Merging nanobiology and usability

Improving the workflow of Dispertech's NanoCET device

Master thesis

Mirjam Meijer

Design for Interaction

Delft University
of Technology

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Design for Interaction
Faculty of Industrial Design Engineering
Delft University of Technology

In collaboration with

Dispertech

Supervisory team

Chair
Dr. ir. J.I. van Kuijk (Jasper)

Mentor
Dr. ir. A. Jansen (Arjen)

Company mentor
A. Caratino (Aquiles)

Executive summary

In this graduation project for the start-up Dispertech, the usability and workflow of their NanoCET device is improved. The NanoCET is a research tool used in hospital and university laboratories, for which the following problem was stated: researchers and technicians working in labs have difficulty setting up and using the NanoCET device and software when conducting a measurement on the size distribution and concentration of nanoparticles. This leads to failed measurements and therefore a waste of time, materials, and samples. As a result of these issues, it is difficult for researchers to trust Dispertech and their NanoCET. The NanoCET faced challenges with its workflow, which is disrupted by going back and forth between the software and the device, with its underdeveloped analysis and measurement software, and missing feedforward and feedback in physical configuration elements like the 'arena', the clamp, and the cartridge. These usage issues have been traced during interviews and observations in the context, a competitor analysis, a functional analysis, a usability inspection, and a streamlined walkthrough.

The final design is developed through explorative prototyping, associative sketching using methods like SCAMPER and morphological charts, and creative sessions with peer students and with Dispertech. The final design is focused on a guided and efficient workflow, facilitated by the device but mainly by the measurement software, see figure 2. (Inter)actions in the workflow of the final design are clustered as well as the process allows. Consequently, the workflow is split up into three phases: 1) Insert cartridge, 2) Prepare device, and 3) Measurement. The physical device shows multiple differences compared to the current NanoCET: the ON/OFF button is visible and easily reachable at the front, the finger indentation of the knob is coloured to emphasize this use cue, there are use cues for (opening) the clamp and the packaging of a cartridge facilitates carrying information, see figure 1. The cartridge itself is redesigned to protect the coverslip and to provide more feedforward and feedback by making use of colours (and shapes) resembling the corresponding phase. The 'arena' is designed to provide use cues and fit the new cartridge. Moreover, the LEDs on the physical device are placed so they are always visible, whether the interaction is performed seated, or standing up. Each LED has a different colour to track the three phases and their colours in the software. In the software, the user sees an overview of the whole process. Information is hierarchically layered, using hover-information buttons to provide extra input when it is required during the process. The least amount of input is required to set up a measurement, supported by automatically filling fields based on the information given earlier. In this way, users experience careful guidance through each step of the workflow.

Before the iteration step towards the final design, a design proposal was tested with eight users (that work) in the context. This resulted in an 'excellent' System Usability Scale score and improvements that are incorporated in the final design presented. Users experienced the design proposal as easy to use, straightforward, and user-friendly with a good workflow. Moreover, half of the user test participants already experienced the design proposal as trustworthy even though an experience prototype cannot deliver actual results. Above all, the redesign of the NanoCET has gained an additional feature to stand out in the competitor field with its guiding software. Because of the improvements, it would be no longer necessary to read the manual before and during the workflow. Therefore the guiding software could be added as a unique selling point of the NanoCET.

The next step would be to conduct user tests with the final design to test the improvements made since the last user tests. Therefore, in those user tests the focus should be on evaluating the workflow, the use cues in the 'arena', the ON/OFF button during first-time use, and the (textual) adjustments in the software. In the meantime, small physical configurations on the cartridge, clamp, and 'arena' could be explored using explorative prototypes, as there are multiple configuration options within the same workflow. Lastly, the role of 'NanoCET instructor' should be further developed. When this function is rolled out, someone should be trained for the function. Then, when the NanoCET goes to the market, the instructor can offer the desired support.

