it easy piece together and glue

I would say the stand and optic unit are on point.

The aluminum profiles

Led,lenses

1. The Body of the optic unit, motor and handle

The position of both the limit switches

The base plates

Yes

everything except the 3d prints

The following I would redesign (The bad)

10 antwoorden

The joining method of the acrylics cover

A list of all materials and their specifications availed with extra as spares.

The 3d printed parts that need to be glued as the glue wasnt sticking right

I felt the cover would easily break

Aluminium profile

Vernier stage ,knob springs

1. Have an enclosure for the pi camera cable to protect it from damage.
2. Have an accessible conduit for the motor cables and the limit switches cables to easen the connection process

The cabling of the camera.

Yes

the 3d

I would redesign it by (The solution)

11 antwoorden

Using a better binding technique instead of glue

Consolidating a lot of components into one component/module making it tidy and more compact.

forming the part using a hot acrylic mold.

I would seek to use a tougher material for the cover.

Maybe I would recommend adding another aluminium profiles for more stability

Maybe removing the turning spring

creating a flexible enclosure for the pi camera cables (Something similar to the cable enclosures used in robotic arms)

would prefer it being passed through the covering of the motor, this is to ensure it safety

The screenshot knob replace it with another faster knob when pressing

Yes

some holes we missing

Any more remarks/tips on today's work?

11 antwoorden

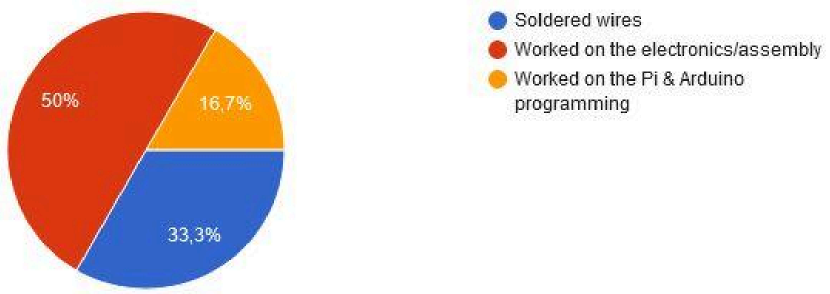
- The assembly of the base was self explanatory
- Was fun, a lot of learning but we "failed" to achieve the day's objective because of missing components.
- make the assembly process in series, or serializability to achieve faster throughput
- It was insightful and I've been encouraged to think outside the box(to improvise) during problem solving. I appreciate the chance to be part of the process.
- Good
- No
- Nop.
- It was awesome working in groups
- Todays work was interesting through dismantling and assembling
- Awesome
- excellent experience

Wednesday

On Wednesday, I was mainly in the group which

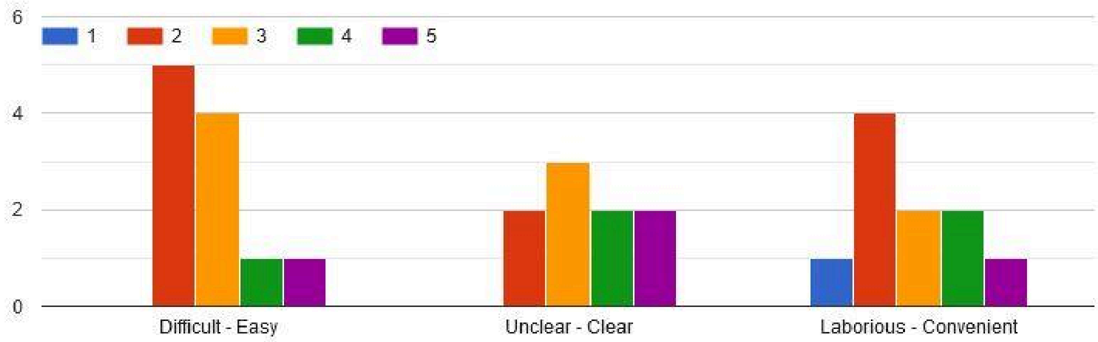
Kopiëren

12 antwoorden



This process on Wednesday was

Kopiëren



The following I would keep as it is (The good)

8 antwoorden

The use of small sized components I.e arduino nano

Instruction manual.

