Future Inventors

An educational program to elicit problem solving skills in upper primary school learners in Lamu, Kenya

Integrated Product Design master thesis **Dorrit Bueters** 4447522

Paper collage "main street" by James Njoroge

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An educational program to elicit problem solving skills in upper primary school learners in Lamu, Kenya

MASTER THESIS
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COVER

Paper collage "wiyoni madukani" by James Njoroge

Preface

As I reflect on this graduation project, I am filled with gratitude for the incredible journey. When I decided to go for the project, I had no clue what it actually would entail, but I knew that I was ready for a challenge. As someone who grew up without any religious affiliation, living in Lamu, a religious centre with a strong cultural identity, was a great, eye-opening learning experience. I learned a great deal about a unique way of life that was unfamiliar to me. However, my main objective was not only to understand Lamu but to collaborate with the locals and design with them. I am proud to say that this collaboration was a great success!

Of course I could not have succeeded in this project without the help of the great people who were involved from the start.

Emma, my partner in crime, my pillar of strength, I cannot be happier that we took on this challenge together.

JC and **Willemijn**, my coaches, thank you for the valuable expertise and support when I needed it.

The **Kenya Red Cross Society** and the whole **IOMe005 team**, I am truly grateful to be welcomed with such open arms. You made us feel safe and supported throughout our stay. I am especially grateful to **Derrick**, **Emmanuel**, and **Nassor** for your invaluable contributions to the project. Thank you for taking on such a new project. It was great to see our collaboration grow throughout the months, and I believe on both sides we learnt a lot from this experience. When I was back in Delft, the remote collaboration continued with a great team of innovators. **Kennedy**, **Grace**, **Laly**, **Solomon**, and **Shamsa**, thank you for all your efforts, positive collaboration and great insights!

Teachers in Lamu, especially Mr. **Geoffrey**, Mr. **Nuri** and Mr. **Daniel**, thank you for welcoming us in your schools with open arms, and trusting in our process. It was an amazing learning experience to be able to collaborate with the learners in the way we did.

Lastly, I am grateful to all my **close friends** and, old and new, **house mates** for their unwavering support throughout this journey. Thank you for always being there to spar about my project or listen to yet another anecdote of my experiences in Lamu.

This project has taught me that an open mindset, curiosity, and a willingness to learn can take you far, even in unfamiliar territory. It has also taught me that my design skills can have a significant impact on communities like Lamu. I hope that this project can inspire others to step out of their comfort zones and take on new challenges. Personally I am sure that this was just the beginning of my intercultural design career.

The view from our house in Lamu

Jumping rope with Emma and the girls at Mahmoud Bin Fadhil Girls Primary

Executive summary

Science, Technology, Engineering and Mathematics (STEM) education plays a critical role in personal and societal development by preparing students for a rapidly changing, technological world. However, implementation of integrated STEM education poses significant challenges for educators, particularly in emerging markets such as Kenya, where resources and investments in teacher training are limited. In rural areas like the Lamu Archipelago, inadequate access to technology and educational resources intensifies this problem, leading to high dropout rates and limited opportunities for learners.

IOMe005, a fabrication lab in Lamu county which is part of Kenya Red Cross Society, is looking to bridge the gap between primary school education and technological literacy for upper primary learners. The fabrication lab intends to train a team of innovators to facilitate a STEM program in local schools where learners are provided with tools to learn about STEM concept in an experiential way.

The goal of this project is to create such a hands-on educational tool and teaching method which promotes problem-solving skills specifically, as this is a vital skill in the ever-changing world.

The final design aims to empower a team of innovators to facilitate extracurricular Future Inventors workshops at Lamu primary schools, where they encourage upper primary learners to become the inventors of the future. In the Challenge-based workshops, learners are presented with a challenge, and can use the ThinkBricks, a set of building blocks, to build prototypes and envision solutions to these challenges. The program core is the Future Inventors manual, which guides the team of innovators step-by-step through the full process of development and facilitation of Future Inventors workshops.

The Intercultural Design Approach was developed and employed during this project. The approach combines various design research activities such as Rapid Prototyping and participatory sessions, to bridge cultural gaps and mitigate the risks of unintended consequences that could negatively impact communities. Building cultural sensitivity, establishing relationships, and gaining a deep understanding of the context through field research were the core activities undertaken to learn about the culture and to design a solution that fits the targeted context.

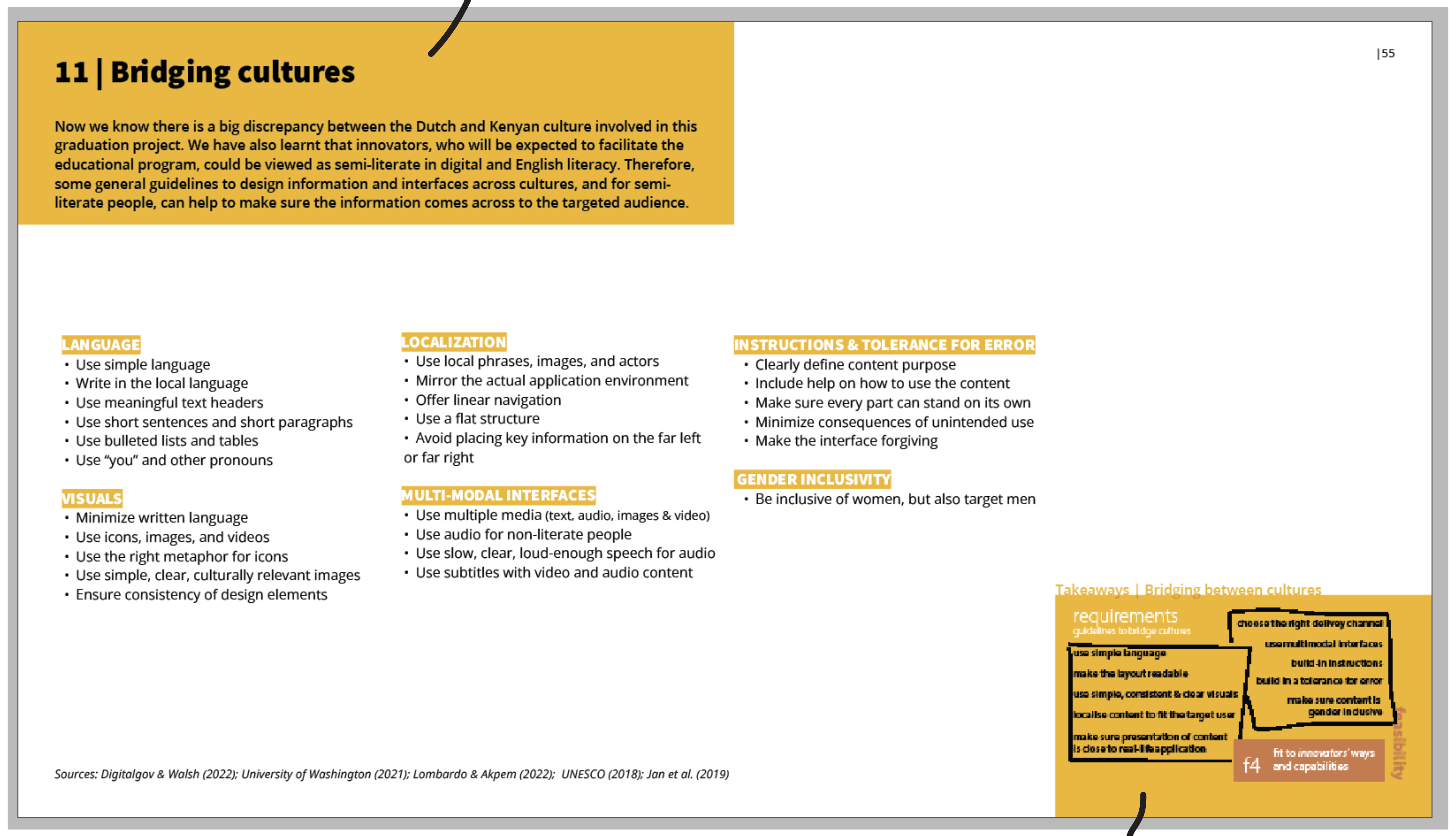
Overview of the final design: the Future Inventors program

Reading guide

Structure

The content table on the next page provides an overview of the five parts in which the report is subdivided. To make reading pleasant, every chapter starts with a brightly coloured box as title, and if applicable, concludes with this as well. When in little time, these boxes can be read as the red line throughout the whole report.

chapter start



|55

11 | Bridging cultures

Now we know there is a big discrepancy between the Dutch and Kenyan culture involved in this graduation project. We have also learnt that innovators, who will be expected to facilitate the educational program, could be viewed as semi-literate in digital and English literacy. Therefore, some general guidelines to design information and interfaces across cultures, and for semi-literate people, can help to make sure the information comes across to the targeted audience.

LANGUAGE
- Use simple language
- Write in the local language
- Use meaningful text headers
- Use short sentences and short paragraphs
- Use bulleted lists and tables
- Use "you" and other pronouns

VISUALS
- Minimize written language
- Use icons, images, and videos
- Use the right metaphor for icons
- Use simple, clear, culturally relevant images
- Ensure consistency of design elements

LOCALIZATION
- Use local phrases, images, and actors
- Mirror the actual application environment
- Offer linear navigation
- Use a flat structure
- Avoid placing key information on the far left or far right

MULTI-MODAL INTERFACES
- Use multiple media (text, audio, images & video)
- Use audio for non-literate people
- Use slow, clear, loud-enough speech for audio
- Use subtitles with video and audio content

INSTRUCTIONS & TOLERANCE FOR ERROR
- Clearly define content purpose
- Include help on how to use the content
- Make sure every part can stand on its own
- Minimize consequences of unintended use
- Make the interface forgiving

GENDER INCLUSIVITY
- Be inclusive of women, but also target men

Takeaways | Bridging between cultures

requirements
guidelines to bridge cultures

use simple language
make the layout readable
use simple, consistent & clear visuals
localise content to fit the target user
make sure presentation of content is close to real-life application

choose the right delivery channel
use multimodal interfaces
build-in instructions
build in a tolerance for error
make sure content is gender inclusive

f4 fit to innovators' ways and capabilities

feasibility

Sources: Digitalgov & Walsh (2022); University of Washington (2021); Lombardo & Akpem (2022); UNESCO (2018); Jan et al. (2019)

chapter end with insights

Glossary

Learners
Upper primary school students

IOMe005 team
The team that leads the activities at IOMe005

Innovators at IOMe005
Upper primary school students

KRCS
Kenya Red Cross Society

STEM
Science, Technology, Engineering & Mathemathics

Singular-truth-mindset
The current mindset in Kenyan education where it is assumed that what the teacher says is true

Experiential learning
Learning by hands-on experiencing something

Learning through inquiry
A learning process where the educator guides learners in their discovery of the learning content

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Boat and people traffic at the seafront of Lamu

Learners in Lamu proudly pointing at the island on a painted map, by Eric Lafforgue

PART 1 design project in a nutshell

In this part the relevance of problem solving education in Kenya gets emphasized. Fabrication lab IOMe005, the client of the project, gets introduced, together with their aim for the project. This aim is phrased into a design brief, and then the final design is presented: the Future Inventors program.

1 | The importance of STEM for rural Kenya

This thesis describes the design of an educational program which elicits problem-solving skills in upper primary learners in Lamu, Kenya. The following paragraphs will highlight the importance of education for a fulfilling life. Science, Technology, Engineering and Mathematics education, later referred to as STEM education, is crucial for societal development. It prepares the next generation for the jobs of the future. Yet, STEM education in emerging countries, and rural areas like Lamu in Kenya is of low quality, which is a challenge that needs to be overcome.

Importance of STEM education

Education is the process of acquiring knowledge and skills, learning social norms, developing reasoning and learning what is wrong or right (World Vision, 2021). Learners (students) should be provided with the tools to gain understanding on the world around them, as it lays the foundation for personal growth and a fulfilling life. STEM subjects play a big role in this process. They describe natural concepts and empower learners to make sense of it, as the world is becoming more advanced.

Every learner has needs in education

Educational needs are intertwined with the basic human needs described by Maslow, which is presented in *Figure 1*. According to Kraaij (2015), children naturally feel the need to discover their environment and learn more about it. When they learn, they become independent and gradually increase their sense of safety. Hands-on STEM education taps into this intrinsic need to discover by learning through inquiry. This motivates learners to actively keep learning (Kraaij, 2015). When taught from an young age, learners develop a strong foundation in STEM, and become empowered in their own development.

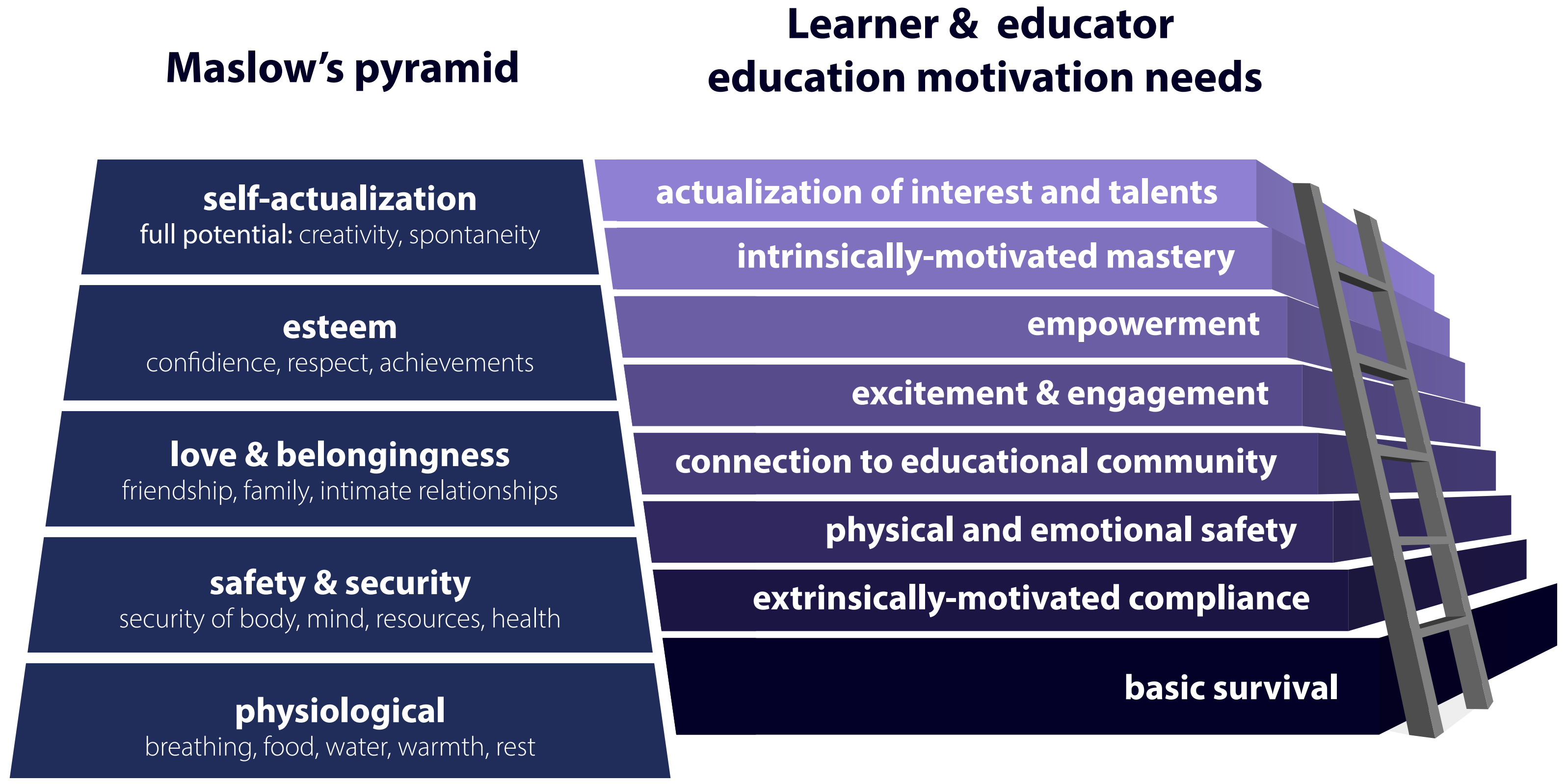


Figure 1: Maslow's pyramid connected to education needs (Maslow, 1943; Gerstein, 2023)

Using STEM to boost societies

Besides individual relevance, STEM education is crucial for societal development. A 2020 UNESCO report states that:

> **"[Despite uncertainty of future trends,] there is general agreement about the knowledge areas and skills that will be increasingly valued in this future, such as, STEM skills alongside critical and creative thinking skills"**
>
> *UNESCO, p. 6, 2020*

Investing in STEM education is especially important for the development of emerging markets such as Kenya. M'mboga Akala states that "the economy is highly dependent on the education sector to provide expertise in terms of human and mechanical resources" (2021). Quality STEM can equip the large youth population in Kenya with the skills needed to solve their communities' challenges. The new job opportunities and investments this attracts can lead Kenya towards a self-sustaining economy, away from reliance on foreign aid (UNESCO, 2020).).

STEM education implementation challenges

Although there is an "immense need for STEM workforce" (Anita et al., 2021, p.1541), too little learners graduate in STEM-topics (Thibaut et al., 2018). Research shows that integrated STEM education increases learner interest (Moore et al., 2020). Yet, such approaches are challenging to implement for educators (Thibaut et al., 2018). They require a significant effort, investment in new skills, collaboration between teachers and access to resources which are hard to acquire. Although this problem is recognized worldwide, it is especially true in emerging country like Kenya. Here, the availability of material resources is limited and teachers are poorly trained (Muthama, 2022). Furthermore, shortages in human resources result in an average teacher-learner ratio of 1:49 (The Africa Report, 2022).

A classical way of educating

The lack of resources in the Kenyan schools leads to learners performing "consistently low for the last nine years for the period 2006 to 2014 with a national mean score below 50% in all science subjects" (Makoba & Odhiambo, 2022). Besides this, the system is characterized by the education of "trivial information" in a classical way (M'mboga Akala, 2021). There is little space for intrinsic questioning and developing problem solving skills.

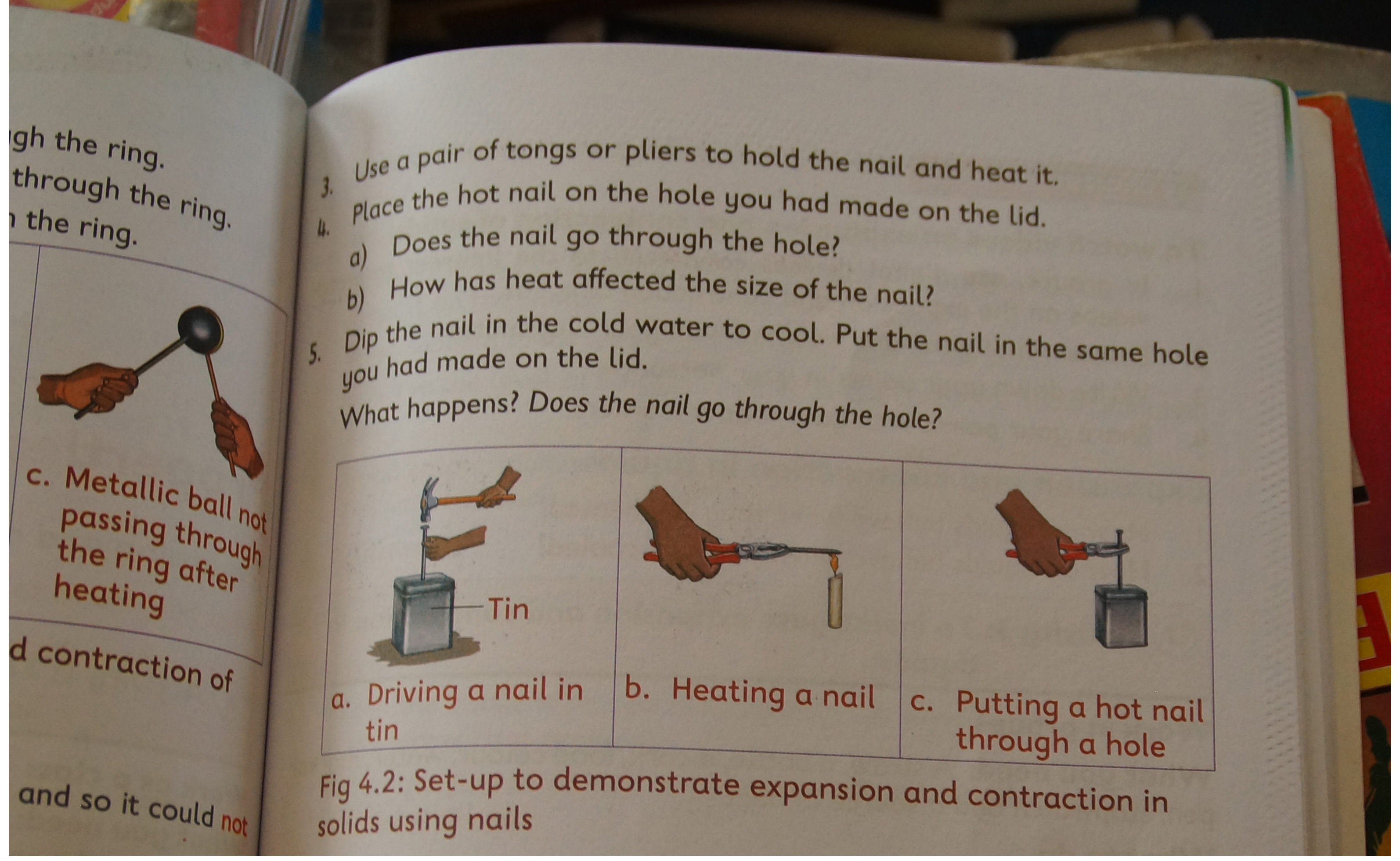
Inadequate STEM development in rural Lamu

Such educational problems generally concentrate in rural places, such as the Lamu Archipelago (see *Figure 2*). Inadequate access educational resources results in poor quality education. Outside of school children are generally not exposed to technology, because life in Lamu is highly traditional. As a result, schools have high dropout rates and opportunities for learners to learn to their full potential are limited.

Attempts to fix this problem

The government of Kenya has recognized the need for a better, future-proof education system. They formulated an ambitious vision for 2030 to improve STEM education. A new system will nurture learners' talents and prepare them for particular jobs (Ministery of Education, 2018) . New knowledge will be constructed on learners' prior knowledge through experiential learning (M'mboga Akala, 2021). Yet, it is widely argued that this new "constructive" curriculum which is currently being implemented, is a "destructive education system" (M'mboga Akala, 2021).

> **"The limitations of constructivism are hence linked to its inability to offer learners from working class a transforming learning experience that transcends their immediate milieu, which eventually entrenches and perpetuates societal inequalities"**
>
> *M'mboga Akala, 2021*



gh the ring.
through the ring.
the ring.

c. Metallic ball not passing through the ring after heating

d contraction of

and so it could not

3. Use a pair of tongs or pliers to hold the nail and heat it.
4. Place the hot nail on the hole you had made on the lid.
   a) Does the nail go through the hole?
   b) How has heat affected the size of the nail?
5. Dip the nail in the cold water to cool. Put the nail in the same hole you had made on the lid.

What happens? *Does the nail go through the hole?*

a. Driving a nail in tin

b. Heating a nail

c. Putting a hot nail through a hole

Fig 4.2: Set-up to demonstrate expansion and contraction in solids using nails

Figure 3: 5th grade practical science exercises requiring a metallic ball and ring (left) and a hammer, nail and tin (right)

> **"The Kenyan education system makes learners' talents get lost"**
>
> *Nassor Abdalla, one of the two engineers from Lamu, 2022*

The education remains classical

Although the intentions with experiential education are sensible, teachers in Lamu explain they often have to replace such exercises by looking at drawings in the book. This is because several of these exercises require highly specific resources, as shown in *Figure 3*.

Motivation & purpose of the project

These persistent challenges with STEM education ask for a comprehensive and sustainable solution. The Lamu-based IOMe005 fabrication lab (an open-access workshop, see next page) wants to take on this challenge. This design project aims to help IOMe005 elicit problem-solving skills in Lamu learners. This will be done through the design of an experiential educational tool and teaching method. With this design, IOMe005 aims to become an integral part of the Kenyan educational ecosystem and make a lasting impact.

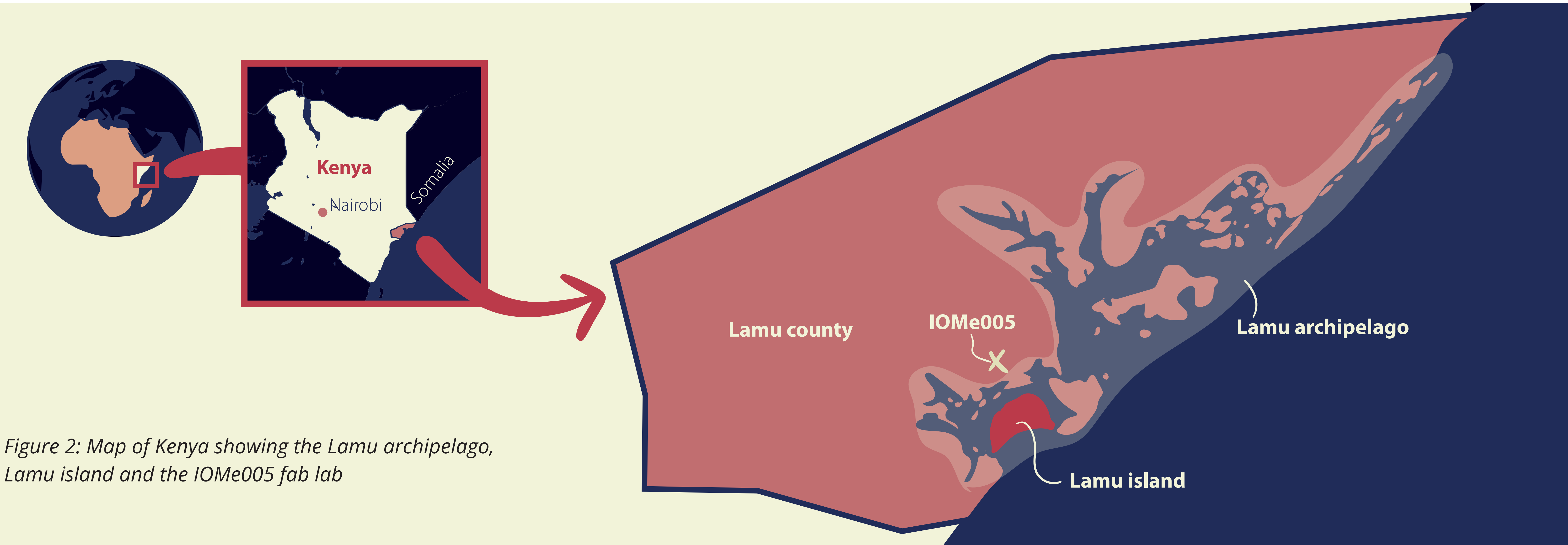


Figure 2: Map of Kenya showing the Lamu archipelago, Lamu island and the IOMe005 fab lab

2 | IOMe005 and its educational intentions

Now we understand the context and relevance of this design thesis, we will learn more about IOMe005 and their aim with the project.

Figure 4: The IOMe005 fabrication lab buildings

A fabrication lab is a small-scale workshop which offers open access to digital fabrication technologies.

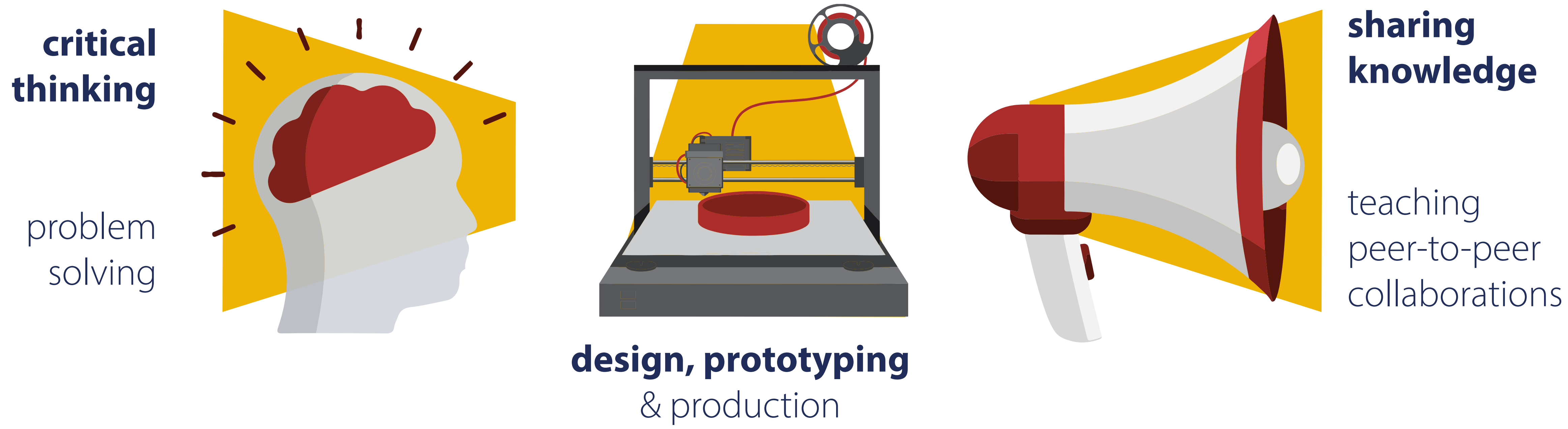
2.1 | Who is IOMe005?

The IOMe005 Lab is a non-profit fabrication lab on the mainland of Lamu county (*Figure 2, p. 9*).Funded by Qatar Red Crescent, Kenya Red Cross Society (KRCS) opened it in November 2021. The lab grew from a need to help the community find ways to solve complex problems locally and become resilient through innovation. As the lab is just over two years old, they are still working hard to make a name and achieve this goal. In order to display its innovative character, the lab is built from several containers (Figure 4). The containers accommodate advanced technologies, such as 3D printers, a CNC machine, a laser cutter.

"You owe it to yourself"

IOMe005 stands for "I Owe Me", with 005 for Lamu's county code. This represents the belief that locals owe it to themselves to put effort in shaping chances for their future. The motto chambua vumbua ("think critically to be able to innovate"), puts critical thinking as a core identity of the lab. Besides this, they put a great emphasis on problem solving skills and thinking out of the box. Additionally, encouraging people to learn from each other and share knowledge is engrained in their way of working. This is reflected in their goal to reach as many people as possible to empower them to share knowledge.

Figure 6: Visualisation of IOMe005's core values



The organization

IOMe005 is led by a small team, consisting of a lead and two lab facilitators, whose main work is to keep the lab running and facilitate all activities. Besides this team, IOMe005 opens its doors to a varying group of innovators, as presented in *Figure 7*. The innovators voluntarily spend their days at IOMe005 to learn how to work with advanced technologies. They do this to grow on a personal level and attract better future opportunities.

Figure 7: All innovators at IOMe005, together with the rest of the team

Main activities of IOMe005

The lab organizes a broad variety of in-house educational programs. These programs teach about a variety of topics, from digital literacy and design thinking, to leadership. Currently the innovators at IOMe005 are the main target group for these activities. Additionally, the innovators are encouraged to work on personal innovative projects. Once they have an idea for an item to produce, the lab facilitators guide them through the full process to putting it to market. Besides this the lab facilitators engage the innovators in the production of small batches of items for outside clients, in order to generate income for IOMe005. Examples of all these items are presented in *Figure 8*. Finally, IOMe005 occasionally organizes other activities, such as the introduction of advanced technology to high school learners.

Figure 8: From left to right: statue made by innovator, collection of laser cut lamp shades, planter made from up cycled trash materials, trophy made for KRCS

Figure 9: The cognitive and physical gap between learners on Lamu island and IOMe005

2.2 | Empower learners through STEM education

IOMe005 believes that the children in the Lamu archipelago have a huge setback when it comes to technology education and literacy, as opposed to their peers in other places of the world where technology is more common. This is why the IOMe005 team envisions rolling out an educational program to open up opportunities for these learners. The program should bridge education in schools and global technological, societal and environmental developments.

> **“At IOMe005, we inspire a youthful generation of problem solvers who apply scientific principles to local knowledge and available resources to find solutions to problems faced in their communities.”**
>
> *Kenya Red Cross on twitter, 2022*

Dual “gap” hindering access to IOMe005
Two main obstacles make it challenging reach primary school learners with IOMe005’s initiatives: There exists a physical and a cognitive “gap” between the learners of the archipelago and STEM at IOMe005, as visualised in *Figure 9*.

The physical gap arises from the long distances and high transportation costs between the island settlements the lab. This journey consists of a part by motorbike or car, a part with a boat, and a part by foot. Additionally, younger children generally have a “smaller bubble” because they rely on others for transportation and supervision.

The cognitive gap arises from children on Lamu island living a traditional lifestyle, with a “singular-truth”-mindset at school and low exposure to technology, which contrasts with the advanced technology and problem-solving mindset at IOMe005, and culture on the mainland. Therefore, it is a challenge is to get STEM embraced at schools on Lamu island.

IOMe005 wants to bring innovation, prototyping & STEM education to local primary school classroom of Lamu, to inspire and empower learners from a young age

The vision of IOMe005

The IOMe005 team strives to roll out an educational program in Lamu primary schools. They want to be a front runner in innovative education and set an example for the government curriculum. The program will be developed and facilitated by a team of innovators, who are supported by the lab facilitators. IOMe005 strongly believes in teaching such a STEM program through experience-based hands-on activities.

Former efforts

In the past year, innovators at IOM005 have making attempts at "STEM kits" to support such a program. With these educational kits, learners learn about a certain STEM concept a hands-on, engaging way. The kits prototyped by innovators show a wide variety of solution directions, as presented in *Figure 10*. These first efforts have sparked conversations within IOMe005 about the educational content of the program. However, further development was not prioritized yet. This is due to the fact that there is no consistent stream of money available to sustain IOMe005. Therefore, the team is often forced to prioritize orders which get money in, interfering with such more long-term projects.

Figure 10: Innovators developing STEM kits

A new way of working for the community

Since 2021 the IOMe005 fabrication lab has been looking for ways to expand its impact through educating local learners. However, visits to primary schools on Lamu island reveal that currently they are not aware about the existence of IOMe005 and its possibilities for learners. According to Derrick from IOMe005, Red Cross activities are currently ad-hoc, short-term, and "the Red Cross has not been focused on education and improvement. The community is not used to talking about education." (2022). Knowing this, it is apparent that IOMe005's plans lie outside of what communities already expect from the Red Cross, which asks for a certain mindset change in communities. To IOMe005 it is important that the program draws attention to the activities the organisation has to offer.

> **"For the innovators who will be in the team, it is crucial that they have a passion for the topic. They'll be selected carefully."**
>
> *Derrick, lead of the IOMe005 team, 2022*

Setting up a team of innovators

IOMe005 intends to train a team of innovators to facilitate the program in local schools. With the lab facilitators' guidance, they will also be responsible for the future development of the program. This structure is necessary to ensure the program experiences minimal interference from other projects at IOMe005. To enable the team of innovators to take on this task, ideally the design of the hands-on STEM tool comes with a teaching methodology and a manual to guide the innovators in this process.

Resources for the program

The intention for the program is to start as soon as possible with small pilots, teaching 10-20 children per lesson. Because the fabrication lab is equipped with advanced production equipment, the physical components of the design should be produced in-house. Derrick from IOMe005 states that he "like[s] to look at it from an "ideal" point of view, instead of a "lack of resources"-mindset" (2022), which means the aim is to provide a complete set of educational resources to every involved learner. For this reason, it is important for the design to be low-cost for IOMe005, and preferably it can be used in a range of educational activities, in order to make it worth the initial investment. Finally, after a first lesson in a school, the resources will remain here and will have to be managed by the teacher who is responsible for the program.

Envisioned content

The IOMe005 team envisions to incorporate a wide range of disciplines into the programs' education, ranging from teaching about physics, electronics and advanced production techniques, to Red Cross-specific subjects such as community service, humanitarian classes and first aid activities. Additionally, in the past during in-house STEM activity-days for primary school learners which IOMe005 already organized twice, learners were stimulated to work together. Incorporating soft skills such as collaborating, besides teaching STEM knowledge, is of high importance to lab facilitator Nassor (2022).

Future of the program

Although the aim is to start locally at Lamu Island, the heart of Lamu county, IOMe005 intends to gradually expand to other rural, coastal places throughout Kenya. Additionally, the fabrication lab aspires integrating programs all the way up to high school education, allowing learners to first build up their skills, and later learn to apply it in real-life problems. In this way, Derrick envisions the creation of a certain symbiosis between the schools and the lab, "where IOMe005 is much more than just a tool supplier " (2022). Due to this urge to expand, the design should allow for future adaptations and additions in order to stay relevant as the program evolves.

Sustainability

Finally, because IOMe005 emphasizes on improving the future, environmentally-conscious material and production choice is preferred.

Figure 11: The STEM disciplines, and how they are interconnected (National Research Council, 2009; Dugger, 2010; Honey, 2014)

3 | Focus on problem solving

Within IOMe005's goal, STEM plays an important role. Now we will first gain deeper understanding of what exactly STEM is, and find out that problem solving is the core skill within this type of education. This realisation will provide a frame for the design brief.

3.1 | Integrated STEM education

What is STEM exactly?

STEM education stands for Science, Technology, Engineering and Mathematics education. Although numerous experts have attempted to define the concept over the years (Barcelona, 2014; C. C. Johnson, 2013; C. C. Johnson et al., 2015; Kelley & Knowles, 2016; Stohlmann et al., 2012; Thibaut et al., 2018), it remains ill-defined (Honey et al., 2014). This can be attributed to the broad spectrum of knowledge and skills, divided among the four disciplines, it covers. *Figure 11* grasps the intricate ways these disciplines are interrelated.

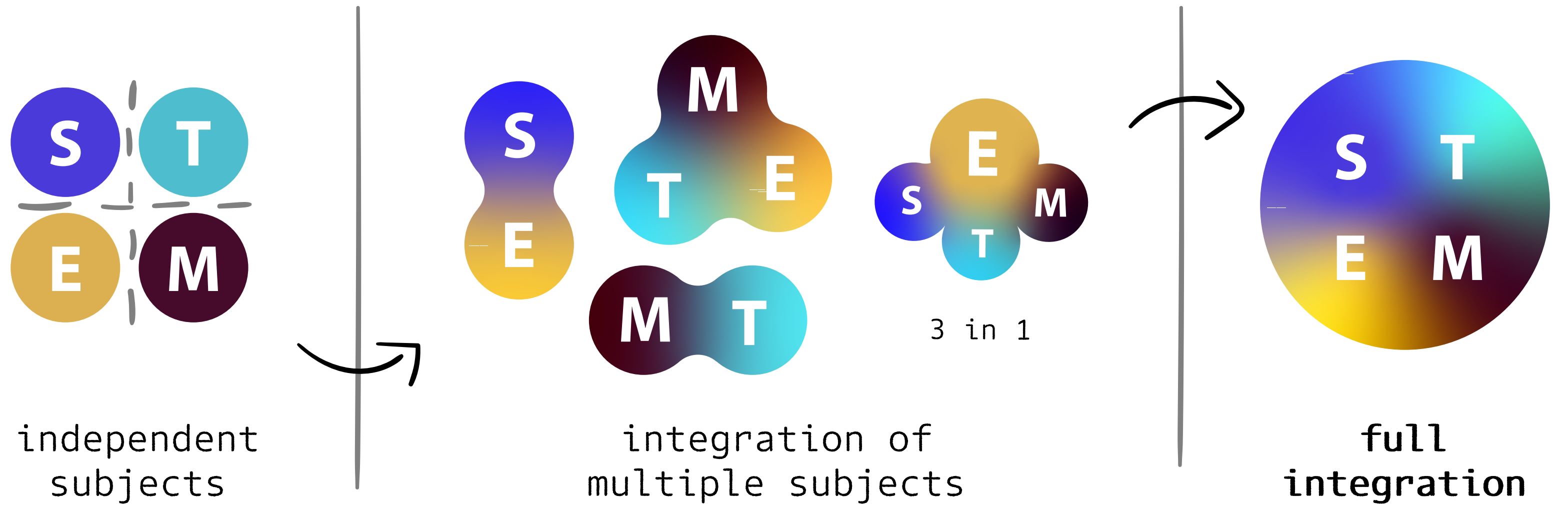


Figure 12: Approaches to STEM education, adapted from El Sayary et al. (2015) with input from Thibaut (2018) and Dugger (2010)

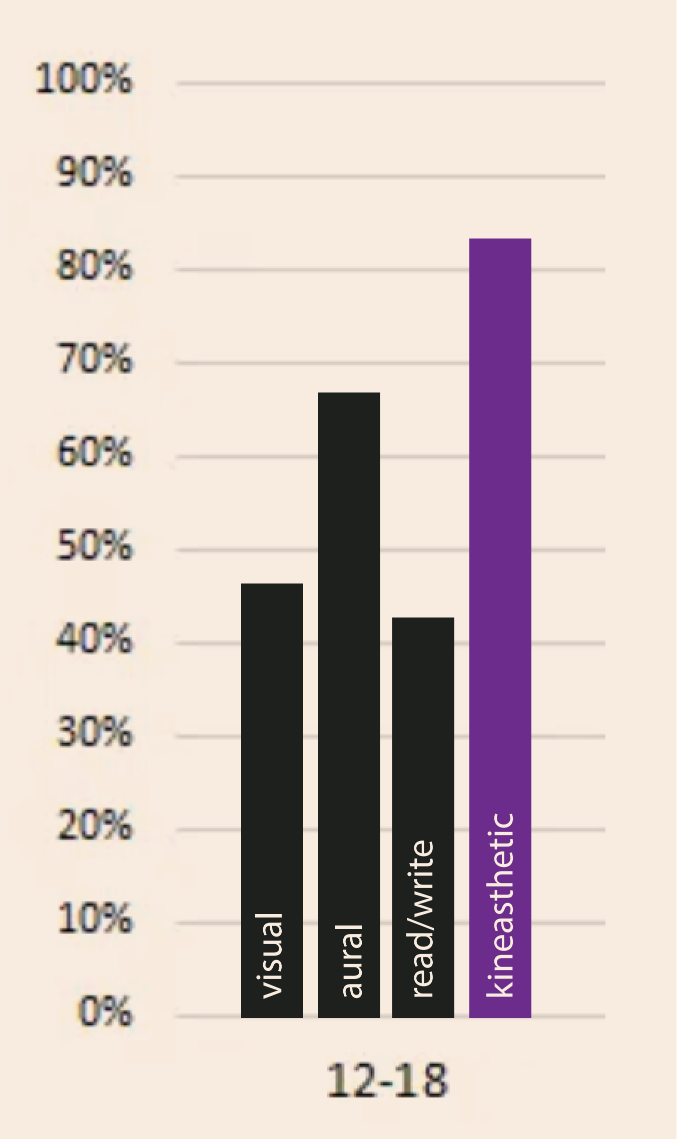
Integrated STEM education

A broad literature review conducted by Kersánszki et al. (2021) states that "over the past 25 years, the focus of STEM education has shifted from individual disciplines to a more integrated or multidisciplinary approach to teaching and learning" (p.127). Currently, STEM is seen as a way of teaching which integrates several, or all four, of the subject areas, resulting in a rich joint learning experience (see *Figure 12*) where a teacher facilitates learning through inquiry where learners actively shape the learnings (El Sayary et al., 2015).

Learning by doing

Integrated STEM education is often educated through experiential, hands-on learning. While every learner has preferred learning styles, education traditionally has relied on visual and auditory learning, where learners require information using respectively pictures and text in books and other media, and by listening to educators instructions. However experiential learning taps into a third learning style which is present since a very young age, kinaesthetic or tactile learning (Gilakjani, 2011), where individuals learn through physical interactions and touch. Although research results vary in learning style occurrences, and individuals can have more than one preferred style, it is widely proven that kinaesthetic learning is a highly prevalent learning style as visualised in *Figure 13* .

Figure 13: Learning preferences of children aged 12-18 years old (VARK, 2020)



3.2 | Focus on problem solving in STEM

> **“Once [learners] develop the confidence to find things out on their own, then they will be able to find out [many] other things , [quicker] than we could ever tell them”**
>
> *Jeff Lisciandrello, education expert, 2020*

Regardless of the specific content that is aimed to be taught to a child, according to Kersánszki et al. The “problem-based learning skill” (2022, p. 128) is a crucial aspect in STEM education. Being engaged in problem solving with a critical mindset is essential for learners to internalize the STEM content effectively.

However as stated in chapter 1, the Kenyan education fails to promote this mindset. Numerous school visits, observations, and interactions with learners and teachers reveal that lessons are taught in a conservative and classical way and with a singular-truth mentality, which will be substantiated in chapter 9. This means that the general belief is that what the teachers says is true, and there is not much space to question this. The result is a school system which discourages curiosity, where learners get demotivated and do not learn to their fullest potential.

Therefore it is crucial to fundamentally change the way education is approached in Lamu. This design thesis emphasises the importance of teaching critical thinking and problem solving skills, and aims to contribute to learners seeing new perspectives and opening up schools in Lamu to other ways of teaching.

3.3 | The design goal

The aim is to design hands-on STEM educational tool and teaching method that will elicit problem solving skills in upper primary school learners on Lamu island

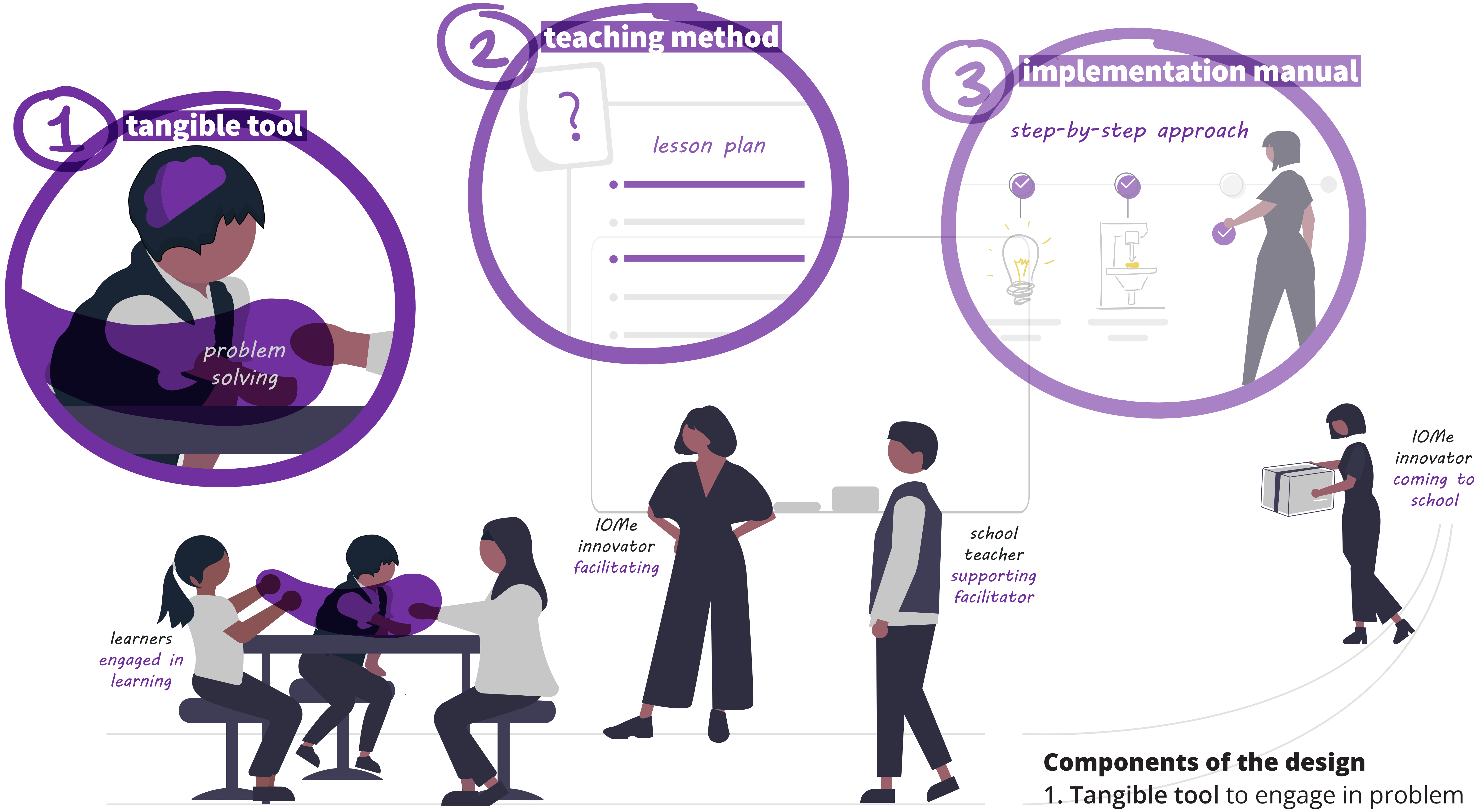


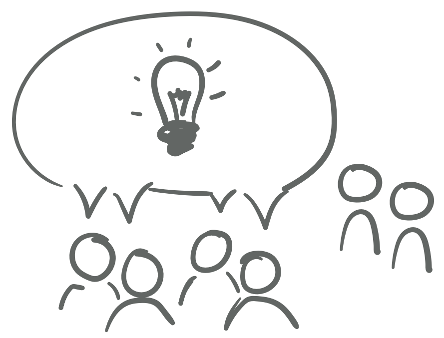
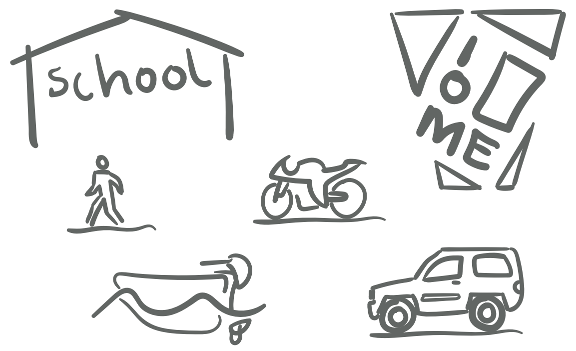
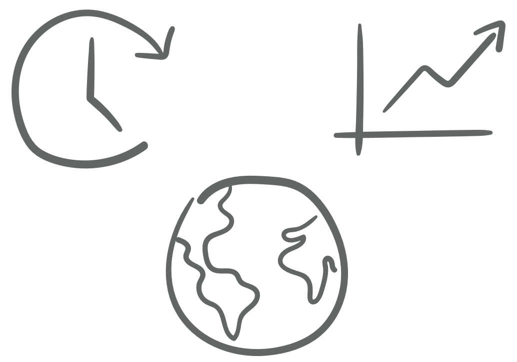
Figure 14: All components of the envisioned design

Components of the design

1. **Tangible tool** to engage in problem solving activities
2. **Teaching method**
3. **Implementation manual** to guide the team of innovators

3.4 | Preliminary design criteria

This sub-chapter presents the first design criteria that flow out of the design brief and IOMe005's aim are categorized in the three layers of the three lenses of innovation.

	desirability do they want it?	**feasibility** can they do it?	**viability** should they do it?
 **using in class**	d1 teaching about problem solving d2 aligns with learner's cognitive world d3 aligns with *innovator's* motivations	f1 produceable in-house at IOMe f2 *innovators* can facilitate lessons f3 adapted to resources at schools	v1 minimal initial production cost
 **Lamu schools and IOMe**	d4 teaching aligns with IOMe's core values d5 fit to local primary schools' ways d6 program raises awareness on IOMe's activities	f4 fit to *innovators'* ways and capabilities f5 can be transported between IOMe & schools, by motor/car/boat/foot f6 design far developed so it can be piloted in near future	v2 can be used in range of educational activities v3 minimal replacement costs
 **long term and environment**	d7 fit with local ways d8 minimal environmental impact of materials d9 engages learners societal developments	f7 program can be facilitated by *innovators* f8 manual enables *innovators* to develop program further	v4 educational program is scalable

Deepening the lenses of innovation

The three lenses of innovation (desirability, feasibility and viability) are widely used in order to evaluate a design. Desirability talks about whether the design is desirable to the stakeholders, feasibility about its potential technically (whether it can be done), and viability looks at the economical side. Within this thesis the aim is to incorporate long-term thinking and environmental criteria into these lenses by splitting them into three layers, as presented in *Figure 15*. The first layer describes the direct usage, the second the system around it, and the final layer incorporates long term and environmental factors.