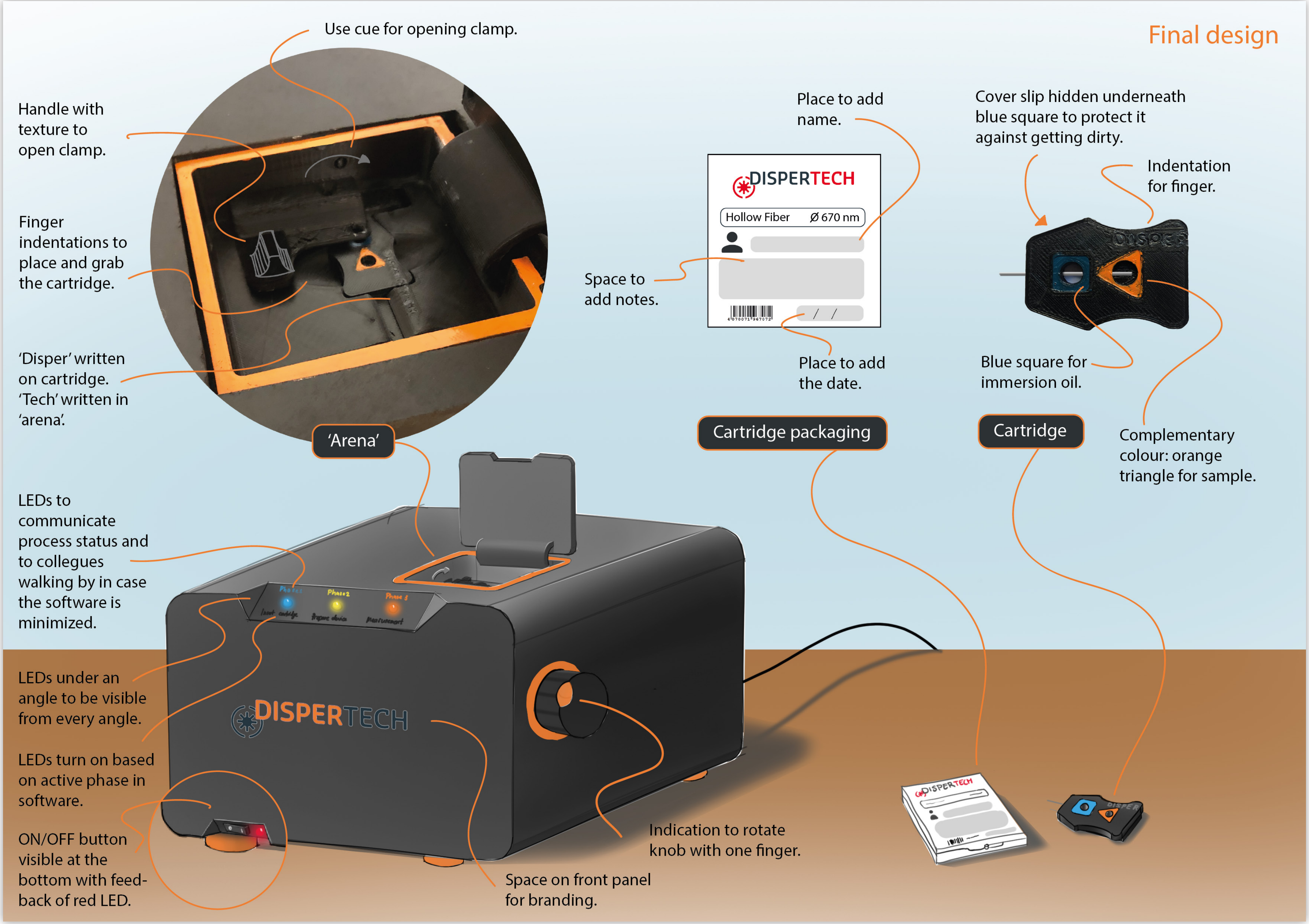


Figure 1. Final design of NanoCET device.