Raspberry pi, makes automation n programming easy

The circuitry was great

The wiring was good

Program

1. Simplicity

Yes

The following I would redesign (The bad)

10 antwoorden

The fixing of the various components to the base

A list of components used to accomplish the day's task.

PCB , and arduino nano cause redundancy

The was too many crisscrossing wires.

Wires

Raspberry pi

1. Have more connectors on components that were been soldered.
2. One can easily place the Arduino nano and motor driver wrongly on the PCB board and as a result end up damaging them.

The mounting stand

Yes

we use connectors instead of soldering because it consumes time

I would redesign it by (The solution)

10 antwoorden

Creating flexible screw holes

Creating a checklist of all components before working on the task.

implement anything on Rasberry pi

I would integrate most electronic components onto a single circuit board to reduce the wires.

By using strict wire colors ,to maintain the wires color code to enable easy identification for easy connectivity.

If the raspberry pi had more multiple USB connector or pins then I think our original problem would be less.

1. I would use j15 connectors in the buck creek converters

Use a stand that would move faster when mounting the item to be soldered this would reduce the time taken

Yes

use connectors

Any more remarks/tips on today's work?

11 antwoorden

The circuit diagram should be available for reference

Was fun, a lot of learning but could have been made way better.

Teamwork is key

Loved the experience, finally got to perfectly strip and soulder the wires and components. My knowledge in electronics was challenged.

Today's work was pretty good .

No

The activities would have been more exciting if we had a more detailed circuit diagram.

It productive being able to have hands on skills and contact with different electronic equipments

The session was challenging since some other parts of microscope were not there but we managed to get everything intact

Awsome

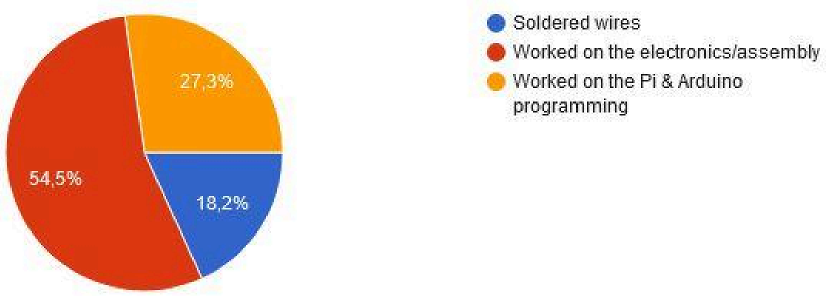
nice experience

Thursday

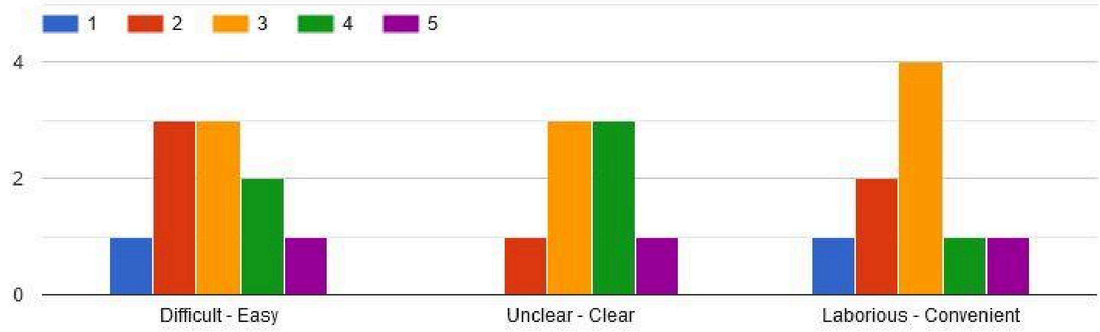
On Thursday, I was mainly in the group which

Kopiëren

11 antwoorden



This process on Thursday was



The following I would keep as it is (The good)

9 antwoorden

The process of soldering

We got to start the project early.