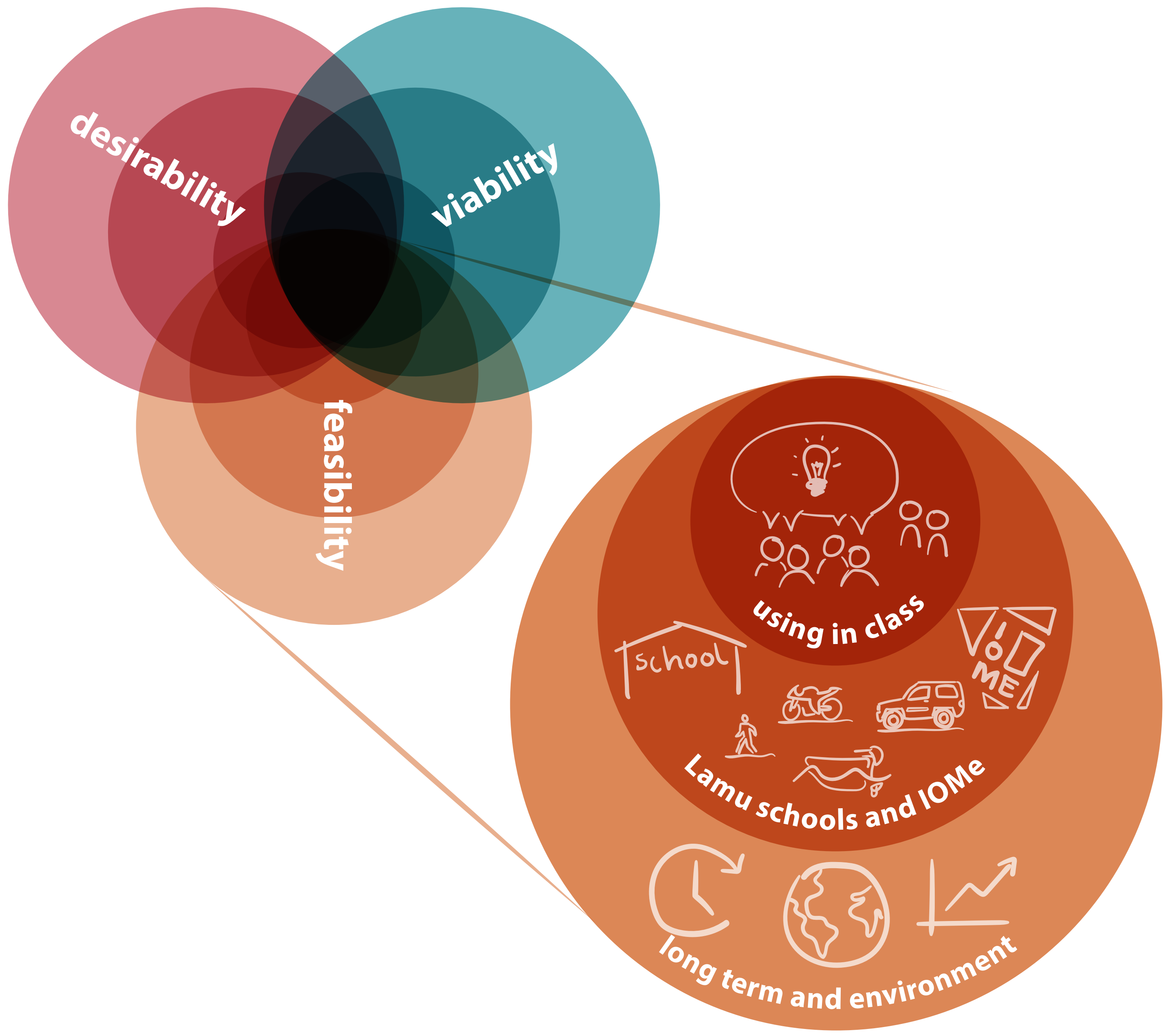


Figure 15: The layered lenses of innovation, inspired by the four-layered framework of Roscam Abbing and Pelgröm (2021)

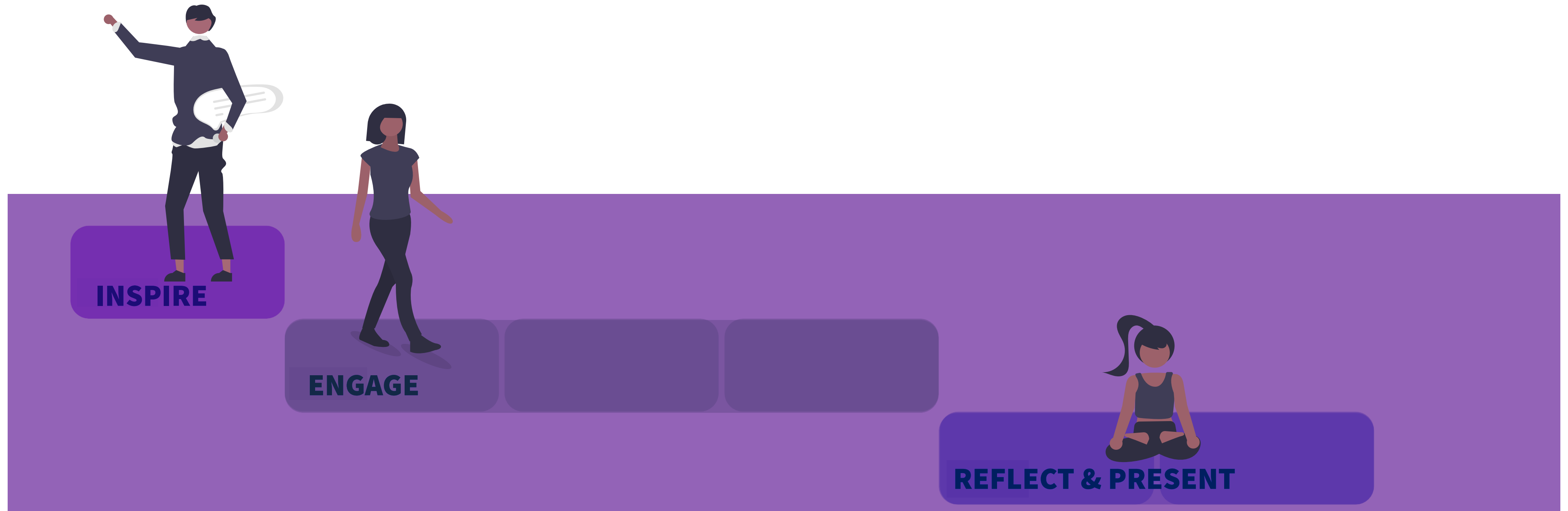
4 | The Future Inventors design overview

This extracurricular program aims to open learners' perspectives by empowering them to be the inventors of solutions for future societal challenges, in order to challenge the current "singular truth" mindset in Kenyan education. See chapter 13 for the full design.

① ThinkBricks

- hands-on tool to **use in experiential STEM activities**
- **versatile**: freedom to construct anything
- material choice **fits Lamu heritage**
- extra required **materials widely available in Lamu**
- **printed onepager** to connect Thinkbricks to implemenation manual

② Future Inventors **Workshops**



- **a framework for workshops** to develop problem-solving skills in learners
- engages learners in **relevant societal challenges**
- truly **inquiry-based-learning** approach
- every workshop focuses on **hard skills and soft skills**
- **innovators gain confidence** by facilitating one part at a time

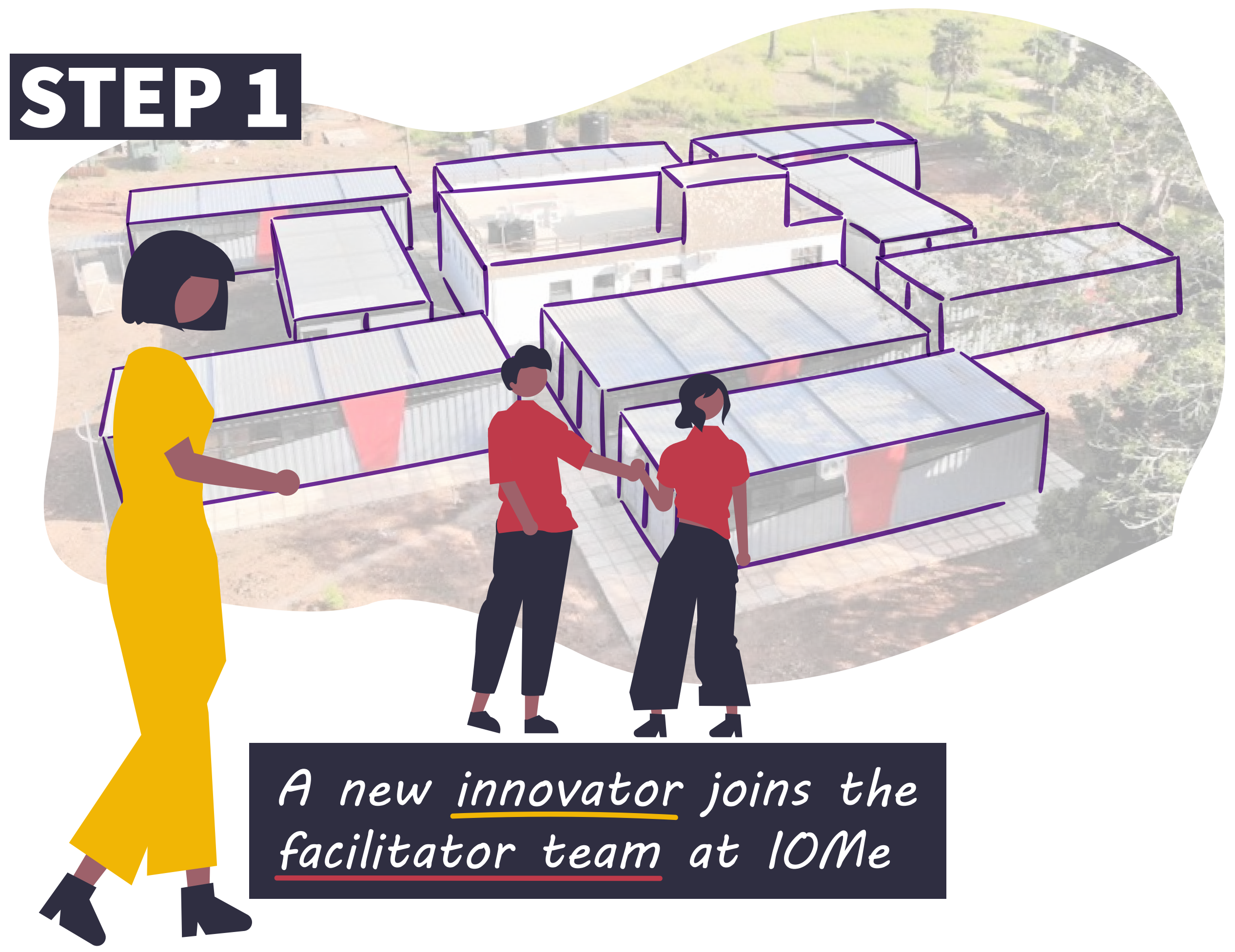
③ Future Inventors **Manual**

- **PowerPoint slide deck containing videos** to guide innovators
- **visual communication** and **B1 English** language for easy understanding
- **gives innovators confidence** to start teaching
- step-by-step approach to **develop the workshop content**
- **implementation checklist** to guide bringing the program to schools

4.1 | User scenario

FACILITATING A PROBLEM SOLVING WORKSHOP

STEP 1

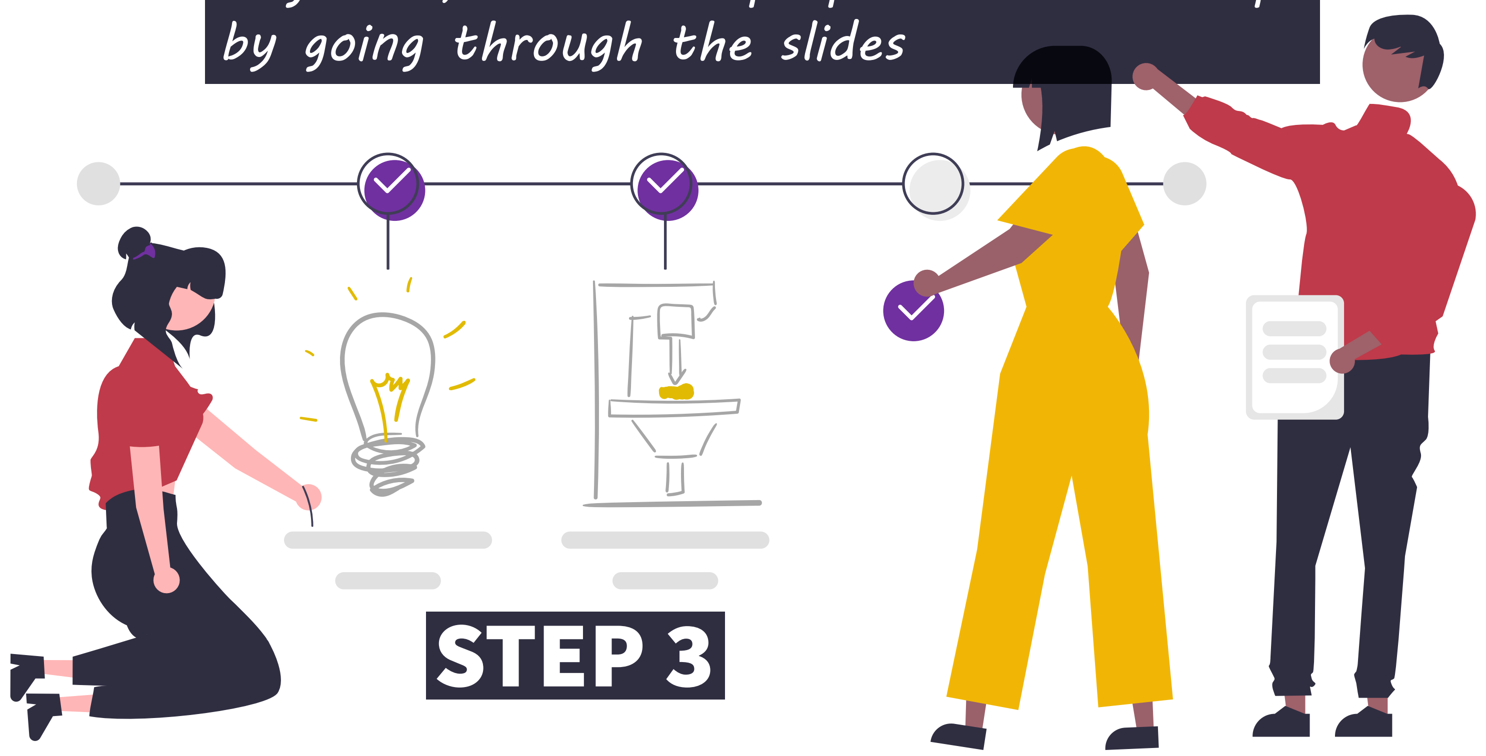


A new innovator joins the facilitator team at IOMe

STEP 2

She opens the facilitation manual slides and watches the explanation videos

Together, the team prepares a workshop by going through the slides



STEP 3

STEP 4

Now it is time to facilitate a problem solving workshop with the ThinkBricks!

THE END

The team feels accomplished:
The learners enjoyed the workshop, and they gained more confidence in facilitating!

Figure 16: The intention of the playpump was children playing while at the same time pumping water (image left), however in reality women ended up using the pumps in an inefficient and non ergonomic way (image right). Images by Ralph Borland

PART 2 intercultural design process

In this second part, the areas which were researched are presented, along with the newly developed Intercultural Design Approach. Its aim is to gather the necessary insights, while limiting unwanted consequences, such as presented in *Figure 16*.

5 | Areas to research

There are multiple research areas which need to be understood within the project, in order to develop a well-founded design with a seamless culture fit and scientific core.

The main areas of research which arise from the design brief are illustrated in *Figure 17*. The theoretical framework on the left entails the needs of learners and teachers within education, leading to rich STEM education. This needs to be incorporated into the design to provide a scientifically proven core. The right side shows the cultural context of the end users. The broad cultural context needs to be understood, to allow for a design that fits the targeted context. For this, the six themes to understand a user context, as described by Mink (2016) will be constantly monitored. Finally, in order to translate the scientific core to this specific cultural context, cross cultural design guidelines provide insights on how to adapt a design to fit a specific culture.

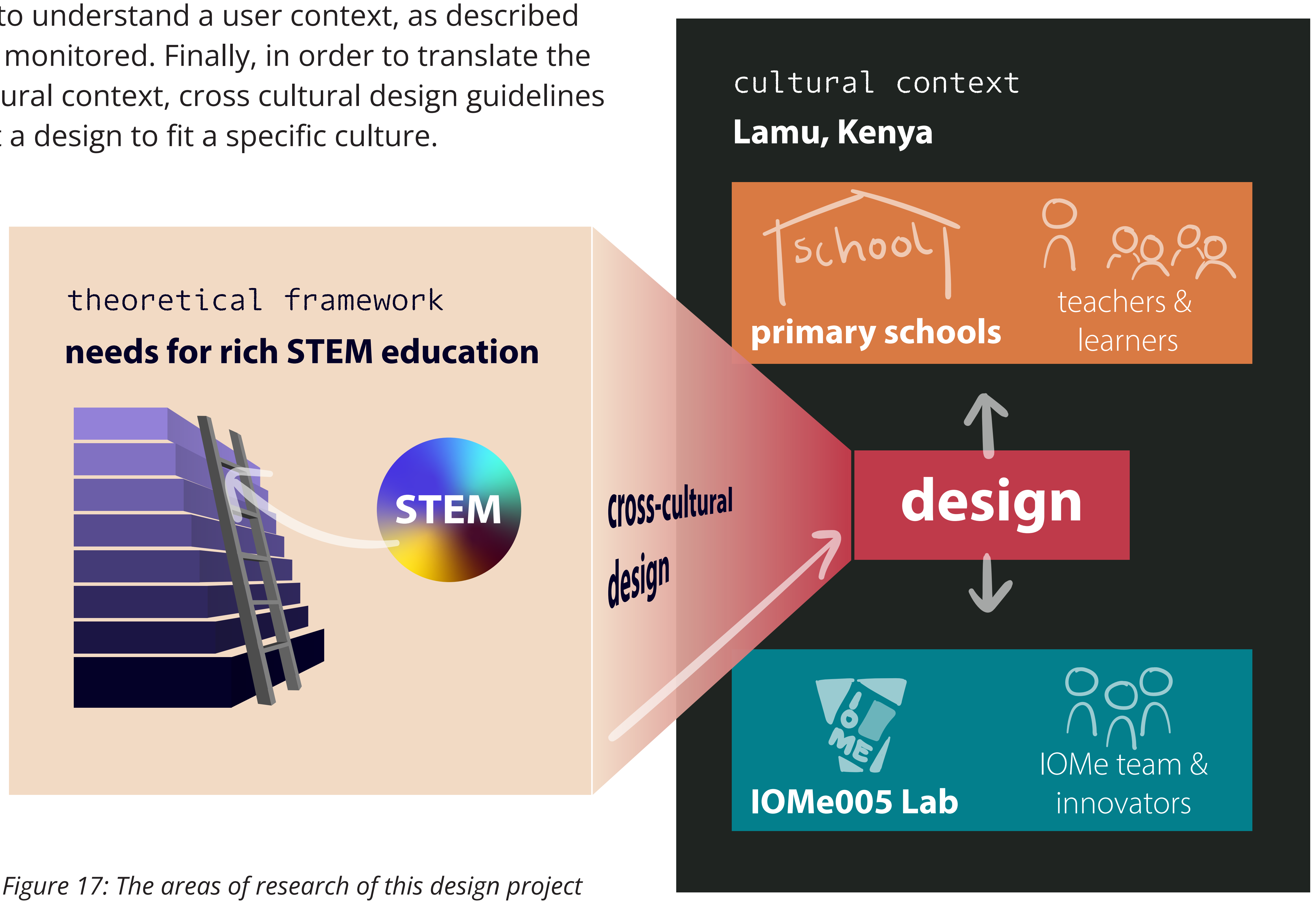


Figure 17: The areas of research of this design project

Six themes to learn about a user context

A comprehensive set of themes to research when conducting activities was identified by Mink (2016), in order to obtain a well-rounded view of the users and their context, and make informed decisions in the design phase. These themes, as presented in *Figure 18,* are used as a guidance throughout all research activities conducted in the analysis-phase of the Intercultural Design Approach, presented on the next page.

living
housing
safety & security
facilities
environment

posessions
products
financial situation
natural property
animals

people
self reflection & dreams
spirituality
knowledge & skills
body & appearance

health
physical health
mental health & emotions
healthcare
food & drinks

relationships
family
community
social life
colleagues

activities
daily activities
free time
participation & organisation
information & communication

Figure 18: The six themes to learn about a user context (Mink, 2016)

6 | Intercultural Design Approach

In order to collect the theoretical and empirical insights to come to an integrated design, the Intercultural Design Approach, as shown in *Figure 19,* was developed. This chapter presents the approach, mindset guidelines, and then dives into the design research phase: how to get to know the culture, learn by making and gain deeper insights.

Necessity for the approach

The need for a new approach arose due to the absence of a concrete integrated product design method which caters the needs of a design project with a significant cultural discrepancy between the designer and the design context. The Intercultural Design Approach targets design projects aimed at disadvantaged populations with a cultural context which is unfamiliar to the designer, as such projects run a risk of significant unintended consequences which could potentially negatively impact communities, as illustrated in *Figure 16, p. 19*.

Bridging cultural gaps

To mitigate the described risk, the designer should travel to the target user, fully immerse themselves in the local culture and context, and actively engage local users in the design process. The design research activities emphasize gaining understanding of a context beyond human-product interactions, "as the lives of most product designers differ substantially from those of the marginalised and disadvantaged" (Mink, 2016, p. 8). In the analysis, establishing relationships and building cultural sensitivity are highly important activities (Mink, 2016). During the synthesis and evaluation phases, the designer is pushed to make quick iterations and present concrete solutions to local stakeholders, which contributes to a shared understanding of the solution space. Rich data is gathered through field research, such as interviews, observations and participatory sessions, because disadvantaged populations are generally not extensively described in literature.

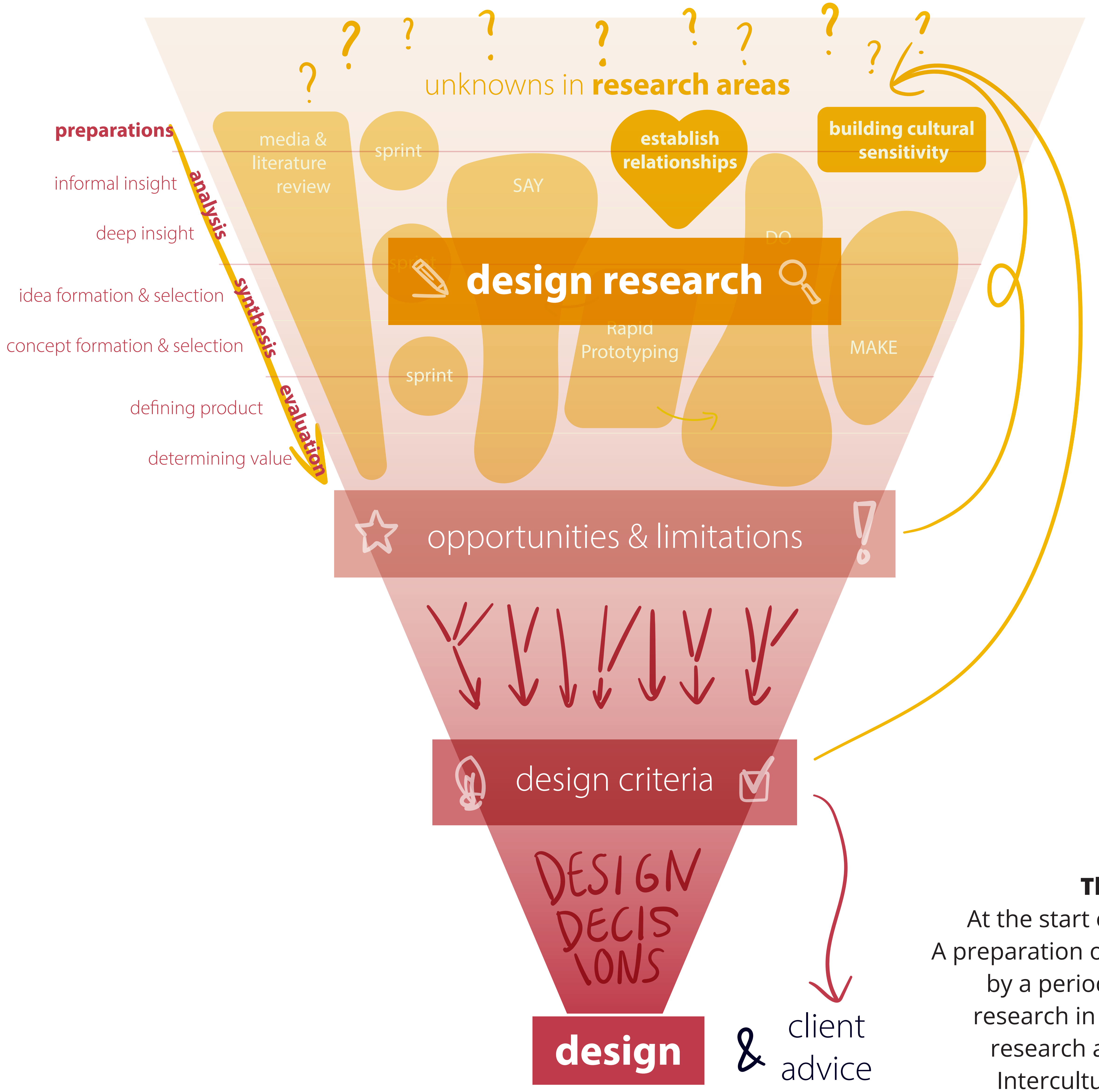


Figure 19: An overview of the Intercultural Design Approach

The approach in practice

At the start of this graduation project, A preparation of five weeks was followed by a period of eight weeks of design research in Lamu, Kenya. The design research activities prescribed in the Intercultural Design Approach, and conducted with local stakeholders in Lamu, are described starting from chapter 6.2.

The influence of culture on behaviour and design

Culture is a complex thing which can be defined as “the collective programming of the mind that distinguishes the members of one group category of people from others” (Hofstede, 2011, p. 3). When looking at national cultures, which are deeply rooted within human beings, every culture can be classified on several cultural dimensions. Every national cultural displays (often unconscious) specific values and preferences, which can differ greatly from one culture to the next, as reflected in *Figure 20*. These differences influence interactions between people of different cultures, but also come to play in determining human-product interactions for different cultures.

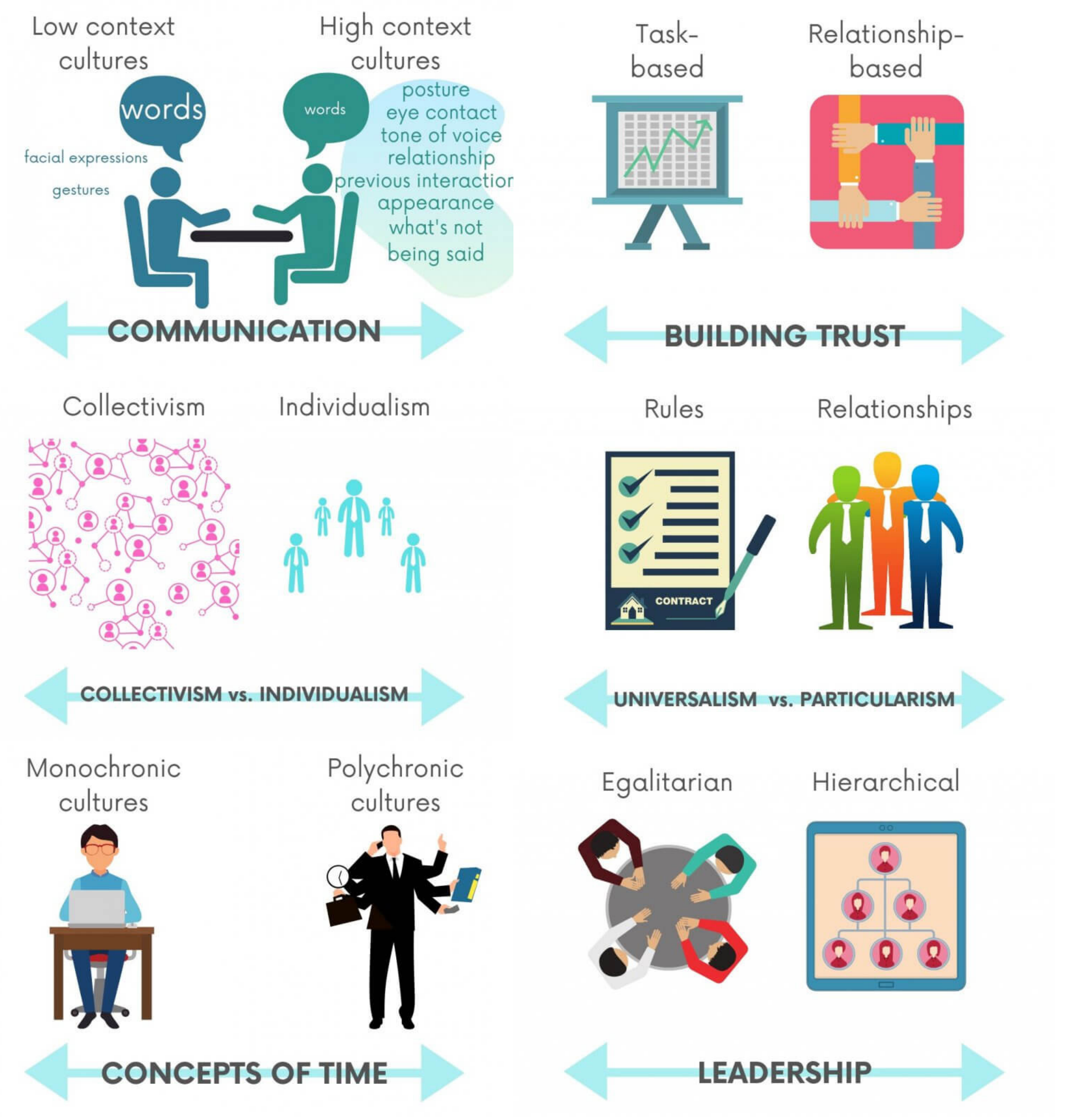


Figure 20: The cultural dimensions as described by Hofstede (2011), demonstrated with the two contrasting sides, by Wiebke Homborg

6.1 | A flexible and open mindset

During the design process, step-by-step learnings were gained on which led to an elaborate advice on which mindset to take on during an intercultural design project. In such a project, one will encounter cultural differences, which have to be approached with openness and curiosity.

FLEXIBILITY & ADAPTABILITY
- Be flexible with the design goal (ready to adapt to findings)
- Be prepared to continuously adapt planned activities

SENSITIVITY TO CULTURAL DIFFERENCES
- Analyse and reflect on insights gained from design research activities
- Continuously sharpen understanding of the design frame with new insights
- Be sensitive to information that could limit or benefit the design

DOCUMENTATION & REFLECTION
- Analyse, interpret and reflect on insights right after design research activities
- Continuously share insights with stakeholders for validation
- Immediately document any insight to avoid losing knowledge

BALANCE
- Balance relationship building with on-site activities and getting work done

COLLABORATION
- Collaboration is critical to build ownership at local stakeholders
- Regularly organize co-creation and feedback sessions

VISUAL COMMUNICATION
- Focus on tangible designs to bridge cultural gap and avoid misunderstandings
- Use quick sketches and low-fidelity prototypes for quick solution evaluation

CULTURAL TRANSLATION
- Use a “cultural translator” to bridge the gap between cultures
- Work with people who know the target culture and understands project aim

RESEARCH IN PAIRS
- Conduct research activities in pairs with one facilitator and one observer
- Improves data reliability through observing and note-taking

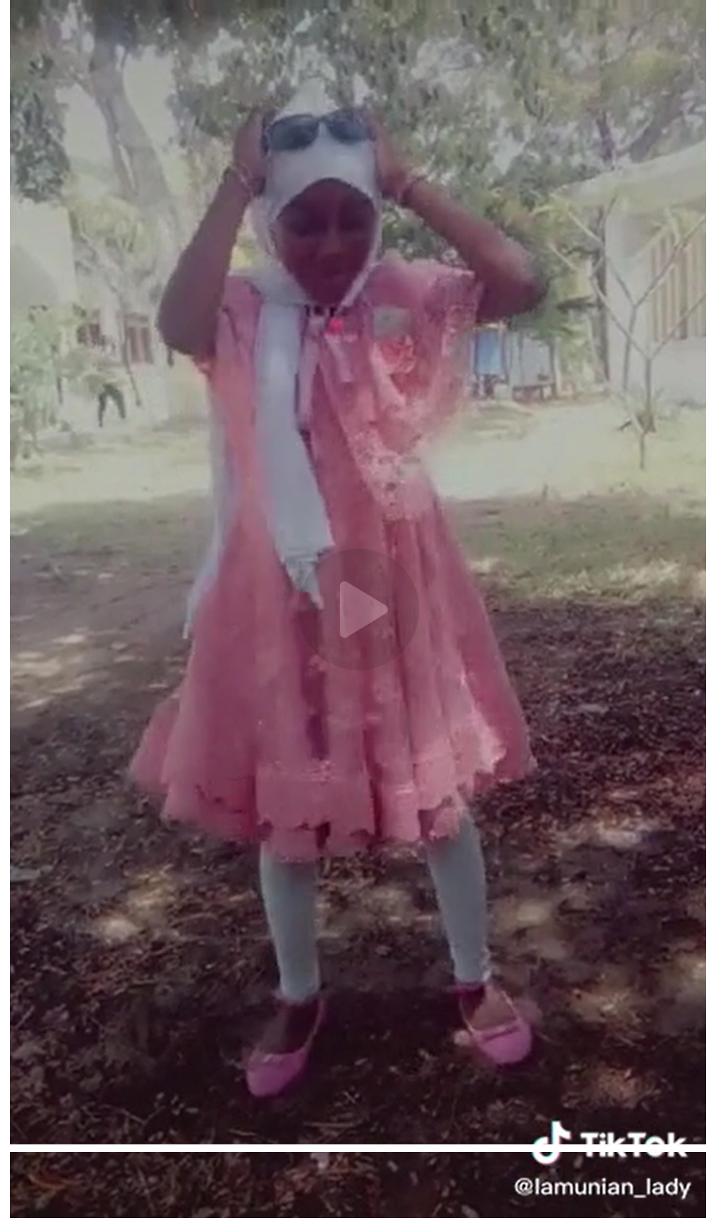


Figure 21: Girl from Lamu dancing to a popular song, by @lamunian_lady

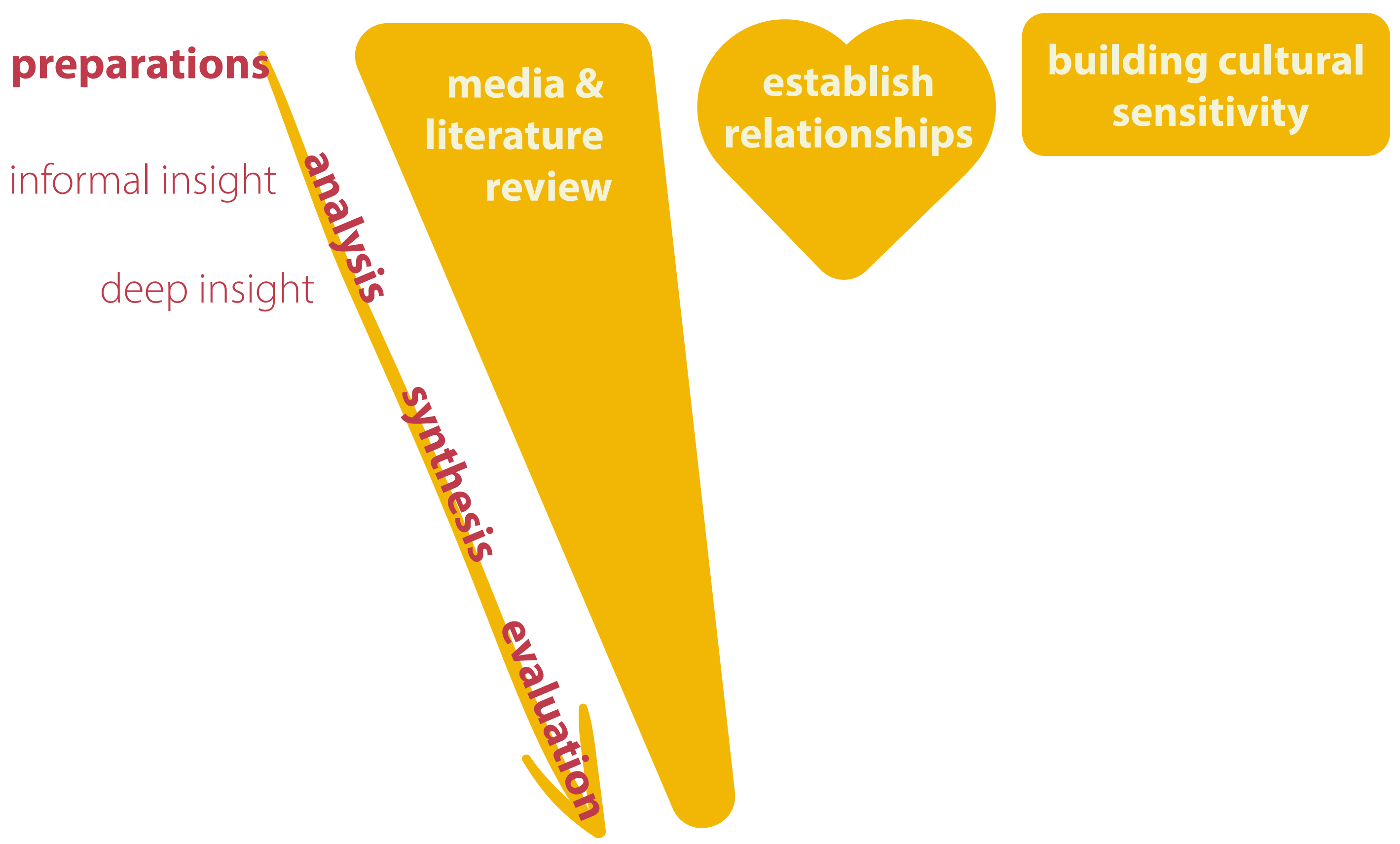


Figure 22: Henna during the cultural festival, photo by Emma de Cocker

6.2 | Getting to know the culture

Media & literature review

Academic literature an essential data source to understand the theoretical aspects of a specific design project. In her approach for the analysis phase of an intercultural design project, Mink (2016) emphasizes the importance of gathering meso- and macro data about the context before departure. This allows a designer to quickly make sense of findings during field research. Additionally, online sources such as social media and podcasts can provide valuable information on the people's lives and perspectives, which contributes to understanding a culture.

Establish relationships

Mink (2016) states it is important to start building local partnerships before travelling, which can be done through (video) calling.

In this project, this was done through numerous video calls with the team of IOMe005, and a call with teachers of several primary schools on Lamu island to introduce the upcoming research activities. When in Lamu, these contacts were strengthened through meeting face-to-face, research activities and informal contact by text messaging.

Building cultural sensitivity

To make the connection with local people easier and build trust, it is useful to start learning their language some time before the visit. Furthermore, gaining consciousness about the different ways cultural dimensions which influence intercultural interactions (Hofstede, 2011) contributes to more understanding in all future interactions.

In this project, informal interviews with three European experts working in the educational field in Uganda and Kenya provided advice and a first view of potential cultural differences. Furthermore, valuable insights were gained by living in the Old Town of Lamu and interacting with local people. Engaging in cultural activities, such as dancing with learners and at the cultural festival, and trying to adapt to their appearance, contributed significantly to the ability to learn about the culture.

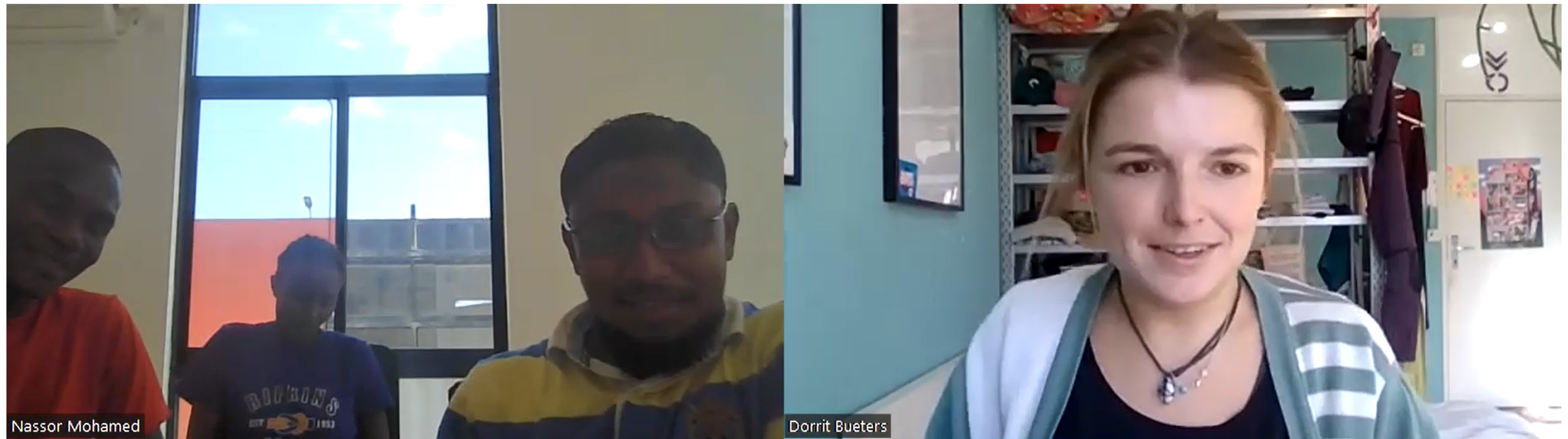


Figure 23: Zoom call with Nassor (right) and a team of innovators

6.3 | Learning by making

Design Sprints

After being initially introduced by Google (Google, n.d.), the design sprint has been adapted and used in various fields. Design sprints accelerate projects by allowing designers to make fast decisions and progress quickly in the design process, leading to rapid validation of a design. Within this Intercultural Design Approach, they contribute to a quick jump to the next phase of the process. To fit the flexible planning of intercultural design projects, they can range between one day up to over a week, during which nothing else is planned and the designer has clear goals, usually with tangible outcomes. In such a sprint, the focus is on speed, where working offline contributes to limited distractions and building on assumptions based on previously collected knowledge. These assumptions, in the shape of concrete sprint outcomes, are then verified in field research.

This specific project kicked off with a sprint on day 1, with the goal to gain clarity on the full design process that was coming up. By covering the full process in one day, an overview of a broad design goal and solution space were developed, together with an overview of the stakeholders, upcoming design research activities, unanswered questions and potential challenges that will be encountered (see *Figure 24*). This contributed to a quick jump from the preparation phase into the iterative design process. Later in the process, after travelling back home from Lamu, a second 1,5-week sprint was conducted to kickstart the development of a concrete design of the teaching method and manual.

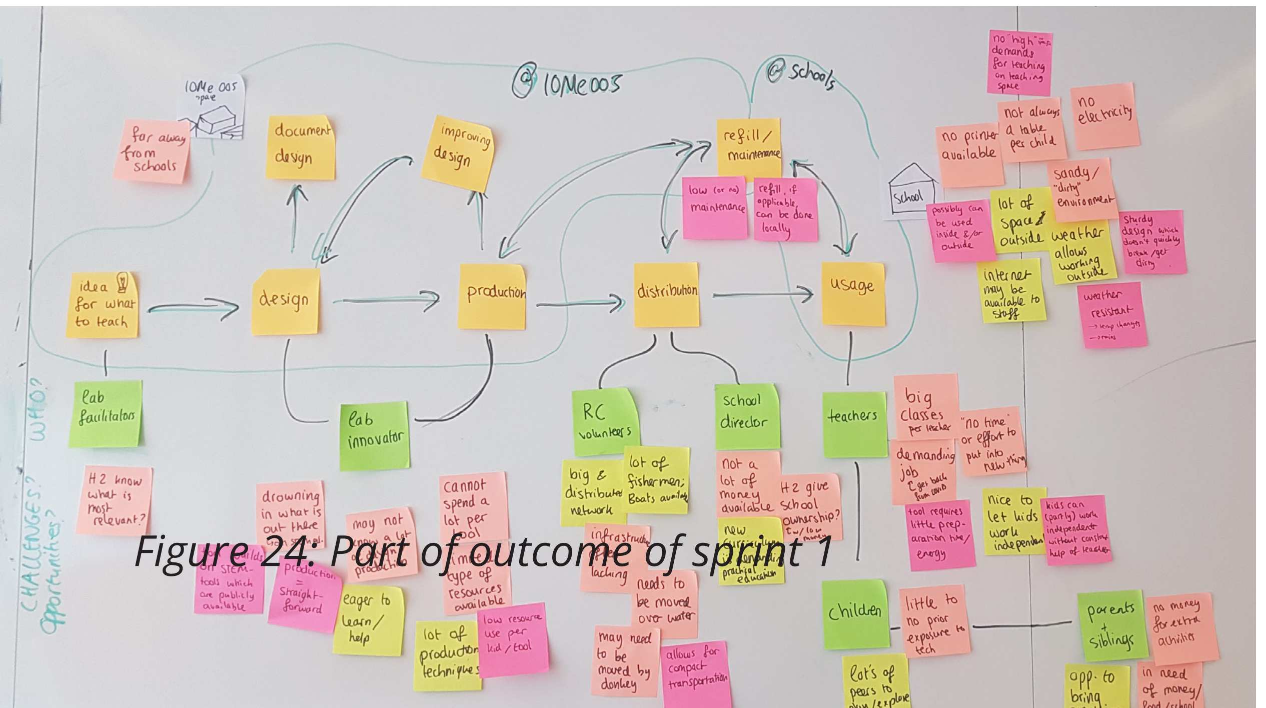
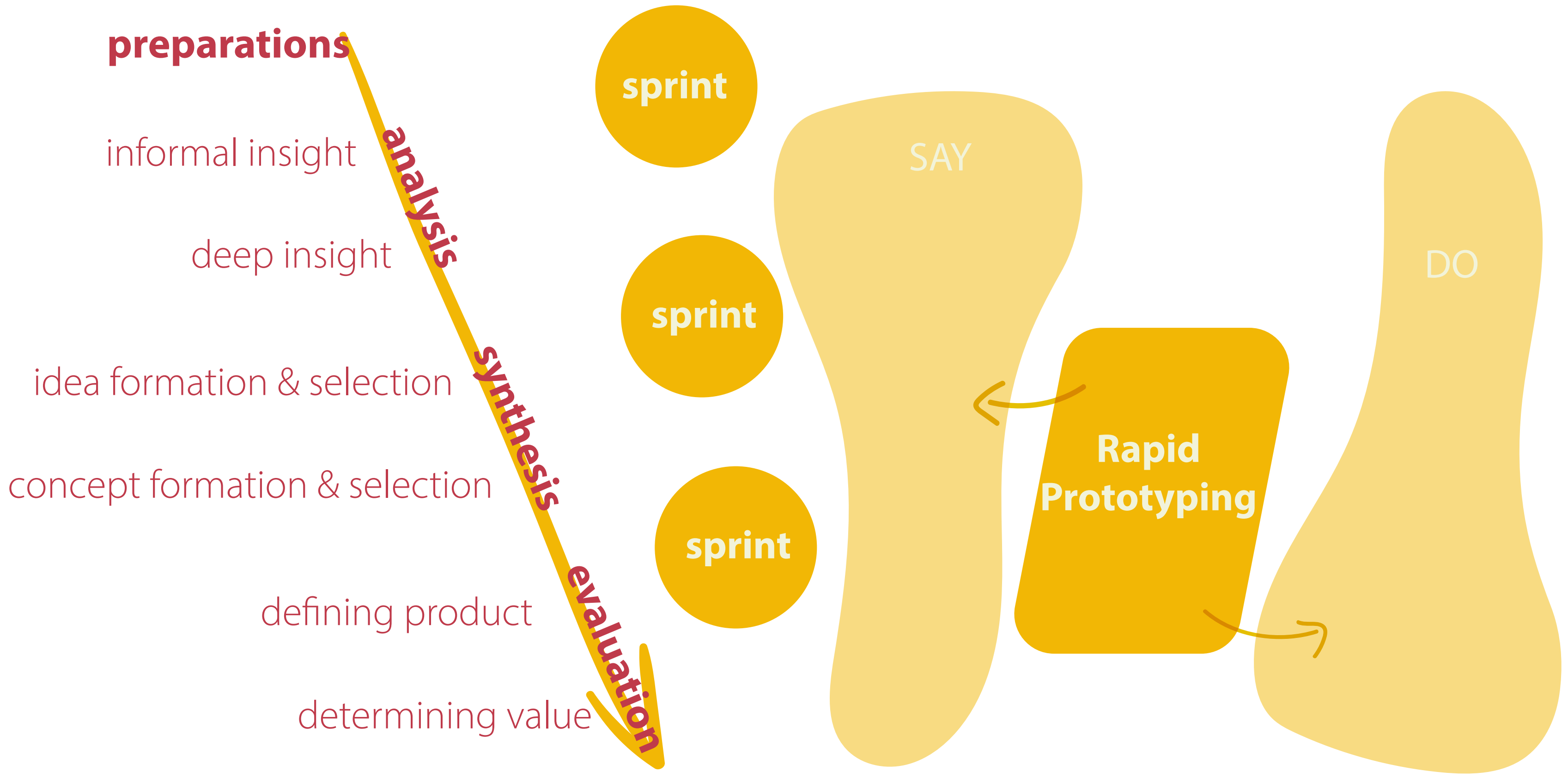


Figure 24: Part of outcome of sprint 1



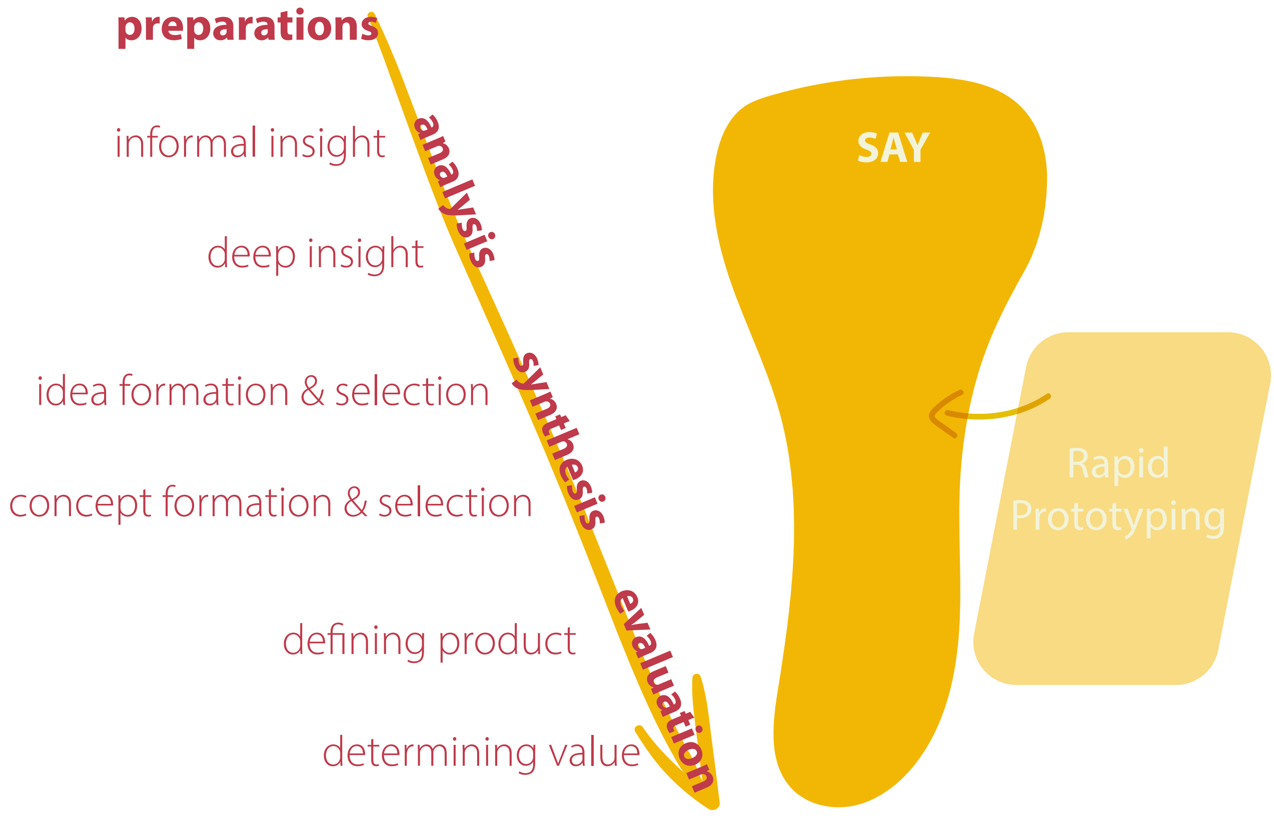
Rapid Prototyping

To quickly bring ideas to a tangible, concrete form, in order to evaluate it with local stakeholders, Rapid Prototyping is an important part of the Intercultural Design Approach. This strategy is generally used to create, test and optimize design features or total designs in an iterative way.