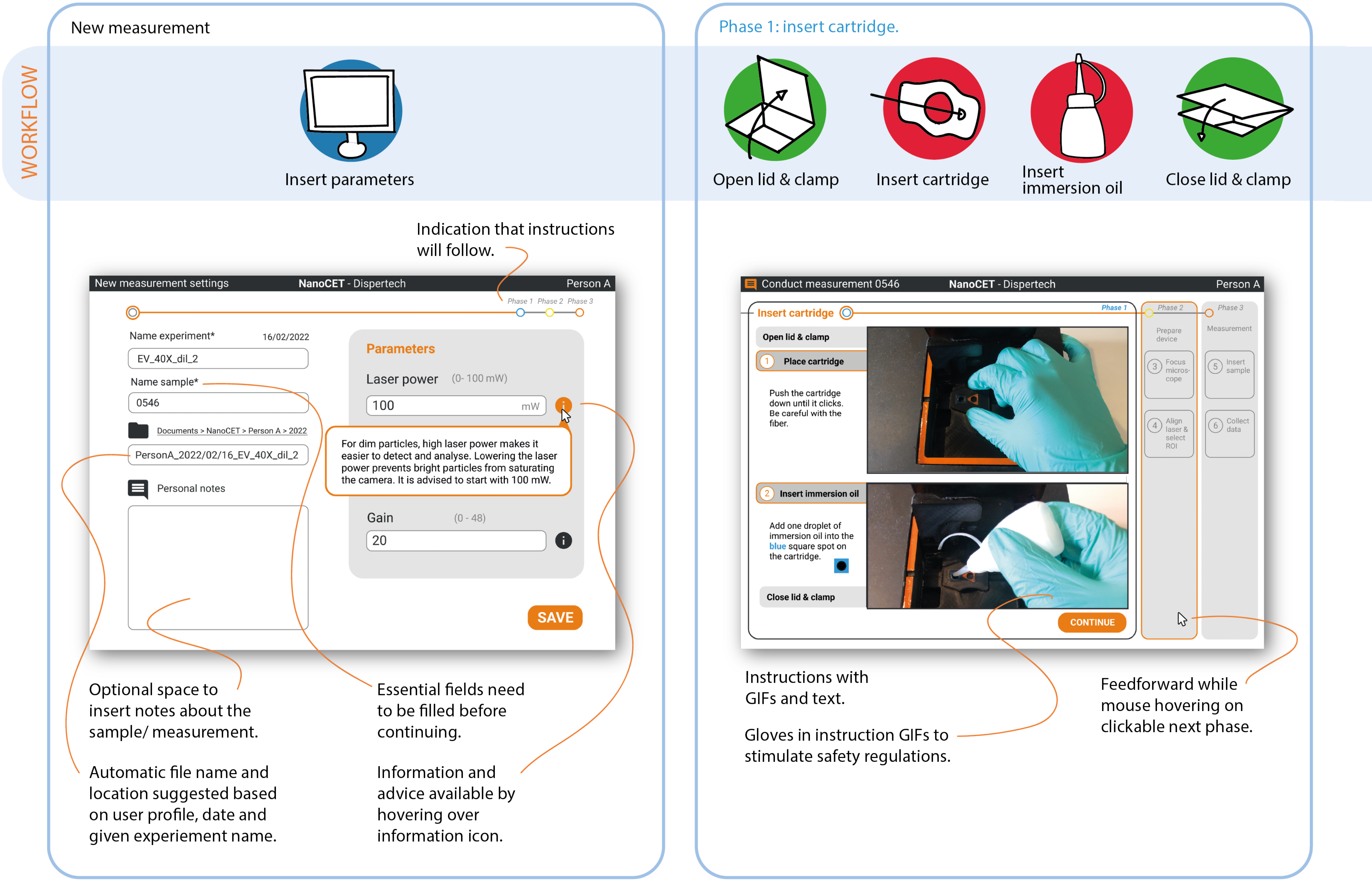
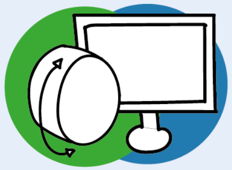


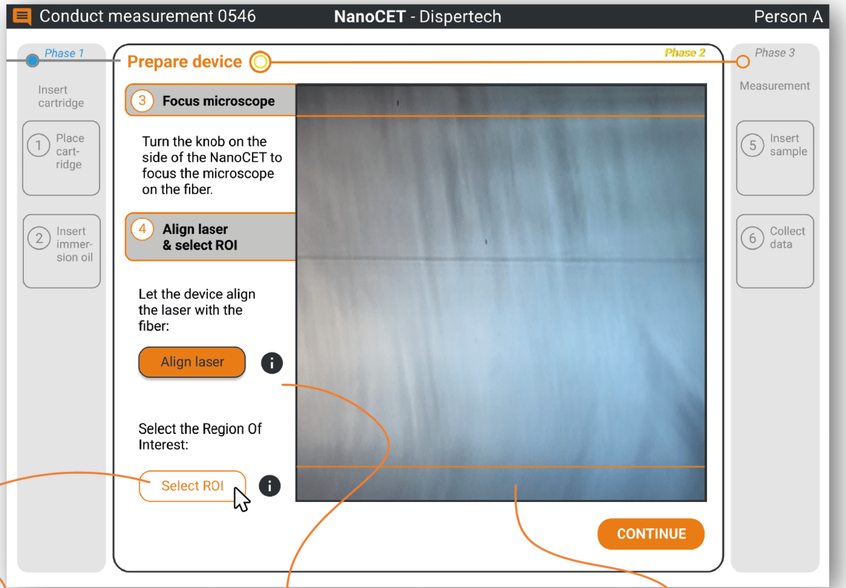
Figure 2. Workflow with the main software screens.

Phase 2: prepare device.



Focus microscope

Align laser and select Region Of Interest (ROI)

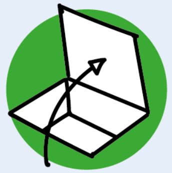


Completed buttons stay orange.

Buttons change color while mouse hovering.