The raspberry pi concept

The optic unit seemed tough as compared to the light microscope already in schools. It fell a few times but we didn't notice breakages.

Customised PCB and Raspberry Pi

All

1. Design simplicity
2. Circuit protection from overvoltage

The positionof the various components eg adruino, raspberry

Yes

The following I would redesign (The bad)

10 antwoorden

- The use of thick wires since the thin wires were easily burnt by the soldering gun
- Include label materials for ease of tracking components.
- the code, resets and fails to run
- The support system could barely hold up the optic unit firm.
- Step down transformer
- Raspberry pi OS
- The circuit did not have a short circuit protection system
- The position of the hdmi port
- Yes
- to use connectors instead of soldering it consume time

I would redesign it by (The solution)

10 antwoorden

- Using other methods of joining one wire to the next
- Including a label maker or something close to that.
- make it as seamless as possible
- I would lock in the head from four directions rather than three.
- By fixing them to their fixed point instead of leaving the hanging
- If there was maybe a tool to test or detect the program instead of trial and error every time
- Adding a primary and secondary fuse
- ... When mounted on the side board it prevents the Locking of the cover and the base.. Changed its position, making it a smooth lock
- Yes
- use connectors

Any more remarks/tips on today's work?

10 antwoorden

The process was self explanatory

Good day, enjoyed the challenges and the solutions we came up with.

owning your work builds creative ways to mastery

Today was challenging as compared to the other days. Really learnt more from the experience.

Today's work was a little bit challenging .

No

Nop

A guide to be provided to ensure that there is a procedure to be followed

Was interesting and got to exchange thoughts with other team members

Good

Overall reflection

What do you think about the Eduscope?

12 antwoorden

It's a innovative approach that will help the underprivileged communities of kenya to access biological resources and knowledge

It's a great project. After learning the internals and seeing what it's capable of, this is something that has the potential of being a ground breaking device.

An amazing workpiece

Loved the idea. It will be a real gamechanger in the medical world.

The Eduscope for sure is better and good

It's good and it will help a lot

It is a nice well thought out project from it's design stage to it's implementation and prototyping stage

It really an important asset in the schools and the medical and research industry, seeing it being used by the different areas interest is my desire

It's amazing

The eduscope is good technology in the medical sector

it was well thought

Are there functions you would like to discard or add to the Eduscope?

11 antwoorden

The ability to use other microscopy techniques so other types of images can be viewed

Add more colors to the exterior for the kids! Make it pop and stand out. Even graffiti with words of inspiration would be great.

auto diagnostics in hospitalls

I would discard the vernier clip. In my perspective it seems to be taking up a lot of space.

Allowing for more Xmagnifications to enable more angle of consideration before conclusion .

No

1. The acrylic body design should be more flexible in terms of assembly and disassembly, it makes more sense if it is fitted by screws instead of glue.

The spring on the adjustment Nob should be removed since it's use could not be realized

Not really

No

the springs on adjustable knob
the body not to glue it instead screw it
the body should have a handle to easy mobility

Any other changes you would change and why?

8 antwoorden

Combine the two microcontrollers (Arduino & Raspberry) by designing and printing a PCB with the features and capacity of the two in one board.

Also, change the exterior panel (body/frame) to interlock like Lego's instead of having to glue it up..at the very least, let them be fastened by bolts.

several thing

I would change the connectivity of wires ,to ensure every wire is to a fixed point than being random .

Maybe a more elaborate map of 5ge the microscope as a whole would help in building and repair.

N/A

A better fabrication technique since the 3d did block some of the ports required for screwing

NA

No

Any other comments or feedback you would like to give us about the Eduscope and its design?

9 antwoorden

No

It's a great design, more work is needed to reduce or tidy up the cabling.

The design is simple. It would be very easy to be used by the target group.