Because this specific design project focuses on education, there is not one perfect solution: on the contrary, there are numerous potentially valuable solutions. This, together with the intention to implement the design in the near future, made it vital to start developing design directions as early as possible. Thus, in order to come to concrete designs, wind energy was picked as a subject within STEM to focus on in the tangible prototypes. The prototypes were used to evaluate the technical feasibility of potential solutions, as conversation starters in informal conversations to rapidly evaluate potential desirability and viability (“SAY” on next page), and in later stages to evaluate the alignment with stakeholders’ needs in participatory workshops (“DO” on p. 27).

Figure 25: Overview of the main tangible prototypes tested in Lamu

IOMe005’s in-house production capabilities allowed short iteration loops of fabricating and testing tangible prototypes, of which an overview is presented in *Figure 24*. The aim was to let local innovators produce most prototypes in order to create ownership. In other parts of the project, the Rapid Prototyping approach was applied in an intangible way in the development of the teaching methodology and manual.



6.4 | Gaining deeper insights

SAY

This first category of research which engages people, focuses on finding out explicit knowledge through informal talks and interviews.

In this project, before travelling to the target context the focus was on gaining knowledge about educational aspects through interviews with teachers. In Lamu, informal insight into the user context and community was obtained through numerous informal talks. Finally, an interview with Lamu upper primary school and extracurricular science teacher Mariam Abubakar, using prototypes as conversation starters, broadened the understanding of certain aspects of the Lamu education system on a deeper level.

Interviews, observations & generative sessions

Because disadvantaged populations are generally not as extensively described in literature as the western world, interviews and participatory (group) workshops are an important sources of data (Mink, 2016). As presented in *Figure 26*, different levels of knowledge can be targeted through activities which engage a potential user, ranging from learning what they say and think (SAY), observing what they do or how they use a product (DO), to gaining deeper insights in what they know, feel and dream about (MAKE). Design research activities should be designed to incorporate one or multiple of these aspects, where the MAKE level naturally incorporates both aspects of SAY and DO activities (Sanders & Stappers, 2013). This deepest level taps into latent knowledge that otherwise might stay hidden.

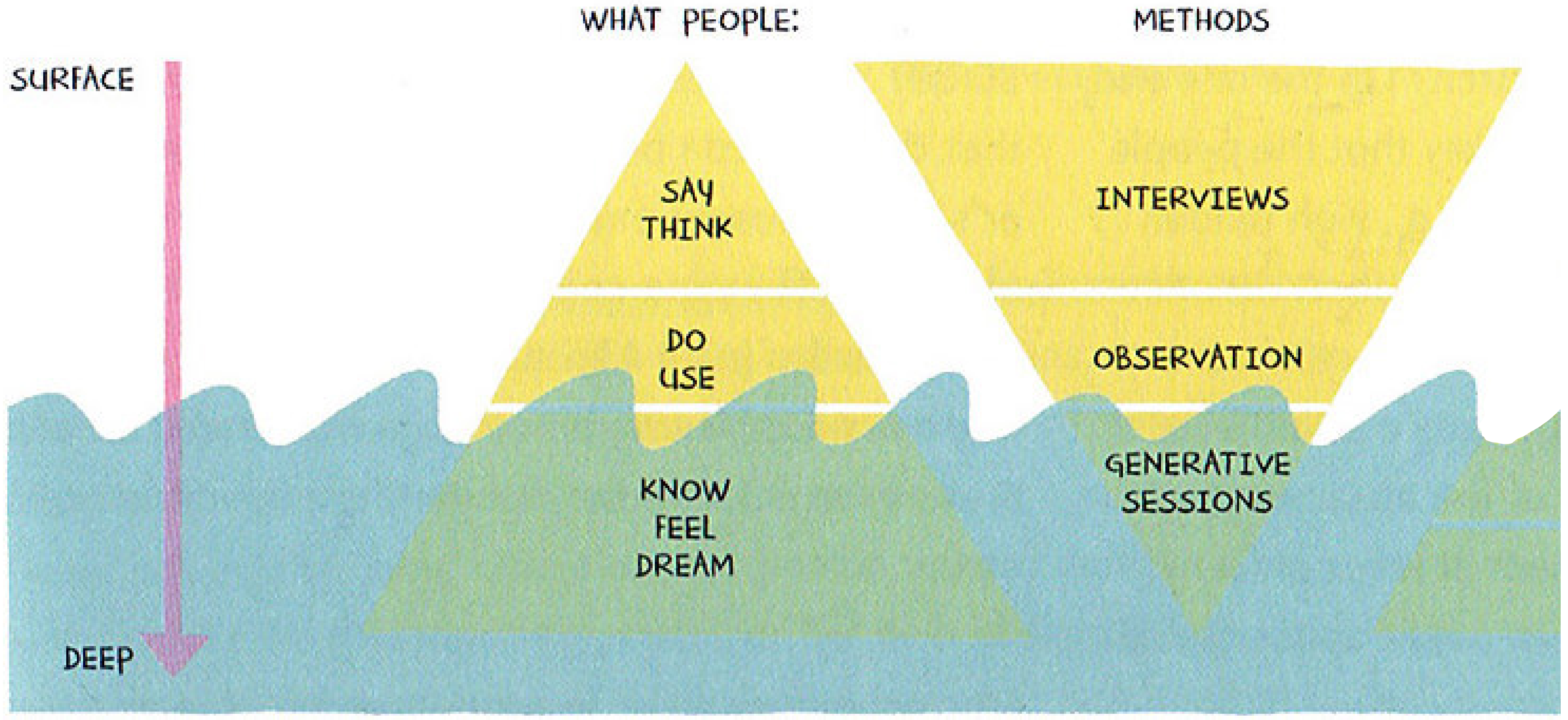


Figure 26: Accessing different levels of knowledge through design research (Sanders & Stappers, 2013)

DO

The DO category of research activities focuses on learning more about the natural behaviour of the target group, and how they would use certain products.

Informal observations while living in Lamu, and visiting locals at home resulted in cultural insights on how the community works. Furthermore, several primary schools were visited and a practical science class was observed, in order to gain insight on the day-to-day life at schools. To gain deeper insights, prototype evaluation sessions with primary school learners from different schools contributed to validating insights and fueling the iterative Rapid Prototyping process in the synthesis and evaluation phase, as presented in chapter 12. Besides the deep insights on the needs and capabilities of the learners, these sessions resulted in additional insights on how Red Cross volunteers would facilitate various teaching methods in a classroom setting.

On the other hand, at IOMe005, informal insights were gained during numerous visits to the facility to work on the design project. Observations provided valuable information on the culture at IOMe005 and how things are organized. Due to the collaboration IOMe005 encourages, opportunities arose to present and discuss the design process and test prototypes with IOMe005 innovators, as shown in *Figure 28*. After moving back to the Netherlands, a team of IOMe005 innovators continued to cooperate in the design process of the teaching method and manual.

Figure 27: Observing at Fatma Lali's practical science class

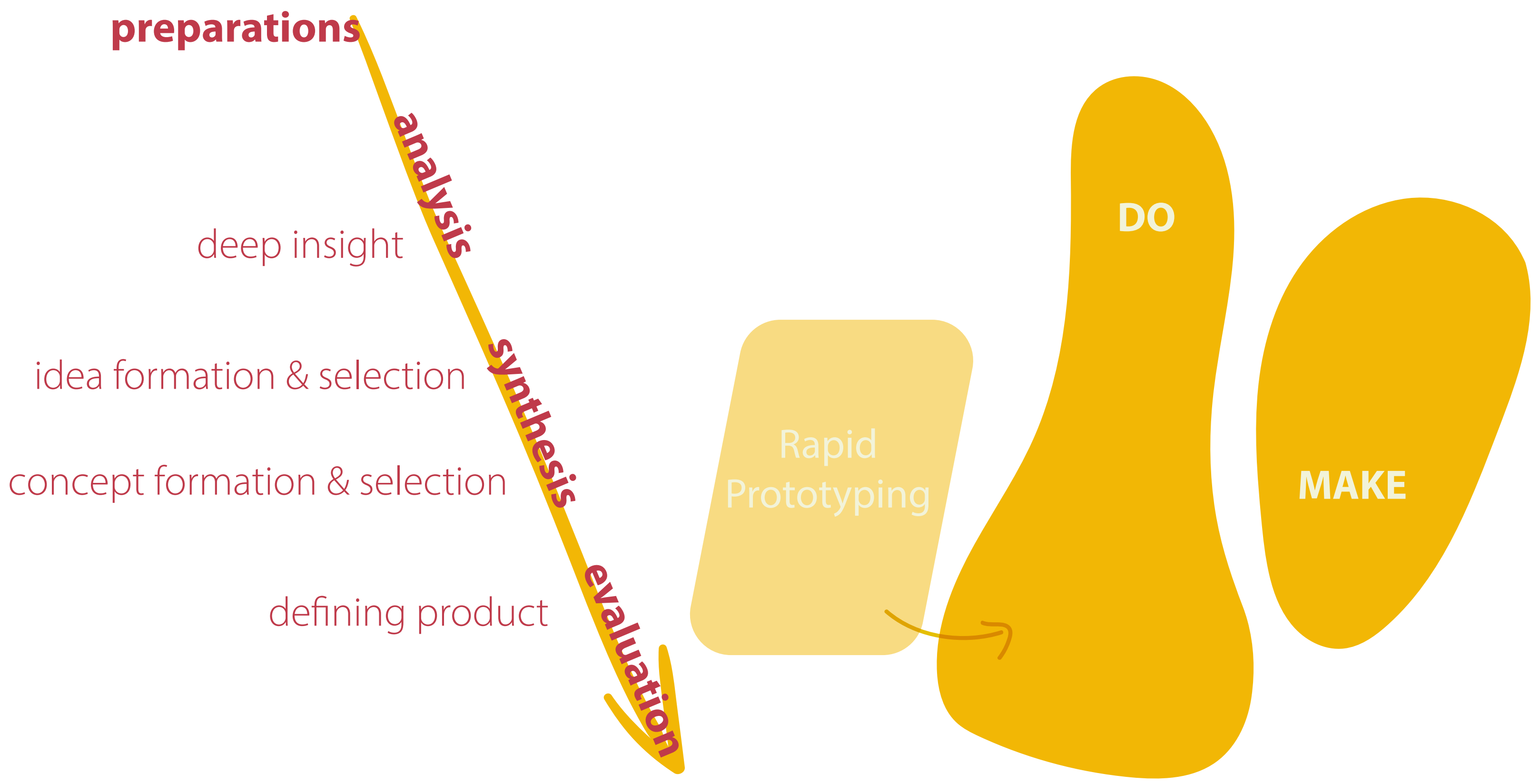


Figure 28: Explaining the design process to innovators at IOMe005

Figure 29: Generative session with teachers from Wiyoni primary and Mahmoud Bin Fadhil Boys & Girls primary

Figure 30: Generative session to get to know the upper primary learners at Wiyoni primary

MAKE

Finally, generative sessions are an important part of the Intercultural Design Approach, as they can tap into what participants know, feel or dream, and empower stakeholders to directly contribute to the development of new iterations.

As a broad exploration of which potential directions the project could go in, two creative sessions were organized with Dutch Industrial Design master students before the project's kick off. In Lamu, at the beginning of the analysis phase, a participatory session with several groups of learners at two primary schools provided deep insights on the lives of the learners (see *Figure 30*), which are described in chapter 8. Furthermore, a cocreation session with the teachers of three primary schools was organised to gather their input and gain understanding on the needs of these stakeholders (see *Figure 29*).

On the other hand a codesign session with IOMe005 staff and innovators, and a participatory workshop with Red Cross volunteers provided deeper insight on how future facilitators would interact and teach with the tangible prototypes.

6.6 | Value & limitations of the approach

Value of the approach
Firstly, when you live in a target context, in this specific case for eight weeks, and you really blend into the life, get to know locals and learn or try to learn the language, it makes you learn much more about the design context than you could imagine in the beginning.

The developed approach aims to rapidly evaluate ideas and solution directions, in order to quickly take biases away and gain more understanding of the design context. In this specific project, the Rapid Prototyping approach lead to quick decisions and the possibility to test prototypes already in the first week in Lamu.

Furthermore the emphasized collaboration with the stakeholders and the client significantly increases the ownership of the client in the project, and makes future implementation easier and more likely. In this specific project, this personal relationship was crucial for mutual understanding and effective work during the remote collaboration later in the project. Having worked together physically made it much easier to make agreements and be able to know how to be able to count on the other party from a distance. Secondly, this relationship led to a trust in which the lab facilitators of IOMe005 felt the safety to be honest and share their critical feedback.

Limitations of the approach
As a designer who is coming from a completely different culture, it is difficult to fully comprehend all cultural differences, even after spending a significant amount of time in a country. Especially getting used to anticipating every specific behaviour of the other culture is something which takes a great amount of time.

Furthermore, communication barriers and biases can affect the project outcomes. When the designer does not speak the local language, there is a high risk of misunderstandings, and you might not pick up every piece of valuable information, or it might get lost in translation.

Besides this, the big emphasis on collaboration leads to a designer taking on a managerial role, with the necessity to clearly communicate deadlines and expectations while not having complete control over the process. At times, this can be a challenging role to be in due to cultural barriers leading to misunderstandings.

In addition, the involvement of an invested client can be crucial in getting activities started.
For this specific project, the Kenya Red Cross was of great value for organizing meetings and getting in contact with important parties like the schools, which might have been challenging without their efforts.

Lastly, data collected in this approach is non-generalizable, as it focuses on highly specific contexts.

PART 3 design research

In this part, limitations, opportunities and requirements which were gathered in design research activities will be presented. The insights will be connected to the preliminary requirements presented at the start of every chapter.

The following content can be expected:

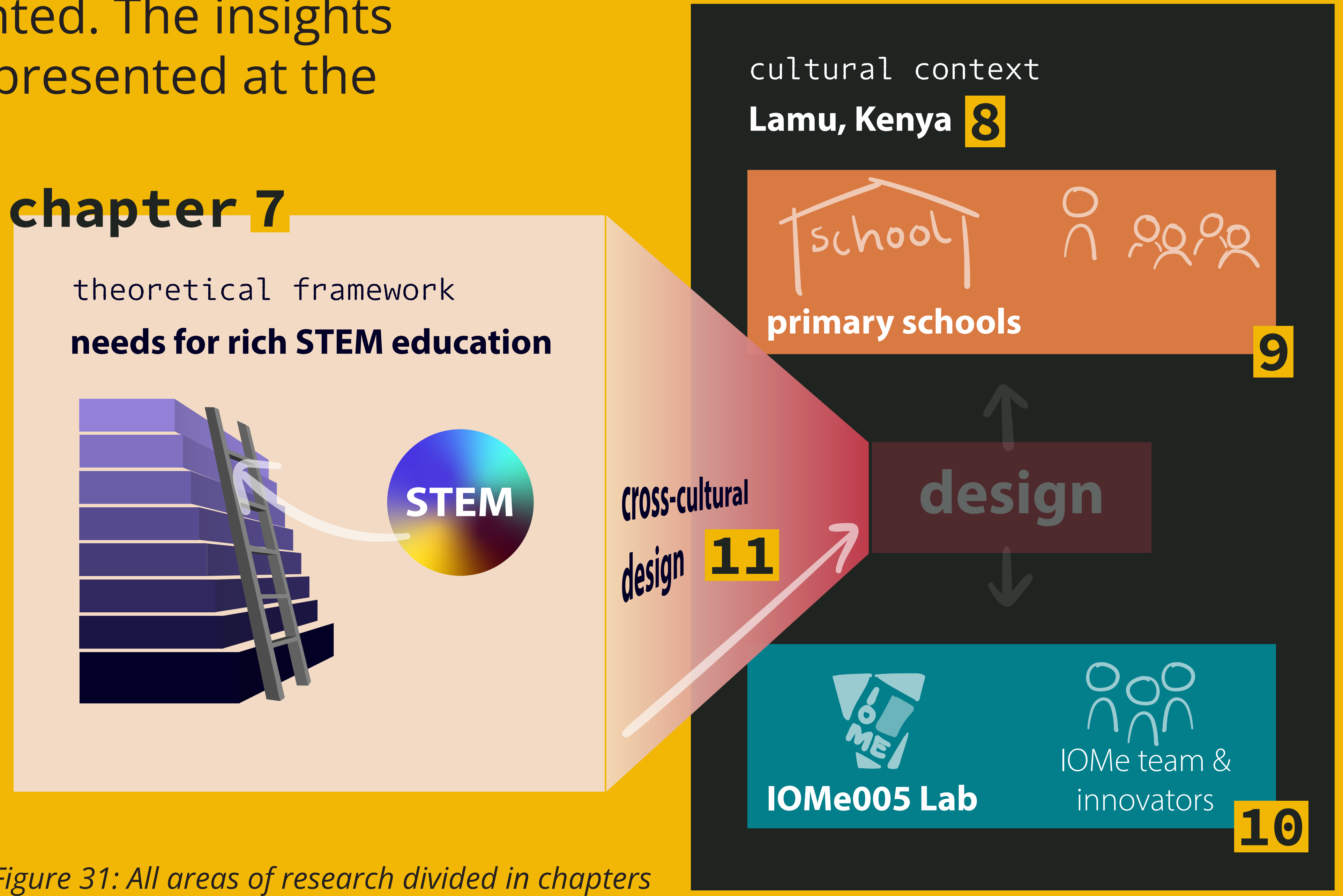


Figure 31: All areas of research divided in chapters

7 | Needs in rich education

This chapter researches how to provide rich hands-on STEM education. The order of the content will follow the educational needs ladder as described by Gerstein (2023), which is crucial for the design of rich educational resources.

desirability

d1 teaching about problem solving

d2 aligns with learner's cognitive world

d3 aligns with *innovator's* motivations

feasibility

f2 *innovators* can facilitate lessons

Doctor of Education Jackie Gerstein identified that learner and educator motivation are "an important predictor of learning and achievement … reinforced by hundreds of studies" (2023). To draw attention to the growth and actualization needs in educational environments Gerstein integrated motivational theories from Maslow (p. 2, Figure 1), Glasser, McClelland and Herzberg into a framework for learner and educator motivation needs, which is presented in Figure 26. An important learning from this ladder is that in essence, learners and educators have the same needs, when it comes to educational activities. Furthermore, in each specific situation and class setting, educators and learners can and will move up and down the ladder, based on which needs are satisfied in the specific moment.

> **"If … safety needs are met, [learner and educator] are not dissatisfied [nor] satisfied … [I]t is now time to put a greater focus on growth needs so that both [educators] and [learners] are motivated, satisfied, and happy with their schools."**

– Jackie Gerstein, Doctor of Education, 2023

growth needs

actualization of interest and talents 8
Need for freedom, autonomy & creativity, and trust in own judgement & capabilities

intrinsically-motivated mastery 7
Need for self-esteem (Maslow) and following intrinsic motivation

empowerment 6
Need for power and achievement, and gaining control

excitement & engagement 5
Need for fun, relaxation & laughter, and relevance for the individual

connection to educational community 4
Need for love & belongingness (Maslow). Is safety or growth depending on the individual

safety needs

physical and emotional safety 3
Need for freedom of (threats of) physical harm, bullying, harassment and humiliation

extrinsically-motivated compliance 2
Needs are centered around avoiding punishment and/or receiving rewards

basic survival 1
Physiological and safety needs (Maslow) focusing on the physical environment

Figure 32: Learner and educator motivation needs ladder, adapted from Ed.D. Gerstein (2023)

7.1 | Step 5
Excitement & engagement

Learner engagement is the level of attention, curiosity, interest, optimism, and passion learners display during educational activities

Need for fun, relaxation & laughter, and relevance for the individual.

You learn best when you have fun

First of all, regardless of age, learning should be fun in order to be effective. Fun experiences, such as jokes and laughter, increase levels of dopamine, endorphins and oxygen, which all boost learning (Willis, 2010). Therefore, Gerstein (2017) states that the level of fun we have positively influences motivation levels of learners as well as educators, and in turn determines our ability to learn and we retain from the new knowledge.

Increasing engagement

A general belief, supported by M.Ed. Dominique van Vonderen, is that education gets engaging when it targets different higher levels of thinking. The taxonomy of Bloom, as illustrated in *Figure 33*, was developed in order to promote these higher order thinking levels, that go beyond the traditional rote learning (remembering facts) education. The lower levels focus on knowledge and how to apply it, which serve as the foundations for the higher levels which aim to stimulate learners to think critically and autonomously solve problems (National Talent Centre of the Netherlands, n.d.). This tool is widely used when designing educational materials. To ensure that every learner gets challenged, it is important to cover multiple levels of thinking within a lesson plan.

> **“Some gifted learners are cognitively very far, whereas the execution of practical activities can be a great challenge”**
>
> *M.Ed. Dominique van Vonderen, 2023*

The potential in extracurricular education

While education within a curriculum often focuses on teaching fixed parameters and measurable knowledge, extracurricular education provides the freedom to adapt the education to increase learners’ engagement. Dominique van Vonderen explains that the lower levels of Bloom are already tapped into in the regular primary school education, which enables her to focus on the higher thinking levels in the design of extracurricular educational activities.

M.Ed. Dominique van Vonderen

Dominique is an education expert working at a progressive Dutch primary school. For the past eight years, she has been developing hands-on educational programs and resources for upper primary learners, which align with the school’s projects.

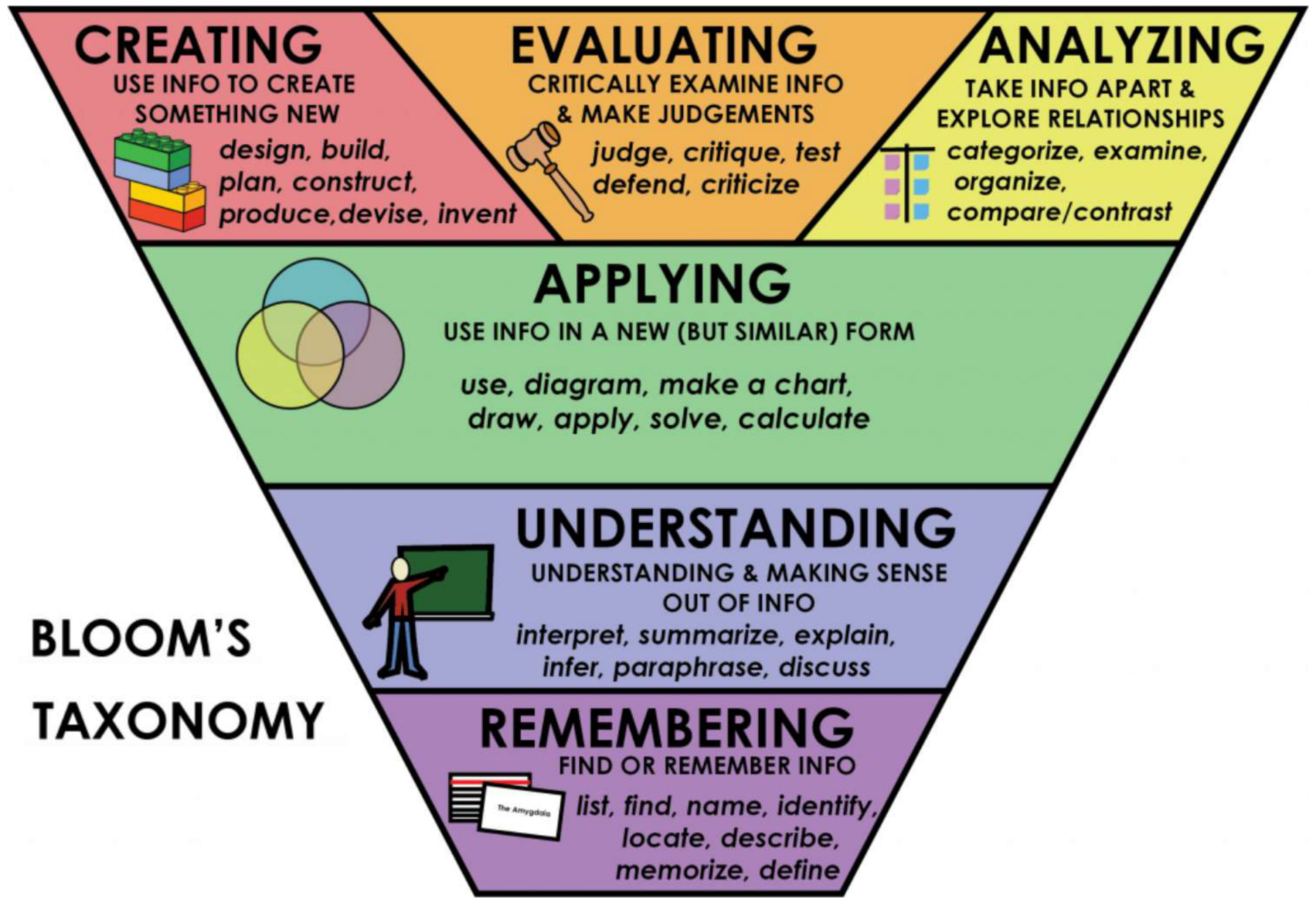


Figure 33: Bloom’s taxonomy adapted from Alger et al. (2018), based on Bloom (1956), by Rawia Inaim

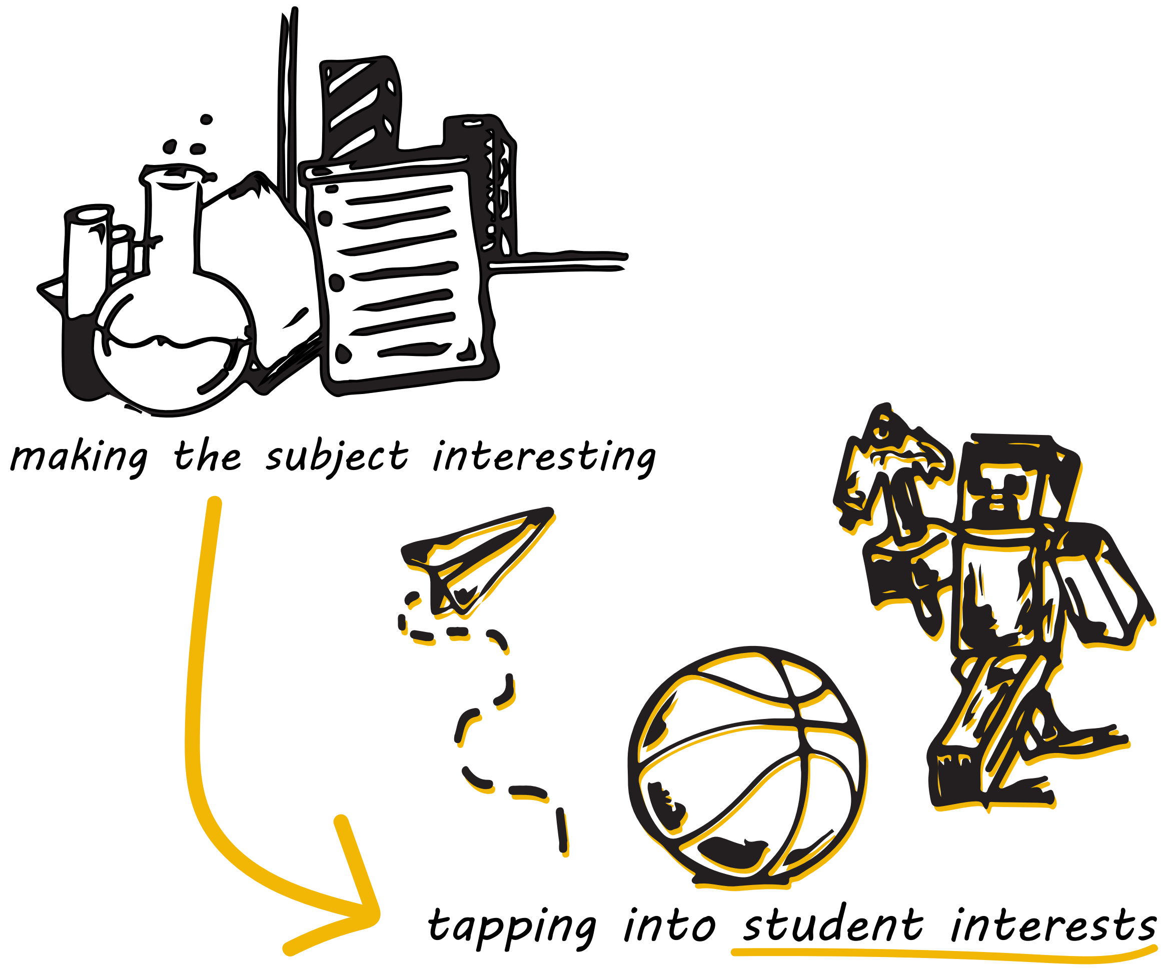


Figure 34: Increasing relevance of education to the learner (Spencer, 2017)

Tapping into learner's interests

When an educational activity sparks the interest and curiosity of a learner, the need for relevance is met. This is sparked when it is connected to the learners' world, through either making the subject interesting to the learner, or going a step further and tapping into learners' interests by teaching about subjects they like, as presented in *Figure 34*. In order to make this shift, it is crucial to find out which things are of interest to the learners, which will be researched in chapter 8.

Making global impact through education

Furthermore, children should see the purpose in what they learn, in order to find it interesting and valuable. Dominique states that educational activities should be layered, where multiple lessons connect to a broad educational purpose or subject, and learners should be encouraged to relate it back to their own lives, for instance by asking them how they could apply a certain concept in their home.

> **"One way that teachers found they could attract attention was by generating problems in which [learners] took on authoritative roles with leadership power … such as school administrators or city leaders"**
>
> *MBA Beckton Loveless, n.d.*

Connecting to this sense of purpose, societal challenges, which could impact the learners' lives, are often at the core of integrated STEM education (El Sayary et al., 2015). Such challenges naturally provide a real and rich context, and invite the learner to combine skills and knowledge from the four STEM disciplines, as presented in the potential solutions in *Figure 35*.

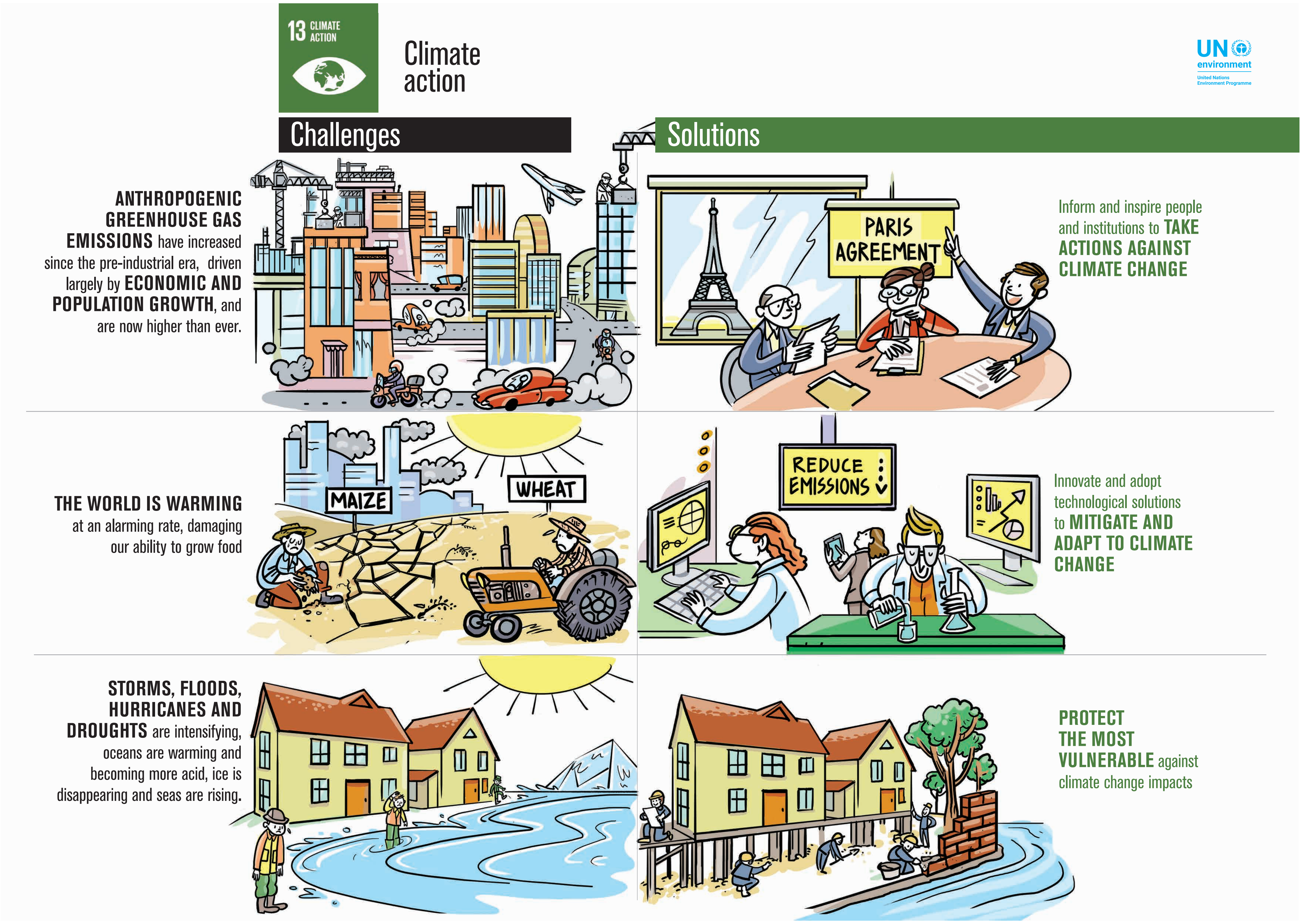
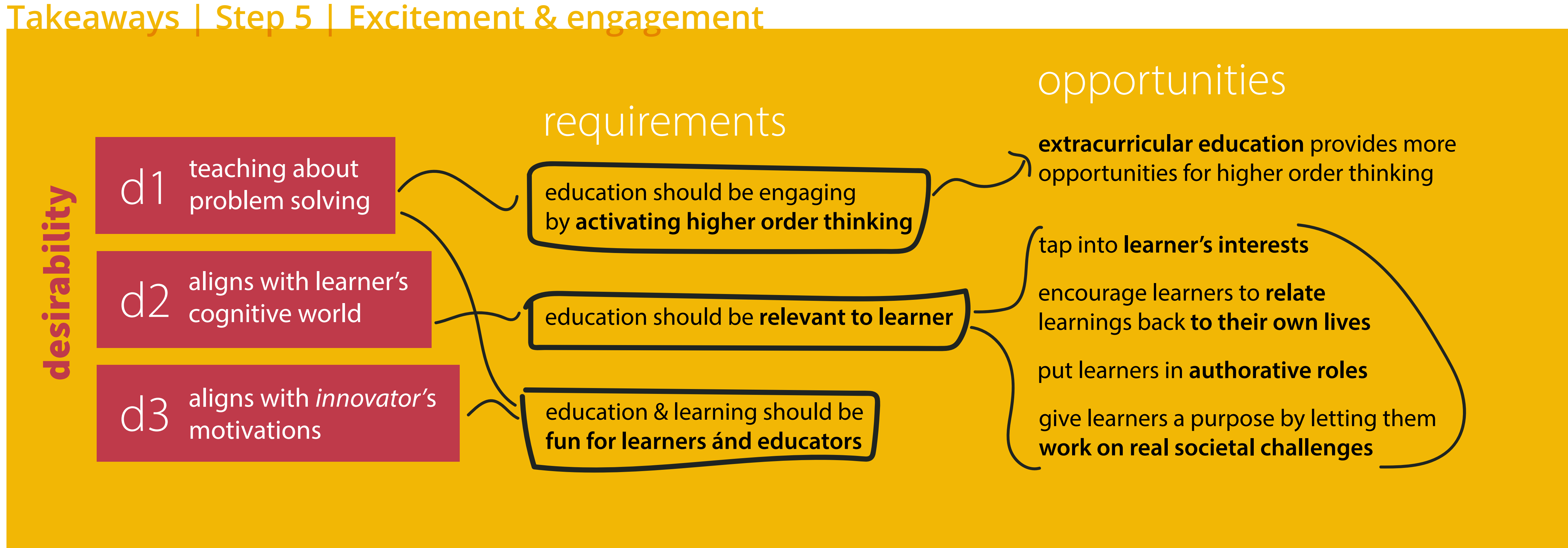


Figure 35: A visualisation of Sustainable Development Goal 13: Climate action (UNEP, n.d.)

Takeaways | Step 5 | Excitement & engagement



desirability

d1 teaching about problem solving

d2 aligns with learner's cognitive world

d3 aligns with *innovator's* motivations

requirements

- education should be engaging **by activating higher order thinking**
- education should be **relevant to learner**
- education & learning should be **fun for learners ánd educators**

opportunities

- **extracurricular education** provides more opportunities for higher order thinking
- tap into **learner's interests**
- encourage learners to **relate** learnings back **to their own lives**
- put learners in **authorative roles**
- give learners a purpose by letting them **work on real societal challenges**

7.2 | Step 6

Empowerment

Need for power, achievement, and gaining control.

Empowerment is the "process by which individuals gain power, access to resources and control over their own lives. In doing so, they gain the ability to achieve their highest personal and collective aspirations and goals"

Robbins et al., p. 91 1998

Within a school setting, power comes from the learner's and educator's ability to choose and equally contribute in the learning, as stated in the underlying need for power described by Glasser (1999). Furthermore, both educator and learner desire to get a feeling of competence and to be recognized in new achievements and skills (Glasser, 1999).

Giving learners a choice

Educator John Spencer (2016) underlines the general belief that learner choice leads to learner empowerment. Freedom of choice can be provided in numerous ways, for example by allowing learners to choose the topic, used resources or intended outcome, or by enabling them to manage their projects by choosing personal methods and working at own pace.

"The "Time" project allowed learners to choose their own research methods. They first explored their own perception of time by completing small tasks within set time frames. Through interviews with visitors, receptionists, and security personnel of the town hall, learners obtained insights into the desires and requirements of various people. These real-life insights increased the relevance of the project for the learners.

Klapwijk on the effect of choice within a school project, 2021

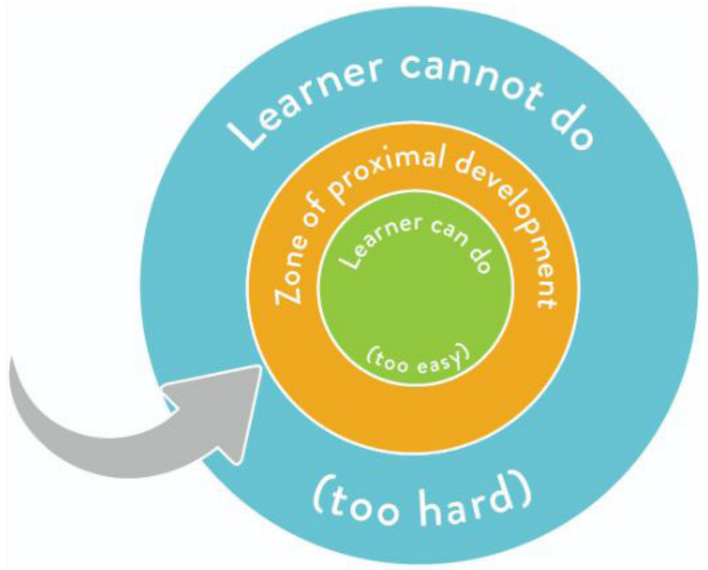


Figure 36: ZPD by Vygotsky

Balancing freedom and guidance

When giving learners a choice, this freedom should be balanced with a certain structure to ensure that learners are aware of what is expected from them, and feel a safe space to make their own choices. Dominique's experiences with Dutch learners show that stronger learners tend to desire autonomy in a more open assignment, whereas weaker learners are seek more guidance on what is expected from them. However, this also greatly depends on the learning culture the children are used to, with which will be experimented in chapter 14. Alternating moments of educators guidance with moments of free work can contribute to this balance.

Acquiring new skills and competences

When the aim is to empower learners with new knowledge or skills, the teaching happens in the zone of Proximal Development (ZPD). As presented in *Figure 36*, this is the cognitive place beyond a person's current level of ability, where they can learn with guidance from an educator, a specific technology or resource, or together with their peers. When educators know the specific learner's ZPD, they can "scaffold" their learning by providing the necessary guidance, such as targeted support, feedback, and opportunities for practice. This helps the learner move beyond their current level of ability and gain new competencies (Mcleod, 2019), while still keeping the learning challenging. Through this process of guided learning, learners become more independent and confident.

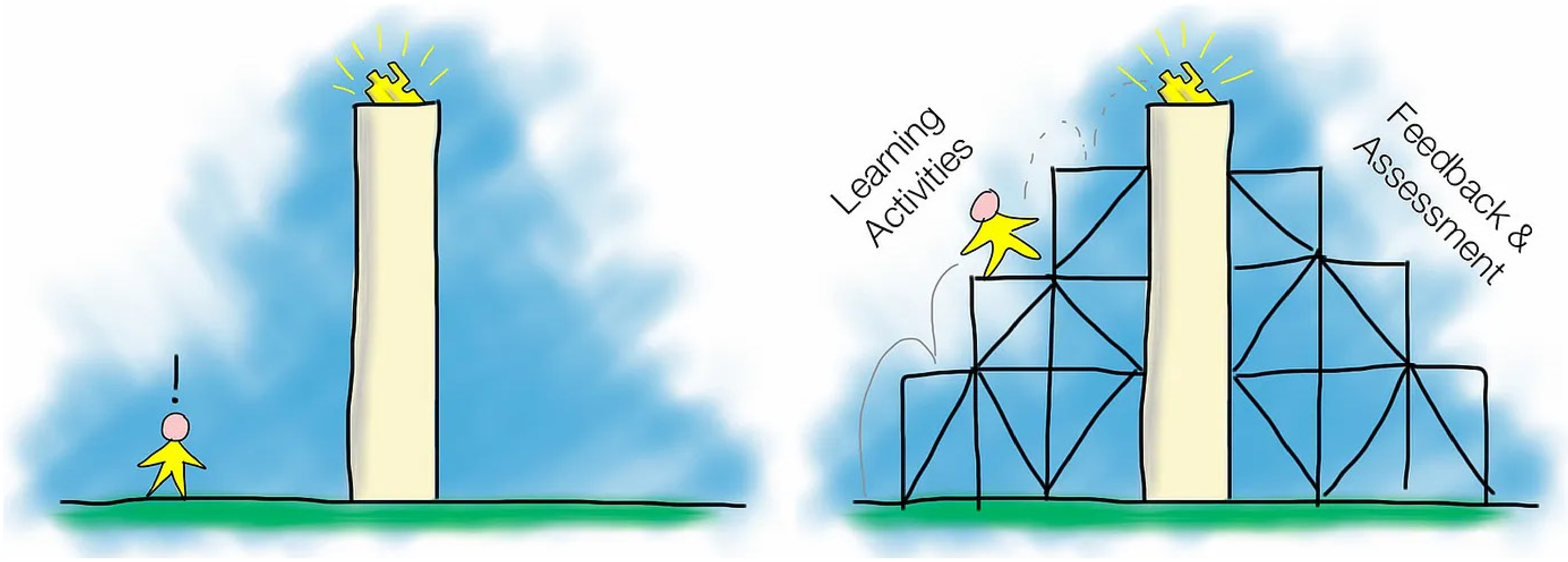


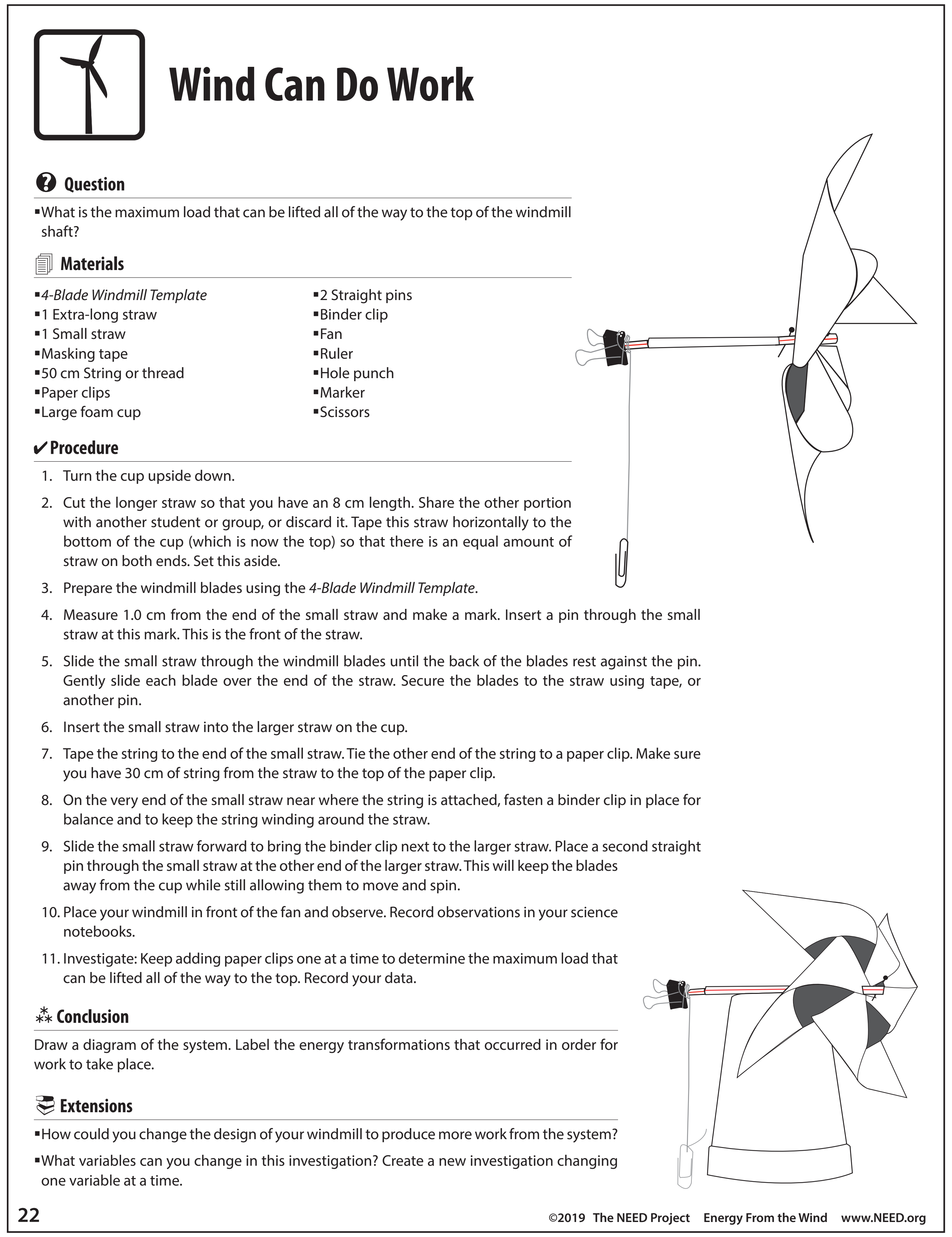
Figure 37: Illustration of how scaffolding works, by Gavatron

Empowering educators

Because educators have needs similar to learners, they also get empowered when they have a choice in what and how to teach the learner (Gerstein, 2017). Furthermore, the educational activity should with their own interests, and the learning goals the educator has for themselves within their job. It is crucial for educators to get empowered and gain confidence in their teaching, by guiding them in their own ZPD. The most effective approach is allowing educators to experience teaching methods and best classroom practices from a learners' perspective (Darling-Hammond et al., 2017), to guide them in their understanding and implementation of effective teaching strategies.

Benchmarking

There are many tools, resources and toys available to assist educators to teach STEM knowledge in a hands-on experiential way, which are often called "STEM kits". Analysing numerous freely available STEM kits (see Appendix 2 and *Figure 38*) showed that STEM kits tend to micromanage the education. They predefine what the learner should make, and provide detailed instructions, which does not empower the learner & limits creativity. Additionally, they have the tendency to micromanage the teaching process by providing a lot of information and detailed steps. This potentially leads to information overload for the educator, which likely hinders their confidence in teaching and makes implementation difficult, as it is seen as "too hard".



Wind Can Do Work

Question

- What is the maximum load that can be lifted all of the way to the top of the windmill shaft?

Materials

- *4-Blade Windmill Template*
- 1 Extra-long straw
- 1 Small straw
- Masking tape
- 50 cm String or thread
- Paper clips
- Large foam cup
- 2 Straight pins
- Binder clip
- Fan
- Ruler
- Hole punch
- Marker
- Scissors

✔ Procedure

1. Turn the cup upside down.
2. Cut the longer straw so that you have an 8 cm length. Share the other portion with another student or group, or discard it. Tape this straw horizontally to the bottom of the cup (which is now the top) so that there is an equal amount of straw on both ends. Set this aside.
3. Prepare the windmill blades using the *4-Blade Windmill Template*.
4. Measure 1.0 cm from the end of the small straw and make a mark. Insert a pin through the small straw at this mark. This is the front of the straw.
5. Slide the small straw through the windmill blades until the back of the blades rest against the pin. Gently slide each blade over the end of the straw. Secure the blades to the straw using tape, or another pin.
6. Insert the small straw into the larger straw on the cup.
7. Tape the string to the end of the small straw. Tie the other end of the string to a paper clip. Make sure you have 30 cm of string from the straw to the top of the paper clip.
8. On the very end of the small straw near where the string is attached, fasten a binder clip in place for balance and to keep the string winding around the straw.
9. Slide the small straw forward to bring the binder clip next to the larger straw. Place a second straight pin through the small straw at the other end of the larger straw. This will keep the blades away from the cup while still allowing them to move and spin.
10. Place your windmill in front of the fan and observe. Record observations in your science notebooks.
11. Investigate: Keep adding paper clips one at a time to determine the maximum load that can be lifted all of the way to the top. Record your data.

Conclusion

Draw a diagram of the system. Label the energy transformations that occurred in order for work to take place.

Extensions

- How could you change the design of your windmill to produce more work from the system?
- What variables can you change in this investigation? Create a new investigation changing one variable at a time.

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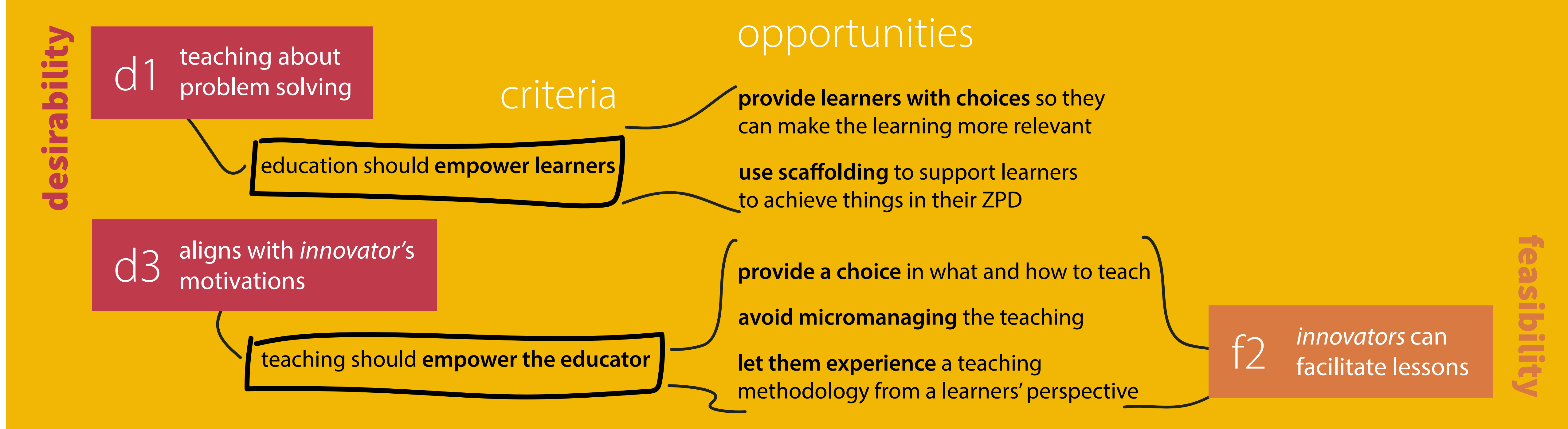
Figure 38: An example of a STEM kit which tends to micromanage the education

Takeaways | Step 6 | Empowerment



desirability

d1 teaching about problem solving

d3 aligns with *innovator's* motivations

criteria

education should empower learners

teaching should empower the educator

opportunities

provide learners with choices so they can make the learning more relevant

use scaffolding to support learners to achieve things in their ZPD

provide a choice in what and how to teach

avoid micromanaging the teaching

let them experience a teaching methodology from a learners' perspective

f2 *innovators* can facilitate lessons

feasibility

7.3 | Step 7
Intrinsically-motivated mastery

Need for self-esteem (Maslow) and following intrinsic motivation.