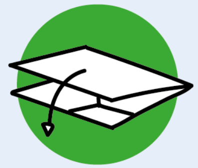
ROI lines that can be dragged around the fiber.

Phase 3: measurement.



Open lid

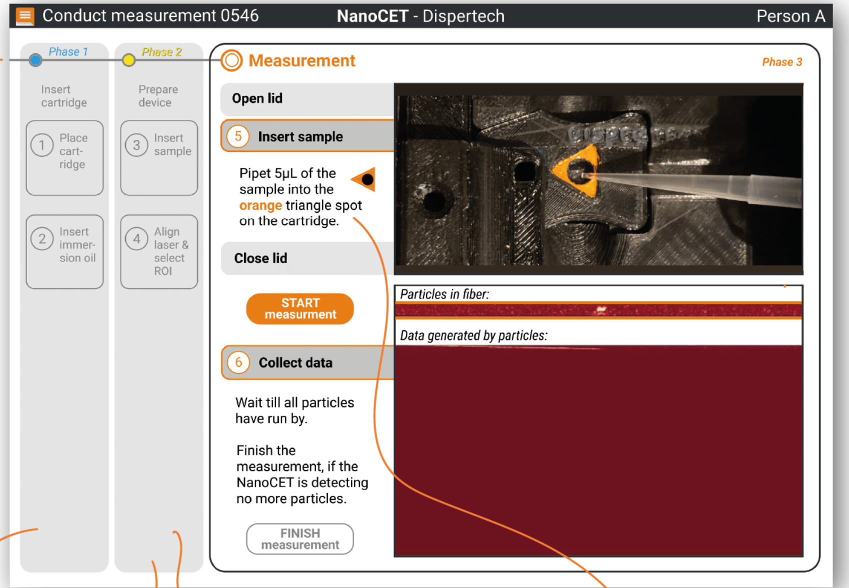
Insert sample



Close lid

Start & finish measurement

Phase colours resemble corresponding LEDs on NanoCET.



Timeline and steps in blocks resemble lab journal structure and function as progress bar.

Inactive phases greyed out, but you can navigate back to a previous phase by clicking on it or by using the keyboard arrows.

Specific written instructions, like sample volume.

Always overview the whole process to collect all necessities at once.

Digital interaction · Physcial interaction · Inserting elements

Table of contents

1 Introduction

The Lycurgus Cup is a famous 4th century Roman glass cage cup. The reason for its fame? Not only its artistic craftmanship, but also the fact that it can appear in two different colours. Figure 3 (The Lycurgus Cup 2016) shows the cup in an olive green colour, and a bright red. One might wonder, is it the same cup? And what makes it appear in two different colours? Well, it is the properties of nanoparticles. The working of the nanoparticles was used in the artifact in such a way that the cup shows green when it is lit from the front (reflected light) and red when it is lit from behind (light passing through) (Daw, 2012). Nanoparticles cannot be seen by the human eye, but they are particles in the size range of 1 - 100 x 10-9 meters: 1 - 100 nanometers (nm) (*'What Are Nanoparticles? Definition, Size, Uses and Properties'*, n.d.).

Over time, the use of nanoparticles has been further developed into the areas of chemistry, energy, medicine, and many more.
In the current fast-growing market of nanoparticle applications, the need for tools that can analyse these nanoparticles rises accordingly.

The start-up Dispertech developed a device that can track biological particles of the human body down to 20 nm. Their device called NanoCET measures two parameters: size distribution and concentration. Concentration shows the number of particles in a sample and size distribution tells how many particles of what size a sample contains. The NanoCET is a research tool to use in hospital or university laboratories to help researchers find out more about these parameters.

Figure 3. The Lycurgus Cup (The Lycurgus Cup 2016).

1.1 The Dispertech NanoCET

To allow extracting parameters from particles, you need to be able to look at them individually. Figure 4 illustrates the NanoCET device and the working principle to look at individual particles.