The Eduscope project is one in a million better than I can think, its design is perfect .

Nop but I would just link to thank team eduscope for taking us through the training on the industrial Design text books from tudelft.

.

The structure is good and still doing more research to make it have more functionalities in terms of viewing the specimen

Keep involving local students

H. Graduation Design Brief

DESIGN FOR our future

TU Delft

IDE Master Graduation Project

Project team, procedural checks and Personal Project Brief

In this document the agreements made between student and supervisory team about the student's IDE Master Graduation Project are set out. This document may also include involvement of an external client, however does not cover any legal matters student and client (might) agree upon. Next to that, this document facilitates the required procedural checks:

- Student defines the team, what the student is going to do/deliver and how that will come about
- Chair of the supervisory team signs, to formally approve the project's setup / Project brief
- SSC E&SA (Shared Service Centre, Education & Student Affairs) report on the student's registration and study progress
- IDE's Board of Examiners confirms the proposed supervisory team on their eligibility, and whether the student is allowed to start the Graduation Project

STUDENT DATA & MASTER PROGRAMME

Complete all fields and indicate which master(s) you are in

Family name	van den Burg 6902	IDE master(s)	IPD ✓ DfI SPD
Initials	V.S.P.	2nd non-IDE master	
Given name	Vincent	Individual programme (*date of approval*)	
Student number	4679326	Medisign	
		HPM	

SUPERVISORY TEAM

Fill in he required information of supervisory team members. If applicable, company mentor is added as 2nd mentor

Chair	Jan Carel Diehl	dept./section	Sustainable Design Engineering
mentor	Stefan Persaud	dept./section	Sustainable Design Engineering
2nd mentor			
client:			
city:	Delft	country:	The Netherlands
optional comments	JC Diehl brings a wealth of experience in sustainable design methodologies, particularly in the healthcare and cultural domain. Stefan's expertise as an Educational Designer brings a contemporary and student-focused approach.		

! Ensure a heterogeneous team. In case you wish to include team members from the same section, explain why.

! Chair should request the IDE Board of Examiners for approval when a non-IDE mentor is proposed. Include CV and motivation letter.

! 2nd mentor only applies when a client is involved.

APPROVAL OF CHAIR on PROJECT PROPOSAL / PROJECT BRIEF -> to be filled in by the Chair of the supervisory team

Sign for approval (Chair)

Jan-Carel Diehl

Digitally signed by Jan-Carel Diehl
Date: 2023.11.17
09:35:05 +01'00'

Name	JC Diehl	Date	17 Nov 2023	Signature	

CHECK ON STUDY PROGRESS

To be filled in by SSC E&SA (Shared Service Centre, Education & Student Affairs), after approval of the project brief by the chair. The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total	EC
Of which, taking conditional requirements into account, can be part of the exam programme	EC

★	YES	all 1st year master courses passed
	NO	missing 1st year courses

Comments:

Sign for approval (SSC E&SA)

Kristin Veldman Digitally signed by Kristin Veldman Date: 2023.12.04 06:54:20 +01'00'

Name K. Veldman Date 4 Dec 2023 Signature

APPROVAL OF BOARD OF EXAMINERS IDE on SUPERVISORY TEAM -> to be checked and filled in by IDE's Board of Examiners

Does the composition of the Supervisory Team comply with regulations?

YES	★	Supervisory Team approved
NO		Supervisory Team not approved

Comments:

Based on study progress, students is ...