> **“Optimism is the faith that leads to achievement. Nothing can be done without hope and confidence”**
>
> *Helen Keller, 1903*

Intrinsic motivation, which involves the personal drive to learn and grow, can be harnessed through new learnings that boost learners’ self-esteem. Through inquiry-based learning approaches, this type of motivation can lead the way for further exploration and discovery.

Awareness of learnings through reflection

The growth of self-esteem is, in part, a result of learners acquiring new skills and competencies. Learners frequently encounter difficulties when attempting to put their newfound capabilities into words (Roël-Looijenga, 2015), while the most impactful learning generally occurs when learners engage in self-monitoring or reflection (Bassachs et al., 2020). Thus, an educator should encourage learners to articulate their learnings (Roël-Looijenga, 2015). Van Vonderen lets learners explain knowledge to their peers, which she views as “the top of the learning” (2022).

> **“When explaining something to somebody else, that is when most of what you have learned really becomes yours”**
>
> *M.Ed. Dominique van Vonderen, 2022*

Awareness about the underlying concepts of the learning can also be raised through reflective exercises. Roël-Looijenga (2015) suggests a group discussion about the learners’ experiences, or by letting learners give feedback to their peers.

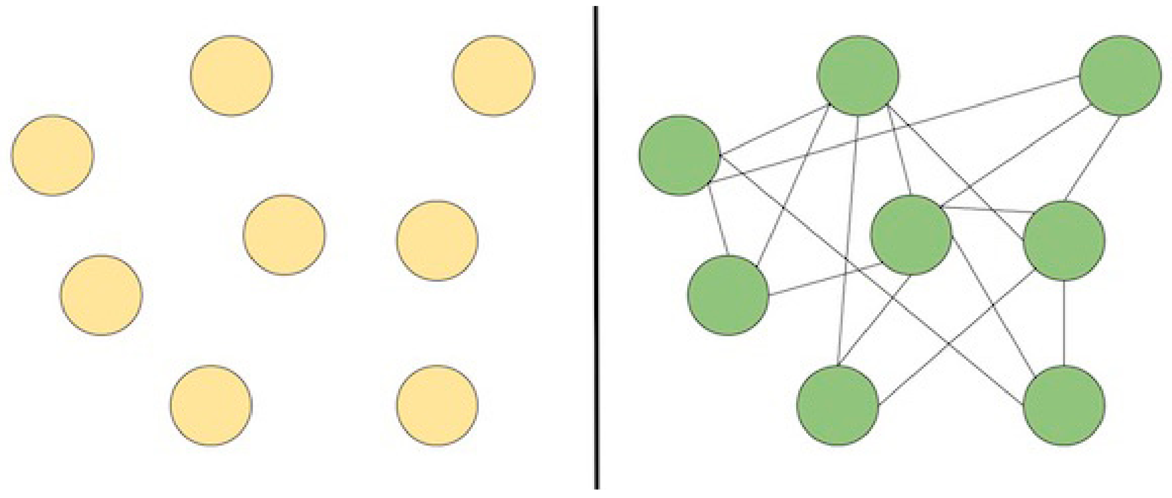


Figure 39: Isolated facts (left) vs. a conceptual understanding (right)by Jeff Lisciandrello

Inquiry-based learning approach

The concept of inquiry-based learning emphasizes the importance of learners seeking information guided by their own questions and curiosity, rather than relying solely on receiving (factual) information from teachers. This approach fits with children’s natural urge to explore their environment. Furthermore, it allows for a deeper understanding of concepts and applications as it pays explicit attention to students’ prior knowledge (El Sayary et al., 2015), and connects new knowledge to this, leading to conceptual understanding (see *Figure 39*)

> **Golden rule: Never tell learners something they can figure out themselves**

Problem-based learning

Problem-based learning (PBL) is a commonly applied type of guided inquiry (Banchi & Bell, 2008), where learners are involved in solving complex, ill-structured problems which are connected to real-world situations. Such open-ended problems are proven to effectively engage and challenge learners, and enable them to apply their prior knowledge in the solving process (Jonassen & Hung, 2008).

Applying PBL in integrated STEM education

The problem-based approach has been widely used in STEM education in recent years, and “[s]everal studies have produced estimates of considering PBL as the best strategy to teach STEM” (p.356, El Sayary et al., 2015). PBL positively influences learners’ interest in a future STEM career (LaForce et al., 2017), and it significantly increases problem-solving skills in comparison to more traditional teaching methods (Parno et al., 2019).

> **Integrated STEM offers learners “a chance to make sense of the world, rather than learning isolated bits and pieces of phenomena”**
>
> *Jeff Lisciandrello, 2020*

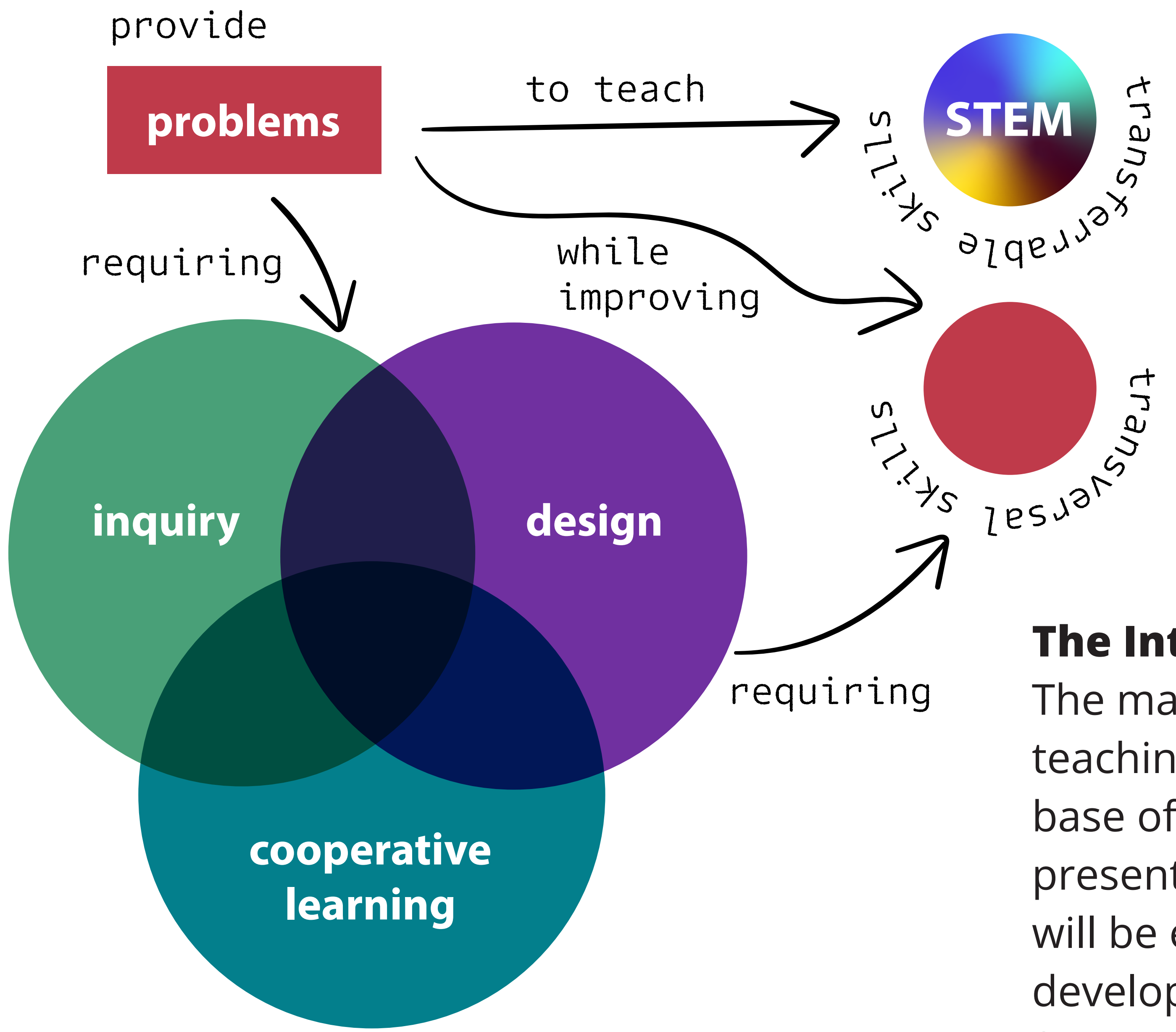


Figure 40: Theoretical framework for integrated STEM teaching, adapted from El Sayary et al., (2015) with input from Thibaut et al. (2018)

The Integrated STEM framework

The main characteristics from PBL STEM teaching, distilled from research, are at the base of the integrated STEM framework, presented in *Figure 40*. This framework, which will be explained in detail on the next page, was developed to serve as the theoretical base of the final workshop design (see chapter 13).

Focus on “problems”

Societal challenges are at the core of integrated STEM education, as they naturally invite the learner to combine skills and knowledge from the four disciplines. Involve learners in solving real-world, open-ended problems with different potential outcomes, which provide incomplete background information which is just enough to develop a solution (Thibaut et al., 2018). Incorporate multiple perspectives and balance fact-based and context-specific factors, to tap into different disciplines (Spencer, 2017). By placing the problem in an engaging and motivating context, the learner’s interest is sparked and they can link the knowledge and skills to their personal experiences. Finally, a rich problem comes with certain constraints or requirements (Guzey et al., 2016).

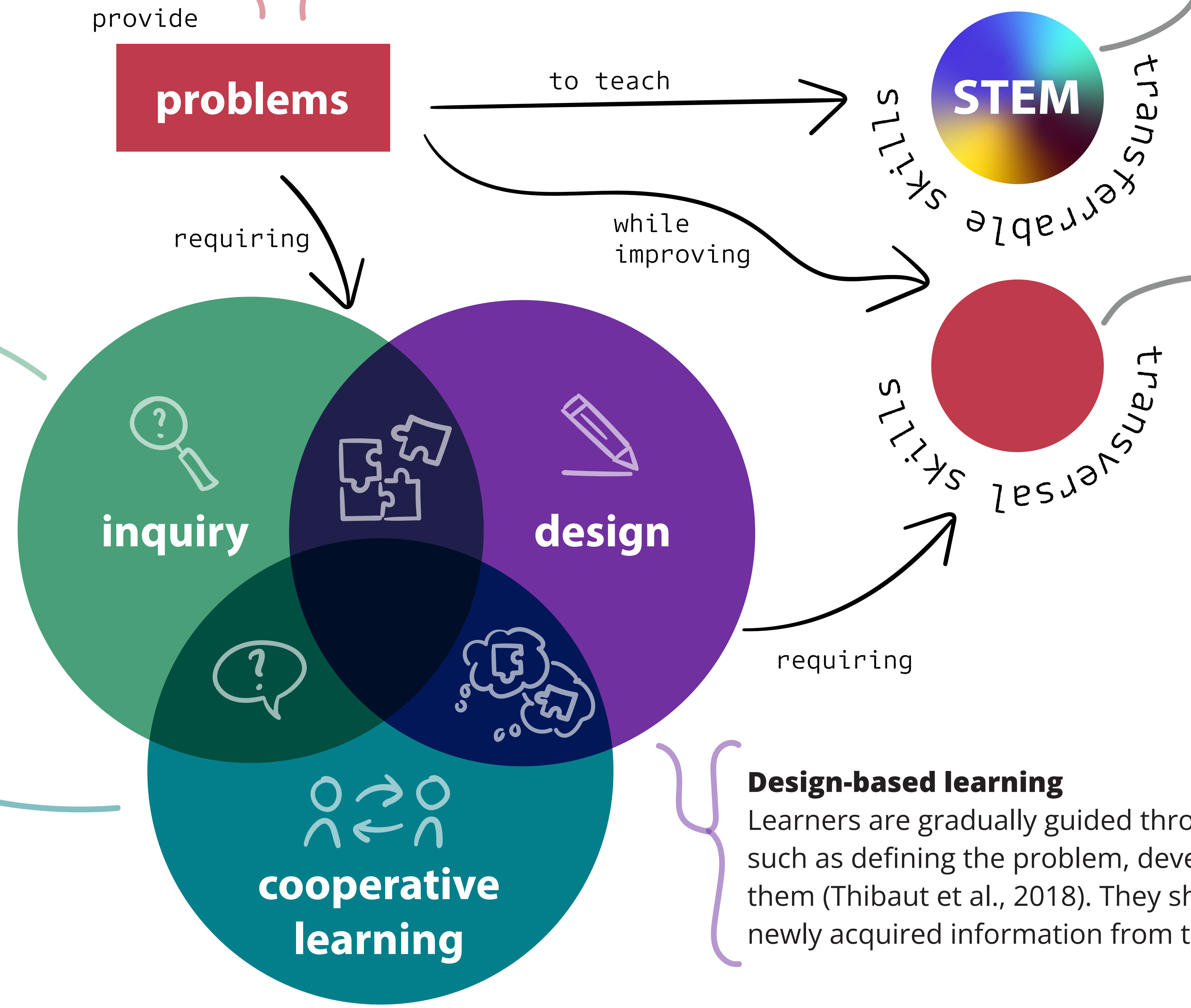
Learn through inquiry

Learners should be encouraged to question their existing knowledge to find flaws in their reasoning and ideas, identify which additional knowledge is required to solve the problem, and how to acquire this knowledge. Through hands-on activities, they will then develop understanding and construct new knowledge (Thibaut et al., 2018). Through questioning, educators can ensure learners are confronted with intended content (Mayer, 2004).

Cooperative learning

Learners are encouraged to learn and be engaged simultaneously (Rigacci, 2022), to ensure that all learners are actively involved and can learn from each other. This contributes to a critical mindset, rather than only basing their “truth” on what the teacher tells them.

Short-term cooperative learning strategies from Kagan & Kagan (2013) suggest that after a question is posed, children are provided with time to think for themselves, and then stimulated to discuss with their peers. In this way opinions on open questions can be formed, and for closed questions the brighter children will be challenged to explain their understanding to their peers.



Integration of STEM

Researchers agree that “making strong connections between the ... STEM-disciplines is necessary for integrated STEM to work” (Thibaut et al., 2018). Furthermore, this integration of disciplines should be made explicit, as learners do not do this spontaneously integrate knowledge on their own (Pearson, 2017).

Transversal skills

Besides acquiring transferable STEM knowledge, this type of education requires and improves transversal skills, such as critical thinking and self-awareness (Kersánszki et al., 2022). These skills are generally more difficult to quantify due to their personal character, which is why traditional schooling tends to focus less on their development. However, in today’s world they are essential for the employability of an individual (Akkermans, 2020), and therefore play a big role in the framework.

Design-based learning

Learners are gradually guided through the iterative phases of an engineering process, such as defining the problem, developing potential solutions, evaluating and optimizing them (Thibaut et al., 2018). They should be encouraged justify design decisions through newly acquired information from their own experiments or research (Wells, 2016).

Figure 41: Theoretical framework for integrated STEM teaching, as presented on last page.

Figure 42: The workshop-model, as presented by Lisciandrello (2020)

Applying PBL in a workshop-model

The PBL guided inquiry approach can be applied within the time frame of one workshop, which makes it the recommended method when educator and learners are not yet used to the inquiry-approach (Lisciandrello, 2020). As visualised in *Figure 42*, this workshop generally has a clear structure, starting with an Inspire-part, a workshop-core, and a Reflect-part.

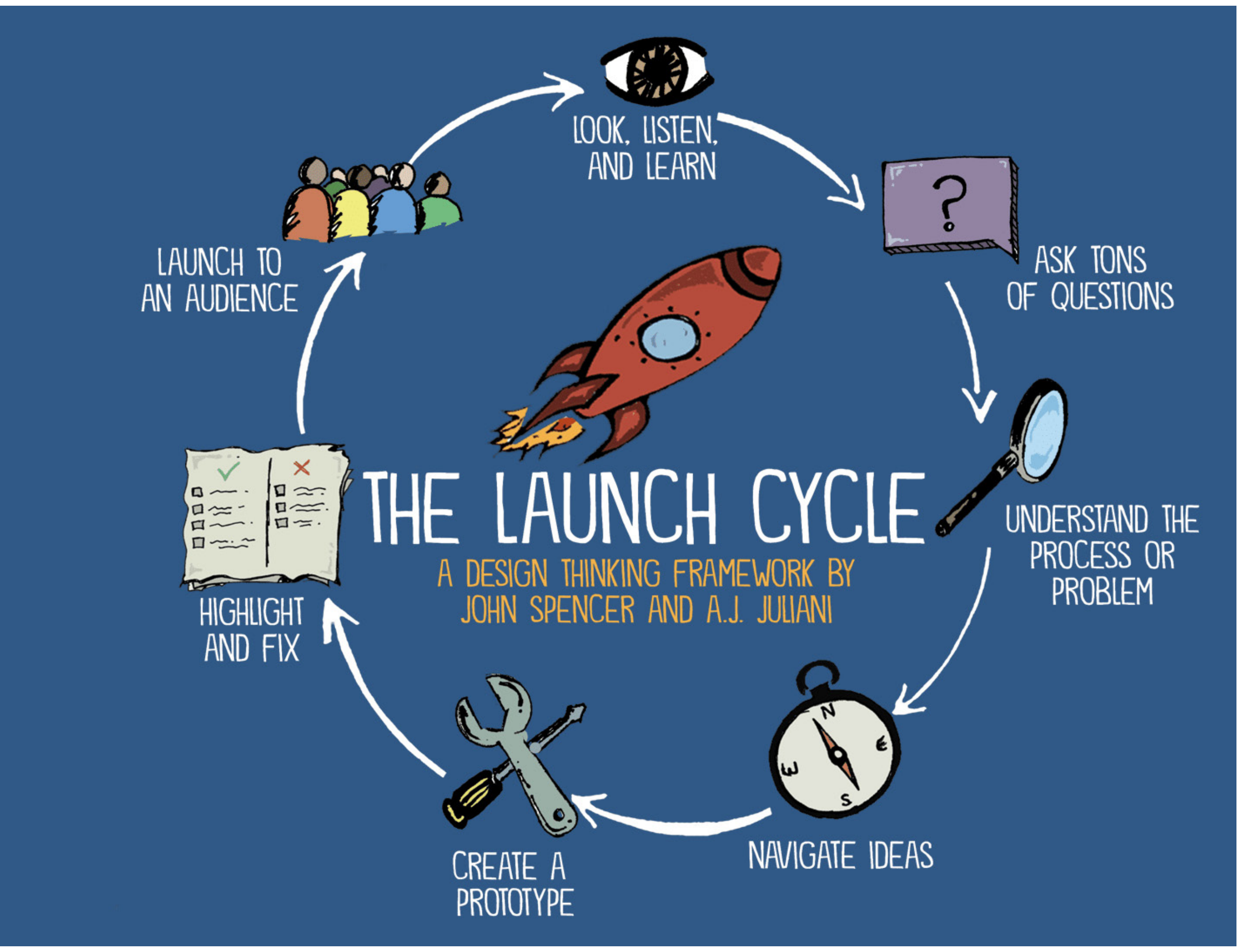


Figure 43: The LAUNCH cycle, an inquiry-based approach to maker-education (Spencer, 2021)

Inspire-part

According to Lisciandrello (2020), a problem-based workshop should always start with a short Inspire-phase. In this part, relevance is shown to the learner, to make them curious and aware of the key idea (Pedaste et al., 2015). It also ensures learners connect the workshop content to prior knowledge and experiences, set a purpose for the workshop, and distributes the expertise to the learners, instead of framing the educator as the only expert (Gerstein, 2016).

In education where learners are expected to make something, Gerstein emphasizes the importance of "Tinkering, Playing [&] Experimenting" as "uncensored, boundary-less, whimsical making, [which] can be considered free play with exploration of the making materials and processes being the goal [of this first phase]" (2016). Other educational activities in this phase can apply user scenarios, guided fantasies and asking learners essential and personal questions to open up their thinking.

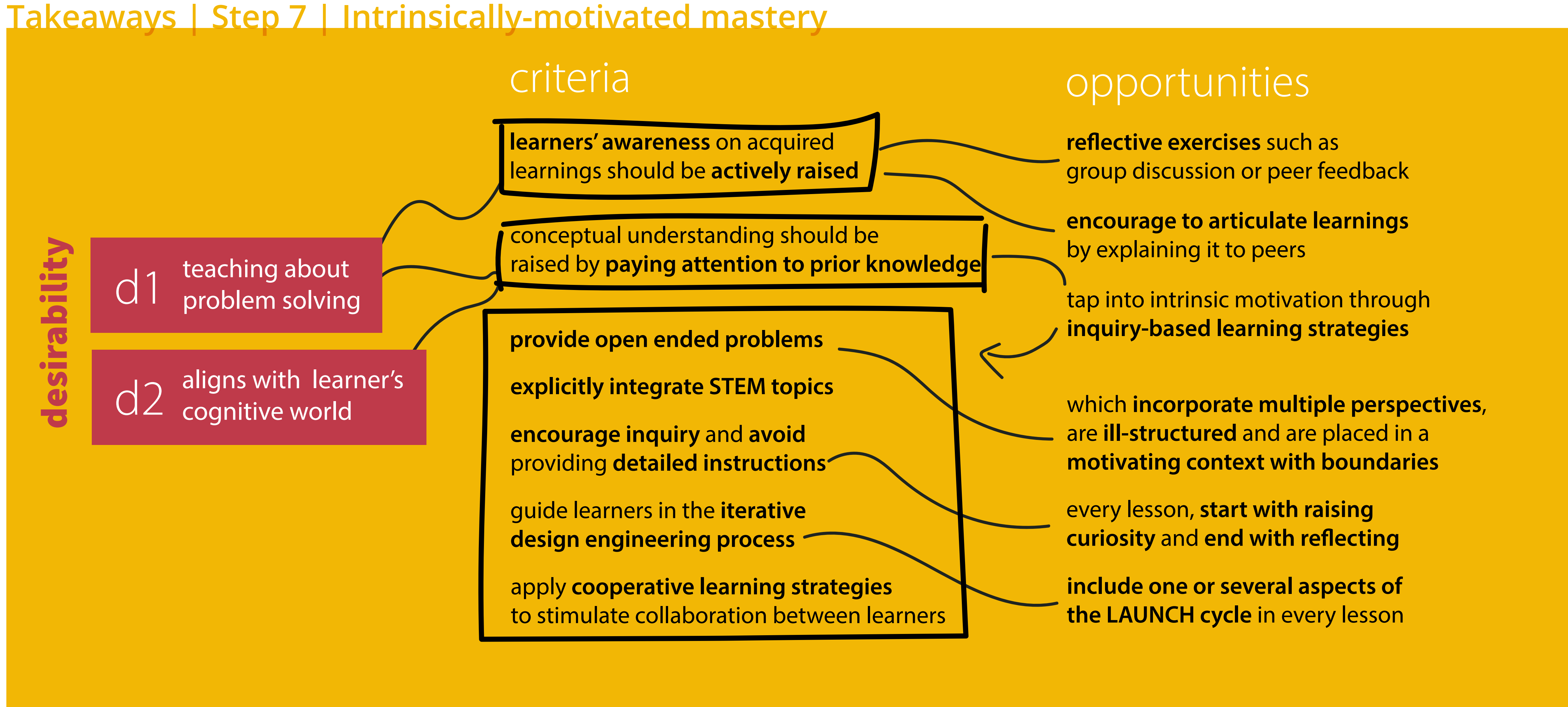
Workshop core

Educator John Spencer has developed the LAUNCH-model, as presented in *Figure 43*, which is a learner-friendly way to take on a design project. One or more parts of this cycle can be completed during the workshop-core. The intention of this workshop-core is to facilitate a process of "productive struggle", where learners engage in effortful activities, in which they face obstacles, make mistakes and learn from them (Lisciandrello, 2020). According to Pedaste et al. (2015), learners should be encouraged explore, experiment and interpret data in a dynamic and iterative process in this part of the workshop.

Reflect-part

Finally, every workshop should end with a "reflect"-phase, where learners "step back, away from their making, to observe and reflect on their processes and results" (Gerstein, 2016). The goal is always to reflect on the making process, which can either be on an individual basis, or based on the presentations of peers (Lisciandrello, 2020). Spencer (2021) emphasizes the importance of letting learners present their work to an audience by naming his whole inquiry approach after this last step: LAUNCH. This can be done through oral presentations, or presentation techniques such as a gallery walk. This sharing also contributes to learners learning from the their peers' work (Gerstein, 2016).

Takeaways | Step 7 | Intrinsically-motivated mastery



desirability

d1 teaching about problem solving

d2 aligns with learner's cognitive world

criteria

learners' awareness on acquired learnings should be **actively raised**

conceptual understanding should be raised by **paying attention to prior knowledge**

provide open ended problems

explicitly integrate STEM topics

encourage inquiry and **avoid providing detailed instructions**

guide learners in the **iterative design engineering process**

apply **cooperative learning strategies** to stimulate collaboration between learners

opportunities

reflective exercises such as group discussion or peer feedback

encourage to articulate learnings by explaining it to peers

tap into intrinsic motivation through **inquiry-based learning strategies**

which **incorporate multiple perspectives**, are **ill-structured** and are placed in a **motivating context with boundaries**

every lesson, **start with raising curiosity** and **end with reflecting**

include one or several aspects of the LAUNCH cycle in every lesson

7.4 | Step 8
Actualization of interest & talents

Creativity in education

Several studies emphasize that incorporating creativity into STEM education is becoming is essential for students to develop innovative problem-solving skills (Sirajudin et al., 2021; Vanichanon et al., 2021; Roël-Looijenga, 2015). To foster a creative mindset, it is crucial to provide learners with a safe and supportive environment which encourages risk-taking, experimentation, and exploration. Furthermore, educators should set clear expectations and goals, and provide regular feedback and encouragement, so learners can share their ideas freely and learn from their mistakes. A successful implementation of creativity in education highly depends on the educators' skill and approach, which is why van Vonderen (2022) emphasizes that educational materials should properly guide educators in this process.

Need for freedom, autonomy & creativity, and trust in own judgement and capabilities.

Learners as the owners of their learning

Within the integrated STEM approach, the way of teaching has been shifting from a classical teacher-directed approach to a highly learner-led approach (Thibaut et al., 2018; Moore et al., 2014). This approach takes choice, as described in chapter 7.2, a step further, by allowing the learner to take ownership over their own learning process, learning style, curriculum and goals. This is based on the idea that all learners learn in a unique way, and thus should design their own learning process (Jensen et al., 2014).

From traditional teacher to facilitator

Learner-led approaches require a mindset shift when coming from traditional education, which is presented in *Figure 44*. While educators generally feel like they do take this type of learning and mindset into account, research shows that active-learning children generally become passive due to the lack of inquiry in their primary education (Kraaij, 2015). This shows the importance of explicitly emphasizing this new mindset when training educators.

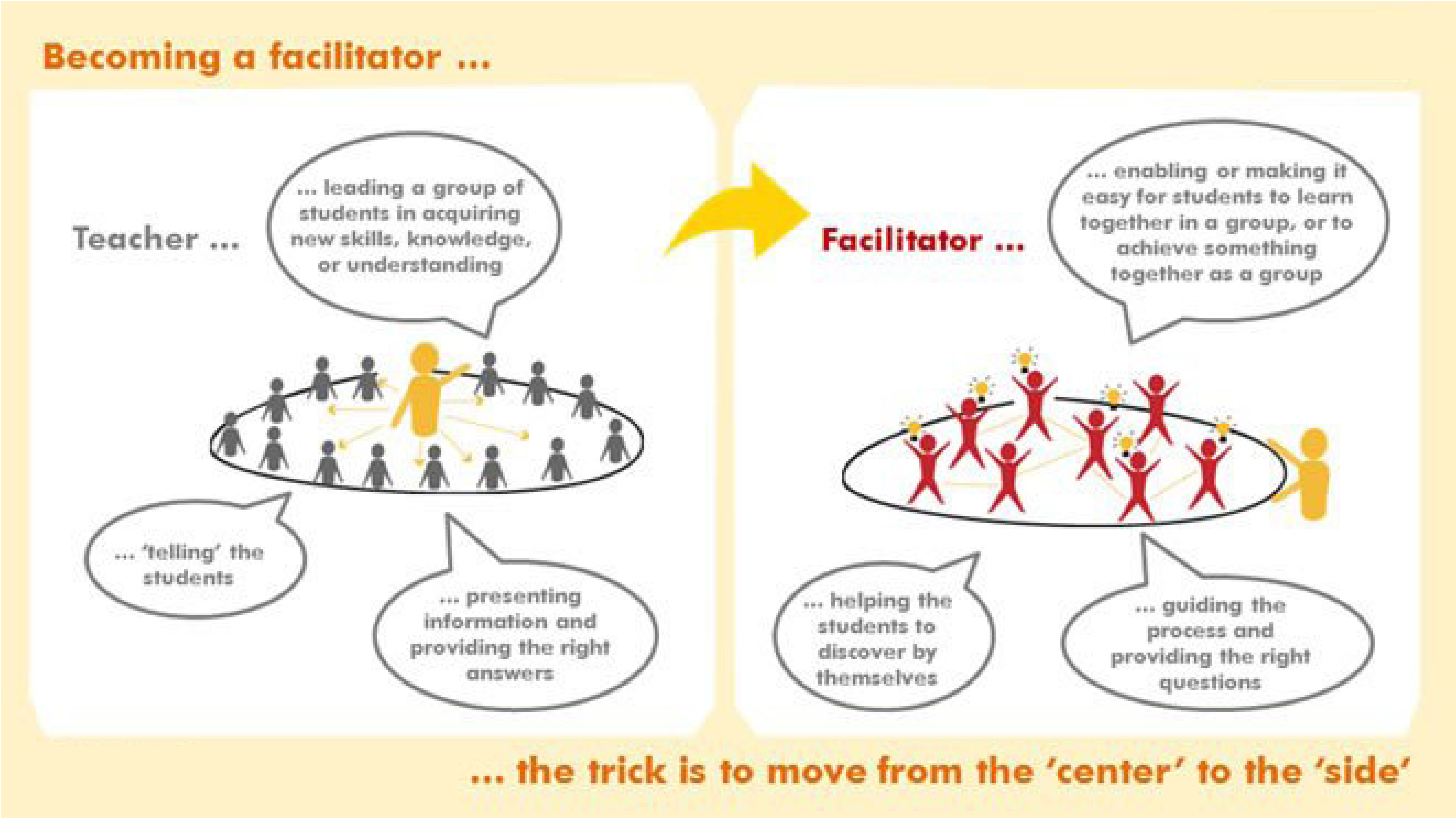


Figure 44: The difference between a traditional teacher and a facilitator in learner-led education, by Illumine

Takeaways | Step 8 | Actualization of interest & talents

desirability

d1 teaching about problem solving

criteria

learners should be provided with **optimal environment for creativity**

the **inquiry-based mindset** should be **explicitly emphasized** to innovators

guidance on how to facilitate creativity should be provided to *innovators*

opportunities

make all **materials** necessary to create with **readily available**

by **showing practical examples**

f2 *innovators* can facilitate lessons

feasibility

8 | Life on Lamu island

To gain an understanding on the life in Lamu, the following sub-chapters will contain images gathered based on the six themes to learn about a culture (see page 20). In the takeaways section, it will become clear which insights are hidden in these images.

All photos are taken by Eric Lafforgue and Emma de Cocker

desirability

- d2 aligns with learner's cognitive world
- d5 fit to local primary schools' ways
- d7 fit with local ways
- d8 minimal environmental impact of materials
- d9 engages learners societal developments

feasibility

- f3 adapted to resources at schools
- f7 program can be facilitated by *innovators*

8.1 | Possessions

> **"A decade ago, there were only two vehicles allowed here [in Lamu]. But there's been an influx of motorbikes in recent years. You can't eat heritage"**
>
> *Lamu local (africanews, 2021)*

Takeaways | Possessions

desirability

- d8 minimal environmental impact of materials
- d9 engages learners societal developments

opportunities

mangrove wood and mvule hard wood are widely available local regenerating materials

societal developments to use in teaching

the strong **tension between modernisation and the preservation of** natural and cultural **heritage**

fuel is getting increasingly expensive so people struggle in their mobility

fish is getting less available and smaller due to overfishing and modernisation

implications

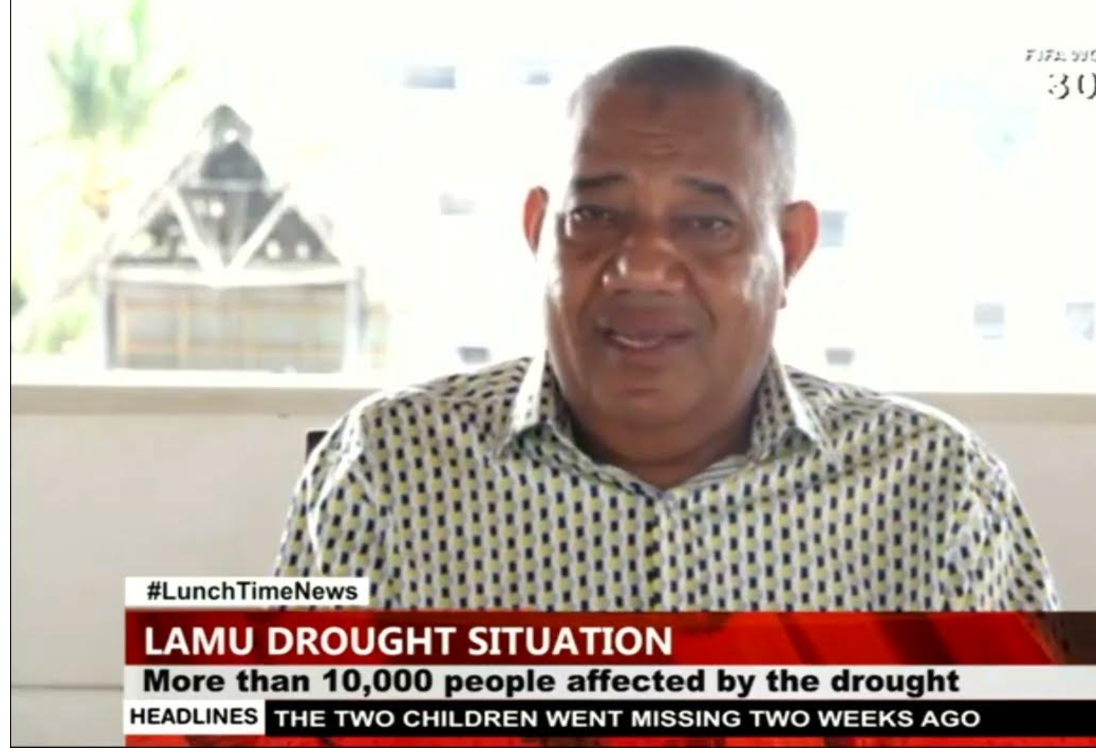
power outages frequently happen in Lamu Old Town and thus at schools

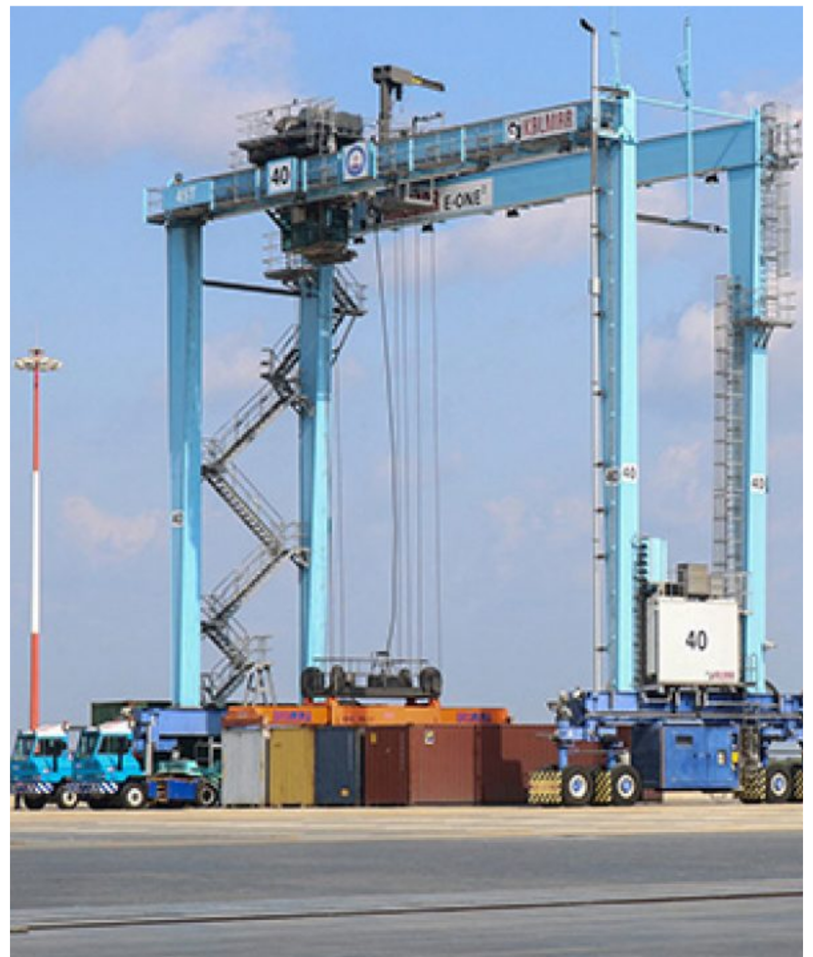
learners do not own smartphones

feasibility

- f3 adapted to resources at schools

8.2 | Living





Takeaways | Living

desirability

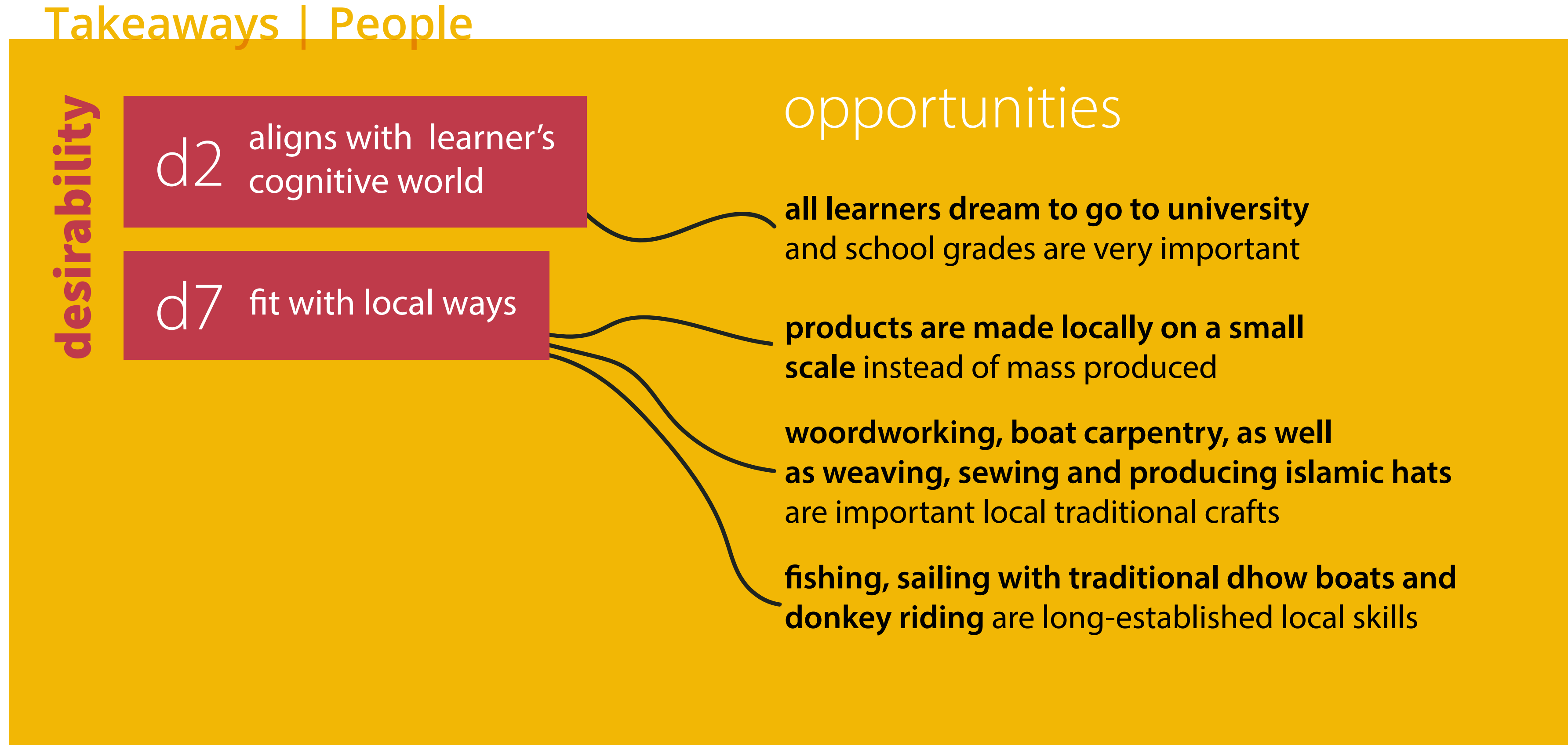
d9 engages learners societal developments

opportunities
societal developments to use in teaching

- **food uncertainty because of droughts** due to rising temperatures and unpredictable rainfall patterns
- **challenging mobility infrastructure** due to mangrove forests, tides and narrow alleys in the settlements
- **Chinese port construction** impacting nature, economy and infrastructure systems
- **natural energy resources widely available in Lamu**, such as wind, sun and tidal currents
- **household waste problem** due to the lack of a proper waste infrastructure

8.3 | People

Takeaways | People



desirability

d2 aligns with learner's cognitive world

d7 fit with local ways

opportunities

all learners dream to go to university and school grades are very important

products are made locally on a small scale instead of mass produced

woordworking, boat carpentry, as well as weaving, sewing and producing islamic hats are important local traditional crafts

fishing, sailing with traditional dhow boats and donkey riding are long-established local skills

8.4 | Health

Takeaways | Health

desirability

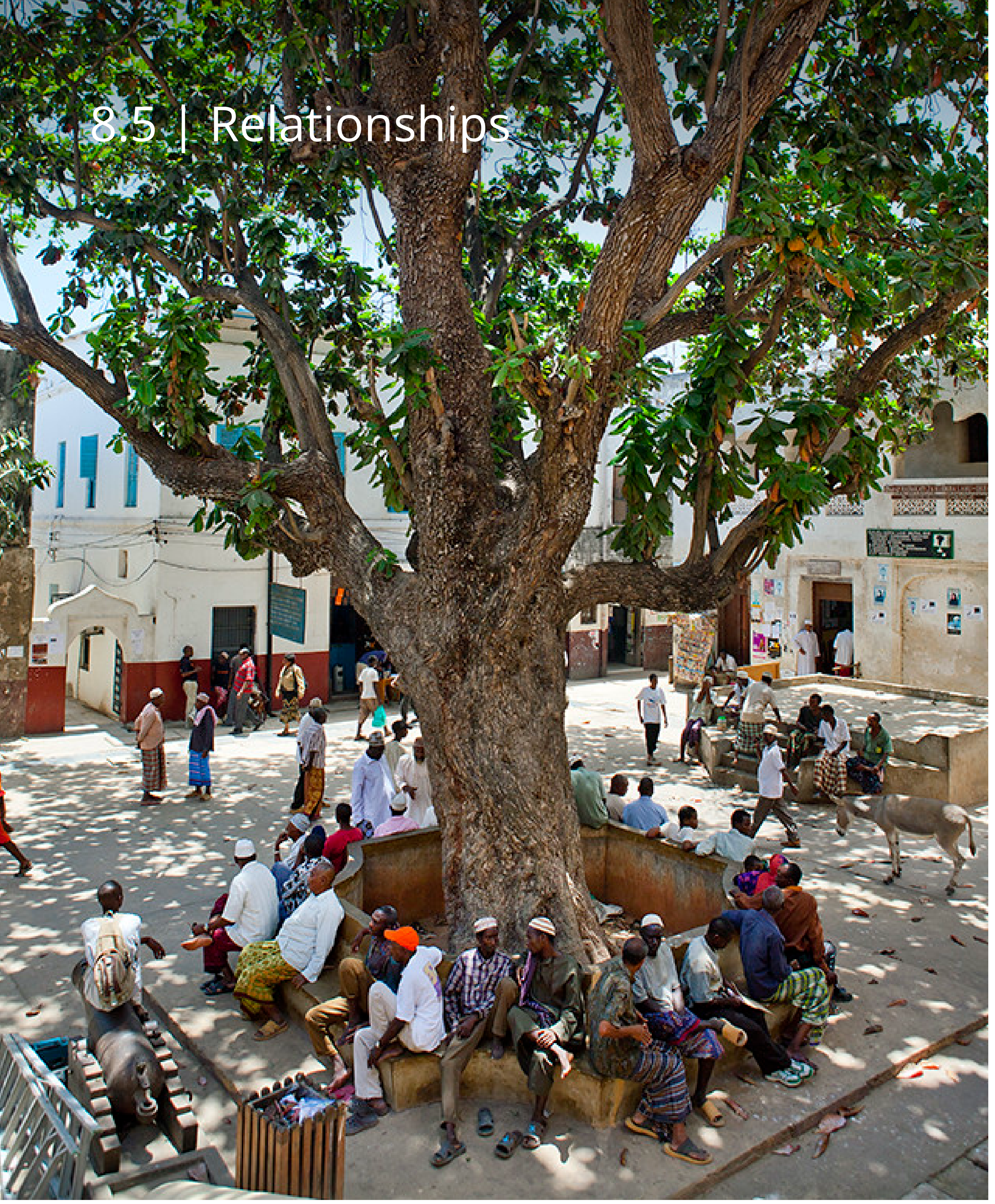
d9 engages learners
societal developments

opportunity

societal development to use in teaching

limited access to drinking water due to persistent droughts puts pressure on people and animals

8.5 | Relationships



Takeaways | Relationships

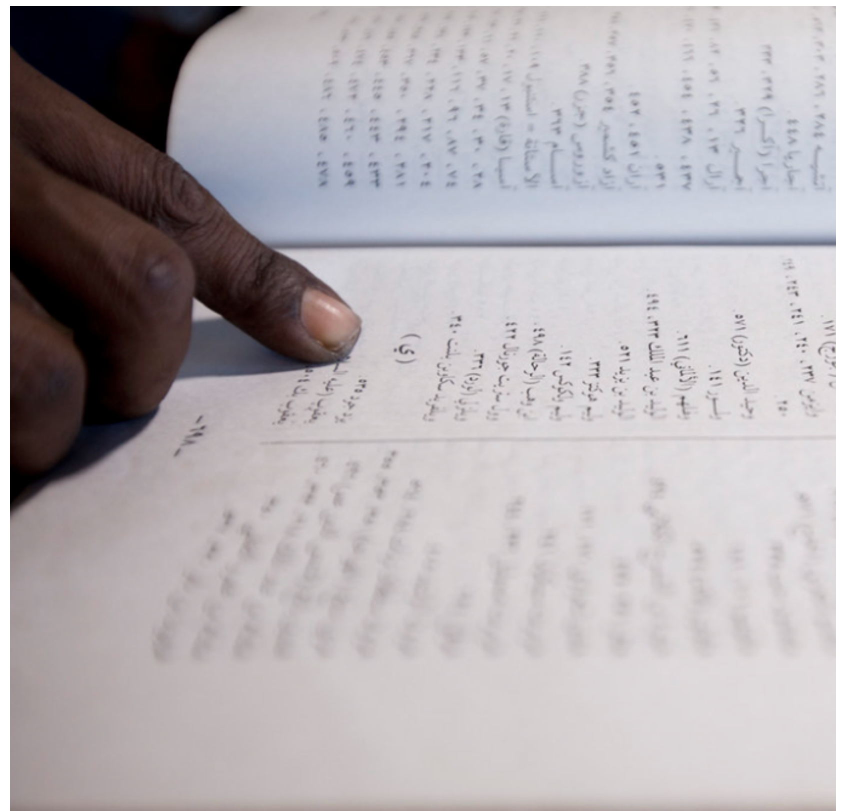
desirability

d5 fit to local primary schools' ways

opportunity or implication

trust and relationships are highly **important** for the **acceptance of innovation** in Lamu

8.6 | Activities



Takeaways | Activities

desirability

d2 aligns with learner's cognitive world

d9 engages learners societal developments

opportunities

children enjoy being active outside

children enjoy creative activities and crafts

children are expected to actively **help with the household chores**

societal development to use in teaching

people living by the day with little income security due to high unemployment rates and big informal economy

implication

full time volunteering might not be **realistic** for most locals

f7 program can be facilitated by *innovators*

feasibility

9 | Primary school education in Kenya

This chapter explores the current Kenyan primary school education, based on literature and empirical research. A short history on the fundamentals of the Kenyan education system will be followed by insights into the current system and its challenges, as they might play a role in the introduction of new educational tools, and finally opportunities for experiential STEM education.

desirability

d1 teaching about problem solving

d2 aligns with learner's cognitive world

d4 teaching aligns with IOMe's core values

d5 fit to local primary schools' ways

feasibility

f3 adapted to resources at schools

viability

v3 minimal replacement costs

9.1 | The history of Kenyan education

Using Western education to convert Kenyans

Before the colonial era, education in Kenya was informal: children learnt basic skills from parents or guardians (M'mboga Akala, 2021). After the Arabs had introduced Islamic schools on the Kenyan coast, Western education was introduced in Lamu in 1557 when Portuguese missionaries established the first monasteries (State University, n.d.). The British rule in Kenya as of 1888 (Black History Month, 2020) led to a new wave of missionaries who started schools in order to convert Kenyans to Christianity. Later, the British introduced a formal education system to expand the education beyond solely religion, and educate Kenyans to serve the colonial administration as translators, administrators and secretaries (M'mboga Akala, 2021). Back then, education was discriminating against Kenyans and such serving jobs were seen as "a glittering prize for an African" (Lawrance et al., 2006).

> **"The main objectives of education were not to help the African live in harmony with their local environment but rather to perpetuate their master-servant status quo between the colonizers and the colonized"**
>
> *J.R. Sheffield, Columbia University, New York, 1973*

Educational reforms too ambitious

Since independence in 1963, the Kenyan government has reformed the educational system several times (M'mboga Akala, 2021), with the aim to open up employment options (Milligan, 2017). Although the latest reform aimed to introduce technical and vocational hands-on education, teacher trainer Sarah Muthama (2022) states that only seven years after its introduction the practical educational activities were abandoned due to lack of human and material resources, changing the system into a highly theory-based curriculum. Furthermore Glewwe et al. (2009) demonstrated that the curriculum was designed for learners who have a higher academic capability and a higher proficiency in the English language than the current learners in the system.

> **"If [a] curriculum covers too much, goes too fast and is too hard compared to the initial skill of the [learners] ... this can produce disastrous results. An overambitious curriculum causes more and more [learners] get left behind early and stay behind forever."**
>
> *Pritchett and Beatty in "Slow down, you're going too fast", p. 280, 2015*

Figure 46: Learners engaged in experiential learning within the CBC, by Bizna Reporter

"The CBC will solve everything"

Because the former system was flawed in many ways, and lacked to produce graduates with the necessary job skills for the human labour force, a new Competency-Based-Curriculum (CBC) is currently being introduced (Momanyi and Rop, 2019; Reporter, 2022). The governments' vision for the CBC is to develop "an engaged, empowered and ethical citizen", (Kenya Institute of Curriculum Development, 2019). The intention is to take an inquiry-based approach focusing on experiential learning activities (*Figure 46*).

Takeaways | The history of Kenyan education

desirability

d4 teaching aligns with IOMe's core values

opportunities

educational goals of the Kenyan government are in line with IOMe's core values and goals

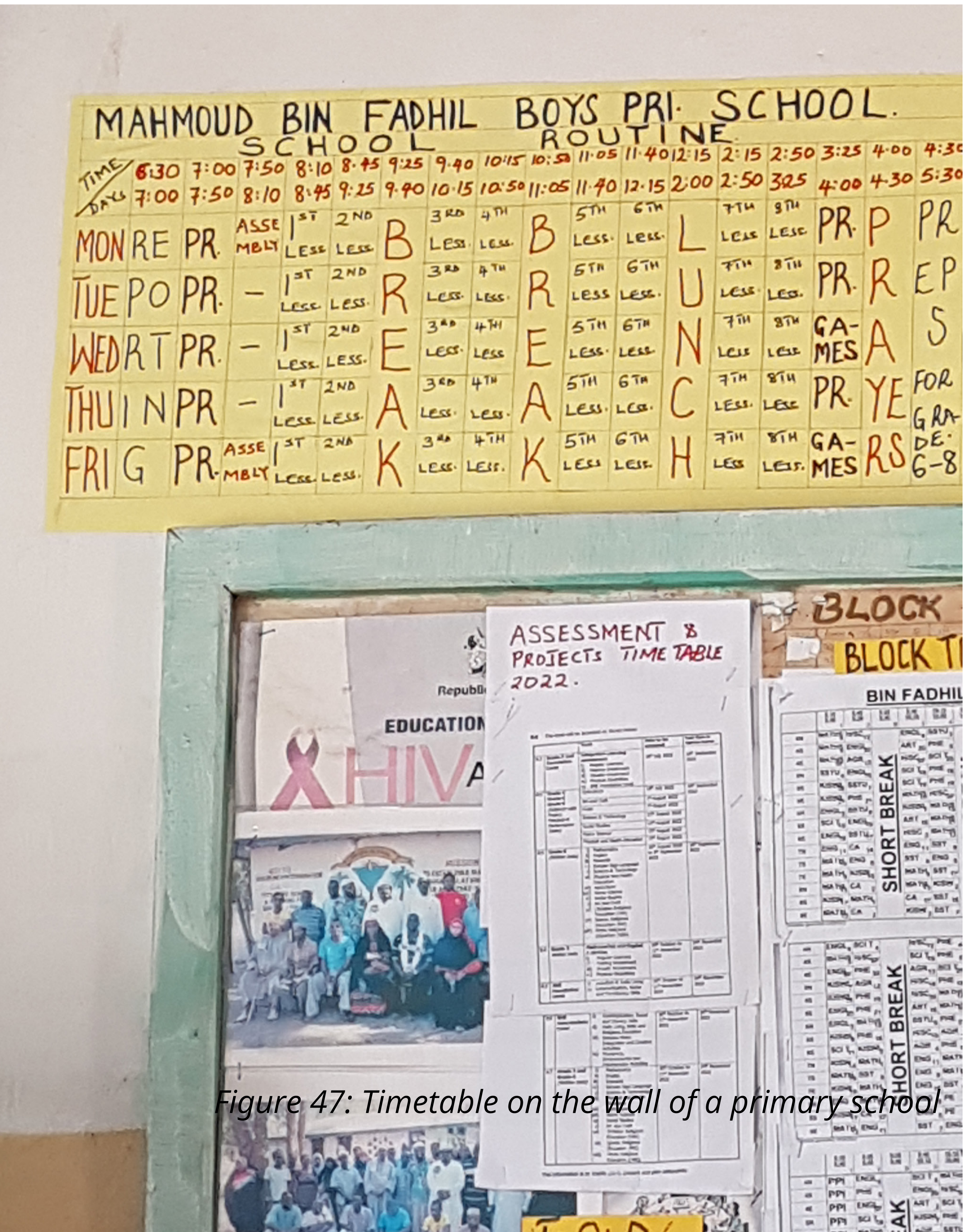
d5 fit to local primary schools' ways

schools (learners and teachers) **are getting familiar with inquiry**-based learning approaches

9.2 | Current education system and its perceived value

The primary school system

Kenya houses public, as well as private schools, and gender-separated as well as mixed schools. Generally, schools in Lamu tend to be owned and run by a small selection of people, and a strong hierarchy on primary schools was observed where the headteacher and the deputy headteacher are most important for the decision making. Primary school lasts for six years, after which learners continue to lower secondary school at roughly the age 12 years old.



MAHMOUD BIN FADHIL BOYS PRI. SCHOOL.
SCHOOL ROUTINE

TIME / DAYS	6:30 7:00	7:00 7:50	7:50 8:10	8:10 8:45	8.45 9:25	9:25 9.40	9.40 10.15	10:15 10:50	10:50 11:05	11.05 11.40	11.40 12.15	12:15 2:00	2:15 2:50	2:50 325	3:25 4:00	4.00 4.30	4:30 5:30
MON	RE	PR.	ASSEMBLY	1ST LESS	2ND LESS	B	3RD LESS.	4TH LESS.	B	5TH LESS.	6TH LESS.	L	7TH LESS	8TH LESS	PR.	P	PR
TUE	PO	PR.	–	1ST LESS.	2ND LESS.	R	3RD LESS.	4TH LESS.	R	5TH LESS	6TH LESS.	U	7TH LESS.	8TH LESS.	PR.	R	EP
WED	RT	PR.	–	1ST LESS.	2ND LESS.	E	3RD LESS.	4TH LESS	E	5TH LESS.	6TH LESS	N	7TH LESS	8TH LESS	GAMES	A	S
THU	IN	PR	–	1ST LESS	2ND LESS.	A	3RD LESS.	4TH LESS.	A	5TH LESS.	6TH LESS.	C	7TH LESS.	8TH LESS	PR.	YE	FOR GRA
FRI	G	PR.	ASSEMBLY	1ST LESS.	2ND LESS.	K	3RD LESS.	4TH LESS.	K	5TH LESS	6TH LESS.	H	7TH LESS	8TH LESS.	GAMES	RS	DE. 6-8

Figure 47: Timetable on the wall of a primary school

A school day in Lamu

On primary schools in Lamu, a school day starts at 7:00 with time to revisit homework, after which the day consists of four blocks of two classes. The regular school program ends at 3:25 in the afternoon, after which there is time scheduled for revisiting homework, or generally on Wednesdays and Fridays for extracurricular activities or play. At 4:00, their official school day ends when learners are free to go for prayers.

Subjects in upper primary school

English, Kiswahili, Arabic, Home Science, Agriculture, Science and Technology, Mathematics, Islamic Religious Education, Creative Arts, Physical and Health Education, Social Studies & ICT.

Mother-tongue education

All education on primary schools is taught in English. The majority of teachers believe this is the best like this, as this is mandatory from the government. However, science teacher Mariam Abubakar experiences that learners get more creative and engaged when allowed to express their thoughts in their mother tongue, which was confirmed during generative sessions with learners. She states that teaching in Kiswahili is especially important "for the weak learners" (2022), which is supported by a 2019 research by Mandillah which states that learners are more likely to succeed in school when taught in their mother tongue.

Low educational value leads to drop-outs

Due to the history of education being used to convert Kenyans to Christianity, distrust in the educational system was common. Furthermore, families engaged in fishing and carpentry did not always see the benefits in sending their children to school or university, and efforts of children are often needed to earn the families' daily bread. These factors have resulted in low percentages of school-aged children attending school and 1.13 million primary school dropouts in 2020 (Unicef, 2021).

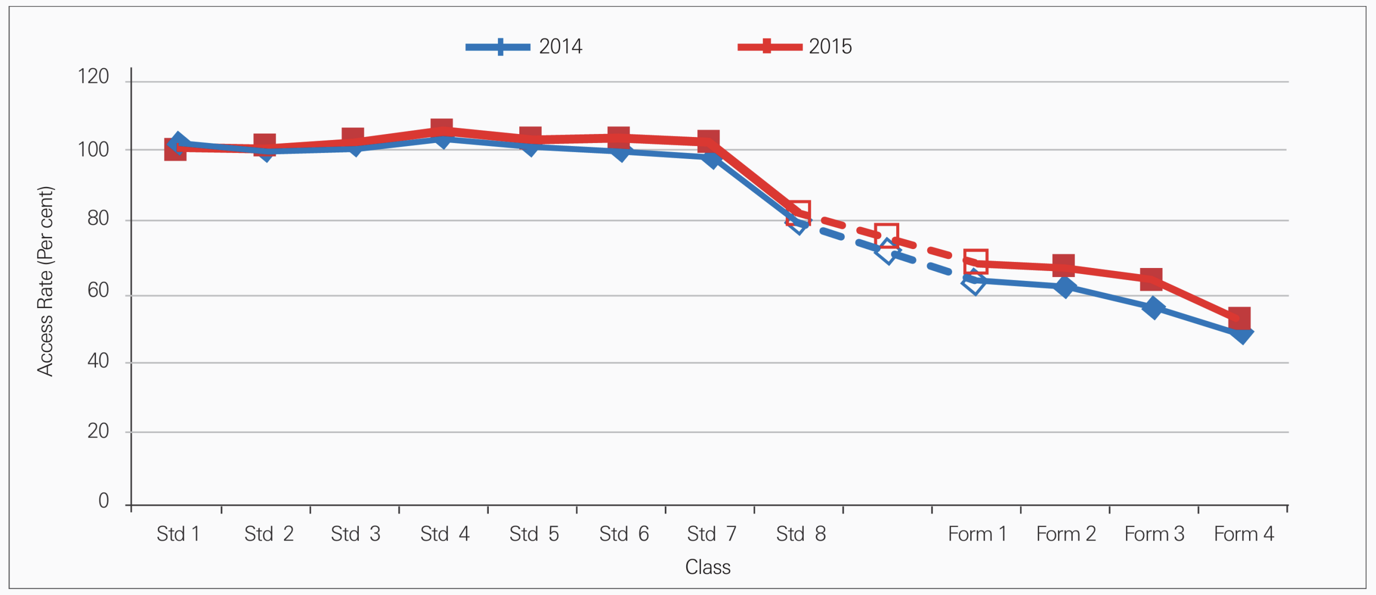


Figure 48: School access rate by grade (UNICEF, 2017)

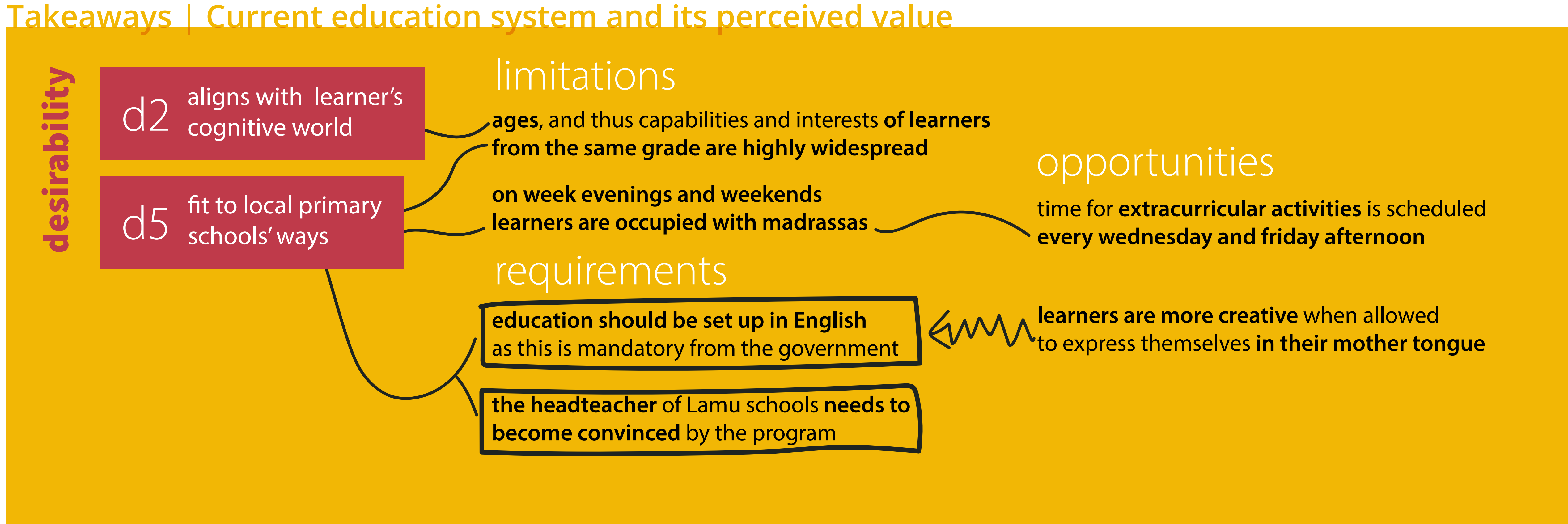
Free Secondary Education

In Kenya, it is relatively common for children to withdraw from education after primary school (see *Figure 48*). As the government strives for a 100% transition of learners to secondary school (Makoba & Odhiambo, 2022), secondary education was made free in 2008 (Olang'o et al., 2021). However, because schools generally require a parental contribution for certain activities or food, and parents have to pay for school uniforms, poverty still play a role in learners dropping out of the system.

Importance of Islamic education

In Lamu, every night after regular primary school and in the weekends, the majority of the learners go to Islamic schools called madrassas. Due to the high importance of religion in the region, parents sometimes decide to take their children out of regular school for a certain time period, in order for them to focus on the Islam. This, together with the high percentage of school drop-outs, explains the fact that in schools in Lamu, ages of learners in the same grade were observed to be widespread.

Takeaways | Current education system and its perceived value



desirability

d2 aligns with learner's cognitive world

d5 fit to local primary schools' ways

limitations

ages, and thus capabilities and interests **of learners from the same grade are highly widespread**

on week evenings and weekends learners are occupied with madrassas

opportunities

time for **extracurricular activities** is scheduled **every wednesday and friday afternoon**

requirements

education should be set up in English as this is mandatory from the government

learners are more creative when allowed to express themselves **in their mother tongue**

the headteacher of Lamu schools **needs to become convinced** by the program

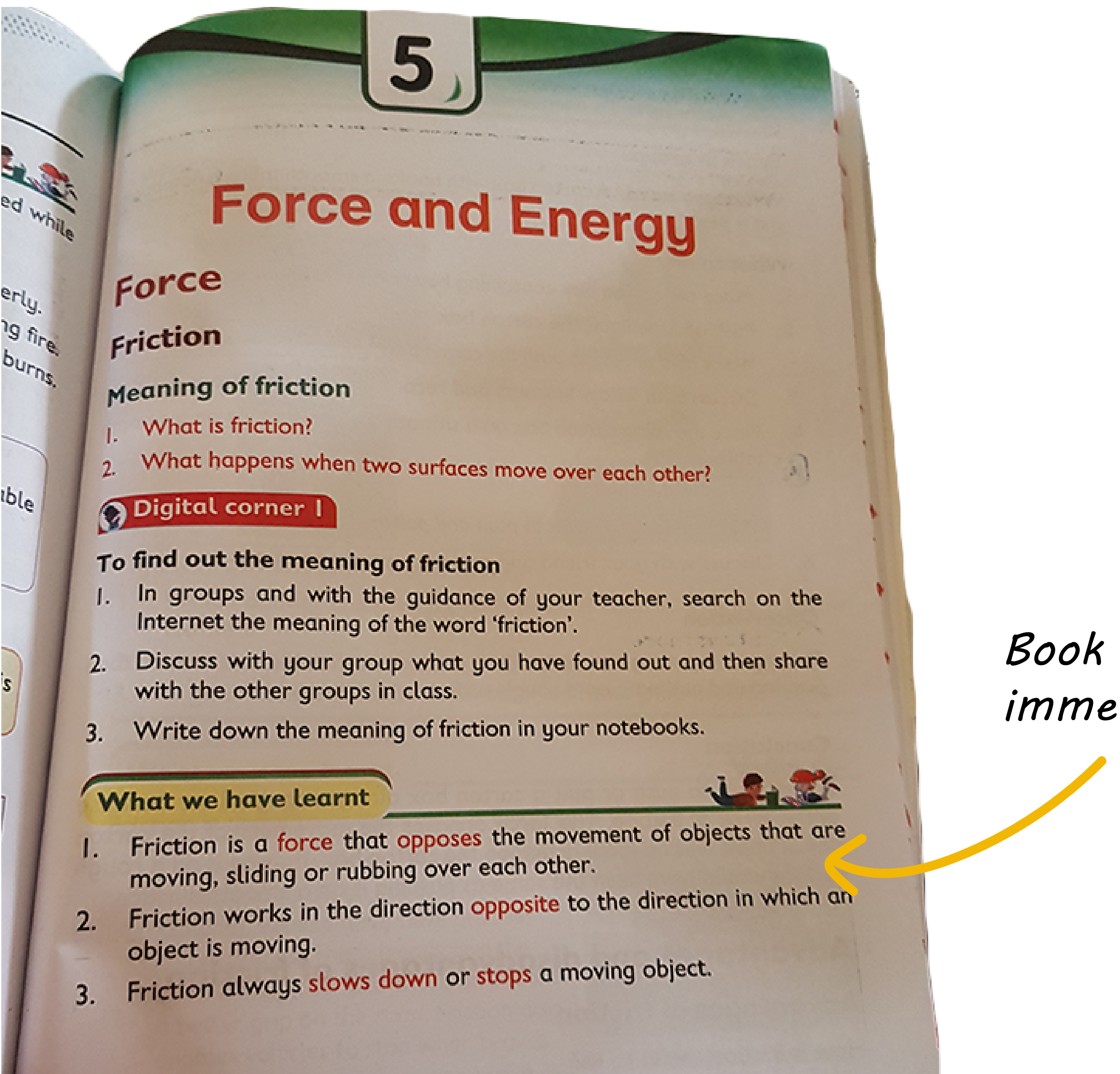
9.3 | What are the challenges with the current CBC system?

> **"Teachers having inadequate skills and knowledge to implement the curriculum, lack of instructional materials and resources, lack of stakeholders' participation, overcrowded classrooms, rigid school systems and management styles, paperwork, especially filling in learners' assessment reports, cumbersome for parents who have at times to do the assignments and lack of cooperation between school and parents."**

M.Ed. Sarah Muthama, Kenyan teacher trainer, 2022

Numerous challenges for the new CBC

The CBC curriculum was introduced with the message that it would solve all issues former system, however Muthama (2022) fears it might have the same disastrous future as its predecessor. Her statement regarding big threats which the CBC is facing, quoted on the top of this page, gets supported by numerous researches (M'mboga Akala, 2021; Ondimu, 2018). Additionally, the switch to free education had a negative effect on the academic results in secondary schools in rural areas, because the resources and school buildings got even more scarce (Olang'o et al., 2021).



5

Force and Energy

Force

Friction

Meaning of friction

1. What is friction?
2. What happens when two surfaces move over each other?

Digital corner 1

To find out the meaning of friction

1. In groups and with the guidance of your teacher, search on the Internet the meaning of the word 'friction'.
2. Discuss with your group what you have found out and then share with the other groups in class.
3. Write down the meaning of friction in your notebooks.

What we have learnt

1. Friction is a force that opposes the movement of objects that are moving, sliding or rubbing over each other.
2. Friction works in the direction opposite to the direction in which an object is moving.
3. Friction always slows down or stops a moving object.

Book gives specific answer or conclusion immediately after every open question

Figure 49: Inquiry-based learning wrongly applied in Kenyan upper primary school books

No truly inquiry-based education

Although intended educational methods, such as the application of inquiry-based learning, might have international progressive appeal (Kaviti, 2018), it can be argued that this approach does not get translated to the education properly (M'mboga Akala, 2021). The inspection of CBC schoolbooks, as illustrated in *Figure 49*, reveals that what is seen as the golden rule of inquiry-based learning, "Never tell students something they can figure out themselves", gets contradicted by providing explicit guidance on conclusions which learners should draw from certain exercises. This can be explained by the finding that the "book writers had not been trained and had limited knowledge about the [CBC] ... hence their ability to write quality books was limited" (Ondimu, p. 20, 2018).

Insufficient teacher training

Numerous sources underline that teachers did not receive sufficient training to apply the curriculum's envisioned learning style as intended (Ondimu, 2018; Muthama, 2022; M'mbogo Akala, 2021). Thus, numerous concerns and insecurities related to the inquiry based approach and the expected way of teaching raised among teachers after the CBC pilot (Ministery of Education Kenya, 2018). According to Ondimu (2018), research in neighbouring countries shows teachers are generally not aware of the objectives of a Competency-Based-Curriculum, and lack understanding and support on how to implement the learning approach in their lessons. As a consequence of insufficient teacher training, teachers would continue using "teacher-centered instructing methods ... against the demands of the ... CBC " (Ondimu, 2018).

> **"[The educational vision of the government] cannot be achieved if we cannot grasp the new transformative curriculum with new approaches of teaching."**

PhD. Charles Mogunde, 2022

The persistent singular-truth mindset

Mogunde describes a "conservative nature of teaching" (2022) of the Kenyan education system, where what the teacher says is correct. This was also observed in a practical science class, where learners were expected to exactly recite what the teacher was saying, with the whole class at the same time. Furthermore, during various practical sessions with primary school learners, they displayed a strong tendency to only give an answer when they were convinced it was the "right" answer. A session with teachers confirmed this view: when asked to start playing a game after a brief introduction, a teacher was hesitant to start without seeing an example first. He stated:

> **"How we teach is that we always first show how it is done before the learners have to do it."**

Mr. Daniel, Lamu primary school teacher, 2022

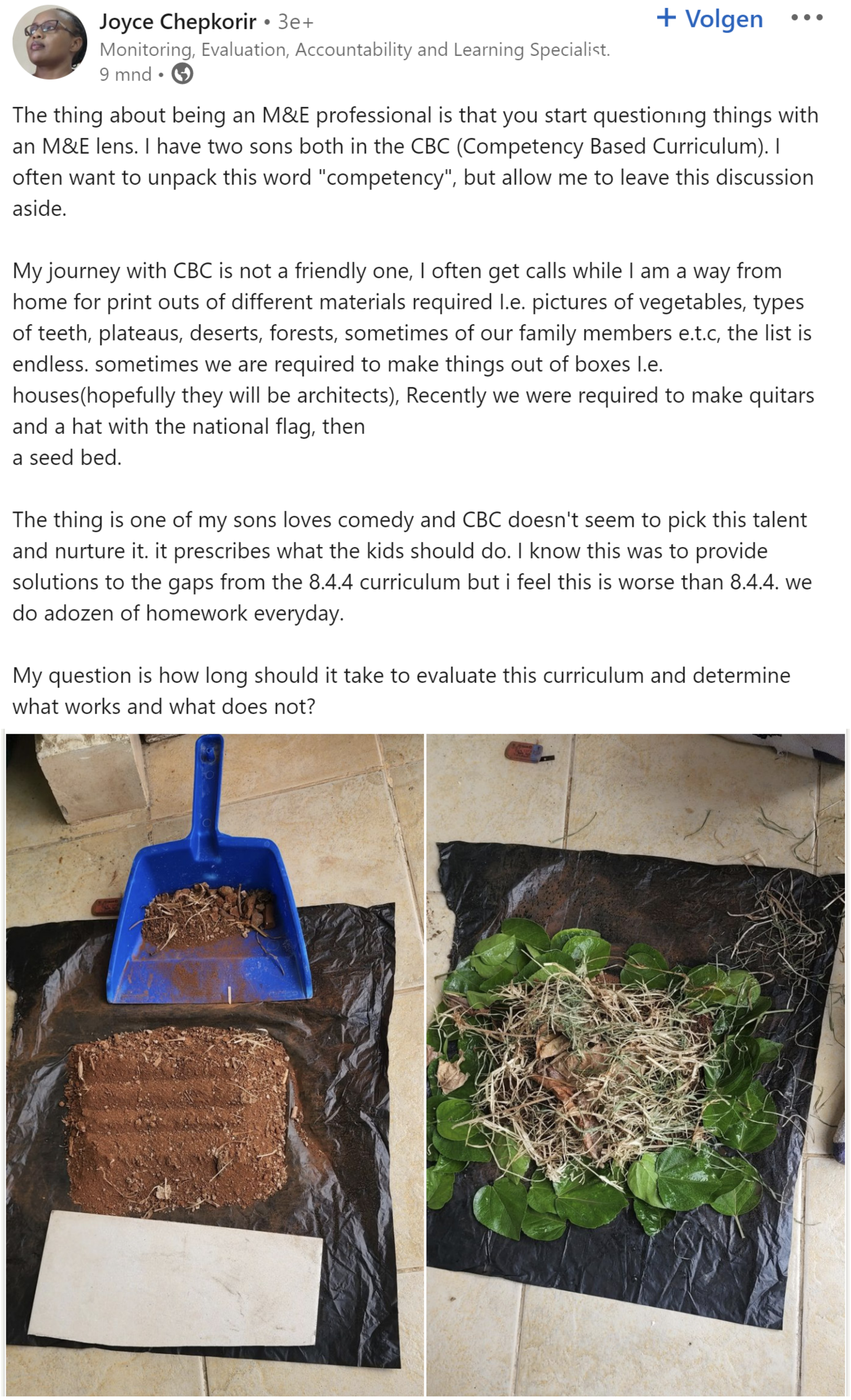
The same mindset was displayed by a Red Cross volunteer in his twenties, who stated that if he would give an inquiry-based class, he would end by inspecting what the children had built, to see whether they were built correctly. Then, he would "find the perfect one" (2022), present it to the class, and explain how to build it. This portrays a clear singular-truth mindset.

Free education, but scarcity of resources
The Competency-Based-Curriculum demands highly specific resource which are only required in specific classes, and are hard to acquire or too expensive for schools (Ndirangu et al., 2003), especially in rural areas (Muthama, 2020). An example was presented in *Figure 3* on *p. 46*. The resulting lack of experiential teaching resources has a direct negative impact on learners' performances (Wanjala & Malechwanzi, 2016). This was confirmed in a session with Lamu primary school teachers, who, when asked to envision extracurricular educational tools, mostly expressed a strong need for specific resources they would need in order to properly teach their regular classes. The reply that "a manageable group is about 4-5 learners per science kit" (Abubakar, 2022), when asked for an ideal amount of practical resources for a class, also portrayed the little resources available.

Improvisation pressurizes teachers and parents
Scarcity of resources has led to the necessity for teachers to improvise with locally available materials to develop their own experiential tools to teach with (Kipkosgei, 2021; Ndirangu et al., 2003), which is even reinforced within the syllabus (Kenya Institute of Curriculum Development, 2019). Although this approach might seem promising, numerous teachers are unwilling, unskilled, or simply too occupied with their job, and therefore cannot improvise in the classroom (Tsuma, 1998). Additionally, teachers are expected to ask parents for assistance in the acquisition of such local resources (Jane et al., 2020; M'mboga Akala, 2021). Managing this process demands a great deal of extra time and energy from teachers, which they do not have due to the big shortage of human resources in the Kenyan education system, and the poor teacher-learner ratio (The Africa Report, 2022; Makoba & Odhiambo, 2022). Especially because parents generally were not sensitized about this role, and thus remained reluctant to do so (Jane et al., 2020).

> **"The new curriculum has placed a burden on the parents. The items the learners keep asking for are so costly. [Furthermore] learners ... are given activities that are complex for their mental and physical abilities. ... Parents are at times forced to come in and do such activities for their young children. The academic activities are difficult to carry out for children whose parents did not receive formal education."**

PhD. Charles Mogunde, 2022



Joyce Chepkorir • 3e+
Monitoring, Evaluation, Accountability and Learning Specialist.
9 mnd •

The thing about being an M&E professional is that you start questioning things with an M&E lens. I have two sons both in the CBC (Competency Based Curriculum). I often want to unpack this word "competency", but allow me to leave this discussion aside.

My journey with CBC is not a friendly one, I often get calls while I am a way from home for print outs of different materials required I.e. pictures of vegetables, types of teeth, plateaus, deserts, forests, sometimes of our family members e.t.c, the list is endless. sometimes we are required to make things out of boxes I.e. houses(hopefully they will be architects), Recently we were required to make quitars and a hat with the national flag, then
a seed bed.

The thing is one of my sons loves comedy and CBC doesn't seem to pick this talent and nurture it. it prescribes what the kids should do. I know this was to provide solutions to the gaps from the 8.4.4 curriculum but i feel this is worse than 8.4.4. we do adozen of homework everyday.

My question is how long should it take to evaluate this curriculum and determine what works and what does not?

Figure 50: A parent unhappy with all effort required for the Competency-Based Curriculum in Kenya

Unsuitable facilities for digital devices

M'mboga Akala (2021) argues that there is a high risk for rural and poor schools to be left behind in the current wave of progress and innovation through the digital literacy curriculum due to challenging accessibility to technology. Although the four schools visited in Lamu during this research did have electricity, only some had a small amount tablets or computers. Furthermore as Muthama (2022) underlines, it was observed that most schools in rural areas have no, limited or unreliable internet access, and "there is no technical maintenance to any available devices" (Muthama, 2022). The latter was also a prominent complaint in Njeru and Itegi's (2018) evaluation of the digital literacy program in a school where the program was only initiated a year ago, and now already 9/28 laptops were malfunctioning:

> **"We need funding for repairs and general maintenance of these [tablets]. Imagine a number of them, like three are not working and we do not know what to do about them."**
>
> *A primary school teacher, p. 23, 2018*

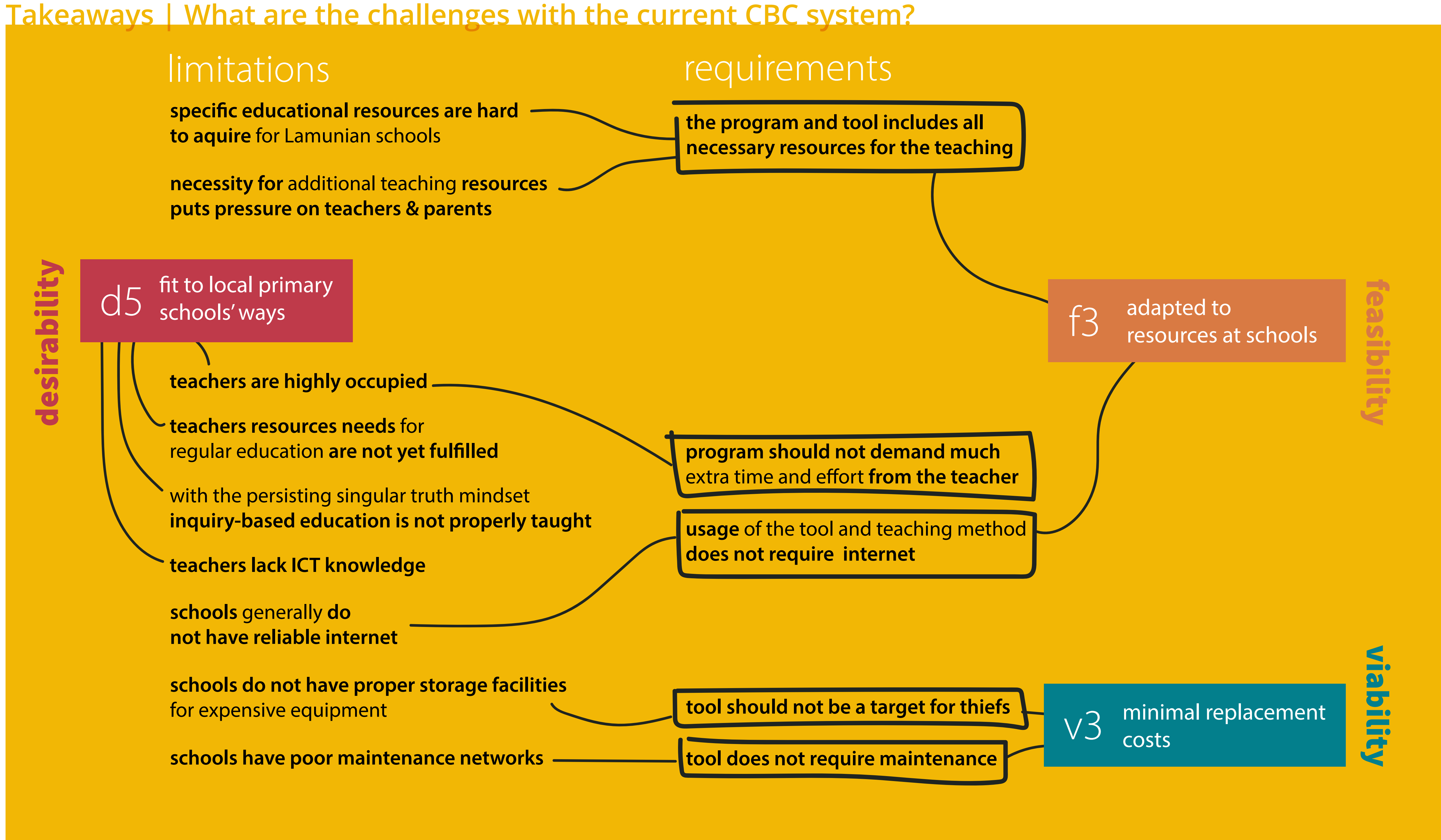
In some schools, inability to power the laptops has even led to abandonment of the digital literacy program (Otieno, 2018). Finally, numerous schools lack proper storage facilities, which leads to the fear that the expensive devices may get stolen (Njeru & Itegi, 2018), which is a valid risk knowing that hundreds of tablets were stolen from four schools in the same county in 2016 (The Daily Nation, 2022).

Lack of ICT knowledge among teachers

But even if the devices are working in schools, teachers lack the ICT knowledge to effectively integrate digital activities into their education: roughly 10-30% of teachers feel competent enough to handle the digital literacy program (Makoba & Odhiambo, 2022; Njeru & Itegi, 2018; Ondimu, 2018). As a result, the available digital resources remain underutilized (Makoba & Odhiambo, 2022), affecting learners' performance (Macharia, 2022). This was also reflected during a visit to primary school Wiyoni, where a teacher admitted their tablets were only occasionally used to display presentation slides. As the main cause, he pointed to the absence of a teacher with experience and knowledge on how to utilize the tablets to their fullest potential, as well as a lack of time and high threshold for inexperienced teachers to acquire this knowledge.

Figure 51: A teacher introducing tablets on a Kenyan school, by Njeru & Itegu

Takeaways | What are the challenges with the current CBC system?



limitations

requirements

specific educational resources are hard to aquire for Lamunian schools

necessity for additional teaching **resources puts pressure on teachers & parents**

the program and tool includes all necessary resources for the teaching

desirability

d5 fit to local primary schools' ways

f3 adapted to resources at schools

feasibility

teachers are highly occupied

teachers resources needs for regular education **are not yet fulfilled**

with the persisting singular truth mindset **inquiry-based education is not properly taught**

teachers lack ICT knowledge

schools generally **do not have reliable internet**

program should not demand much extra time and effort **from the teacher**

usage of the tool and teaching method **does not require internet**

schools do not have proper storage facilities for expensive equipment

schools have poor maintenance networks

tool should not be a target for thiefs

tool does not require maintenance

v3 minimal replacement costs

viability

9.4 | What is the potential for experiential STEM education?

Support of experiential learning

Although the implementation of CBC has been facing numerous challenges, all teachers who have been consulted during this research believe the practical classes are highly important for the learners' understanding and mental health . A reflection after the 2018 CBC pilot supports this positive attitude towards a more inquiry-based and learner-led teaching style (Ministery of Education Kenya, 2018), and Mbwayo et al. state that with the CBC "children can excel in their areas of strength and reduce stress related to academic performance," (p.11, 2019).

Interest in STEM subjects

Throughout the numerous research activities conducted with Lamu learners, they showcased a clear enthusiasm in hands-on STEM education exercises (see *Figure 53*). In the generative session conducted with learners (*Figure 52*), as shown in *Figure 30* in the design research approach, it became apparent that practical classes are the things that vividly stick to the learners' memories. Furthermore, learners' interests seem to be especially sparked when a subject allowed them to understand themselves and their lives better (e.g. biology), or when their knowledge about a subject could empower them to help out other people (e.g. in healthcare). This interest aligns with the focus on societal problems within STEM education (see chapter 7), which in turn can also contribute to engaging both girls and boys, as girls showed a greater interest in social subjects.

Challenging the mindset can be done

Experiments to challenge the singular-truth mindset in Kenyan learners trough truly inquiry-based exercises with different levels of guidance revealed that the learners were highly inventive when properly guided. The necessity to gradually introduce more inquiry became clear, as learners got lost when not receiving any guidance, however, providing too much guidance resulted in little space for creativity. Through experimenting, the ideal amount of guidance seemed to be to give visual examples which showcase hints and empower learners in their own process of solving a challenge.

Figure 52: Learner in generative session actively writing about favourite subjects in school

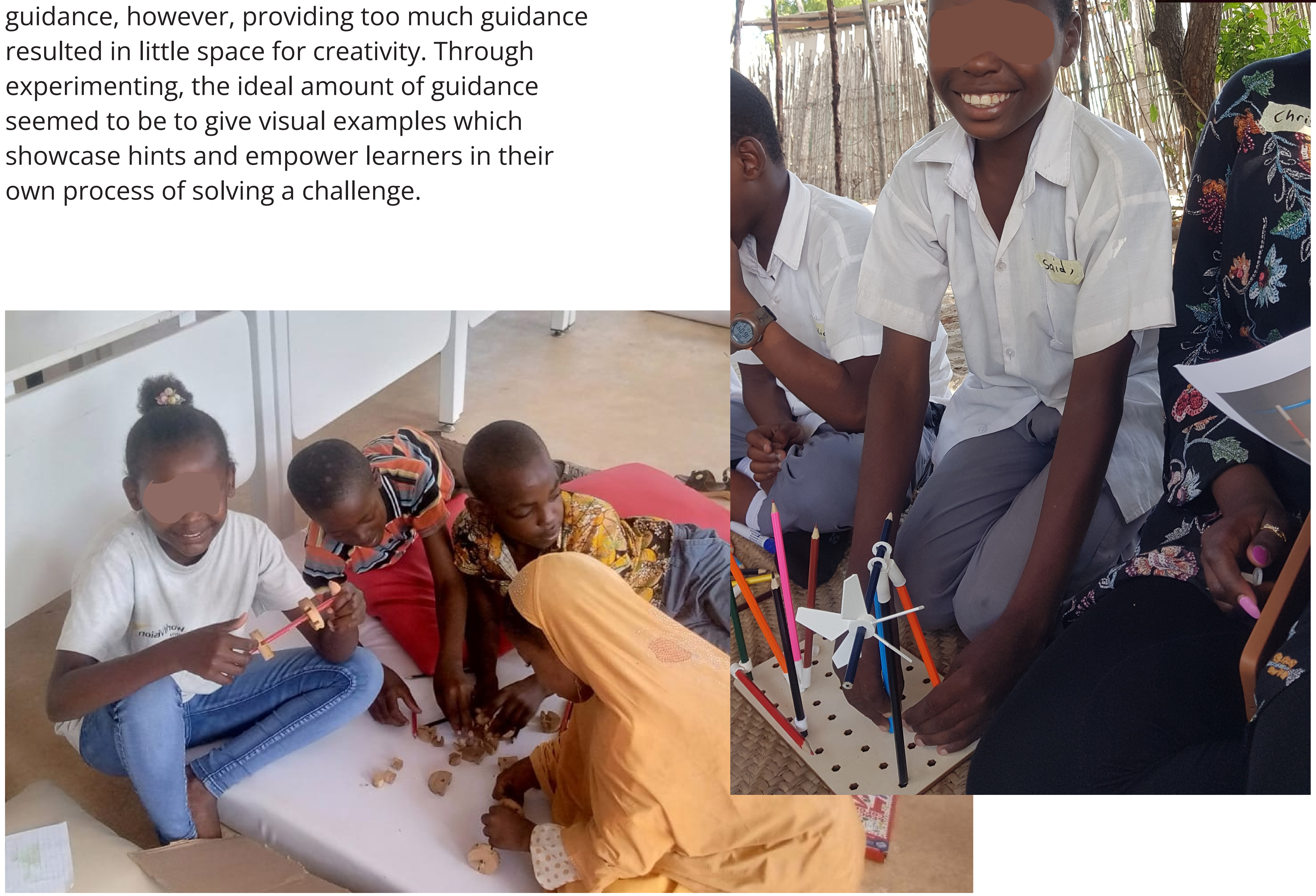


Figure 53: Learners proudly showing their work in progress

Infrastructure for extracurricular education

In Kenyan schools there is an infrastructure in place for extracurricular clubs, often set up by a teacher or organization, to engage learners voluntarily in a specific subjects. The clubs range from the nation-wide Amani club initiative, with its main goal to maintain peace and social cohesion (National Cohesion and Integration Commission, 2022), to clubs on a specific subject, such as the Science club from Mariam Abubakar. Numerous schools in Lamu even had Red Cross clubs, which organized activities around first aid and health education, however due to a lack of activities provided to the learners these have been inactive lately. However, there is an infrastructure in place, to revive a Red Cross club, as long as they are provided with enough activities. When intending to start a new club, Lamu teachers suggested to introduce the program in a regular class to all learners, after which the interested learners can decide to continue with the club's activities.

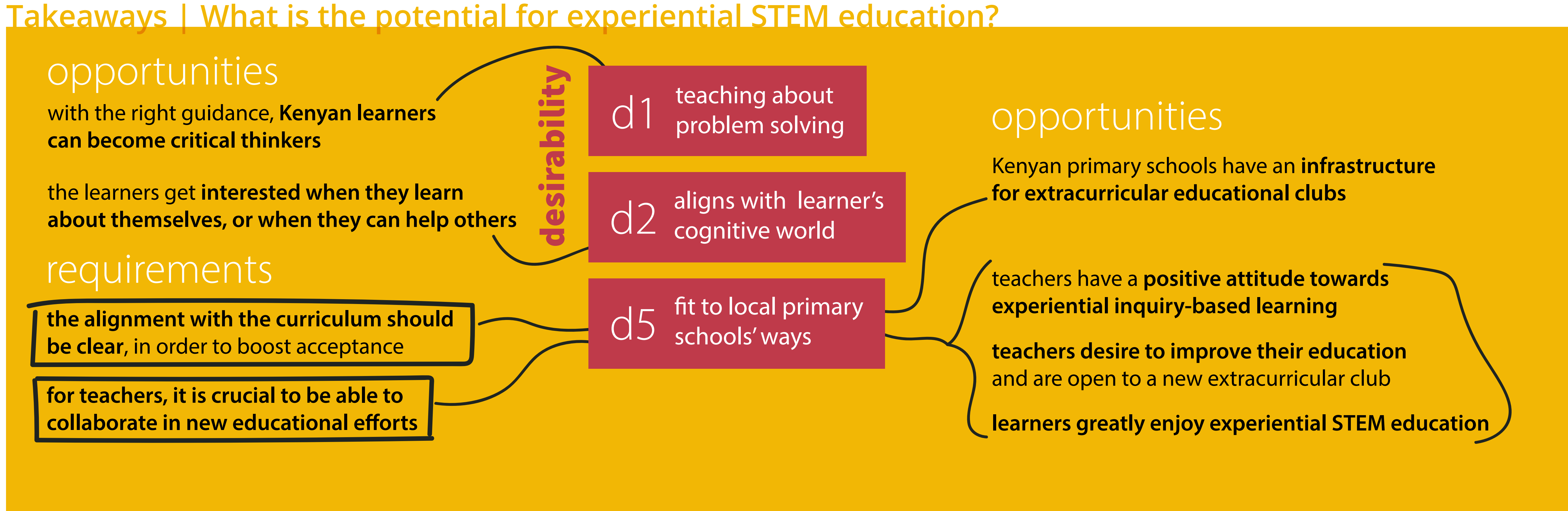
Desire for improvement

Furthermore, a certain willingness to improve the education within schools is portrayed by numerous teachers in the way they have been actively invested into this graduation research, and have opened the doors of their schools for several participatory sessions. The teachers expressed to be open to the initiative of a new extracurricular program, however they believe it is crucial to be able to collaborate with IOMe005's innovators in the program:

> **"If it depends on the volunteers only, the project will fail"**
>
> *Mariam Abubakar, 2022*

Finally in Mariam's experience, who has been attempting to introduce new experiential STEM tools herself, it is especially important to point out the alignment of the newly introduced tool with the curriculum, as this will boost acceptance within schools and government.

Takeaways | What is the potential for experiential STEM education?



opportunities

with the right guidance, **Kenyan learners can become critical thinkers**

the learners get **interested when they learn about themselves, or when they can help others**

requirements

the alignment with the curriculum should be clear, in order to boost acceptance

for teachers, it is crucial to be able to collaborate in new educational efforts

desirability

d1 teaching about problem solving

d2 aligns with learner's cognitive world

d5 fit to local primary schools' ways

opportunities

Kenyan primary schools have an **infrastructure for extracurricular educational clubs**

teachers have a **positive attitude towards experiential inquiry-based learning**

teachers desire to improve their education and are open to a new extracurricular club

learners greatly enjoy experiential STEM education

10 | IOMe005 and its innovators

In this chapter, the IOMe005 organization and its people will be further explored, because the *innovators* within IOMe005 will be the people bringing the education to schools. It will start with main information about the Red Cross and IOMe005 organizations, after which insights about the innovators at IOMe005 follow. These insights were gained throughout half a year of collaboration with the IOMe005 team and its *innovators*.

desirability

d3 aligns with *innovator's* motivations

d4 teaching aligns with IOMe's core values

d7 fit with local ways

viability

v4 educational program is scalable

feasibility

f1 produceable in-house at IOMe

f2 *innovators* can facilitate lessons

f3 adapted to resources at schools

f4 fit to *innovators'* ways and capabilities

f7 program can be facilitated by *innovators*

f8 manual enables *innovators* to develop program further

10.1 | About IOMe005

KRCS and its link with IOMe005

Kenya Red Cross Society, who set up IOMe005, usually focuses on distributing food, medicines and basic necessities, educating about health risks and mitigation strategies, and providing emergency aid in situations such as droughts or floods. The facility of IOMe005 is located on Red Cross property, and IOMe005 uses KRCS facilities for transport.

Figure 54: From left to right: an innovator, lab facilitator Nassor, a second innovator, and lab facilitator Emmanuel, at IOMe005

The people at IOMe005

The IOMe005 team consists of the lead Derrick Mugasia, supported by lab facilitators Nassor Abdalla and Emmanuel Mutisya, whose main work is to keep the lab running and facilitate all activities (see *Figure 55*). Most activities at IOMe005 are focussed on, or supported by, the innovators, who are youth roughly between 16 and 30 who come to IOMe005 to work on a broad range of skills. Innovators often initially come to improve their digital literacy, after which the lab facilitators try to get them interested in learning about other subjects such as design thinking and advanced technologies.

Figure 55: IOMe005's lead Derrick in his office

The prior knowledge and experience of people coming in at IOMe005 differs greatly, from teens just coming from high school, to locals planning to start their own business. Because innovators tend to remain only for limited time periods of about 6-12 months at IOMe005, the team is constantly recruiting new innovators to support the programs within the Lab.

IOMe005's main activities

The main activities organized by the IOMe005 team can be roughly divided in three categories:

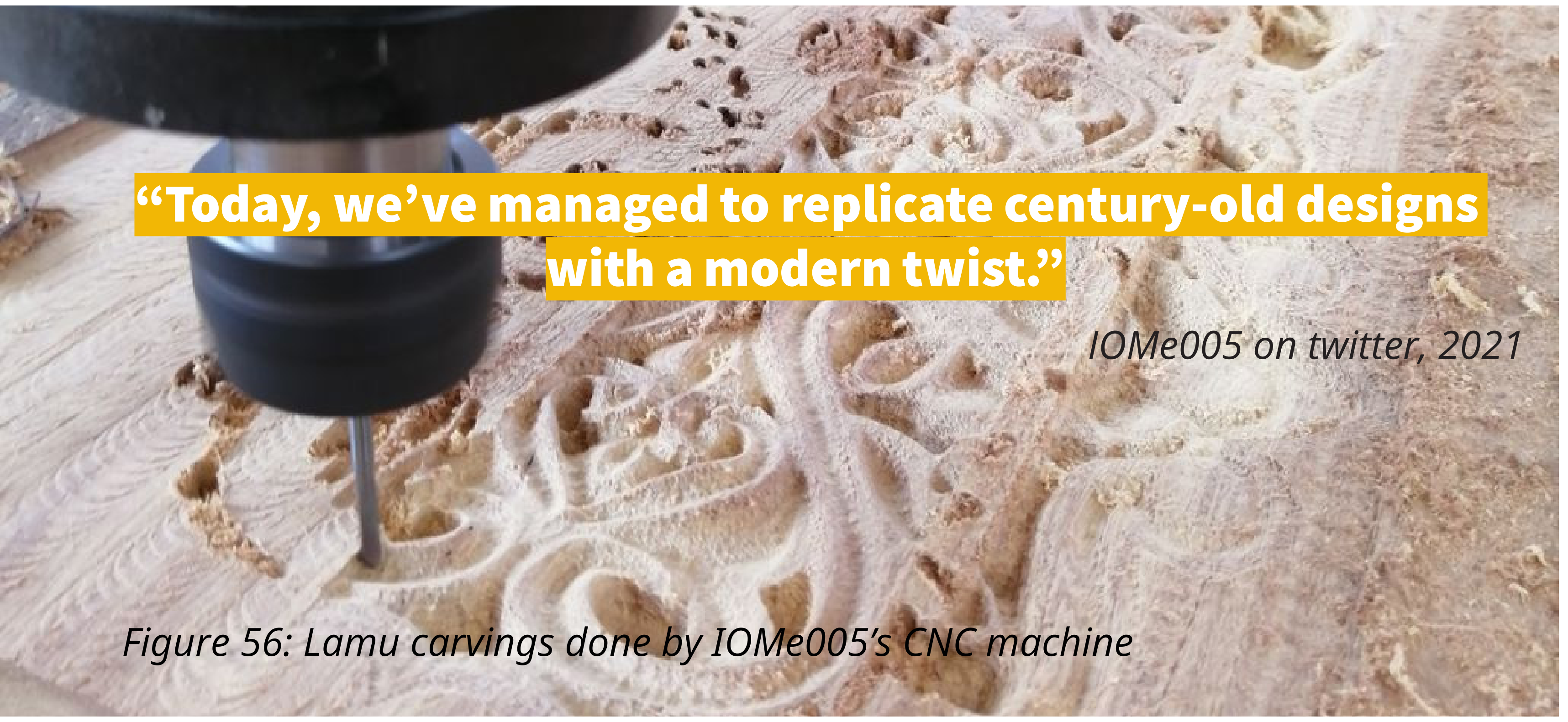
- In-house education programs for innovators & local parties
    - Digital literacy
    - Leadership & innovation
    - Prototyping & production techniques
    - Design thinking

- Supporting ideas of innovators
    - Guiding the design process
    - Financial contributions to innovative projects
    - Providing knowledge on marketing of produced items

- Acquisition
    - Reaching out to potential partners
    - Production of small batches of items to generate income

IOMe005's way of working

Generally at IOMe005, it is of high importance to stimulate collaboration between everyone who works there, and outside visitors, in order to benefit from everyone's knowledge. When teaching, IOMe005 always needs to accommodate for little prior knowledge of innovators and other learners, which is done by starting at a basic entry level and slowly building up the knowledge. Finally, because Lamu is a place with rich history, IOMe005 always strives to connect to this history and the artisanal traditions by incorporating it in their work (see *Figure 56*), in this way integrating culture and tradition to meet modernisation.



> **"Today, we've managed to replicate century-old designs with a modern twist."**
>
> *IOMe005 on twitter, 2021*

Figure 56: Lamu carvings done by IOMe005's CNC machine

Personal projects of innovators

In order for innovators to learn a targeted skill, such as 3D modelling, the lab facilitators strive to put them to work in existing client projects, or help them come up with their own projects. In innovator's personal projects, the lab facilitators urge the innovators to envision a clear end goal, target market and user in mind, and think through the future viability of their ideas, before they start producing it. Also, they aim to encourage innovators to take ownership of all aspects of their learning, including the planning and contact with clients.