★	ALLOWED to start the graduation project
	NOT allowed to start the graduation project

Comments:

Sign for approval (BoEx)

Monique von Morgen Digitally signed by Monique von Morgen Date: 2023.12.05 10:10:45 +01'00'

Name Monique von Morgen Date 5 Dec 2023 Signature

DESIGN FOR our future

TU Delft

Personal Project Brief – IDE Master Graduation Project

Name student Vincent van den Burg Student number 4,679,326

PROJECT TITLE, INTRODUCTION, PROBLEM DEFINITION and ASSIGNMENT
Complete all fields, keep information clear, specific and concise

Project title Designing Affordable and Accessible Microscopy for Medical Education in Kenya

Please state the title of your graduation project (above). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

Introduction

Describe the context of your project here; What is the domain in which your project takes place? Who are the main stakeholders and what interests are at stake? Describe the opportunities (and limitations) in this domain to better serve the stakeholder interests. (max 250 words)

Reliable and high-quality microscopes are indispensable for medical education, yet in Kenyan universities, students face significant barriers to accessing diagnostic devices like microscopes. These crucial tools often remain prohibitively expensive for local institutions, and the lack of proper maintenance compounds the issue. The core objective of this project is to democratize digital microscopy, making it more affordable and accessible for the training of medical students in Kenya. The initiative was initially set in motion by former students, and my role involves field-testing their inaugural prototype within Kenyan educational settings. Subsequently, I will assess how to enhance the microscope's performance and develop an improved iteration.

The project's context lies in bridging the accessibility gap in diagnostic equipment within Kenyan universities. The primary stakeholders are Kenyan medical students, who stand to benefit from this endeavor. The project domain revolves around the integration of digital microscopy into the Kenyan medical education curriculum.

In this domain, there are opportunities such as cost-effective solutions, local maintenance and repair strategies, technology transfer, collaboration with local industry, and curriculum integration. However, resource constraints, regulatory compliance, infrastructure considerations, and skill development for local technicians may pose limitations.

By capitalizing on these opportunities and mitigating limitations, the project aspires to create a more accessible, cost-effective, and sustainable solution for medical education in Kenya. The central focus remains on the well-being and educational progress of Kenyan students, ensuring they have the necessary tools to thrive in their medical studies.

→ space available for images / figures on next page

introduction (continued): space for images

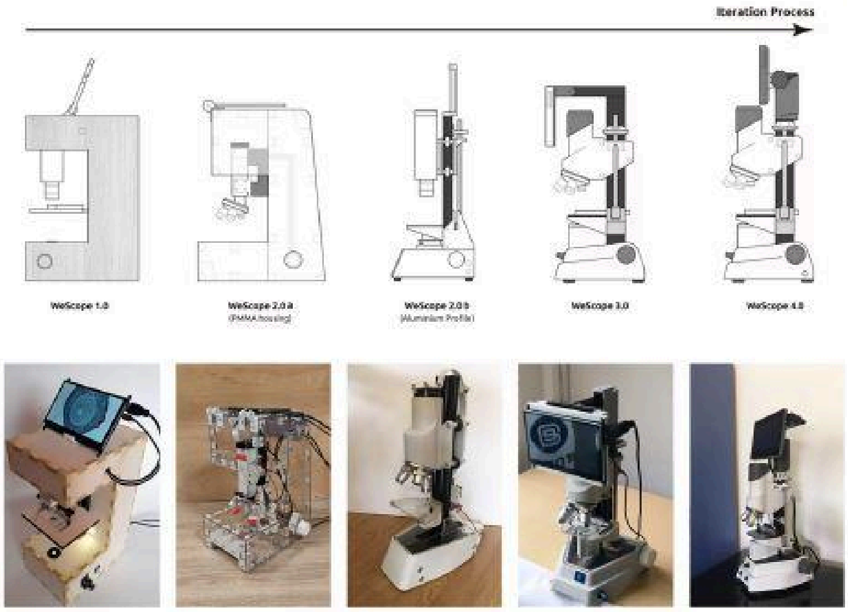


image / figure 1 WeScope Iteration process

image / figure 2 WeScope user experience

Problem Definition

What problem do you want to solve in the context described in the introduction, and within the available time frame of 100 working days? (= Master Graduation Project of 30 EC). What opportunities do you see to create added value for the described stakeholders? Substantiate your choice.
(max 200 words)

During my master's project, my primary objective is to field-test a previous iteration of the microscope, aiming to analyze areas that require improvement. Subsequently, I intend to undertake the design of an enhanced version of the microscope. My goal in the design of the new microscope is twofold: first, to incorporate the identified improvements, and second, to explore cost-effective materials suitable for use in Kenya. Furthermore, I aim to engineer the digital microscope in a way that allows for local production in Kenya, particularly when maintenance or repairs are needed.