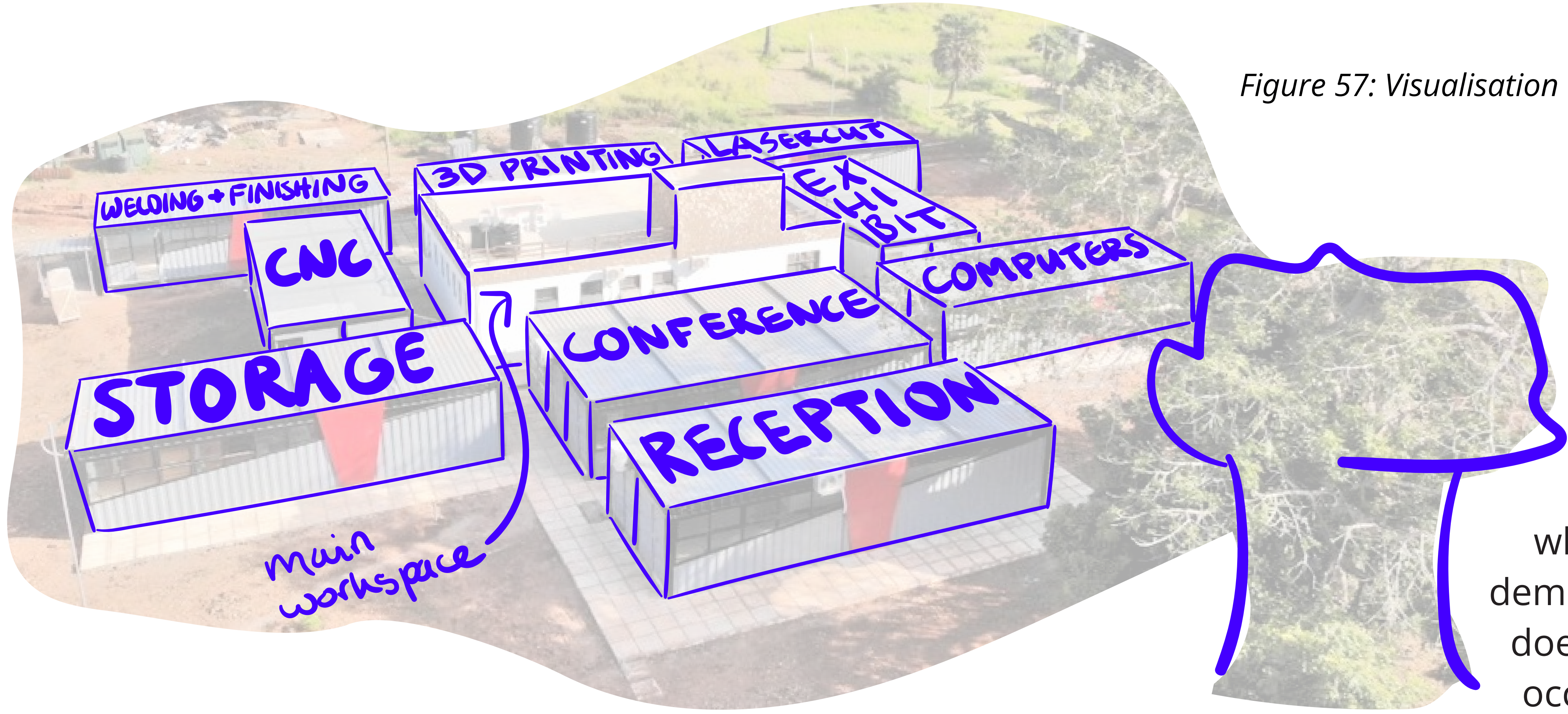


Figure 57: Visualisation of the facilities at IOMe005

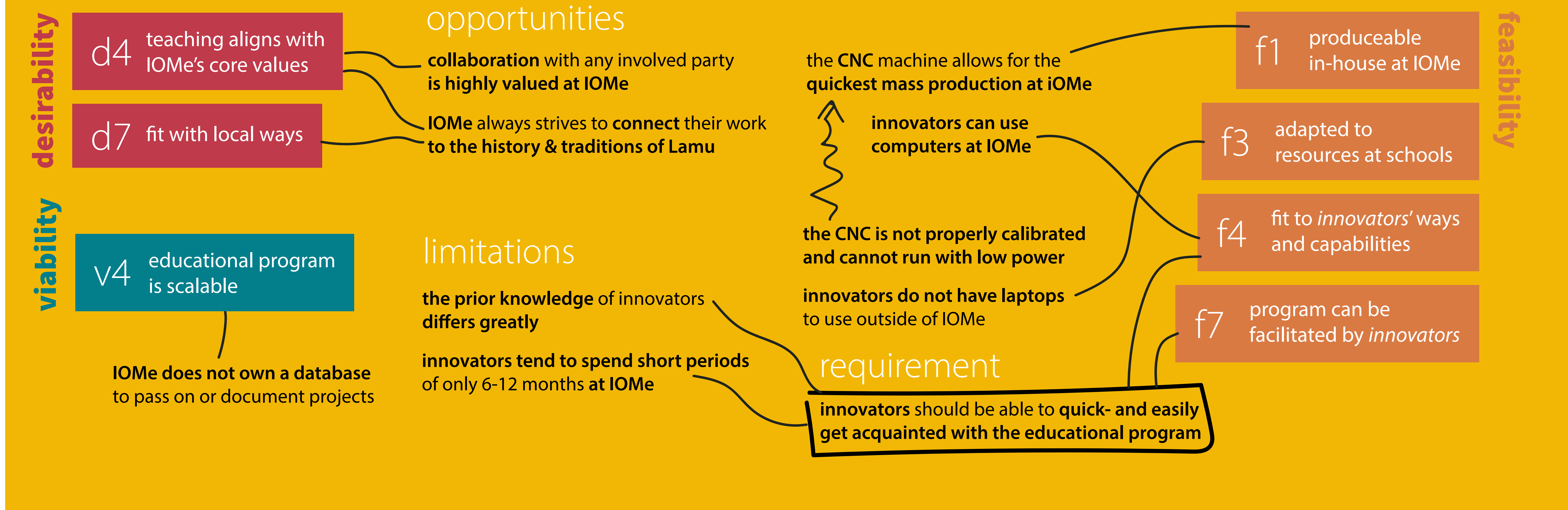
Passing on projects

Due to the dynamic nature of a fabrication lab, where multiple events and projects are run alongside each other and unexpected last-minute jobs can sometimes interfere with the planning, the focus of the IOMe005 team and innovators at IOMe005 continuously changes. However, there is no clear database within the IOMe005 organization to keep track of current projects, or document and showcase past projects, which makes building on prior knowledge challenging. Especially because innovators tend to spend short periods of time at IOMe005.

Resources available at IOMe005

As visualised in *Figure 57*, the IOMe005 facility contains of CNC, welding, finishing, 3D printing and laser cutting production facilities. Besides this, the Red Cross buildings on the same site contain printers to print on paper. The CNC allows for quick mass production, however when prototyping, finding the right cutting settings demands trial and error as the machine the machine does not get properly calibrated. Furthermore occasionally the area experiences low power, which makes the big CNC machine unusable while 3D printing and laser cutting is still possible. There are numerous computers with internet available for the innovators, who generally do not own a personal laptop. The facility also contains a storage container, however, due to the big changes in temperature and humidity over the seasons, storing materials is challenging. Therefore when materials are needed, generally a motorcycle driver is arranged and paid to buy the specific resource. Due to the rural location, there is limited choice in resources to prototype with.

Takeaways | About IOMe005



desirability

d4 teaching aligns with IOMe's core values

d7 fit with local ways

viability

v4 educational program is scalable

opportunities

collaboration with any involved party **is highly valued at IOMe**

IOMe always strives to **connect** their work **to the history & traditions of Lamu**

the **CNC** machine allows for the **quickest mass production at iOMe**

innovators can use computers at IOMe

limitations

IOMe does not own a database to pass on or document projects

the prior knowledge of innovators **differs greatly**

innovators tend to spend short periods of only 6-12 months **at IOMe**

the CNC is not properly calibrated and cannot run with low power

innovators do not have laptops to use outside of IOMe

requirement

innovators should be able to **quick- and easily get acquainted with the educational program**

feasibility

f1 produceable in-house at IOMe

f3 adapted to resources at schools

f4 fit to *innovators'* ways and capabilities

f7 program can be facilitated by *innovators*

10.1 | Who are the innovators?

Who are they?
Most innovators are young people who live relatively close to IOMe005, often on the mainland, and just come from high school. They visit IOMe005 daily for a short-term period of half a year to a year, to gain new skills which help them in their further education which they generally aim to start with after this period. However, there are also some innovators who live on Lamu Island and travel to IOMe005 to use the available tools for the production of items they wish to sell within their small businesses on the island.

Motivations of innovators
In general, innovators initially want to learn digital literacy because they see value in this skill in their lives and future career opportunities. However, these people are often eager to learn other skills and gain experience which can help them in the future. Therefore the IOMe005 team attempts to interest them in more advanced skills after this basic training. However, sometimes innovators only see the real value in what they have learnt, after they complete a certain project, which is why generally lab facilitators have to play an active role to keep encouraging the innovators throughout the projects they take on.

Capabilities of innovators
Due to the range of age and prior experiences, the innovators have different skillsets. Some of them are experienced in Lamu crafts or making arts, while others are already experienced with advanced machines. Because they spend an intensive period of time at IOMe005, they clearly support the values and way of working of IOMe005. They are learning to develop digital skills and think critically about their designs. Innovators generally acquire new skills by looking at video tutorials, where they highly appreciate the way such videos clearly explain the exact necessary steps to take.

Challenges for innovators
Their level of English is generally below average, and they are most comfortable discussing in Kiswahili. In briefings for pilot lessons conducted with the innovators, it became clear that generally they experience difficulties when working with a manual which consists of big amounts of English textual instructions. Lab facilitator Emmanuel even explained that he never reads any manuals, he just tries things out himself. Additionally, although the IOMe005 team encourages innovation, often at IOMe005 items are made based on templates found on the internet, because they are still learning and developing their design skills. Finally, because they are still learning how to use the computer, they generally need a bit of time to get used to new computer programs.

Figure 58: IOMe005's current innovators at the tree next to the facility. Together with Nassor (lower left corner), Emmanuel (upper right corner) and Emma (lower right corner)

Takeaways | Who are the innovators?

desirability

d3 aligns with *innovator's* motivations

d4 teaching aligns with IOMe's core values

opportunities

innovators come to IOMe to learn digital skills **to improve future opportunities**

innovators clearly **understand core values of IOMe**

innovators often acquire new **skills through video tutorials**

feasibility

f2 *innovators* can facilitate lessons

f4 fit to *innovators'* ways and capabilities

limitations

the prior knowledge of innovators **differs greatly**

innovators are still developing their computer & design skills

innovators have difficulties with reading big amounts of text

innovators' level of **English is low to average**

11 | Bridging cultures

Now we know there is a big discrepancy between the Dutch and Kenyan culture involved in this graduation project. We have also learnt that innovators, who will be expected to facilitate the educational program, could be viewed as semi-literate in digital and English literacy. Therefore, some general guidelines to design information and interfaces across cultures, and for semi-literate people, can help to make sure the information comes across to the targeted audience.

LANGUAGE

- Use simple language
- Write in the local language
- Use meaningful text headers
- Use short sentences and short paragraphs
- Use bulleted lists and tables
- Use “you” and other pronouns

VISUALS

- Minimize written language
- Use icons, images, and videos
- Use the right metaphor for icons
- Use simple, clear, culturally relevant images
- Ensure consistency of design elements

LOCALIZATION

- Use local phrases, images, and actors
- Mirror the actual application environment
- Offer linear navigation
- Use a flat structure
- Avoid placing key information on the far left or far right

MULTI-MODAL INTERFACES

- Use multiple media (text, audio, images & video)
- Use audio for non-literate people
- Use slow, clear, loud-enough speech for audio
- Use subtitles with video and audio content

INSTRUCTIONS & TOLERANCE FOR ERROR

- Clearly define content purpose
- Include help on how to use the content
- Make sure every part can stand on its own
- Minimize consequences of unintended use
- Make the interface forgiving

GENDER INCLUSIVITY

- Be inclusive of women, but also target men

Sources: Digitalgov & Walsh (2022); University of Washington (2021); Lombardo & Akpem (2022); UNESCO (2018); Jan et al. (2019)

Takeaways | Bridging between cultures

requirements
guidelines to bridge cultures

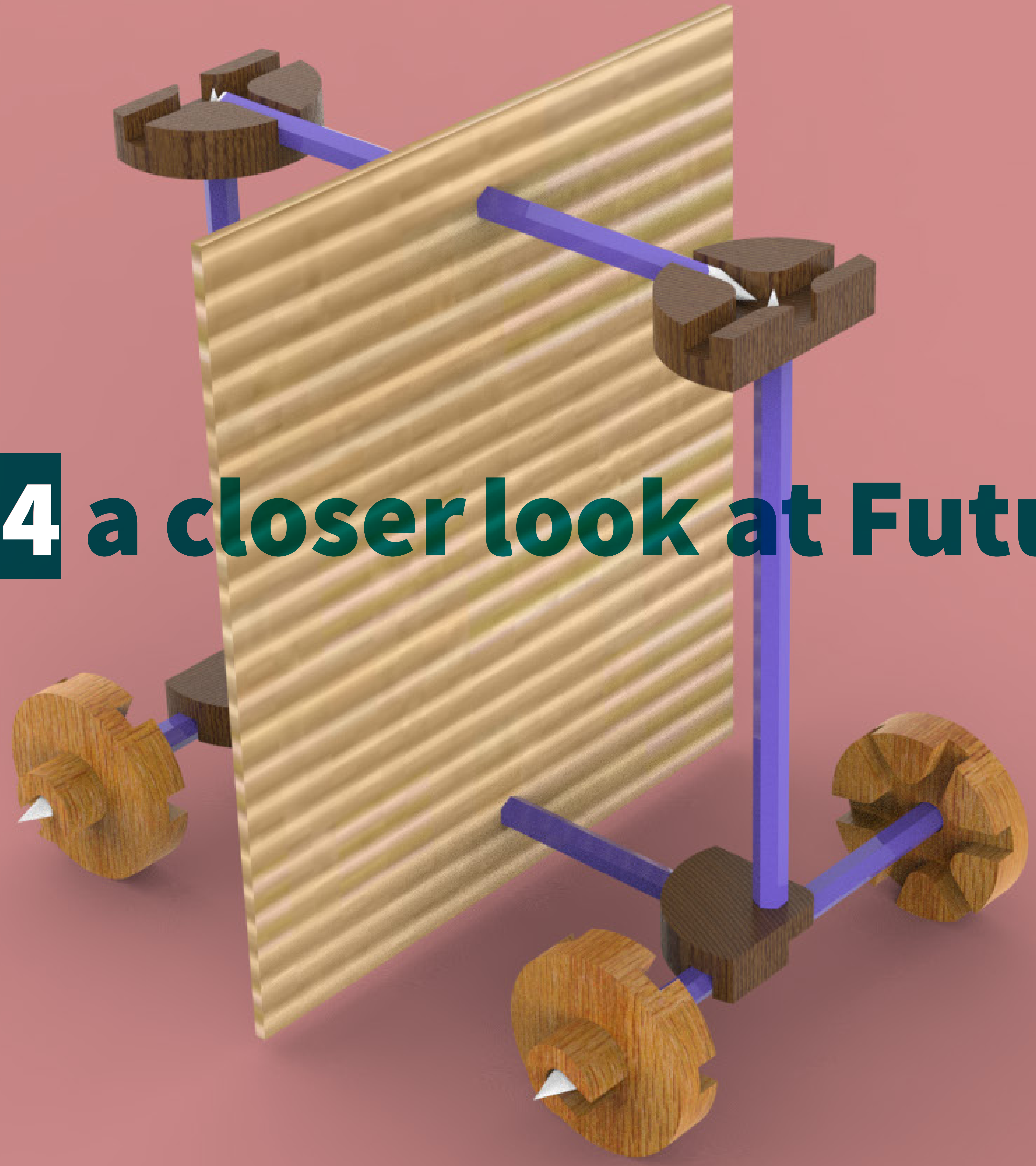
use simple language
make the layout readable
use simple, consistent & clear visuals
localise content to fit the target user
make sure presentation of content is close to real-life application

choose the right delivey channel
use multimodal interfaces
build-in instructions
build in a tolerance for error
make sure content is gender inclusive

f4 fit to *innovators'* ways and capabilities

feasibility

PART 4 a closer look at Future Inventors



Now we have a broad understanding of the design context, its limitations and opportunities, the next part will finish the design process. First, the iterative design synthesis process will be presented. Then, the final design and all its details, together with an advice for next steps of implementation will be presented. Finally, the design will be evaluated on feasibility, viability & desirability by using the design criteria which were developed in “PART 3 | design research”.

Render by Kennedy Birya, innovator at IOMe005

12 | Design iterations

The following pages will reveal the route that was taken to come to the final design, per aspect of the design. For the main prototypes and user evaluations, clarity is given on the why, the value, learnings and next steps. Then, a final evaluation, guiding a team of innovators to facilitate a workshop for upper primary school learners at IOMe005 will provide final insights.

12.1 | ThinkBricks

1 first functional prototypes

- Rapid prototypes early in process to start giving tool a shape
- Focus on teaching about wind energy to come to concrete ideas
- Intention to design a tool which allows for big freedom to build
- Physics mechanisms incorporated into the design
- Aim for “functioning“ design for learners to experience STEM

Figure 59: First functional prototypes of the tangible tool

how was it evaluated?

Through an **iterative process**, the prototypes were rapidly **judged on functionality**, after which the next iteration was made.

2 3D printed building kit

- Small 3D printed parts which can connect to pencils
- Broad freedom to build, e.g. wind turbines and cars
- Can make functioning prototypes, for example turning windmill
- Was selected to test with learners in Lamu

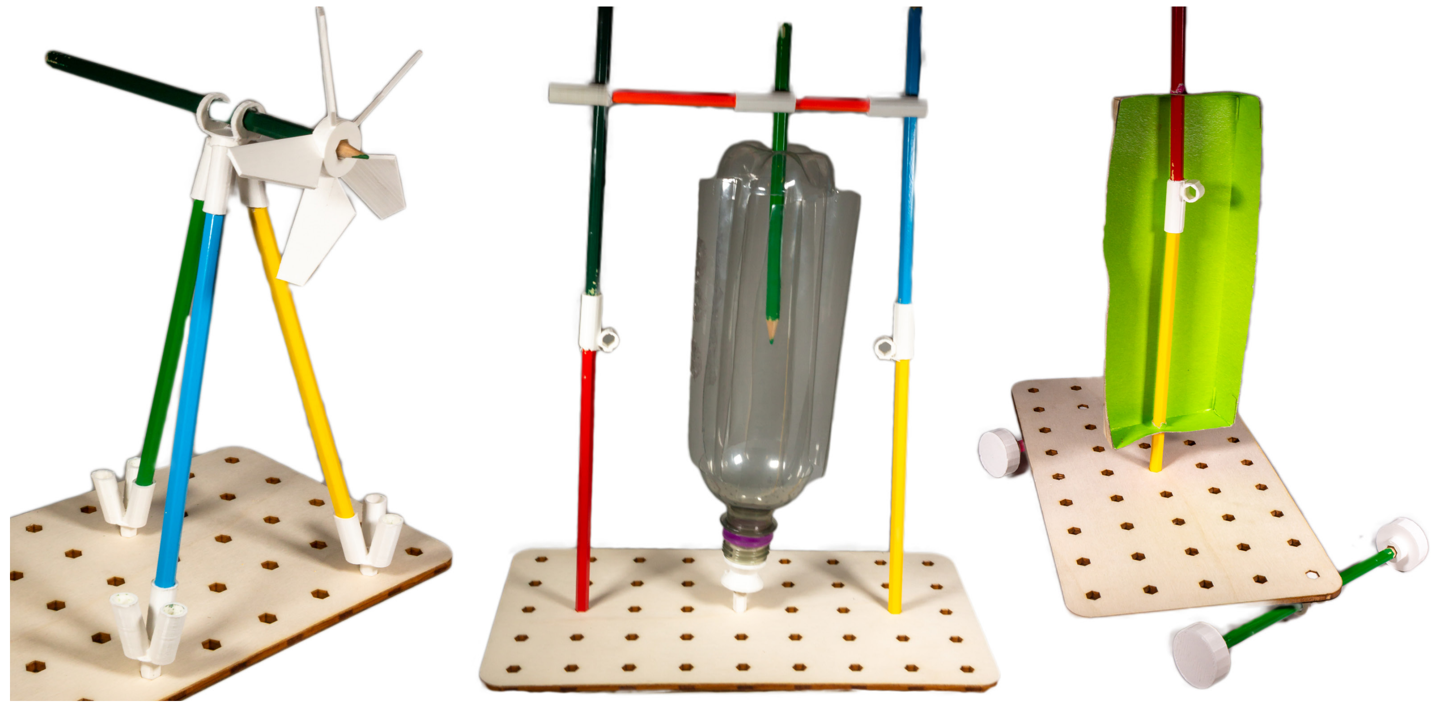


Figure 60: 3D printed building kit prototype

how was it evaluated?

Several sessions were conducted with learners on a mixed primary school in Lamu to evaluate how learners reacted to the prototype.

main learnings

plus

Learners greatly enjoyed the building activity

minus

- Learners needed examples, so building was not intuitive
- Learners disliked the plastic
- Things that were built remained fragile due to the weak connections
- The building plate limited freedom
- The small parts easily got lost
- Quickly broke due to the thin plastic
- Fabricating is highly time consuming

3 wooden building kit

- CNC wooden blocks with the same main functionalities as prototype 2

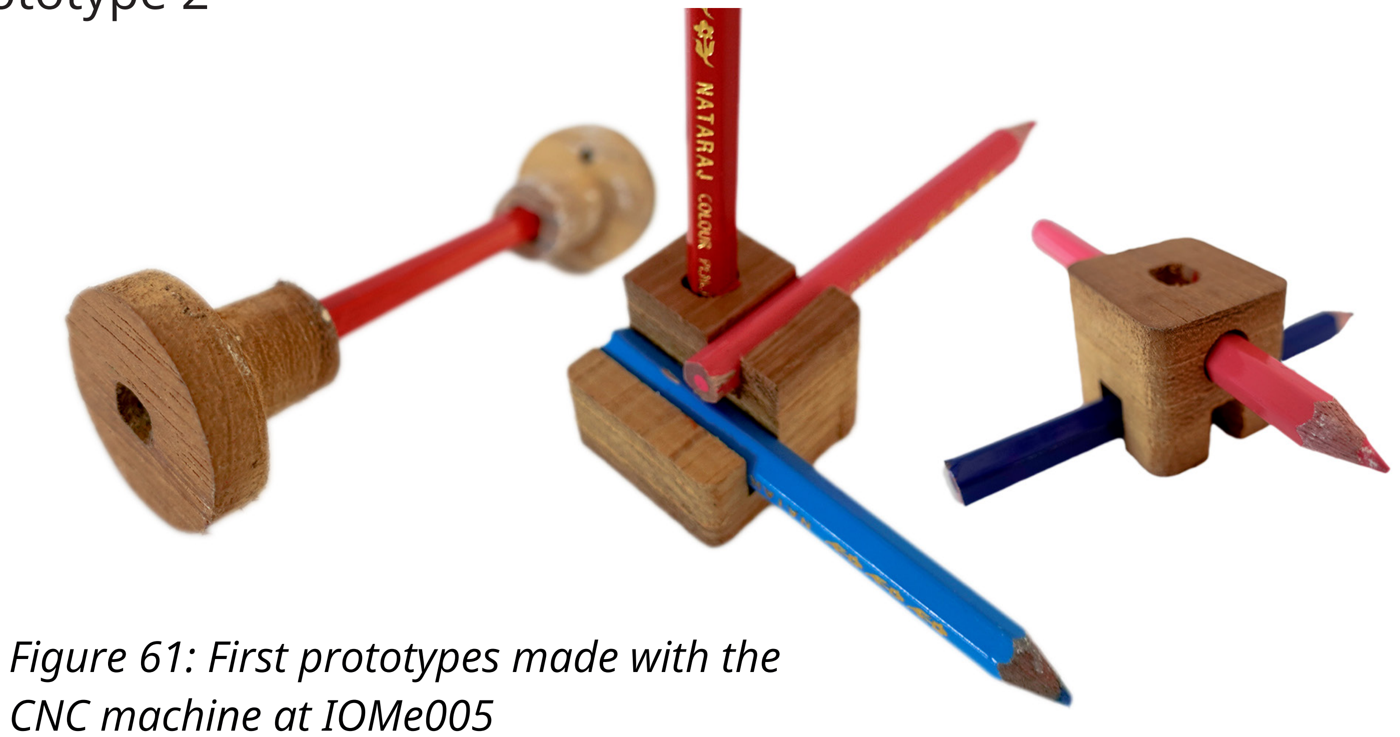


Figure 61: First prototypes made with the CNC machine at IOMe005

how was it evaluated?

Innovators at IOMe005, and **Red Cross volunteers & teachers** on Lamu island, were asked to build with and **evaluate the prototype**.

main learnings

minus

The blocks still were not yet intuitive, as building did not go as smooth as intended

plus

+ The parts were robust and the size was positively judged
+ The blocks sparked ideas for the teachers to build set-ups to support their current education

what were the next steps?

Although the **material greatly improved the perceived value** of the prototype, one **final iteration step** in Lamu, starting with **clay prototypes**, and some iterative cycles together with the IOMe005 team was necessary to **come to the final shapes**.

Figure 62: Clay prototypes

12.2 | Challenge-based workshop

This sub-chapter contains the iterative process to find a teaching methodology which fits the learners, as well as the way of teaching of innovators. Every step represents a separate test session.

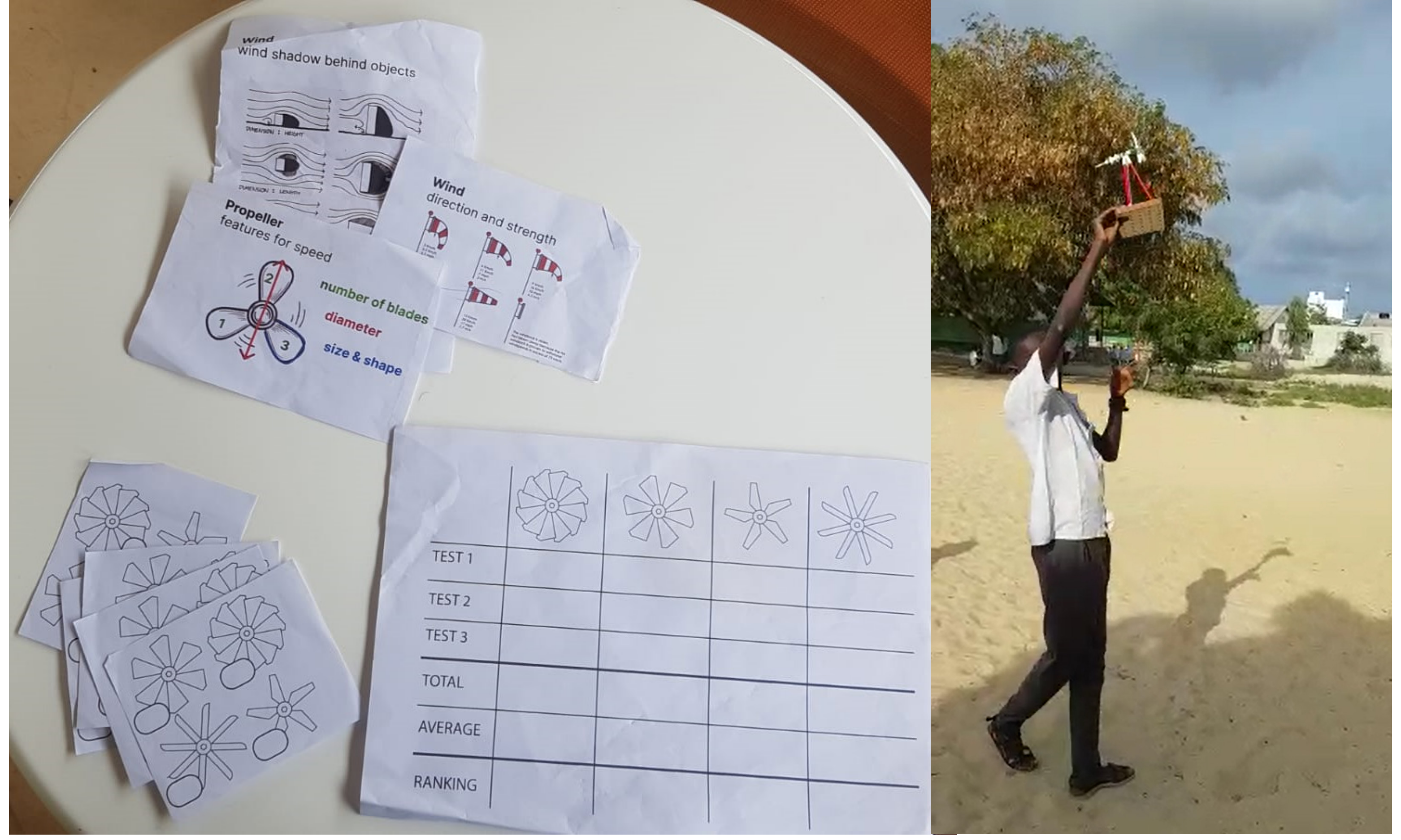


Figure 64: Educational materials presented to learners (knowledge cards, prediction cards & measurements log sheet), and learner trying to let wind turbine turn

Figure 65: Anonimised learners proudly presenting their own created wind turbines, with volunteer Hashim at the right side of the photo

Figure 63: Learners engaged in brainstorming after building wind turbines according to photo examples (see bottom of the image)

1 brainstorming & building

As a first test of a teaching method, the 3D printed prototype (see last page) was given to upper primary learners.

goal

Learn about their prior STEM knowledge, see how they take on brainstorming, and find out how much guidance they require in the building

outcome

Although learners enjoyed the building, they needed quite some examples they did not seem to be actively problem solving

2 incorporating scientific knowledge

goal

Test out different ways of learning to see how the learners can work more scientific. This is done by letting learners explain concepts to peers through "knowledge cards", predict the most efficient windmill, and scientifically research their prediction.

outcome

It became clear that due to the unpredictable nature of the context (and weather), and low resource setting, the measuring was not doable. Thus it was decided to focus more on problem solving in the next iterations, and less on specific STEM knowledge.

3 whole design process

In this test, Red Cross volunteer and engineer Hashim (see *Figure 65*) was guided into facilitating a class where he took the learners through a design process to create wind turbines with locally available resources.

goal

See how learners react on a design process, and how the facilitator takes up this task.

outcome

The learners were actively engaged and the freedom given to them led to clear problem-solving behaviour. However, a full design process was too much to take on in just one lesson. The process should be simplified in the next iteration.

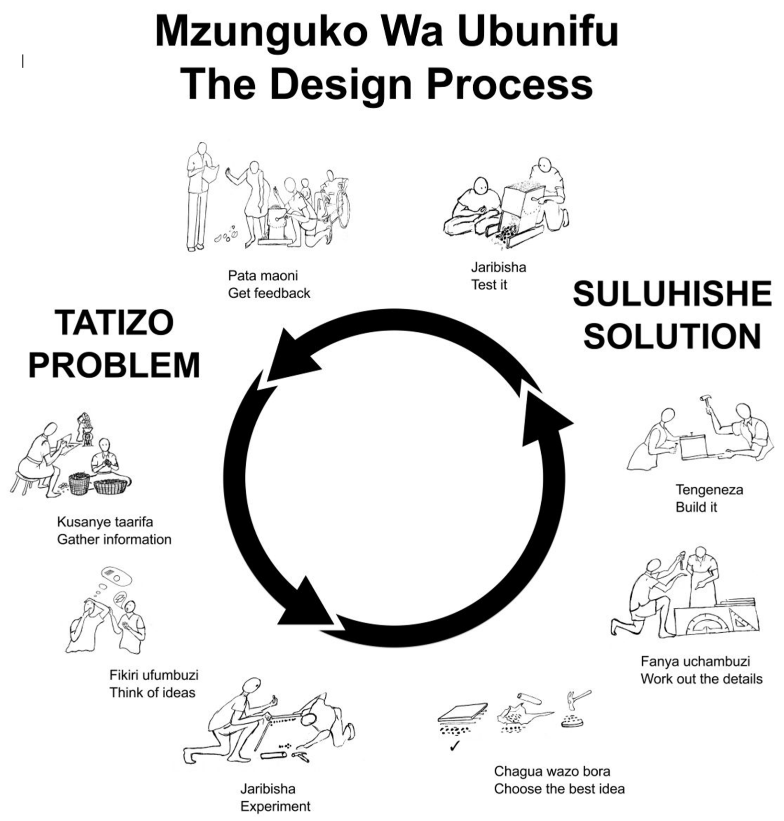


Figure 66: The design process in Kiswahili and English, as presented to Hashim

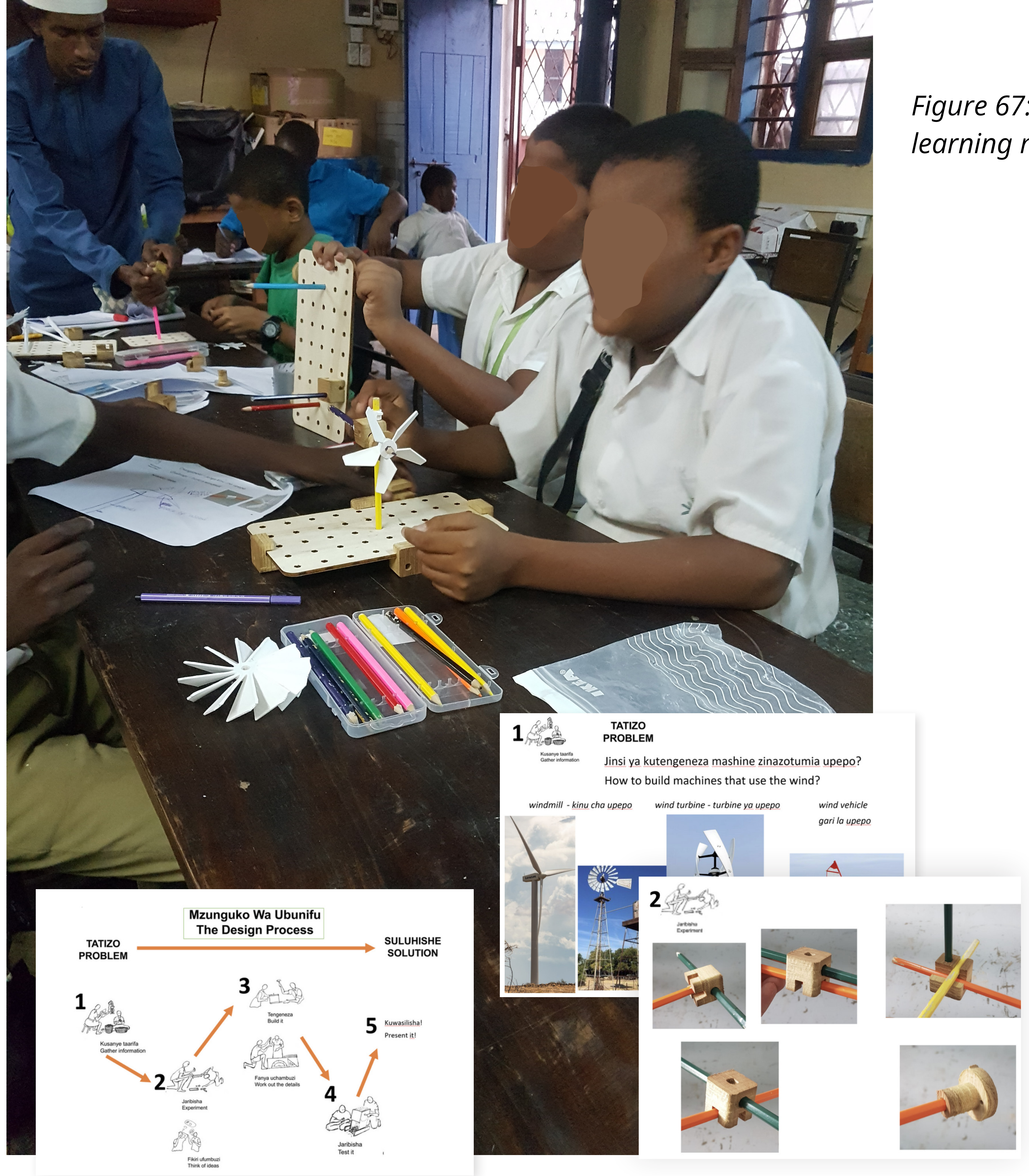


Figure 67: Hashim (upper left corner) facilitating a workshop, with the learning materials which overlay the image

plus

The teaching methodology taught the learners to think outside of the box:

> **"I learn that the pencils can be used to help in other areas not only drawing. "**
>
> *Innovator who was a learner*

4 simplified design process

goal

Test whether a simplified version of the design process is easier to guide for the facilitator and leads to more accomplishment. At the same time testing whether a small amount of guidance is sufficient.

outcome

The facilitator managed the process really well, and the real-life examples guided the learners well enough to all make something that works. However, still it was a bit too much at the same time to go from nothing to a "full design"

plus

To Nassor it is not even just a kids workshop, it can also be an adult workshop

Figure 68: Facilitation at IOMe005 of the first remote workshop where innovators made wind cars, as shown in picture on the right.

5 the workshop model

This first remotely organized test was prepared in advance and sent to the innovators through a written manual (see notion manual on next page). The innovators then prepared the workshop and facilitated it with other IOMe005 innovators as learners. This workshop focused on making a car which can be moved by the wind.

goal

Find out how the innovators deal with facilitating a structured workshop, which has three parts, starting with Inspire, Engage, and Reflect (as explained in chapter 7), and focusses on a smaller part of the design engineering process.

outcome

plus

It was a learning experience for the innovators, and it made them excited to start facilitating such sessions for primary school learners.

> **"Here with the students we learnt something. Going outside, we would learn more. You gain courage and learn how to control some people and how to control the learners, gaining their trust, what are you supposed to say, what not. How you are supposed to handle and guide them."**
>
> *Innovator who was a facilitator*

interesting

Time was limited, so still the process expected from the learners should be further condensed to only one part of the full process

Naturally, **each innovator took one part to facilitate**, to first gain confidence in this part

interesting

12.3 | Future Inventors manual

In this sub-chapter is presented which channels were explored to guide the innovators in the preparation of the facilitation.

1 Notion

- Workshop plan is already developed for the innovators
- Notion software is clean and user friendly once it is set up
- Incorporation of videos and visuals in explanation part for more clarity
- Plan comes with to-do list to prepare the class

TEST WORKSHOP - Wind car

← BACK TO MAIN PAGE

▾ Workshop purpose

The **purpose** of a workshop is what we want learners to learn or experience. This is connected to the **main activity**, which is how the learners will achieve this.

What is the purpose of this workshop?

A first attempt to design a workshop with a Challenge-Based-Learning (CBL) approach, and let learners experience building with the ThinkBricks for the first time.

What is the main activity of this workshop?

Letting learners **build a car that can be moved by using the wind.**

This is relevant to the future inventors program because wind will be one of the energy sources that is increasingly important in the future.

▾ Skills

Every workshop also has a goal for which **skills** to teach the learners.

Soft skill	Hard skill	Knowledge
SCAMPER	Building / constructing	Friction & energy
	Making a building plan	Renewable energy

▸ Challenge

"It is the year 2100 and fuel is getting enormously expensive. Therefore a switch to using natural resources to provide energy is necessary. In Lamu there is so much wind all year round, and therefore the government has decided to make wind the main source of energy for cars. Therefore you, a team of engineers, have been asked to design a wind car!"

RESTRICTIONS & REQUIREMENTS (e.g. time available / resources available / certain showcase / build plan)

- The car needs to be able to drive from A → B (two lines on the floor, spaced 4 metres apart) using only (self generated) wind (how to generate?)
- The car will have to be made from the provided ThinkBricks, which can be used together with pencils, cardboard and duct tape.
- They need to make a building plan (drawing of all components and how they work together) and let it be checked (have them explaining it) before starting to build
- As a showcase, the learners will have to demonstrate the car to (hopefully) drive from A → B

How to spark curiosity for the challenge? → *2 Challenge & relevancy to the learner*

Connect to what the learners already know well

→ a dhow/sailboat

How to potentially solve the challenge? → *2 Solving the challenge*

▸ This needs to be tested with the new ThinkBricks, but here are some examples on how I tried to solve it with the former bricks I designed:

▸ Furthermore, here is a building plan of how I (Dorrit) envision it to be able to build with the ThinkBricks.

please note that this building plan and this way of building are not the way I expect the learners to build it, because as stated before, it is most important that there is NOT just one truth; learners should be free to explore and come up with their own solutions.

▾ ☑ Preparations for the facilitator

In this part, the necessary preparations for the facilitators are presented. The boxes may be checked if that specific part is prepared (in case that is helpful) and everywhere on this page in red are the places written that have to be looked at or prepared by the facilitators. Everything in this page may be changed by the two facilitators during the preparations.

TO DO

- ☑ ~~Click items like this so you can keep track of things you already did~~
- ☐ Go through the planned workshop and all parts of the workshop to understand the expectations
- ☐ Test the main activity (*see 2 Solving the challenge*); is it possible to build this wind-car?
  - ☐ If yes; adapt *"how to potentially solve the challenge?"* up here to how you found out
  - ☐ If no; adapt the challenge to something that is possible (in the given time)
- ☐ Define what the requirements and restrictions should be *(see up at "restrictions & requirements")*
  - ☐ Define the A → B requirement
  - ☐ Decide on how to use existing wind or how to let learners generate it themselves
- ☐ Define which background knowledge connects to this *(see "Knowledge" at the "skills"-section up)*, and do a little bit of research to make sure you as facilitators are "experts" in the topic
- ☐ Decide on main ground rules for learners, based on the CBL info provided
  - ☐ Draw up the ground rules on a sheet to present on the workshop
- ☐ Prepare an agenda sheet with a rough overview of the workshop
- ☐ Print the overview of the workshop, so you can keep this at hand while giving the workshop
  - How to print the workshop overview?
- ☐ Prepare all resources →

Specific resources necessary (per learner)

- ☐ ThinkBricks
  - ☐ 4x round part with 8,5 mm (wide circular) hole
  - ☐ 10x stopper part
  - ☐ 2x each type of other part (all with 7,5 mm holes)
- ☐ Cardboard or paper
- ☐ Knife or scissors
- ☐ Tape, such as duct tapeSS
- ☐ Something to make / use the wind (a funnel or a hand fan?)
- ☐ Potentially some learners could also use the wooden sheets with the hexagonal holes, which I used in my first prototypes

▾ 1 INSPIRE 2 +

Step	Intention	Activiti(es)	Content of activity / facilitator notes	Minutes	Group s...	Resources?
1 Opening		Oral workshop opening	Introduce general agenda of the workshop, CBL & ground rules and the main topic of workshop	5	Total group	Sheet with ground rules Agenda sheet
2 Challenge & relevancy to learner		Present classical Group brainstorm	Purpose Connect challenge to what they know already which is driven by wind: a Dhow → name devices driven by wind together (group brainstorm) and define how a dhow works (how it is driven by wind / which aspects are important / which does it have / etc.)	5	Total group	Board + writing material

+ New

▾ 2 ENGAGE 3 +

Step	Intention	Activiti(es)	Content of activity / facilitator notes	Minutes	Group s...	Resources?
1 Activity introduction & expectations		Present classical	important requirements to present: - Show a line from A → B with 4 m in between in which the car has to drive - Explain how they will use the wind - After this, the students will work in groups of 3	5	Total group	Board + writing material
Energizer	To gain a clear understanding of the potential uses of all the different blocks	Guided SCAMPER building	Do the SCAMPER exercise to build a **swing** (like on the playground) & make them see the outcome change gradually	7	[3] Small gr	ThinkBricks & pencils
2 Solving the challenge	To practice with thinking about what to build/design FIRST, and only THEN doing it	Mind map Draw a build plan Build with ThinkBricks	**Expectations for learners:** Mindmap which parts a wind car needs Draw a plan to build with the available parts Check the plan with the facilitator → Make sure the students first only use the blocks and writing materials, and only get the pencils to build after their plan is checked. In this way they are forced to first make a clear plan. Build the design (and iterate where necessary)	18	[3] Small gr	Paper + writing materials ThinkBricks & pencils

+ New

▾ 3 REFLECT 3 +

Step	Intention	Activiti(es)	Content of activity / facilitator notes	Minutes	Group s...	Resources?
1/2 Reflection	Let learners get used to reflecting on the process, instead of the final outcome, and learn from their actions	Short discussion Written reflection	Plan vs. Real life: Let learners look at, and discuss the differences between their building plan and the thing they finally built, and all write down three things they could learn from this or do different in the future	7	[3] Small gr	Paper + writing materials
1/2 Showcase		Demonstrate solution Oral presentation	**Expectations from learners:** Demonstrate the car driving from A → B (fitting with the given requirements) Present main learnings from differences between plan and building (from reflection)	10	Total group	
3 Closing		Photo with whole group	This is just a one-time workshop, so focus on what is learnt by the learners, instead of what will happen in the next workshop		Total group	(phone) Camera

Figure 69: Notion page where the innovators were presented with the workshop plan

how was it evaluated?

Remotely, this online **manual was sent to a team of innovators**, after which they were **asked to facilitate a workshop** at IOMe005 with other innovators as learners.

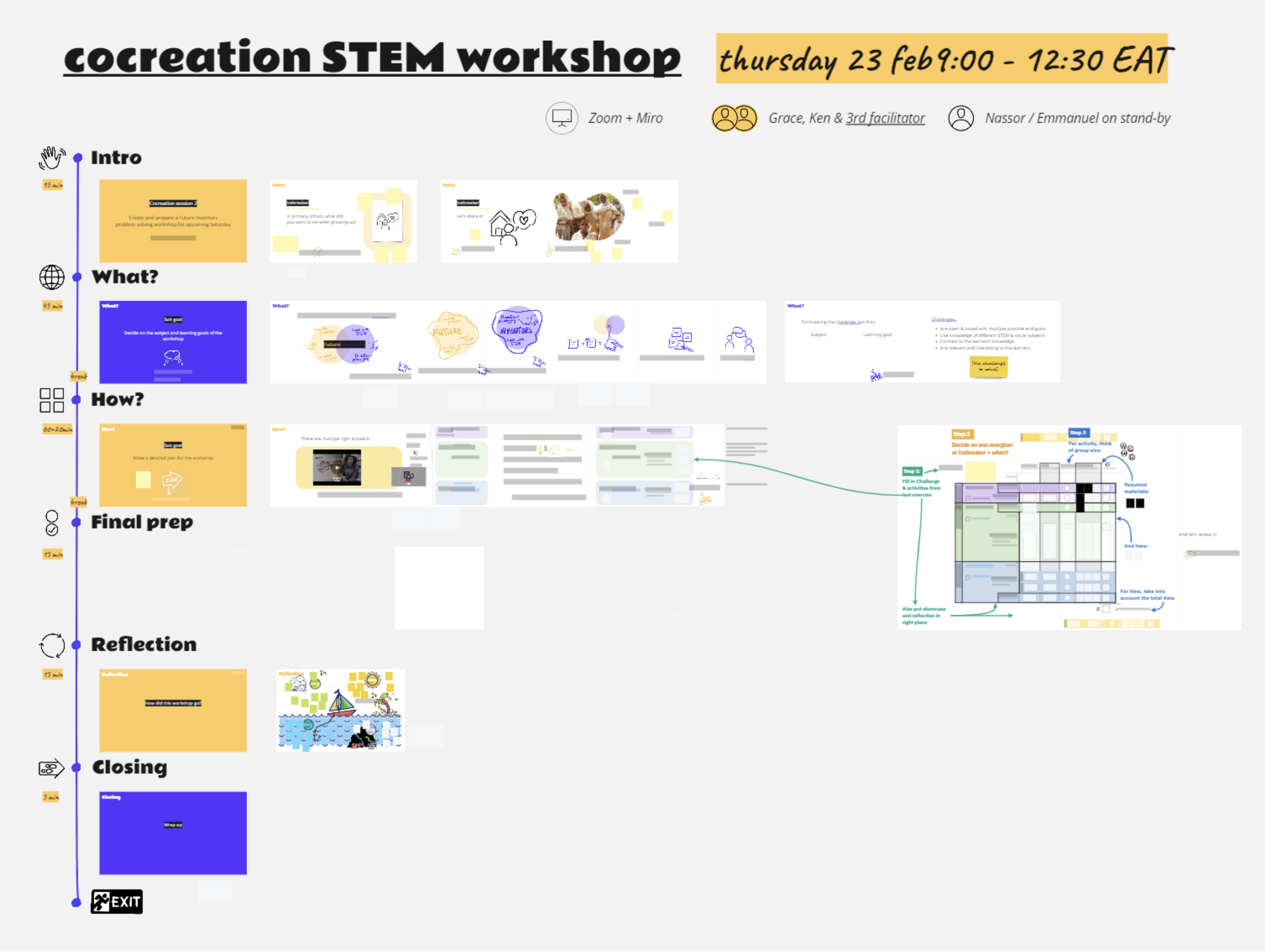
main learnings

minus

- The amount of text gave innovators an **information overload**: they needed help from a lab facilitator to understand the manual
- Navigation was **not intuitive**
- The preparatory tasks at the beginning needed to also **incorporate practical preparations**

plus

Innovators **valued the to-do list**



cocreation STEM workshop thursday 23 feb 9:00 - 12:30 EAT

Zoom + Miro

Grace, Ken & 3rd facilitator

Nassor / Emmanuel on stand-by

Figure 70: Miro board intended to function as interactive manual

2 Miro

- Manual guides innovators to fill in their own workshop plan
- Intention to present the manual content in a more visual way
- Miro software generally works intuitive and can be adapted
- Walk-through manual in live session for more guidance

how was it evaluated?

Two online sessions were organized to **guide a team innovators through the Miro manual**, which was the same team as for the Notion manual.

main learnings

plus

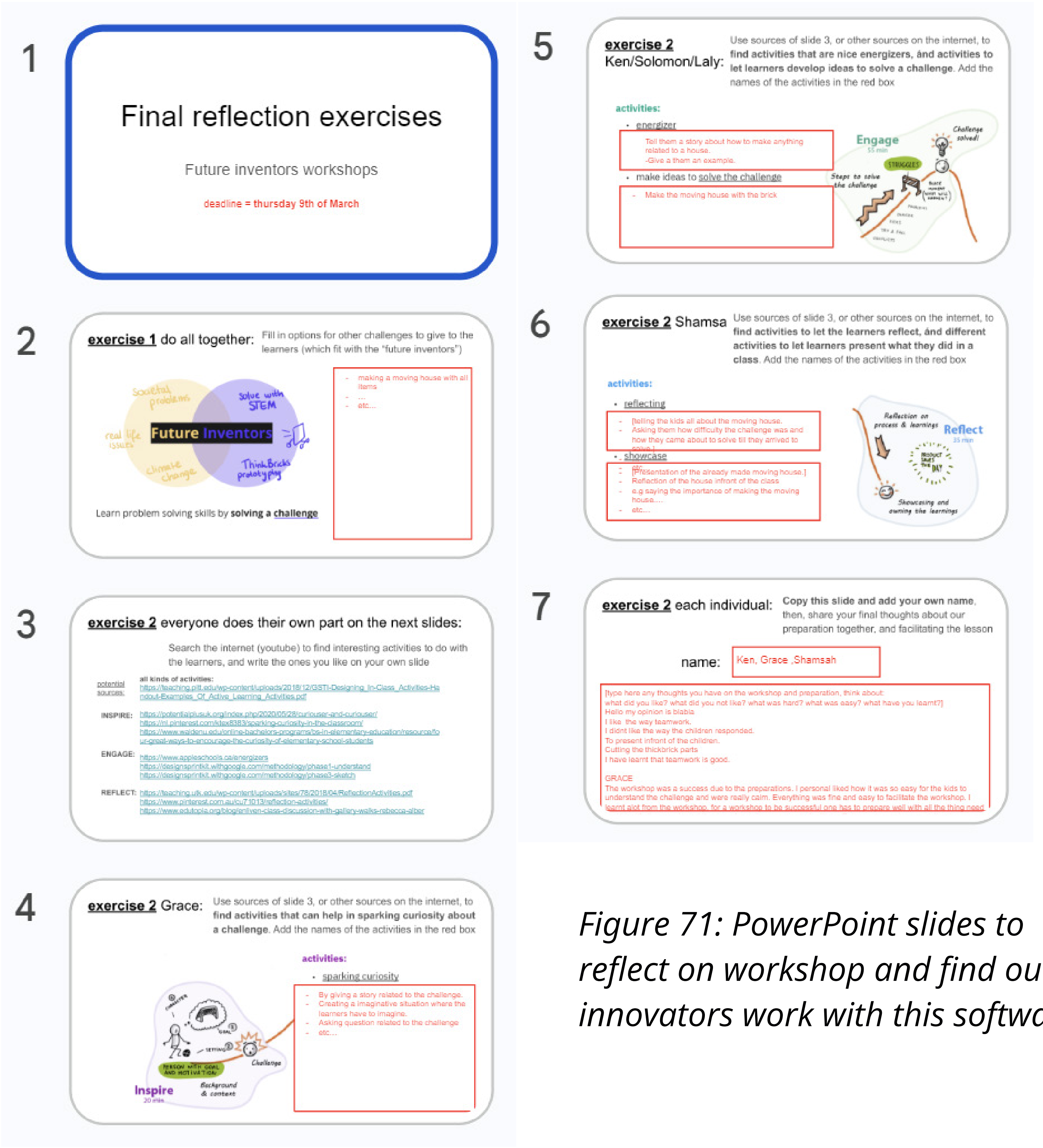
The workshop **facilitation went better** because the innovators had **filled in the plan themselves**

minus

- Innovators **struggled with Miro**: it was not intuitive
- **Starting up Miro took a long time** due to the internet at IOMe005

See next page for full outcome of the evaluation

interesting



1

Final reflection exercises

Future inventors workshops

deadline = thursday 9th of March

2

exercise 1 do all together: Fill in options for other challenges to give to the learners (which fit with the "future inventors")

Learn problem solving skills by **solving a challenge**

- making a moving house with all items
- ...
- etc...

3

exercise 2 everyone does their own part on the next slides:

Search the internet (youtube) to find interesting activities to do with the learners, and write the ones you like on your own slide

potential sources:

all kinds of activities: https://teaching.pitt.edu/wp-content/uploads/2018/12/GSTI-Designing_In-Class_Activities-Handout-Examples_Of_Active_Learning_Activities.pdf

INSPIRE: https://potentialplusuk.org/index.php/2020/05/28/curiouser-and-curiouser/ https://nl.pinterest.com/ktex8383/sparking-curiosity-in-the-classroom/ https://www.waldenu.edu/online-bachelors-programs/bs-in-elementary-education/resource/four-great-ways-to-encourage-the-curiosity-of-elementary-school-students

ENGAGE: https://www.appleschools.ca/energizers https://designsprintkit.withgoogle.com/methodology/phase1-understand https://designsprintkit.withgoogle.com/methodology/phase3-sketch

REFLECT: https://teaching.uwk.edu/wp-content/uploads/sites/78/2018/04/ReflectionActivities.pdf https://www.pinterest.com.au/cu71013/reflection-activities/ https://www.edutopia.org/blog/enliven-class-discussion-with-gallery-walks-rebecca-alber

4

exercise 2 Grace: Use sources of slide 3, or other sources on the internet, to **find activities that can help in sparking curiosity about a challenge**. Add the names of the activities in the red box

activities:

- sparking curiosity
  - By giving a story related to the challenge.
  - Creating a imaginative situation where the learners have to imagine.
  - Asking question related to the challenge
  - etc...

5

exercise 2 Ken/Solomon/Laly: Use sources of slide 3, or other sources on the internet, to **find activities that are nice energizers, and activities to let learners develop ideas to solve a challenge**. Add the names of the activities in the red box

activities:

- energizer
  - Tell them a story about how to make anything related to a house.
  - -Give a them an example.
- make ideas to solve the challenge
  - Make the moving house with the brick

6

exercise 2 Shamsa: Use sources of slide 3, or other sources on the internet, to **find activities to let the learners reflect, and different activities to let learners present what they did in a class**. Add the names of the activities in the red box

activities:

- reflecting
  - [telling the kids all about the moving house.
  - Asking them how difficulty the challenge was and how they came about to solve til they arrived to solve.]
- showcase
  - [Presentation of the already made moving house.]
  - Reflection of the house infront of the class
  - e.g saying the importance of making the moving house....
  - etc...

7

exercise 2 each individual: Copy this slide and add your own name, then, share your final thoughts about our preparation together, and facilitating the lesson

name: Ken, Grace ,Shamsah

[type here any thoughts you have on the workshop and preparation, think about: what did you like? what did you not like? what was hard? what was easy? what have you learnt?]
Hello my opinion is blabla
I like the way teamwork.
I didnt like the way the children responded.
To present infront of the children.
Cutting the thickbrick parts
I have learnt that teamwork is good.

GRACE
The workshop was a success due to the preparations. I personal liked how it was so easy for the kids to understand the challenge and were really calm. Everything was fine and easy to facilitate the workshop. I learnt alot from the workshop. for a workshop to be successful one has to prepare well with all the thing need

Figure 71: PowerPoint slides to reflect on workshop and find out how innovators work with this software

3 Powerpoint slides

- Slides to fill in by innovators to evaluate on the last workshop
- Medium which might be most familiar to innovators
- Developed in order to test this as a medium for the manual

how was it evaluated?

After the facilitation of the workshop for learners, the facilitators were sent a small slide deck with some evaluation questions to fill in on the slides.

main learnings

minus

Innovators **did not fill in the slides**, unless when they were stimulated by the IOMe005 team

plus

- + The innovators were **able to fill in the slides**
- + Powerpoint slides can also be **accessed without internet**

During the process, it became clear that it helps the innovators to divide certain roles, such as a team leader and a timekeeper

interesting

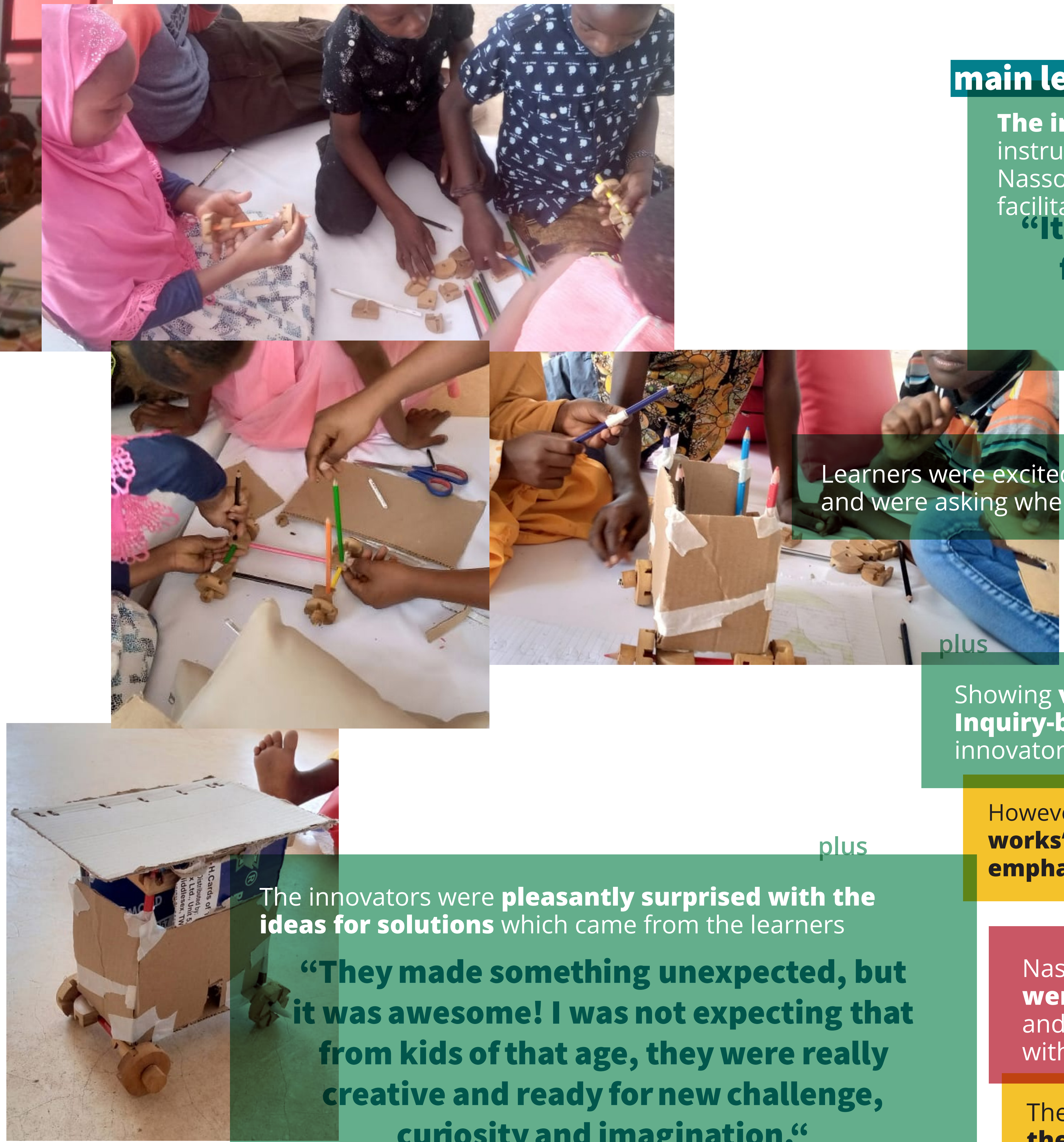
12.4 | Final design test

Evaluating the complete design

The goal of this evaluation is to (1) guide a team of innovators to develop a Challenge-based workshop themselves, to (2) prepare the innovators for the facilitation of this workshop, in order to finally (3) let them facilitate the workshop to upper primary school learners at IOMe005. By guiding them through this process, the intention is (4) to find the right channel and "portion size" to present information to innovators, for it to be manageable to them. Furthermore, this was a moment to (5) gain final insights on the advantages and disadvantages of the ThinkBricks.

Initial plan and adaptation

The intention for this evaluation was to guide the innovators through the Miro manual (which was presented in the last page) in a 3-hour remote session, to let them finalize the workshop plan independently. However, it was during this session that it became clear that Miro was not intuitive for the innovators, and more time was required to go through every step of the workshop preparation. Therefore a second session was scheduled, where innovators brainstormed with post-its, after which the session facilitator filled out the workshop plan, based on their main outcomes. After the workshop facilitation, an online meeting with the innovators and lab facilitator Nassor, who had observed them during the workshop, provided insights on the process.
Finally, several Powerpoint slides for the innovators to fill in after the workshop facilitation provided insights on this new channel.



plus

The innovators were **pleasantly surprised with the ideas for solutions** which came from the learners

> **"They made something unexpected, but it was awesome! I was not expecting that from kids of that age, they were really creative and ready for new challenge, curiosity and imagination."**
>
> *Innovator*

Figure 72: Several pictures showing the learners actively engaged during the final evaluation of the design

Cocreated workshop plan

During the two sessions, the innovators decided to challenge the children to build a moving house. They believed this would be relevant to them, because in Kenya people often have to move for their job. As an example they gave farmers, who are forced to move in droughts or when their lands get infertile.

main learnings

plus

The innovators felt empowered because instead of following instructions, they decided how to give the workshop themselves. Nassor also stated that they **"outdid themselves"** as facilitators.

> **"It was awesome, it was much better [than the first time]. Now we made it by ourselves"**
>
> *Innovator*

plus

Learners were excited about what they had been doing, and were asking when they could continue on their projects

This shows that **one challenge could be split** in multiple workshops

interesting

Also, building with the ThinkBricks greatly **sparked the children's curiosity and creativity for solutions**

plus

Showing **videos explaining the intended Inquiry-based teaching** made the innovators clearly understand this concept

interesting

However they sometimes had the **urge to explain to learners "how something works"**, instead of allowing trial and error. Thus the final manual should clearly **emphasize the value of "productive struggle"** (see *chapter 7.3, p. 37*)

minus

Nassor had the feeling that the **innovators were a bit too fixated on the schedule**, and they could not freely teach and interact with the learners

Therefore, it should be emphasized to them that the **main intention for the workshop plan is to guide**, and improvisation should be encouraged

minus

After some time during the first 3-hour remote session, the **concentration of the innovators was disappearing**

interesting

Thus, the final manual should **break the preparation into several short sessions**

minus

Lab facilitator **Nassor missed the focus on STEM knowledge** in the final workshop and challenge, such as the integration topics like friction

interesting

Although the innovators were encouraged to think of **STEM-related challenges**, this should be more clearly incorporated into the final workshop manual

13 | The Future Inventors

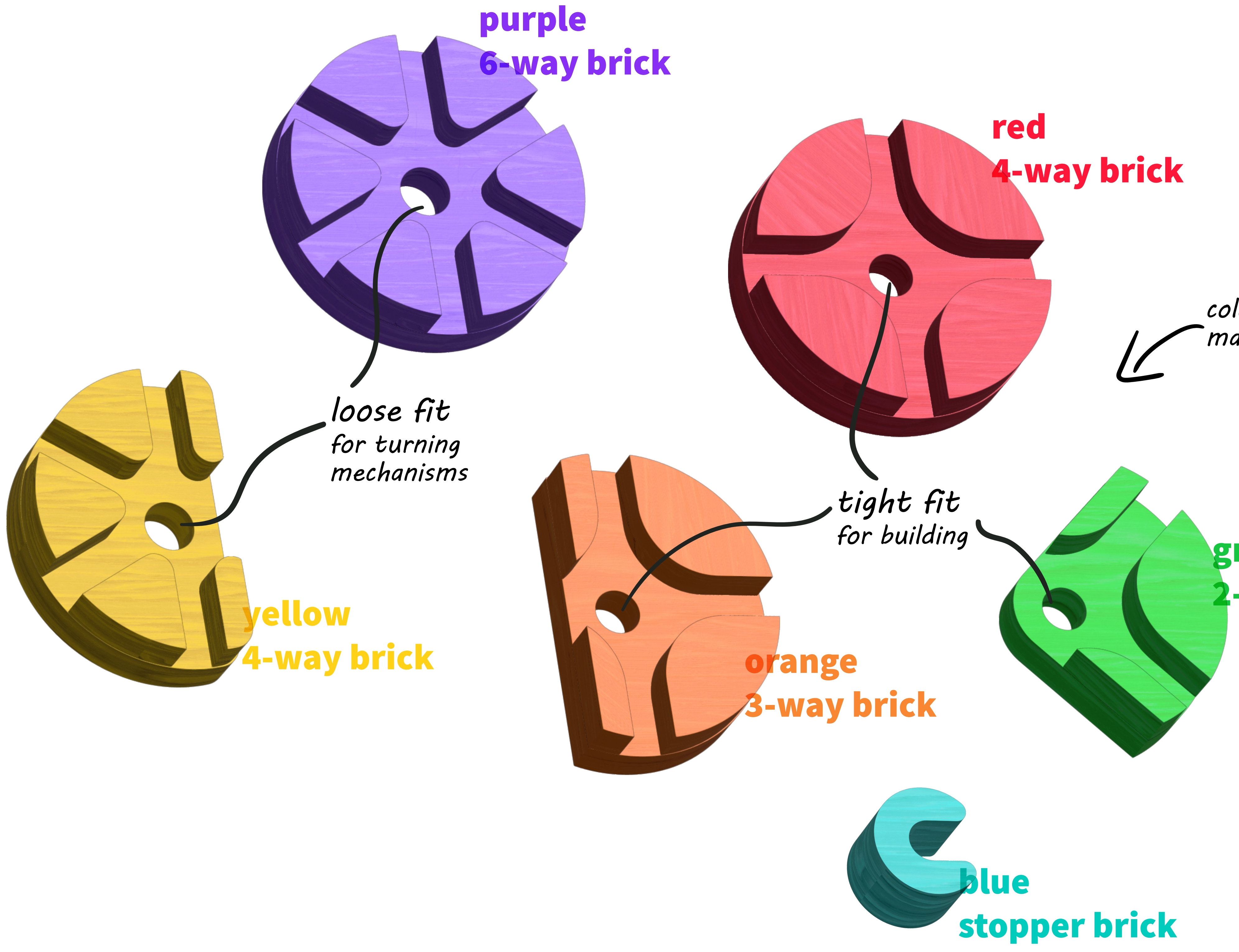
The final design consists of the ThinkBricks,
the Challenge-based workshop, and the
Future Inventors manual which brings it all together.

13.1 | ThinkBricks

"They are just like LEGObricks, but now they are ThinkBricks, because you have to think about how to use it."

Nassor, lab facilitator at IOMe, pc, 2023

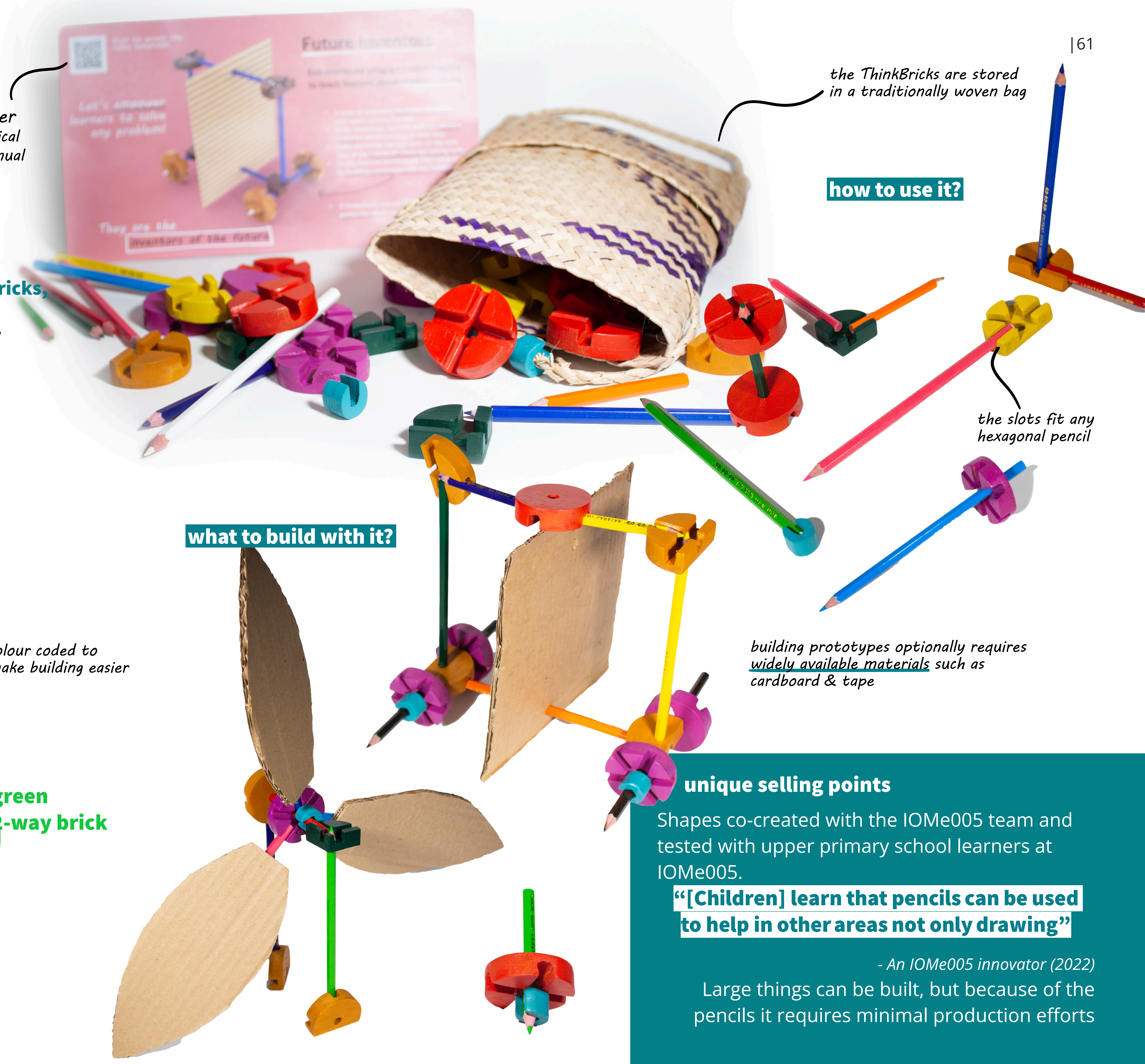
what is it? versatile building blocks which allow learners to freely build prototypes to communicate their solutions to societal challenges they are presented with



loose fit
for turning mechanisms

tight fit
for building

colour coded to
make building easier



a laminated onepager
connects physical
ThinkBricks to digital manual

the ThinkBricks are stored
in a traditionally woven bag

how to use it?

the slots fit any
hexagonal pencil

what to build with it?

building prototypes optionally requires
widely available materials such as
cardboard & tape

unique selling points

Shapes co-created with the IOMe005 team and tested with upper primary school learners at IOMe005.

"[Children] learn that pencils can be used to help in other areas not only drawing"

- An IOMe005 innovator (2022)

Large things can be built, but because of the pencils it requires minimal production efforts

using wood fits with the carpentry traditions in Lamu, and is a familiar material to the children

the wood is sourced locally in Lamu

how are they produced?

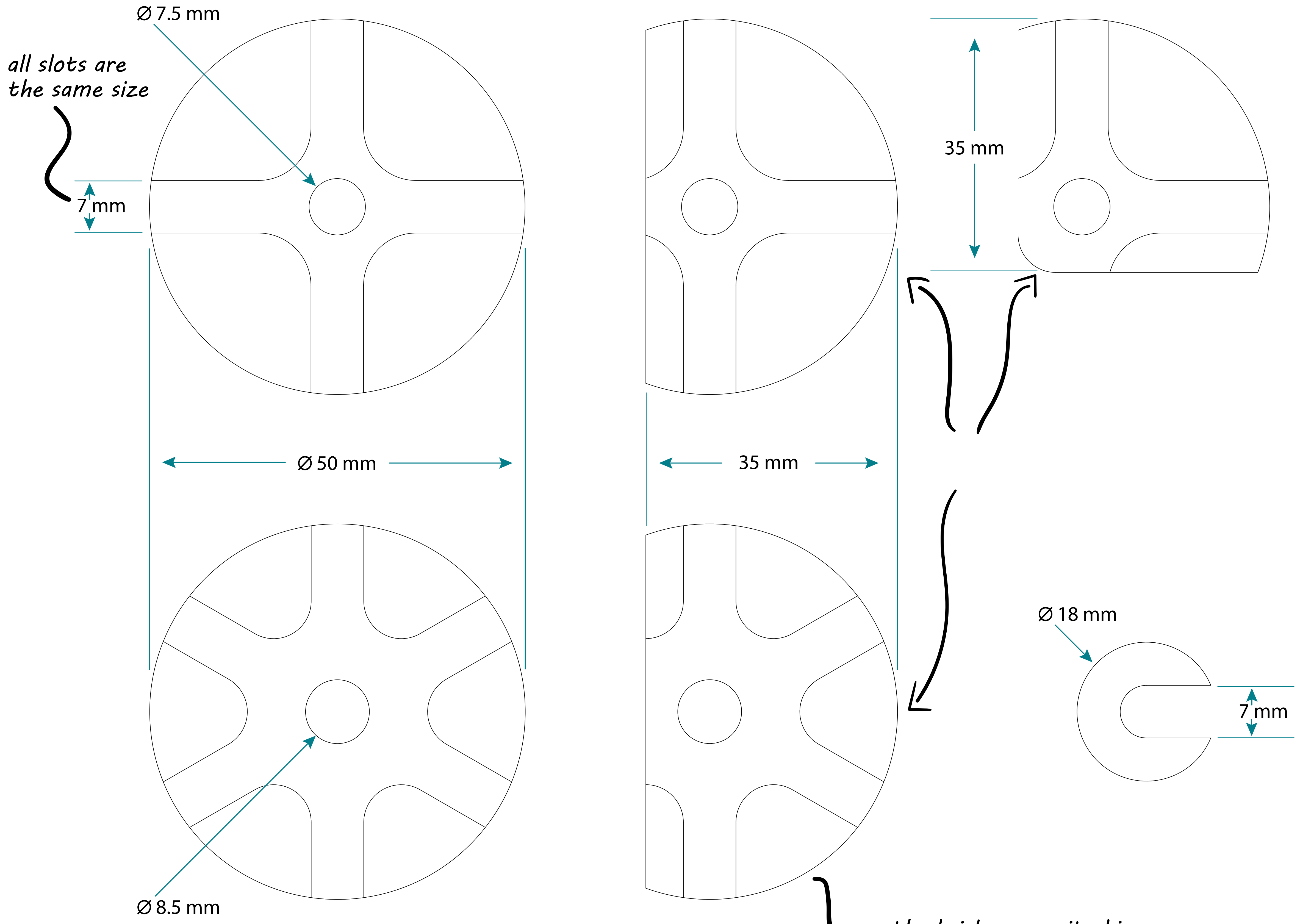
ThinkBricks are cut from sheets of Mvule wood with the CNC machine at IOMe005

IOMe's innovators have refined the CNC settings of the bricks, so they feel ownership over the product...

...and if they want to adapt the design or develop new bricks in the future, they can!

after the bricks are cut, they are sanded and painted manually

and what are the measurements?



all slots are the same size

they won't quickly break due to their robust shapes

the bricks are quite big, so they do not easily get lost

and what does this cost?

Costs for 5 sets of 35 ThinkBricks

One sheet of Mvule hardwood:	2000 KES
Machining costs:	1750 KES
1 can spray paint:	250 KES
5 packs of pencils:	900 KES
5 storage bags:	1600 KES +
	6500 KES for 5 sets

one complete set of ThinkBricks, which can be used by two learners together, costs IOMe005 1300 KES (9 euros)

13.2 | Challenge-based workshop

because extracurricular education allows for more freedom in how to educate

what is it? *an extracurricular workshop program was developed, to teach problem solving skills to upper primary learners*
they take part in a club which hosts several (bi)weekly extracurricular workshops in a row

in the first workshop:
learners are presented with a **challenge**

societal problem

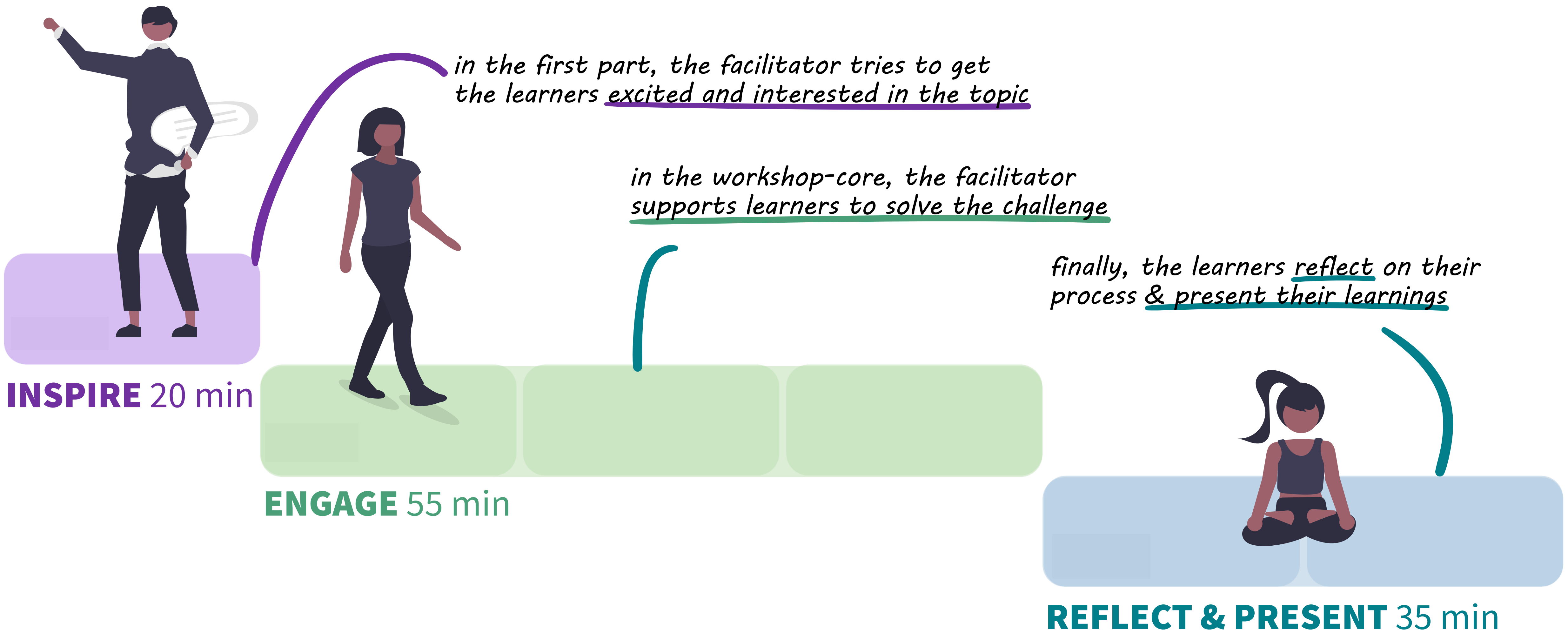
challenge relates to learners' lives

gives learner authorative role

> **Example challenge:**
> In Lamu, farmers face big problems because of droughts that keep happening. It's really hard for them to grow crops on their land that is not very fertile. You are a team of clever engineers who have to come up with ideas for renewable energy that can help the farmers and make their lives better.

solution demands STEM knowledge

every **workshop** *will be facilitated by a team of IOMe innovators, where every innovator becomes expert at facilitating one part:*



in the first part, the facilitator tries to get the learners excited and interested in the topic

in the workshop-core, the facilitator supports learners to solve the challenge

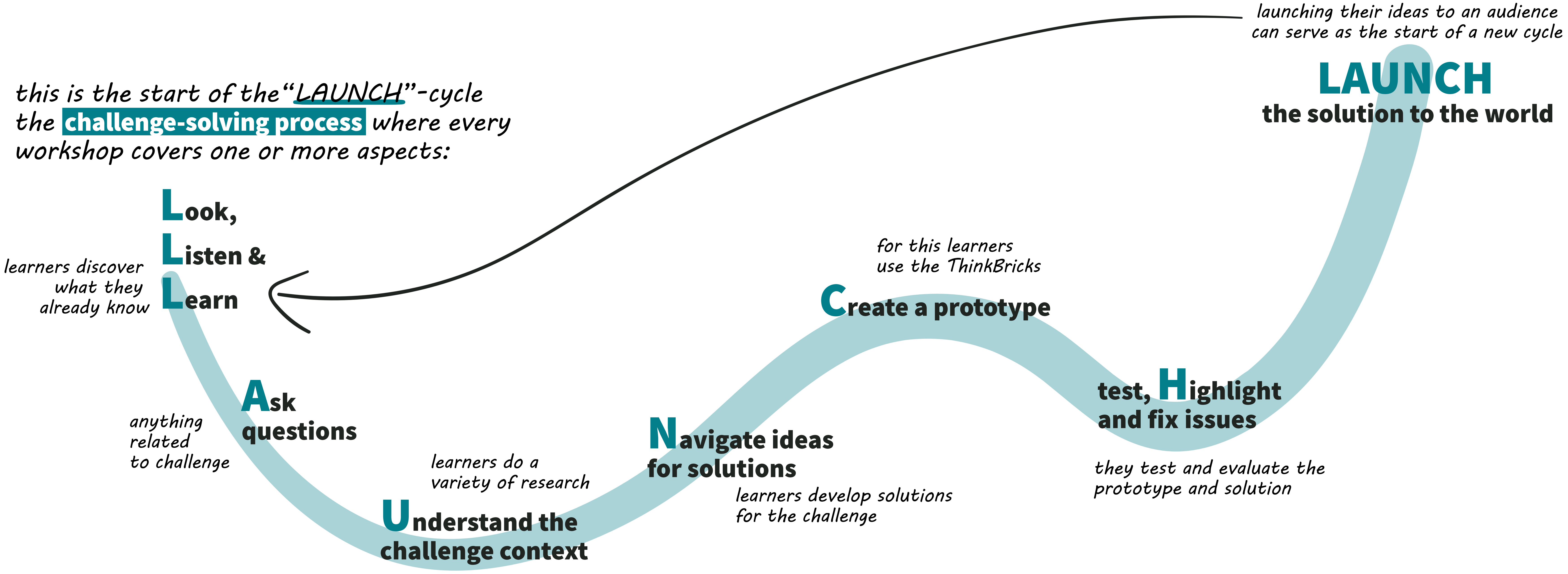
finally, the learners reflect on their process & present their learnings

INSPIRE 20 min

ENGAGE 55 min

REFLECT & PRESENT 35 min

this is the start of the "LAUNCH"-cycle
the **challenge-solving process** *where every workshop covers one or more aspects:*



launching their ideas to an audience can serve as the start of a new cycle

LAUNCH
the solution to the world

learners discover what they already know

Look,
Listen &
Learn

anything related to challenge

Ask questions

learners do a variety of research

Understand the challenge context

Navigate ideas for solutions

learners develop solutions for the challenge

for this learners use the ThinkBricks

Create a prototype

test, Highlight and fix issues

they test and evaluate the prototype and solution

unique selling points

Facilitators gradually gain confidence by facilitating one different part at a time.

"The courage we did not have, we gained it. For us it is a learning process, with more practice it will be more perfect"

Innovator after first time facilitating

Breaking down the challenge-solving process into smaller parts makes it more manageable, while still providing depth in the education.

13.3 | Future Inventors manual

what is it?

a set of powerpoint slides containing tutorial videos guides the team of innovators through the whole process of preparing a workshop, facilitating it, and thinking about their next workshop

main intention

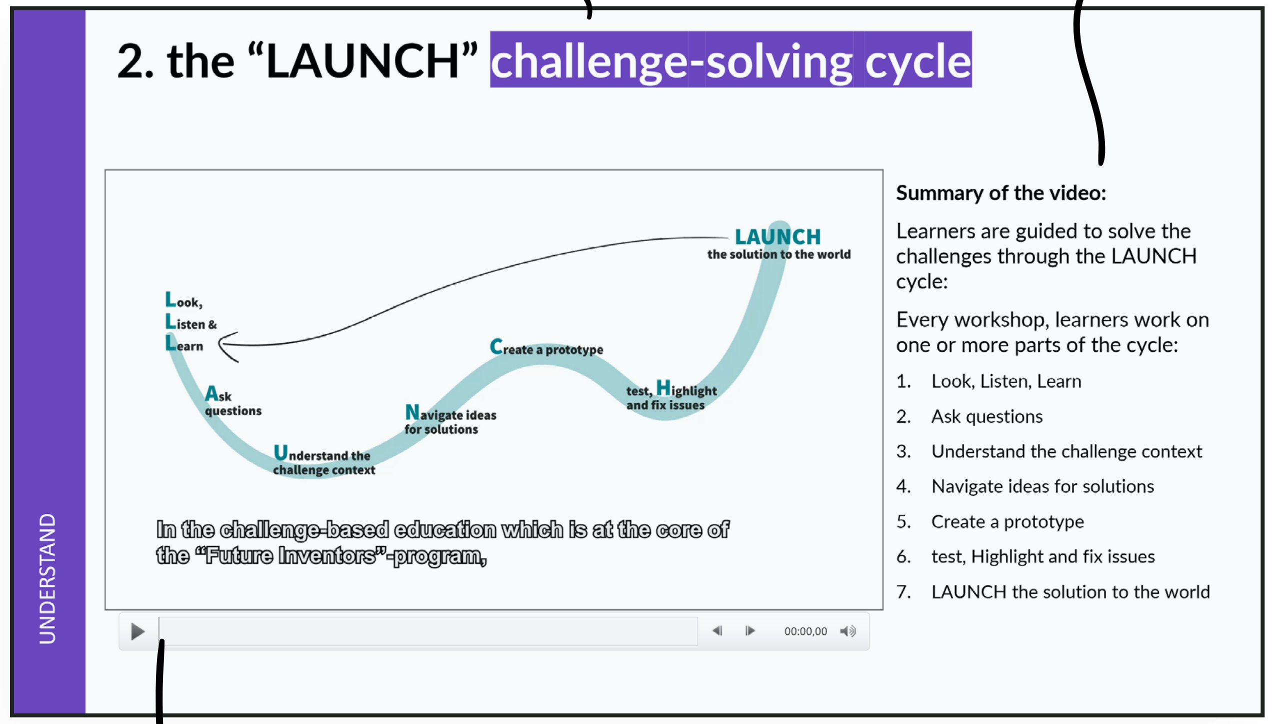
enable innovators to set up their own workshops: this is the only way they can give engaging workshops and gradually grow their confidence

Powerpoint as a channel with multimodal information

every slide presents part of whole explanation

video summarized in key points

Example slide:



2. the "LAUNCH" challenge-solving cycle

In the challenge-based education which is at the core of the "Future Inventors"-program,

Summary of the video:

Learners are guided to solve the challenges through the LAUNCH cycle:

Every workshop, learners work on one or more parts of the cycle:

1. Look, Listen, Learn
2. Ask questions
3. Understand the challenge context
4. Navigate ideas for solutions
5. Create a prototype
6. test, Highlight and fix issues
7. LAUNCH the solution to the world

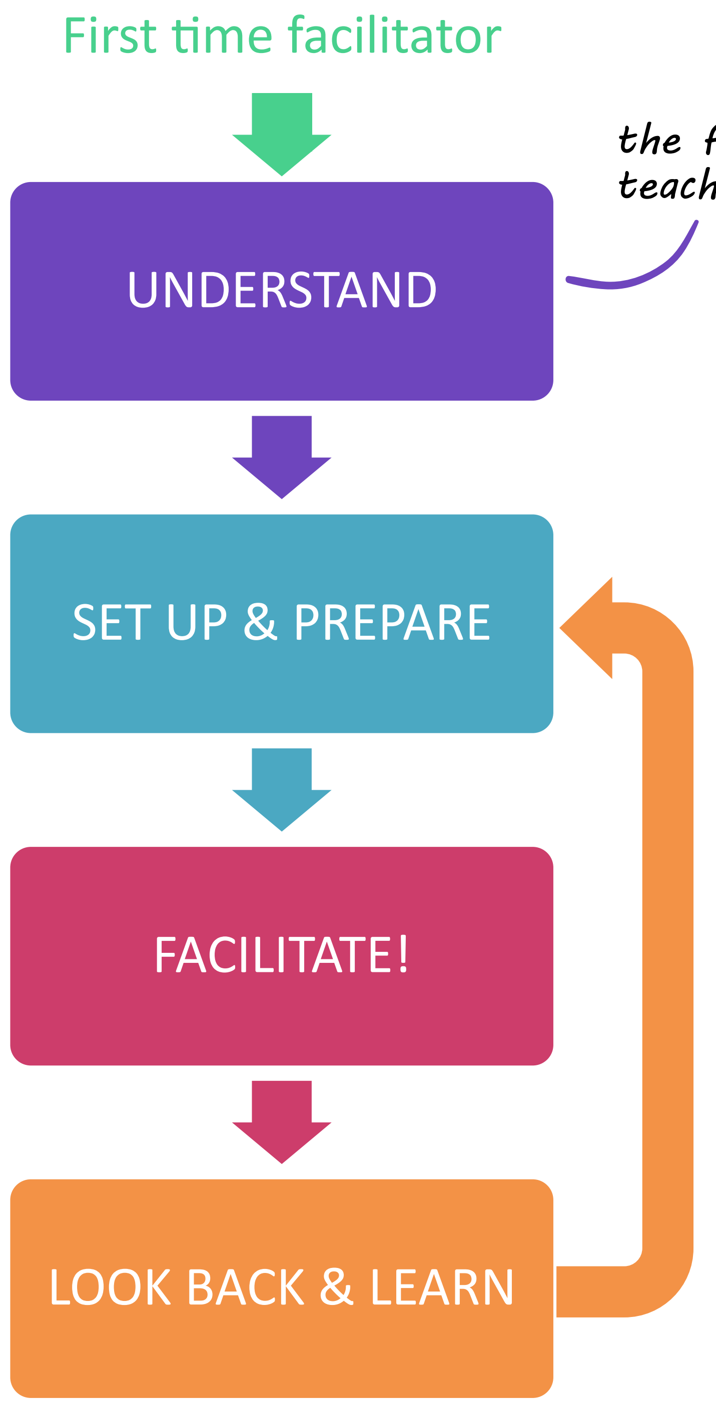
every video contains a voiceover who speaks English with a Kenyan accent

video's contain subtitles

use of visuals to support explanations and screen-captures to guide through manual

content flow

the content of the manual is designed to be usable by first-time facilitators newly arriving at IOMe005:



First time facilitator

UNDERSTAND

SET UP & PREPARE

FACILITATE!

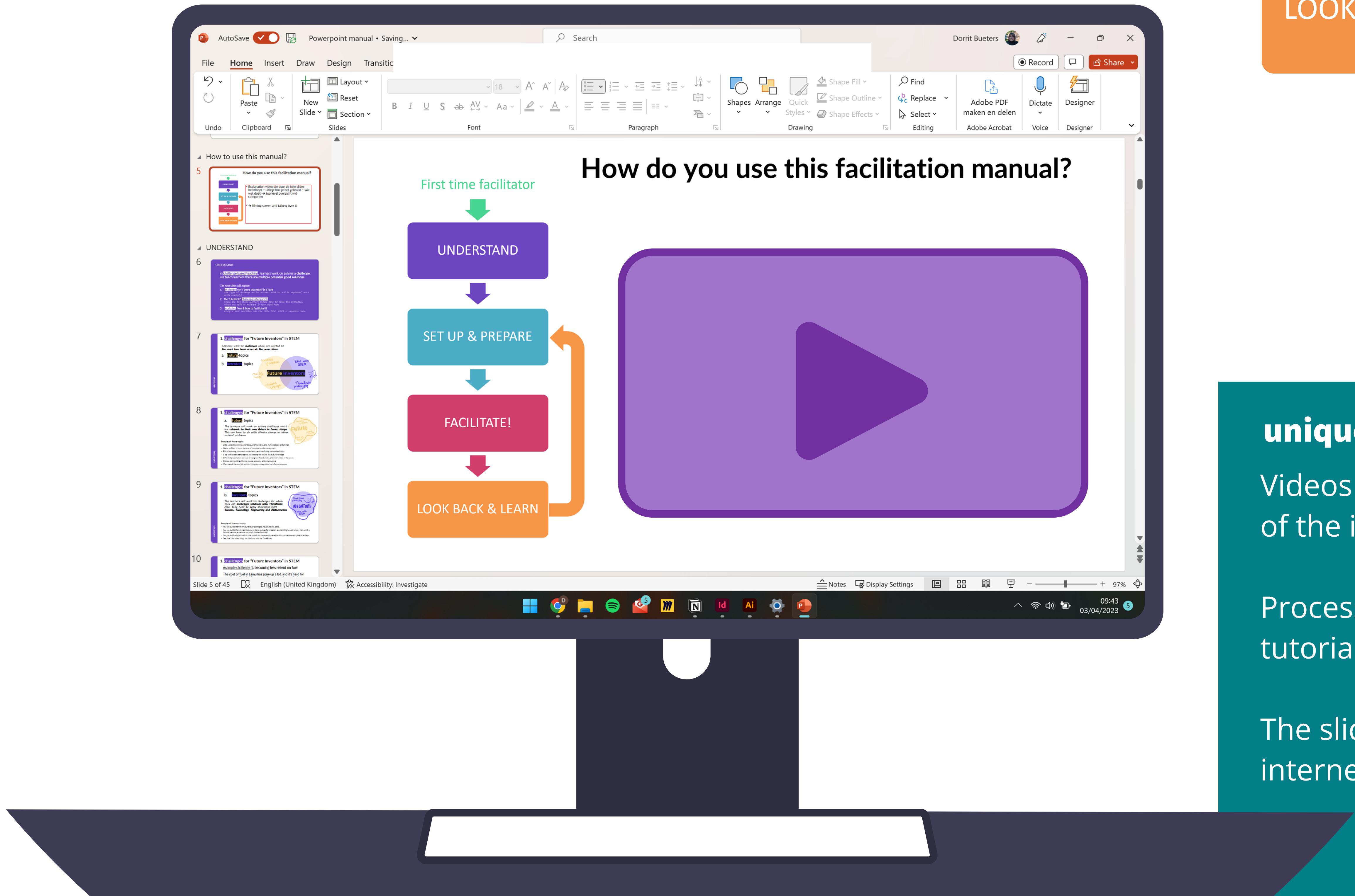
LOOK BACK & LEARN

the first slides explain the teaching methodology

then, step-by-step tutorials guide innovators to brainstorm about, and develop a workshop

they are also encouraged to think through any practicalities they might have to arrange

then, after facilitating, they are guided to reflect on how it went, and what their next steps will be



How do you use this facilitation manual?

unique selling points

Videos are localised in order to fit to the culture of the innovators

Process broken up in clear steps with video tutorials, fitting the innovators' way of working

The slides can be accessed without requiring internet access

14 | Advice to IOMe005

This chapter will provide recommended future steps for the IOMe005 team to implement the Future Inventors program. The steps are divided into three phases: the first phase is where the program is fully developed and piloted, in the second phase the program is rolled out to primary schools, and the final phase describes far-future recommendations when expanding the program.

PHASE 1 Preparation & pilots

Production

1. Cut the ThinkBricks in such a way in relation to the wood grain so they don't break
2. Finish the bricks manually by drilling the holes (7,5 and 8,5 mm) and plan the wood to ensure every slots fits a pencil
3. Buy six spray paint colours, adapted to the learners likes, hang the bricks on an iron wire and fully paint them in two layers
4. Make sets of ThinkBricks and buy woven bags to fit the bricks
5. Print and laminate the one-pager file to pack with the bricks

Prepare for facilitation

6. Form a team of enthusiastic innovators speaking good English
7. In the weeks after reading this report, reserve a few mornings or afternoons with the lab facilitators and the team of selected innovators to go through the manual and follow the tutorials to develop a workshop plan

Trial Pilots

8. Plan some pilot workshops and invite local children to enable the team of innovators to develop confidence in facilitating

Documentation

9. Make sure to save the manual PowerPoint file and ThinkBricks cutting files in a secure location and make copies for backup in an accessible location
10. Keep track of changes to the program for future reference

Design of ThinkBricks - final note

Although new ThinkBricks can be fabricated freely, it is advised to first pilot the program with the current bricks. Although they might not fit for seamlessly for every purpose, the idea of the bricks is to be basic in order to maintain freedom for the children to build. However, when a certain brick is missing, it may always be added.

PHASE 2 Bringing Future Inventors to schools

Preparation for implementation

1. Develop a detailed overview on how the program connects to the current curriculum, in order to be appealing to schools
2. Mobilize a local Red Cross volunteer on Lamu island to assist in reaching out to schools on the island
3. With the help of the volunteer, connect to a local school, appoint a responsible teacher to set up a club. To generate more enthusiasm among teachers, demonstrate and explore ways teachers can use the ThinkBricks in their regular education
4. Have the responsible teacher attend the pilot program at IOMe005 to make them clearly understand the program
5. Plan a pilot program at the school. In Lamu island, it is most effective to schedule the program during the planned "game"-afternoons during the weekdays
6. Facilitate the workshops at the school. Ensure a separate room at a school to prevent overcrowding with curious learners

Program evaluation & adaptation

7. Continuously reflect on the program's effectiveness and adapt as necessary

Potential adaptations to the program

8. It could be beneficial to develop a specific casing for the ThinkBricks which has clear compartments for the different bricks to prevent loss
9. Optionally, use specific pencils to prevent theft and make them easily recognizable

PHASE 3 Future steps to expand the program

Improving efficiency

1. Calibrate the CNC machine to reduce manual labour necessary in making the slots fitting and drilling the middle holes. Then, ThinkBricks can also be fabricated to be used in other parts of Kenya

Funding

2. Seek funding to give monetary compensation to facilitators, to ensure a continuous commitment. Think of hiring a team leader specifically for the program or providing a compensation or meals for the facilitating team on workshop day
3. For funding, think of partnerships with companies and organizations in any field, as the open nature of the program and ThinkBricks allows for a range of collaborations. An example would be a wind-energy company, as the bricks allow to build a broad variety of objects powered by wind
4. Another option is to work with experts in the field who can give small lectures in the Inspire-part of the workshops

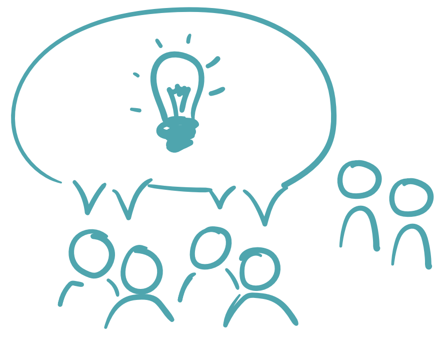
Record-keeping and sharing

5. Develop a database to save developed workshop plans centrally, to share them with Future Inventors initiatives which can be set up in other parts of Kenya

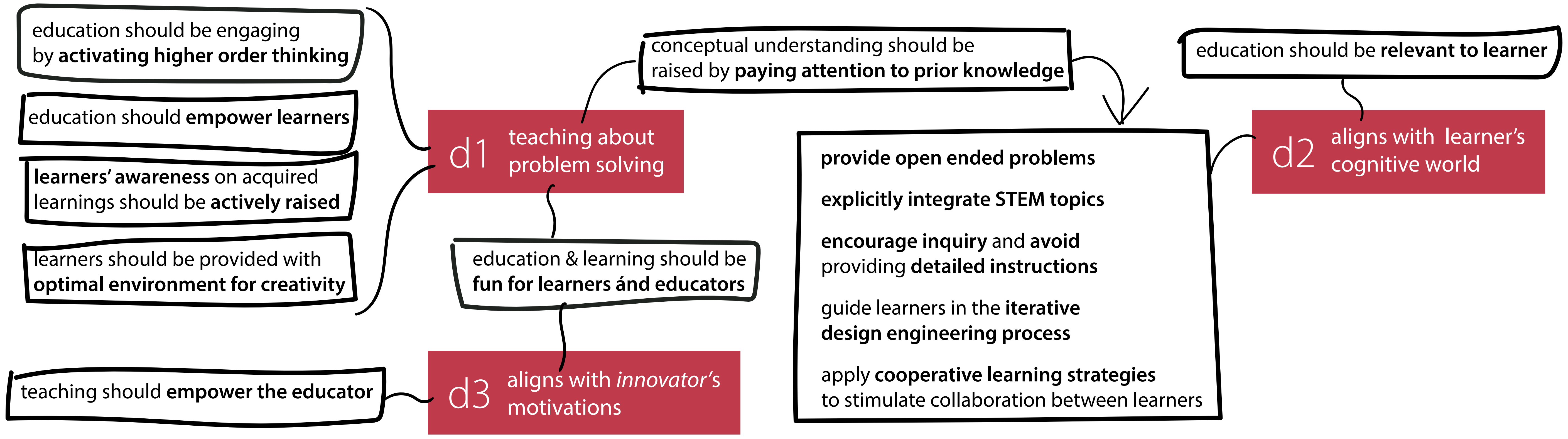
15 | Evaluation of the final design

Now, the requirements which were presented throughout “PART 3 | Design Research” are gathered and used to evaluate the design on desirability, feasibility and viability.

desirability do they want it?



using in class



education should be engaging by **activating higher order thinking**

education should **empower learners**

learners’ awareness on acquired learnings **should be actively raised**

learners should be provided with **optimal environment for creativity**

teaching should **empower the educator**

d1 teaching about problem solving

conceptual understanding should be raised by **paying attention to prior knowledge**

education & learning should be **fun for learners ánd educators**

d3 aligns with *innovator’s* motivations

education should be **relevant to learner**

d2 aligns with learner’s cognitive world

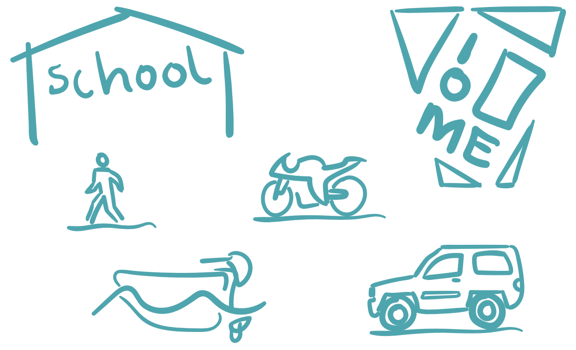
provide open ended problems

explicitly integrate STEM topics

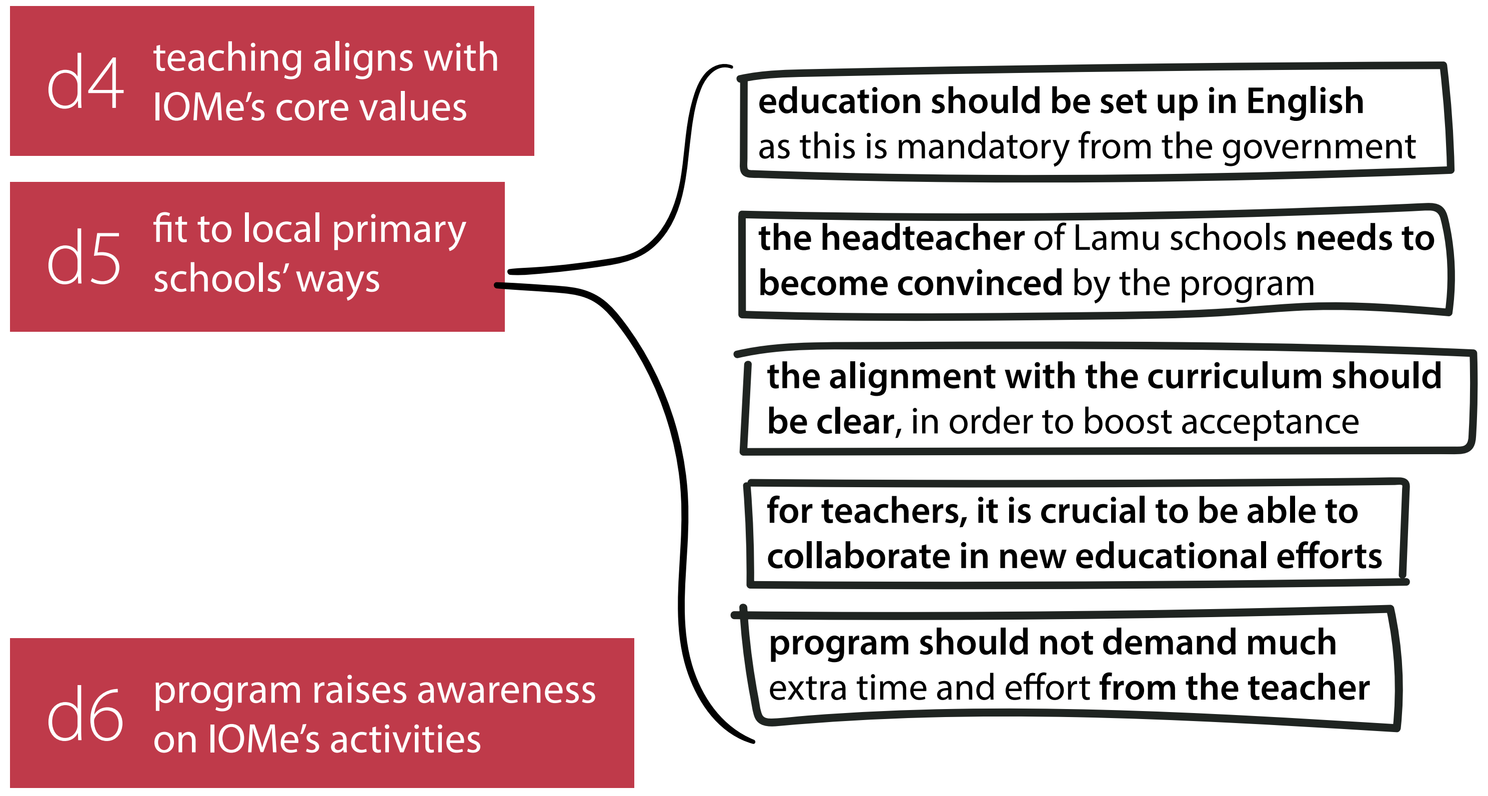
encourage inquiry and **avoid providing detailed instructions**

guide learners in the **iterative design engineering process**

apply **cooperative learning strategies** to stimulate collaboration between learners



Lamu schools and IOMe



d4 teaching aligns with IOMe’s core values

d5 fit to local primary schools’ ways

d6 program raises awareness on IOMe’s activities

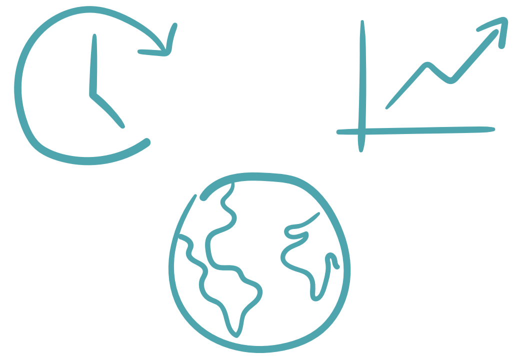
education should be set up in English as this is mandatory from the government

the headteacher of Lamu schools **needs to become convinced** by the program

the alignment with the curriculum should be clear, in order to boost acceptance

for teachers, it is crucial to be able to collaborate in new educational efforts

program should not demand much extra time and effort **from the teacher**



long term and environment

d7 fit with local ways

d8 minimal environmental impact of materials

d9 engages learners societal developments

15.1 | Desirability

Using in class

In this first lens, what makes the total design desirable the fact that inquiry-based learning approaches are encouraged throughout the manual, to make sure the education is engaging and empowering for learners. Furthermore, the ThinkBricks allow for free building and open up learners’ perspectives because of all possibilities. On the other hand, as presented on the last page, innovators expressed to feel empowered by learning how to facilitate. The manual aims to guide while encouraging the innovators to come with their own input.