The core problem I aim to address is the development of an affordable microscope that can be both manufactured and enhanced within Kenya. This approach is intended to support its utilization in medical education for the benefit of students.

Assignment

This is the most important part of the project brief because it will give a clear direction of what you are heading for. Formulate an assignment to yourself regarding what you expect to deliver as result at the end of your project. (1 sentence) As you graduate as an industrial design engineer, your assignment will start with a verb (Design/Investigate/Validate/Create), and you may use the green text format:

During this master's project, the primary focus will be on developing an affordable and locally producible digital microscope, aimed at enhancing medical education for students in Kenya.

Then explain your project approach to carrying out your graduation project and what research and design methods you plan to use to generate your design solution (max 150 words)

For my graduation project, I will begin by conducting interviews as a research method to assess the possibilities and limitations surrounding the design and utilization of the microscope in Kenya. Throughout the entirety of the project, I will adopt the 'double diamond' design method to avoid tunnel vision and enhance creativity. In addition, I will employ the 'rapid prototyping' design method to create quick iterations for rapid testing in Kenya, with the aim of comprehensively mapping the microscope's capabilities and limitations. The 'lean startup method' will be used to prioritize the core of this microscope – affordability and accessibility in Kenya – and to ensure no unnecessary features or materials are added. This approach will allow me to develop an effective and impactful design solution. As a result of all this, the project will bring the inaugural prototype, which is at a TRL of 4 "Proof of concept Prototype", to a TRL of 8 where the BOM is Finalised and the 0 Series is produced.

Project planning and key moments

*To make visible how you plan to spend your time, you must make a planning for the full project. You are advised to use a Gantt chart format to show the different phases of your project, deliverables you have in mind, meetings and in-between deadlines. Keep in mind that all activities should fit within the given run time of 100 working days. Your planning should include a **kick-off meeting, mid-term evaluation meeting, green light meeting** and **graduation ceremony**. Please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any (for instance because of holidays or parallel course activities).*

Make sure to attach the full plan to this project brief.
The four key moment dates must be filled in below

Kick off meeting	20 nov 2023
Mid-term evaluation	22 jan 2024
Green light meeting	25 mrt 2024
Graduation ceremony	22 apr 2024

In exceptional cases (part of) the Graduation Project may need to be scheduled part-time. Indicate here if such applies to your project

Part of project scheduled part-time	
For how many project weeks	
Number of project days per week	

Comments:

Motivation and personal ambitions

Explain why you wish to start this project, what competencies you want to prove or develop (e.g. competencies acquired in your MSc programme, electives, extra-curricular activities or other).

Optionally, describe whether you have some personal learning ambitions which you explicitly want to address in this project, on top of the learning objectives of the Graduation Project itself. You might think of e.g. acquiring in depth knowledge on a specific subject, broadening your competencies or experimenting with a specific tool or methodology. Personal learning ambitions are limited to a maximum number of five.
(200 words max)

I wish to embark on this project driven by a strong passion for contributing to affordable and accessible medical education in Kenya. This project presents an opportunity to not only address the critical need for cost-effective diagnostic tools but also to prove and enhance my competencies in research, design, and innovation. Through this journey, I aim to demonstrate my ability to conduct effective interviews and research methods, analyze complex problem domains, and design innovative, sustainable solutions.

In addition to the core project objectives, my personal learning ambition is to develop a deeper understanding of cross-cultural design and the dynamics of implementing a project in a resource-constrained environment. I want to foster skills in adaptability, empathy, and resilience as I work in Kenya, collaborating with local stakeholders, navigating potential obstacles, and ensuring that the microscope serves the intended community effectively. Ultimately, I aspire to not only contribute to medical education but also to grow as a socially responsible and globally conscious designer.