Lamu schools and IOMe005

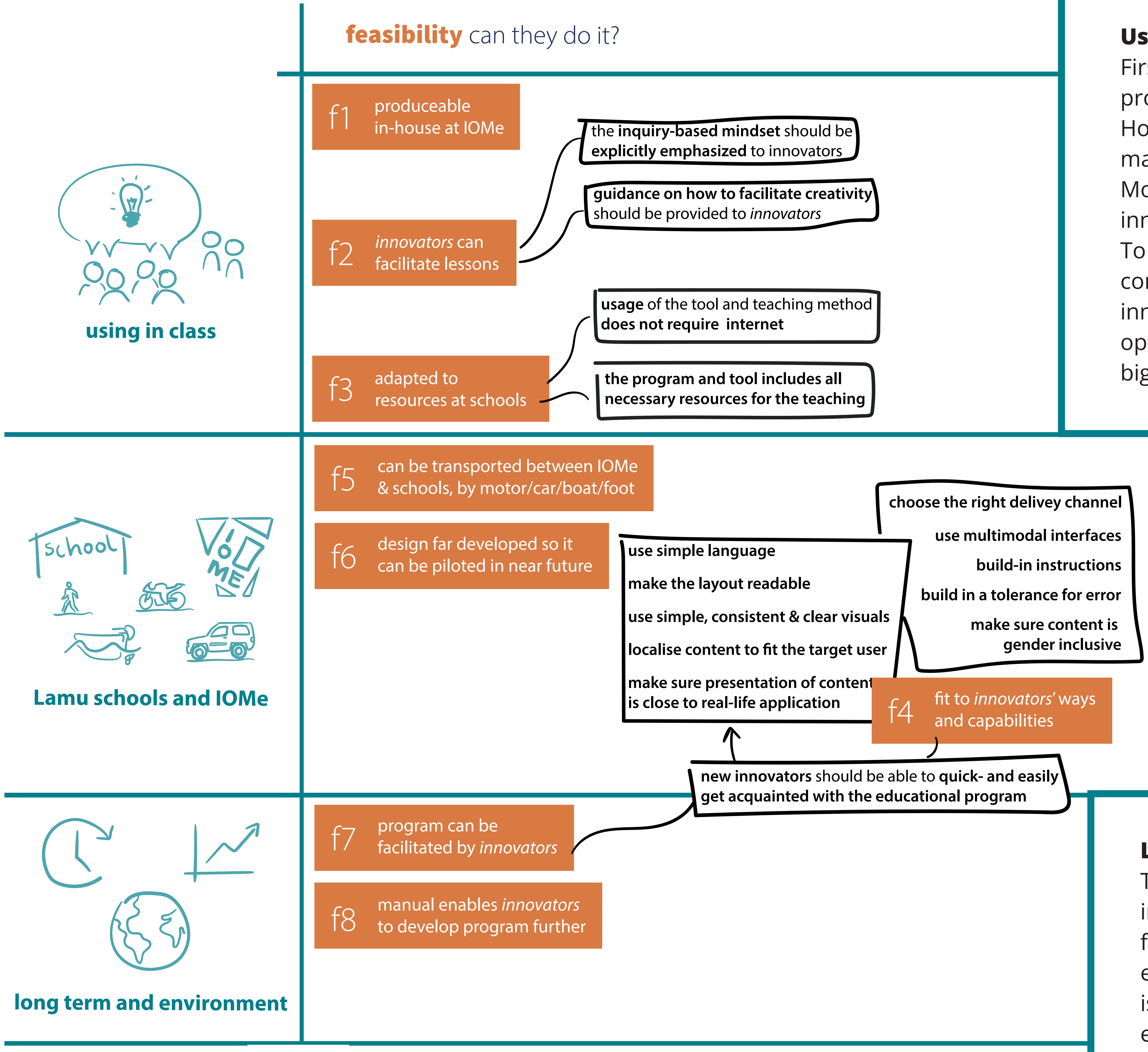
The Future Inventors program is designed to align with IOMe005’s core values, and automatically raises awareness in schools by visiting innovators. It also strives to align with schools’ ways, however there is a big discrepancy between the two, thus, to allow for more freedom, Future Inventors is extracurricular. To convince schools and boost acceptance, actions from IOMe005 are required, as presented in the client advice, chapter 13. Moreover, teachers are not pressured as facilitator take up the effort of the program.

Beyond the scope of the project

The challenge-based workshop framework was found to be also applicable in other types of meetings and sessions at IOMe005, which maximizes the input of this project. Furthermore, although not directly desired, teachers also learn about real inquiry-based teaching when assisting in the facilitation. They can then apply in their own classes, and in this way gradually challenge the singular-truth mindset.

Long term and environment

Finally, looking at the long term, the ThinkBricks are made from wood to fit with Lamu culture ánd have a minimal environmental impact. Furthermore, the program engages learners in solving societal problems which are related to their own lives, which empowers to take their future in their own hands.



feasibility can they do it?

using in class

f1 produceable in-house at IOMe

f2 *innovators* can facilitate lessons

the inquiry-based mindset should be **explicitly emphasized** to innovators

guidance on how to facilitate creativity should be provided to *innovators*

f3 adapted to resources at schools

usage of the tool and teaching method **does not require internet**

the program and tool includes all necessary resources for the teaching

Lamu schools and IOMe

f5 can be transported between IOMe & schools, by motor/car/boat/foot

f6 design far developed so it can be piloted in near future

f4 fit to *innovators'* ways and capabilities

use simple language

make the layout readable

use simple, consistent & clear visuals

localise content to fit the target user

make sure presentation of content is close to real-life application

choose the right delivery channel

use multimodal interfaces

build-in instructions

build in a tolerance for error

make sure content is gender inclusive

long term and environment

new innovators should be able to **quick- and easily get acquainted with the educational program**

f7 program can be facilitated by *innovators*

f8 manual enables *innovators* to develop program further

15.2 | Feasibility

Using in class

First of all, the ThinkBricks are designed to be produced with the CNC machine at IOMe005. However because the machine is quite inaccurate, manual finishing is necessary.
Moreover, the manual design aims to take innovators by the hand in how to facilitate lessons. To access the manual, innovators only need a computer at IOMe005. To facilitate workshops, innovators only need to bring the ThinkBricks, optionally some other materials to build with, and big paper sheets with the workshop agenda.

Beyond the scope of the project

Important in the feasibility of this project was the collaborative way of developing the design. Because the innovators have been actively involved in the design, evaluation and prototyping process, they will feel a certain ownership over the program. It is expected that this approach will positively influence further implementation, because they understand the program well.

Lamu schools and IOMe005

Sets of ThinkBricks will be packed in bags, which are easy to take along as an innovator travelling to Lamu island. The blocks and the bag material both can withstand water and high temperatures, because the materials are commonly used in Lamu.
Furthermore, the design is ready to be fabricated at IOMe005, and the tutorials in the manual are ready to be used to develop workshops and start a program pilot. The guidelines from chapter 11 to bridge the gaps between the designer and the innovator are applied in the manual in order to fit the innovators' ways of working and digesting information.

Long term and environment

The manual strives to explain the program to first-time facilitators, so new innovators at IOMe005 can quickly join in the program. In this way the manual fits how the pool of innovators keeps on changing. Furthermore, the manual enables innovators to develop the program, because at the core of the manual is the idea that innovators should design their own workshop plans, in order to enable them to facilitate good workshops and gain confidence in their own way.

15.3 | Viability

viability should they do it?

using in class

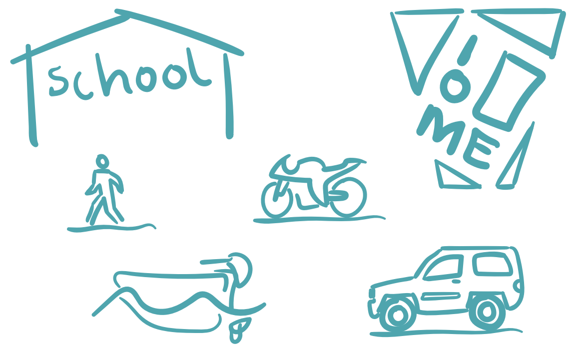
V1 minimal initial production cost

Using in class

The production costs for the ThinkBricks are roughly 9 euro per set, because they are made solely of locally widely available materials, and are produced in-house by volunteering innovators. The only other costs to bring the program to schools is the transportation of innovators, where using RedCross facilities can minimize this cost.

Beyond the scope of the project

Beyond just viability in terms of money, this project proves that a system which can be easily adopted and expanded, as explained in the third lens, is as important for a viable and future-proof system. By empowering locals to pick up the project and develop it as desired, value beyond money can be created, by spreading open-access quality education and stimulating collaboration through the design.



Lamu schools and IOMe

V2 can be used in range of educational activities

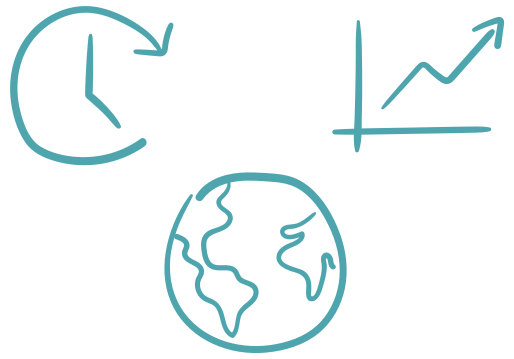
V3 minimal replacement costs

tool should not be a target for thiefs

tool does not require maintenance

Lamu schools and IOMe005

Furthermore, the ThinkBricks are designed to teach about countless different STEM topics, which makes them worth the initial investment for IOMe005. Besides this, the tool is expected not to be a target to steal because of its low material value and no integration of high-tech. This also contributes to the fact that no maintenance is necessary to the ThinkBricks. However, although the bricks are big in size and brightly coloured, they might still get lost and need to be replaced. Therefore a final recommendation on the casing was given in the client advice in chapter 14.



long term and environment

V4 educational program is scalable

Long term and environment

As stated before, the intention of the manual is to enable innovators to design their own workshop plans. Therefore, this manual can be shared across Kenya with other branches of IOMe005. Then, ThinkBricks can be sent, or if a CNC machine is available, locally produced. Although it is intended to teach with the ThinkBricks, the workshop framework can also be applied in other contexts.

Enjoying three coconuts, because it is good for the health! Photo by Emma de Cocker

PART 5 personal reflection

The total design project will be closed off with a reflection on the past six months.

16 | Looking back on the graduation journey

Reflecting on my graduation journey, I examined three aspects of it:
The most surprising experience, the most meaningful lesson and the most challenging part.

MOST SURPRISING

my passion for education

The most surprising experience was discovering my passion for designing an educational tool. Initially, I was drawn to the project's hands-on nature and the impact I could make on the rural region of Lamu. However, as I worked on the project, I realized that education was a personal passion. I recognized how crucial my own education had been in shaping me into the person I am today. I have had a rather free schooling, allowing me to discover who I am and what I want. It can often be frustrating to me when I hear stories of people who did not enjoy their education in this way. In this project, I got to use this frustration in the Kenyan educational system as a boost to work on my design to improve this system. Designing an educational tool also provided me with the freedom to try out different approaches, making it an enjoyable experience. In fact, I furthered my education in this area by becoming a kitesurfing instructor, and now continuing this educational path.

MOST MEANINGFUL

the intercultural collaboration

The most meaningful lesson was learning about the intercultural design process. Collaborating with a client from a vastly different culture taught me the importance of building relationships. I quickly developed an intercultural design approach that helped me make decisions and pushed me to do research, analyse, set a new goal, and research again. I realized the importance of constant testing and evaluating with stakeholders, which led to a design that I stood behind, and stakeholders were already bought in. Working closely with future users helped me understand what is essential and what's not, leading to a better design. This was the most meaningful lesson of this total project: A design is only so good as the stakeholders believe it is.

MOST CHALLENGING

planning realistically

The most challenging part of the project was managing the planning up until the end. While starting the project, I formulated the ambition to maintain a good mental state by giving myself the freedom to take days of to do other things besides graduation. However, at the end of my project, my planning was often overly optimistic, and deadlines would sneak up on me. My tendency to go the extra mile in design projects and my perfectionism would then hinder this free time. This tension forced me to learn how to balance work and free time and prioritize tasks, which still proves challenging. However I believe that bit by bit I learn how to judge the time a task takes more realistically.

Overall, the graduation journey taught me a lot about my passions and my approach to design. It allowed me to explore new areas of design and taught me the importance of building relationships in any project. Due to the great amount of cocreation, I learnt to let go of my “designer ego“ and embrace any outcome of the design. I am very proud of what finally came from this project.

references & appendices

17 | References

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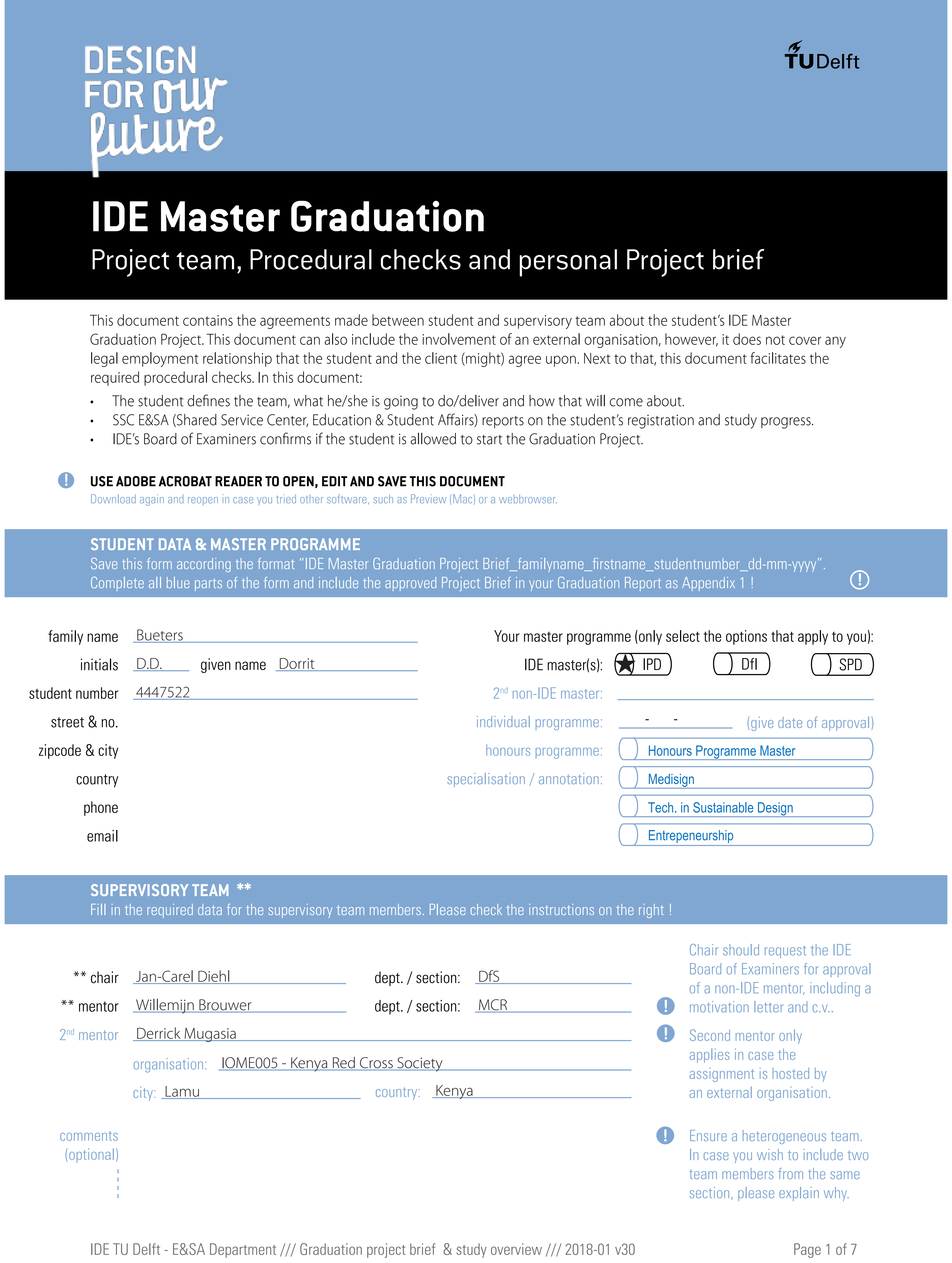
Appendix list

1. Design brief
2. Benchmarking

Design brief [1/4]



DESIGN FOR our future

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

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

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT

Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME

Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy".
Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name: Bueters
initials: D.D. given name: Dorrit
student number: 4447522
street & no.:
zipcode & city:
country:
phone:
email:

Your master programme (only select the options that apply to you):
IDE master(s): ● IPD ○ DfI ○ SPD
2nd non-IDE master:
individual programme: - - (give date of approval)
honours programme: ○ Honours Programme Master
specialisation / annotation: ○ Medisign
○ Tech. in Sustainable Design
○ Entrepeneurship

SUPERVISORY TEAM **

Fill in the required data for the supervisory team members. Please check the instructions on the right !

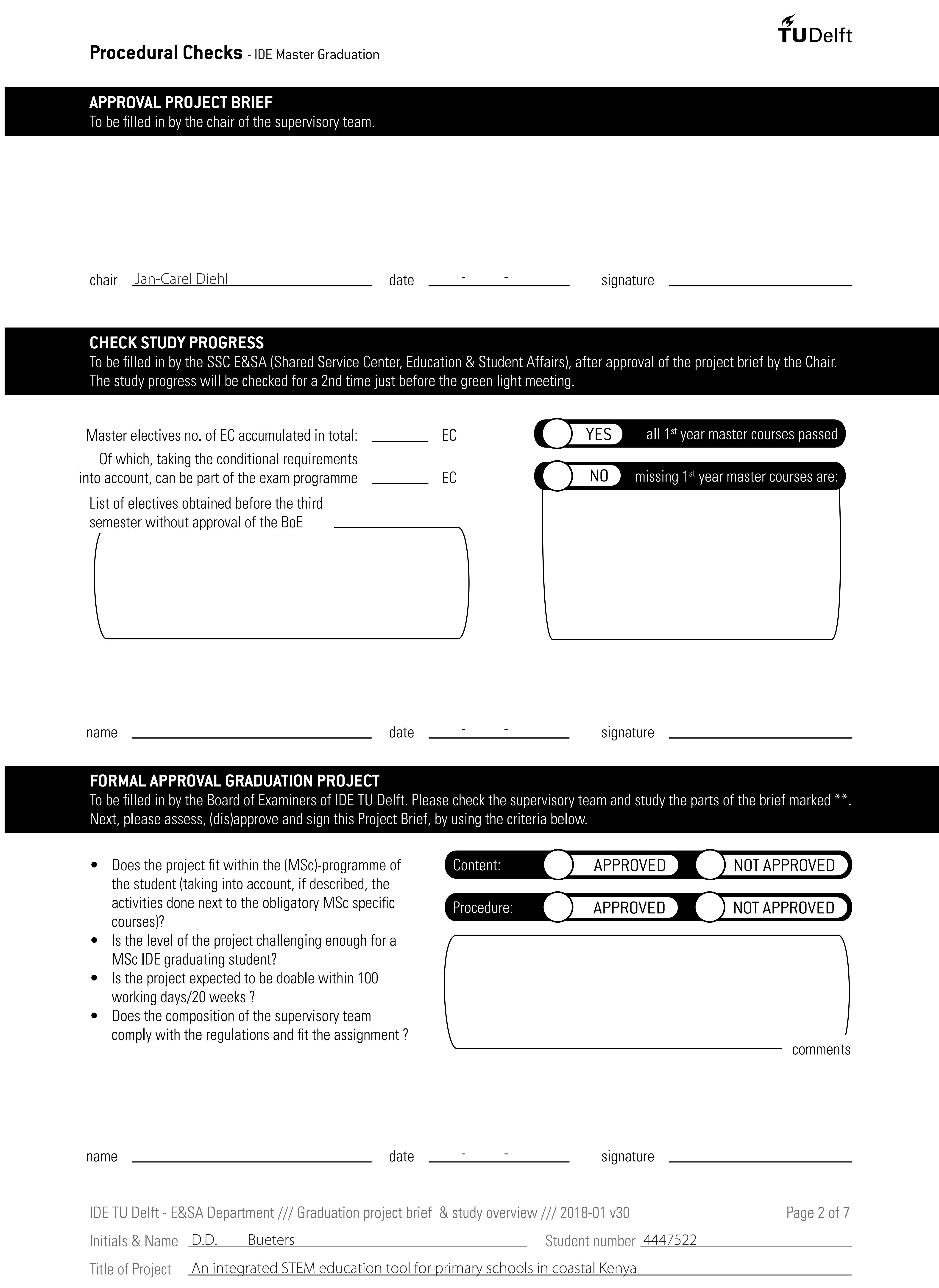
** chair: Jan-Carel Diehl dept. / section: DfS
** mentor: Willemijn Brouwer dept. / section: MCR
2nd mentor: Derrick Mugasia
organisation: IOME005 - Kenya Red Cross Society
city: Lamu country: Kenya
comments (optional):

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

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

IDE TU Delft - E&SA Department /// Graduation project brief & study overview /// 2018-01 v30 Page 1 of 7



TU Delft

Procedural Checks - IDE Master Graduation

APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair: Jan-Carel Diehl date: - - signature:

CHECK STUDY PROGRESS

To be filled in by the SSC E&SA (Shared Service Center, 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 the conditional requirements into account, can be part of the exam programme ____ EC
List of electives obtained before the third semester without approval of the BoE

○ YES all 1st year master courses passed
○ NO missing 1st year master courses are:

name: date: - - signature:

FORMAL APPROVAL GRADUATION PROJECT

To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **. Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: ○ APPROVED ○ NOT APPROVED
Procedure: ○ APPROVED ○ NOT APPROVED
comments

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Initials & Name: D.D. Bueters Student number: 4447522
Title of Project: An integrated STEM education tool for primary schools in coastal Kenya

Design brief [2/4]

An integrated STEM education tool for primary schools in coastal Kenya — project title

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

start date 26 - 09 - 2022

23 - 03 - 2023 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

This project involves the IOMe005 makerspace, an initiative of Kenya Red Cross Society (later referred to as KRCS), which is located in Lamu county in coastal North-East Kenya. This rural area, which consists of an archipelago of over 65 islands, is greatly influenced by the sea. Traditional woodworking and boat carpentry are an important part of the culture, locals mainly live off fishery, agriculture, and rather recently tourism. There is little access to internet and electricity, no manufacturing plants or big commercial businesses.

The aim of IOMe005 is to create a collaborative space that gives local innovators and enthusiasts, adults and children, access to advanced technologies and production methods to create and test new concepts, products and businesses. The space consists of several containers which house 3D printers, a CNC workshop, laser cutters and engravers and milling, welding, moulding and modelling machines.

Since 2021 the makerspace has been looking to expand its impact by educating local children in Science, Technology, Engineering and Mathematics (STEM) in a practical and hands-on manner at the makerspace. Now the goal is to bring this practical STEM education to the local classrooms. In the future they aim to expand this impact to other rural and coastal areas throughout Kenya.

MAIN STAKEHOLDERS
IOMe005 lab facilitators: The core employees who are well educated, and whose main work is to keep the lab running and facilitate all activities. Whenever they have a specific (STEM) project, they give this to an innovator and guide them through it.
IOMe005 innovators: Locals, adults and youth, who come to the makerspace to learn about new technologies and who could take on IOME005 projects is working on.
Red Cross Volunteers: KRCS has a big network of volunteers, which are locals who are available to help with any (emergency) activities the Red Cross undertakes.
School board: Multiple schools are often owned by the same person. Therefore these directors are very important when it comes to the implementation of innovations.
Teachers: The teachers at the schools play a big role in the education of the children.
Children: This project focusses on children in upper primary school (10-12 years old).

MAIN OPPORTUNITIES & LIMITATIONS:
The KRCS has a big support base and network already built up within Kenya, which could play an important role in this project. However, there is not a lot of money and resources available as Lamu is quite a poor county and the challenging infrastructure can make obtaining materials costly and challenging.

The number of primary school dropouts was 1.13 million children in 2020 due to reasons such as child labour, poverty and a general low perceived value of education. (Unicef, 2021). There is also a big shortage of human resources in the Kenyan education system, which results in a poor teacher-learner ratio. (The Africa Report, 2022)

Finally, in Lamu people greatly value the cultural traditions of their community, such as woodworking, and it is very important to keep this local culture alive. When handled right, this can be a big opportunity to make something which fits their culture, but it can also be a limiting factor when done wrong.

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introduction (continued): space for images

This image shows the main problem and it's limitations and challenges. On top in green very generally, and below in yellow more detailed on the lamu situation. The problem on which will be focussed is marked in blue.

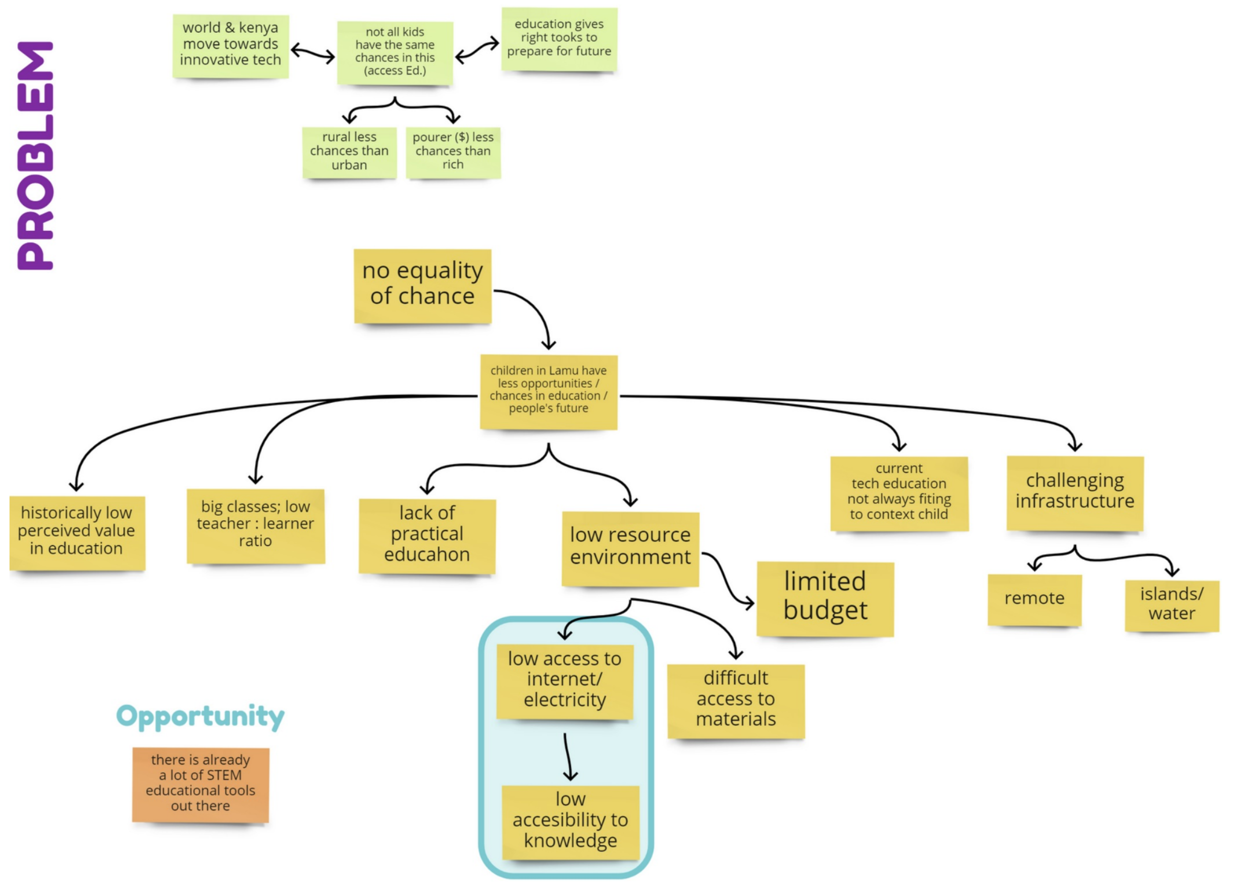
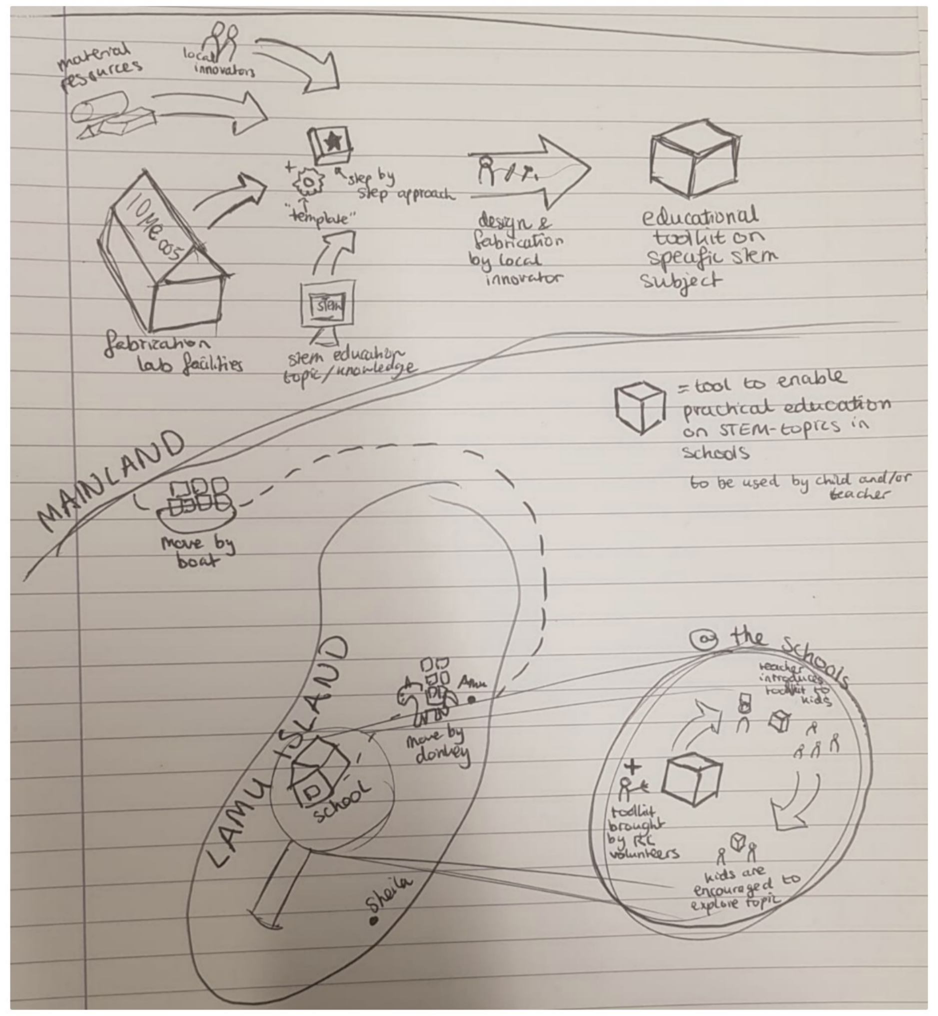


image / figure 1: Overview of the problem and a focus within this problem



This image shows an overview in which the solution will live:

On the mainland of Lamu at the IOMe005 makerspace, local innovators are provided a way to design and make an educational toolkit.

This toolkit is then shipped in small boats to Lamu island, where it will be introduced to the children by the teachers or Red Cross volunteers.

image / figure 2: Ecosystem of envisioned solution

Design brief [3/4]

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

Globally in the world, as well as in Kenya, technological innovations are greatly changing the way we live and work. To be prepared for a changing future and stay resilient in a changing world, it is important for children around the world to learn about technology from a young age. It is believed that, next to the personal growth STEM education brings, this form of education is one of the best ways to improve the development of Africa. (Ibironke, 2021)

There are numerous initiatives to make STEM education fun and interesting for children all around the world. Currently not all children have the same access these educational resources, which leads to inequality of future opportunities. Lamu island is a place where local children's exposure to technology and STEM knowledge is significantly lower than their peers in other parts of the world.

Its rural and coastal character results in a challenging road, internet and electricity infrastructure. Because of this, relatively lower monetary and material resources are available for STEM education of local children. Thus, although the Government's new Competency Based Curriculum demands children to be taught in a practical manner, there is hardly any practical STEM education taught in schools on Lamu island. Because of this theory-focused education, most children struggle to stay motivated throughout their school carreer: In their 2022 research on STEM in Kenya, Makoba & Odhiambo state that "performance in [STEM subjects] at the secondary level have been consistently low for the last nine years for the period 2006 to 2014 with a national mean score below 50% in all science subjects."

In this project, the issue to be addressed is therefore the fact that the rich availability of STEM educational resources, for example to be found on the internet, does not find its way into the schools at Lamu island, leading to inequality in educational opportunities. Because a lot of children do not finish primary school, the focus lies be on this category, to create interest in STEM from a young age. Later this is envisioned to be expanded to other age groups.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

I aim to design a practical STEM educational tool which enables the IOMe005 makerspace to bring STEM education to the schools on Lamu island. The secondary goal of this project is to enable IOMe005 innovators to replicate the development process of this educational tool, to ensure they know how to take the project further once the first tool has been successfully implemented.

Education specific, this tool aims to enthuse primary school children from 10-12 years old for STEM, and to encourage them to learn through exploration and experimentation. The aim is not to revolutionize the way STEM education is taught, but to get inspired from what has already been developed and adapt it to fit it in the Lamu context with its opportunities and limitations.

To be able to start developing and testing tangible solutions early in the design process, a specific STEM topic is already chosen around which this educational tool will evolve, namely wind energy.

Thus the expected outcome of the project are:
1. An educational tool on wind energy to be produced in the IOMe005 makerspace by IOMe005 innovators and transported to and used in schools on Lamu island. This toolkit will contain of a tangible part, along with an envisioned interaction of how to approach the learning.
2. A recommendation on the process to design this type of educational tool, for tools on other STEM topics.

In order to successfully design this tool, it is important for me to find out:
- What user needs to take into account? Considering all sub-users in the system from design to implementation
- Which human and material resources are locally available and which other context-specific factors, such as environment and culture, should be taken into account in the creation of an educational tool?

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PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and 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 activities.

start date 26 - 9 - 2022 23 - 3 - 2023 end date

☑ Aa Name
☑ DAY 1 - START PROJECT
☑ SPRINT 1 - Setup project + walk through
☑ SPRINT 2 (1/2) - Specify potential sub-proble
☐ SPRINT 2 (2/2) - Specify potential sub-problems
☐ DAY 12 - KICK OFF
☐ Benchmarking visually (moodboards etc.)
☐ After SPRINT 2 - Discuss possible directions
☐ Preparation interviews / sessions with kids /
☐ Prototyping promising directions
☐ @ LAMU
☐ First visit to the IOMe005 facility
☐ Immersion and observation in schools
☐ Writing of first research insights
☐ Ideation on new insights
☐ Meeting Team / IOMe005
☐ Ideation / further development of ideas
☐ Sessions with teachers / children
☐ Prototyping in lab to test in the sessions
☐ Documentation of prototyping & session outcor
☐ DAY 38 - MIDTERM
☐ SPRINT 3 - Developing specific concept directio
☐ Further sessions with teachers / children
☐ Documentation of all activities so far
☐ Detailed concept development
☐ Writing draft report
☐ Validation of design through (online) user re
☐ Documentation of concept features + how to re
☐ DAY 80 - GREEN LIGHT
☐ Final design adaptations
☐ Writing final report
☐ Prepare graduation presentation
☐ DAY 100 - GRADUATION

The main methodology used in this project is Rapid Prototyping: periods of producing prototypes will be alternated with user research, user testing and cocreative sessions. The outcome of these sessions will then result in new prototypes to be tested.

Because the time spent in Kenya will be rather unpredictable, multiple activities per week are planned to allow for enough flexibility.

This planning is based on a 5 day work week. Several free days are planned to allow for travelling to and from Lamu. Furthermore a total of 21 extra free days are planned, of which 10 free days during Christmas and New Year, and 11 flexible days: 4 before the Midterm, 3 between the Midterm and the Green Light, and 4 after the Green Light. This is to allow for the learnings to sink in and allow for enough time for physical exercise to ensure well mental wellbeing throughout the project.

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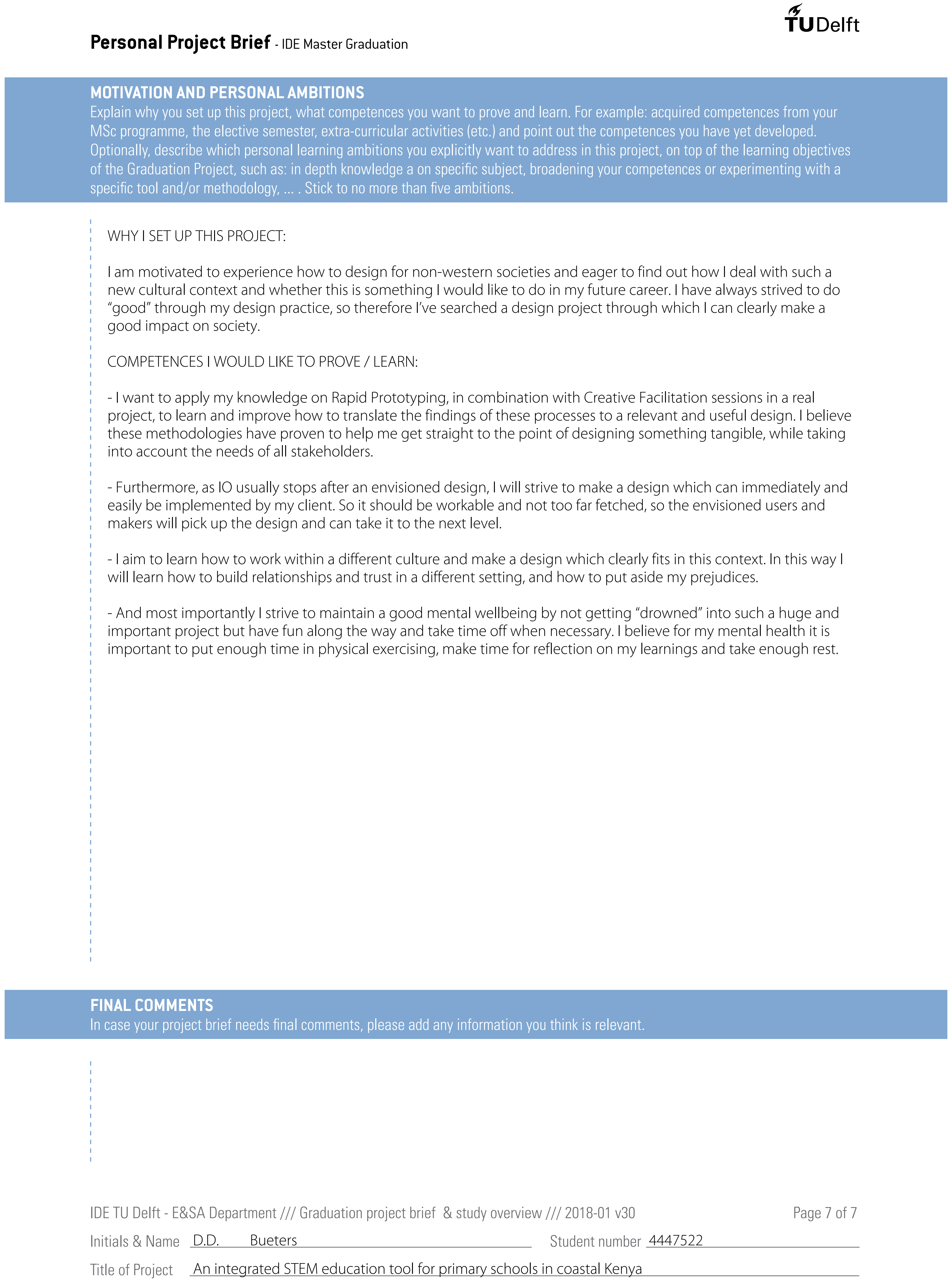
Design brief [4/4]



Personal Project Brief - IDE Master Graduation

TU Delft

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

WHY I SET UP THIS PROJECT:

I am motivated to experience how to design for non-western societies and eager to find out how I deal with such a new cultural context and whether this is something I would like to do in my future career. I have always strived to do "good" through my design practice, so therefore I've searched a design project through which I can clearly make a good impact on society.

COMPETENCES I WOULD LIKE TO PROVE / LEARN:

- I want to apply my knowledge on Rapid Prototyping, in combination with Creative Facilitation sessions in a real project, to learn and improve how to translate the findings of these processes to a relevant and useful design. I believe these methodologies have proven to help me get straight to the point of designing something tangible, while taking into account the needs of all stakeholders.

- Furthermore, as IO usually stops after an envisioned design, I will strive to make a design which can immediately and easily be implemented by my client. So it should be workable and not too far fetched, so the envisioned users and makers will pick up the design and can take it to the next level.

- I aim to learn how to work within a different culture and make a design which clearly fits in this context. In this way I will learn how to build relationships and trust in a different setting, and how to put aside my prejudices.

- And most importantly I strive to maintain a good mental wellbeing by not getting "drowned" into such a huge and important project but have fun along the way and take time off when necessary. I believe for my mental health it is important to put enough time in physical exercising, make time for reflection on my learnings and take enough rest.

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.

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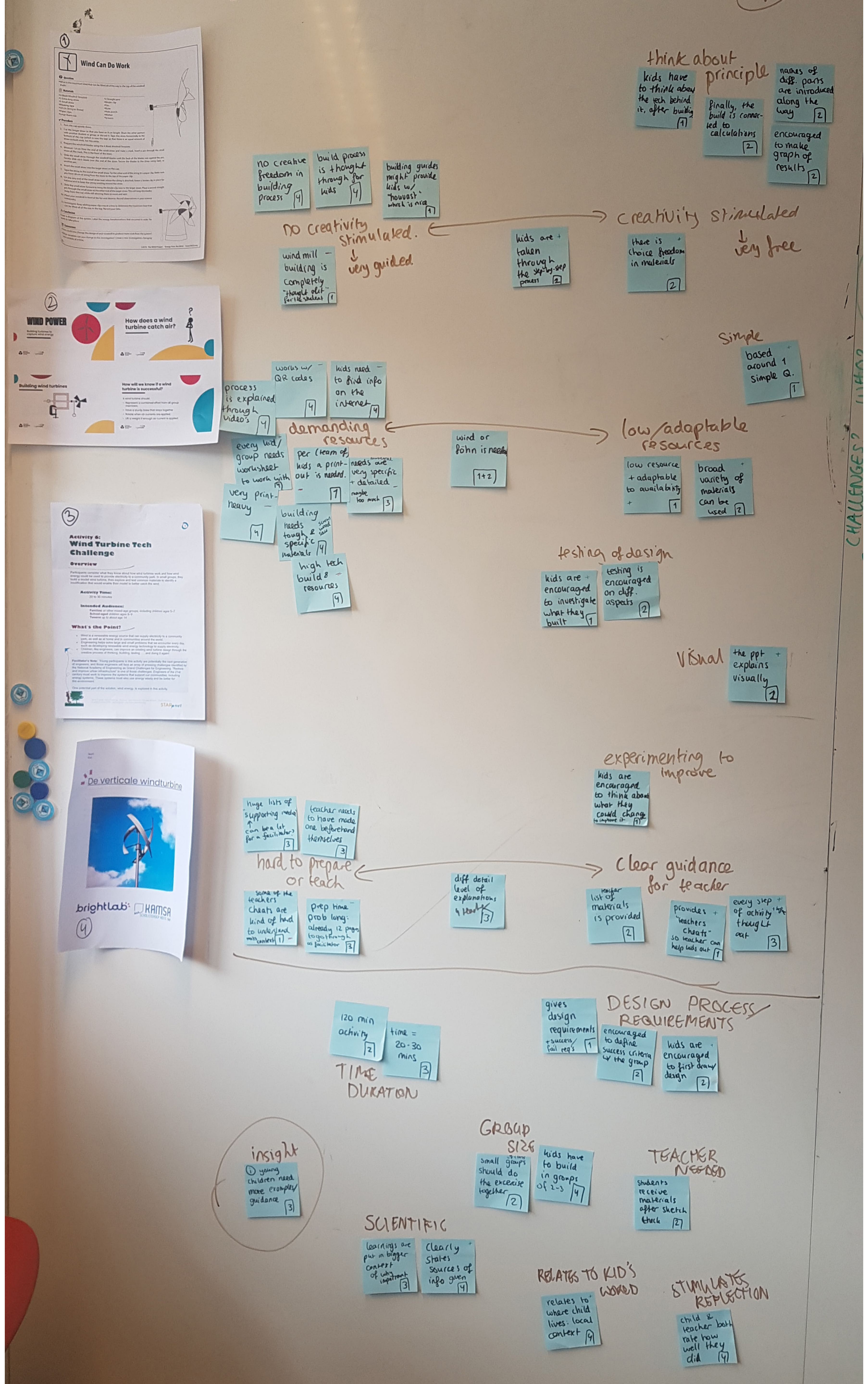
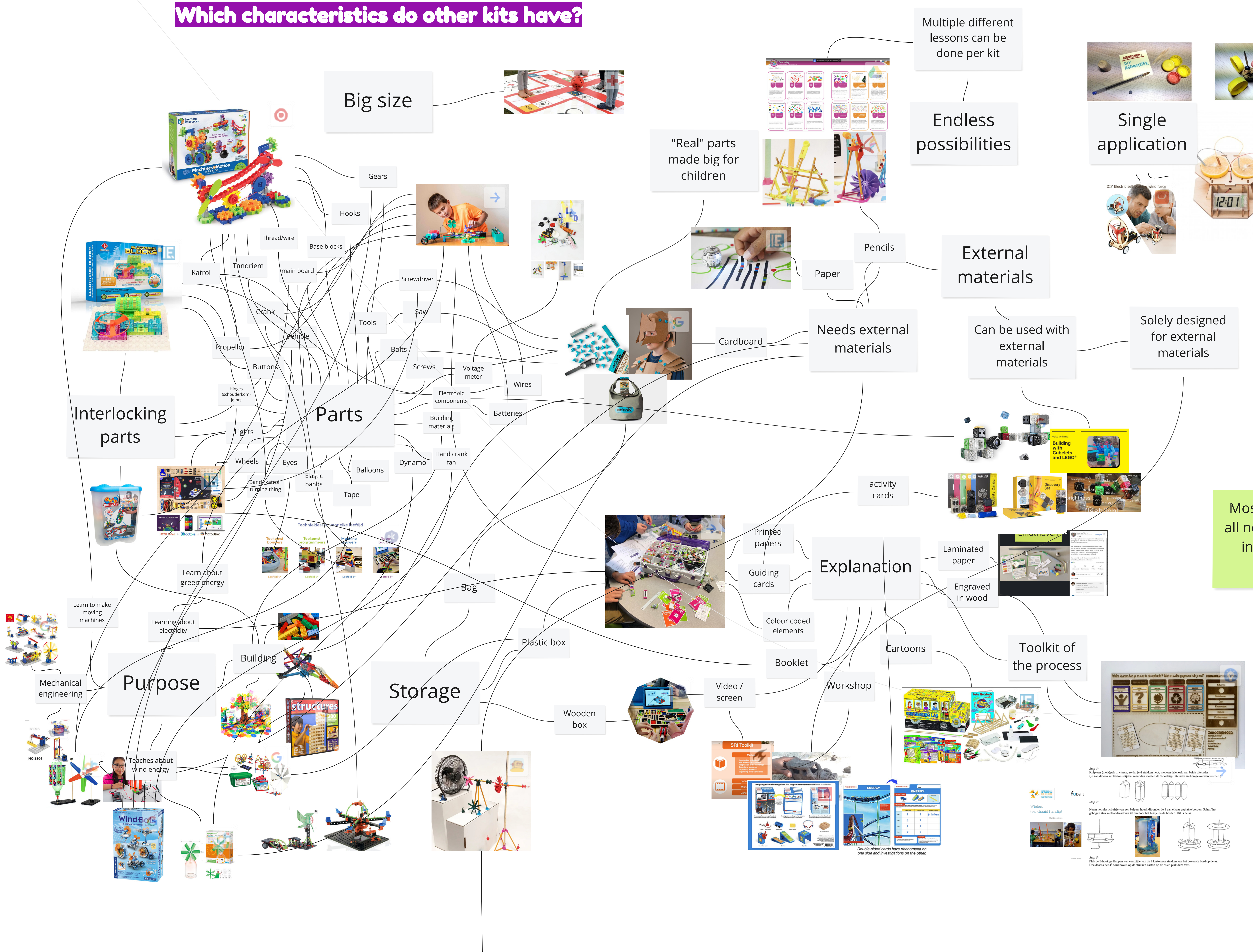
Benchmarking [1/2]

Sprint outcome



Benchmarking [2/2]

Which characteristics do other kits have?



Big size

"Real" parts made big for children

Multiple different lessons can be done per kit

Endless possibilities

Single application

Pencils

Paper

External materials

Cardboard

Needs external materials

Can be used with external materials

Solely designed for external materials

Interlocking parts

Parts

Gears

Hooks

Thread/wire

Base blocks

Katrol

Tandriem

main board

Screwdriver

Crank

Saw

Tools

Vehicle

Propellor

Bolts

Buttons

Screws

Voltage meter

Wires

Hinges (schouderkom) joints

Electronic components

Batteries

Lights

Building materials

Hand crank fan

Wheels

Eyes

Dynamo

Balloons

Band "katrol" turning thing

Elastic bands

Tape

activity cards

Printed papers

Guiding cards

Explanation

Laminated paper

Engraved in wood

Colour coded elements

Cartoons

Toolkit of the process

Booklet

Workshop

Video / screen

Bag

Plastic box

Wooden box

Storage

Learn about green energy

Learn to make moving machines

Learning about electricity

Mechanical engineering

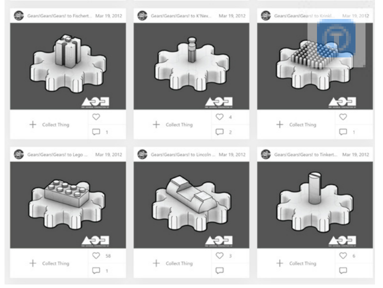
Purpose

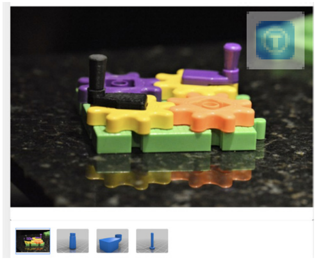
Building

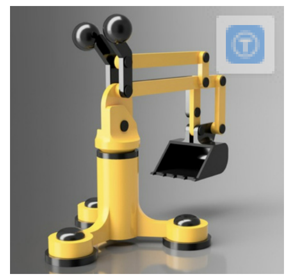
Teaches about wind energy

How could the components be made?

Possibilities with 3D printing







Which components do other kits have?

Most / all kits contain all necessary materials in it itself; are not context-fixed

Kits that evolve around electronics are very expensive (hundreds of euros)

A lot of kits are electronic based

Possibilities with wood