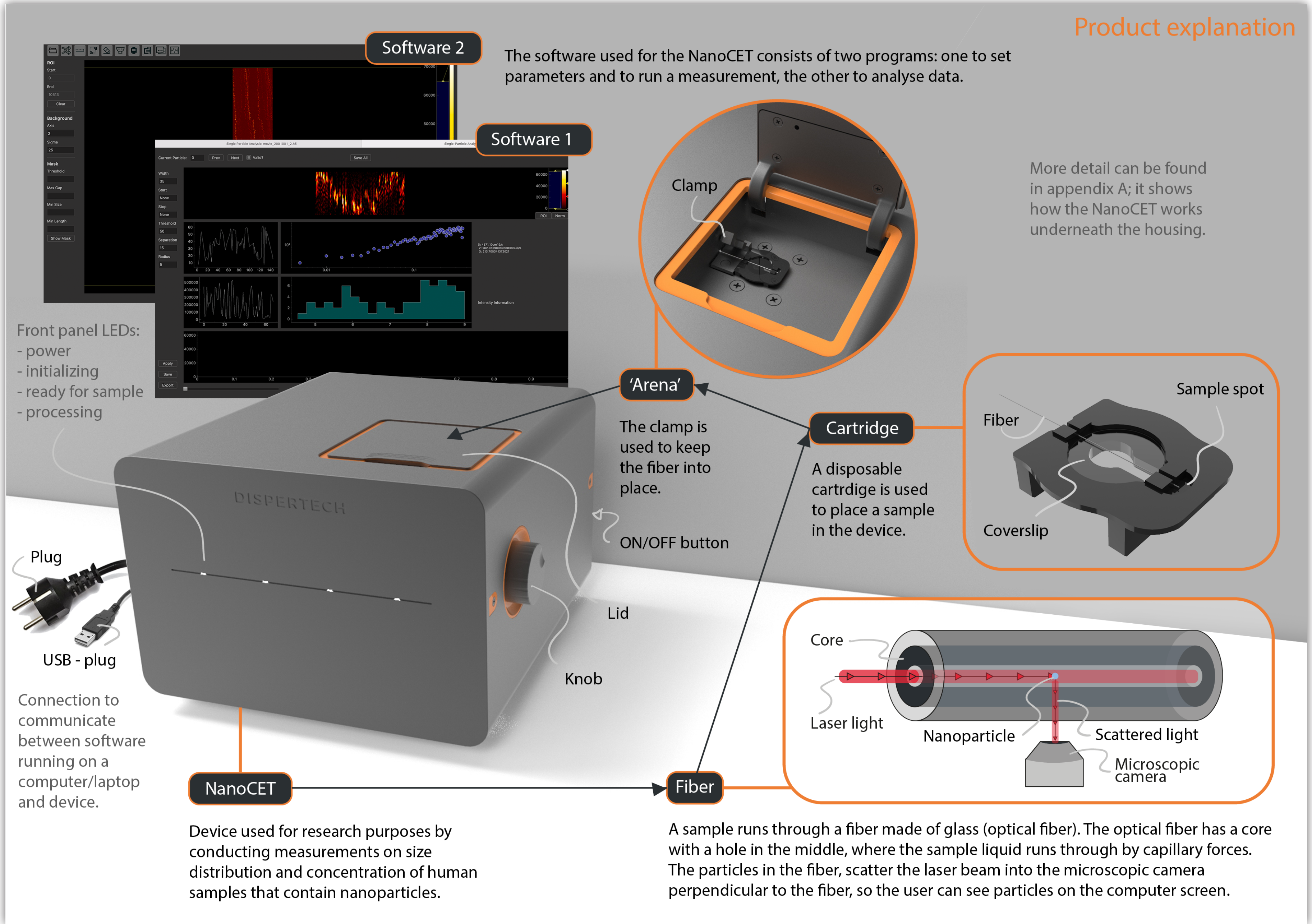


Figure 4. Product description of NanoCET.

1.2 The workflow from start to finish

The current workflow with the NanoCET starts with turning on the device and software. On the computer screen, two screens need to be split as the camera view on the fiber and Software 1 are not integrated, and the user needs to see both screens at the same time, see figure 5.

Up next, the user needs to open the lid, the clamp, and the cartridge packaging to insert the cartridge in the 'arena' of the NanoCET. Then, immersion oil needs to be added on top of the coverslip to merge the edges of the fiber and the coverslip, so the lens effect of the cylindrical fiber is avoided and the camera can view the fiber core clearly.

In the next step, the camera needs to be focused on the fiber by turning the knob and seeing the camera focus on the screen. Under those circumstances, the lid needs to be closed to create a dark environment.

Now the laser can be automatically aligned with the core of the fiber by clicking a button.

Then, the parameters for a measurement can be inserted in Software 1: the gain and exposure of the camera and the laser power.

After this, the lid needs to be opened again to insert the sample onto the cartridge. When the lid is closed again the Region of interest (ROI) can be selected so only the relevant video frames are saved.

Now, the measurement can be started by clicking 'Save movie'.

When the particles stop running by, the button 'Stop saving' can be clicked.

Now that the measurement is done, the cartridge can be removed. Software 2 can be used to analyse the data generated during a measurement with Software 1. A full scenario in pictures describing the current workflow of conducting a measurement with the NanoCET can be found in appendix B.

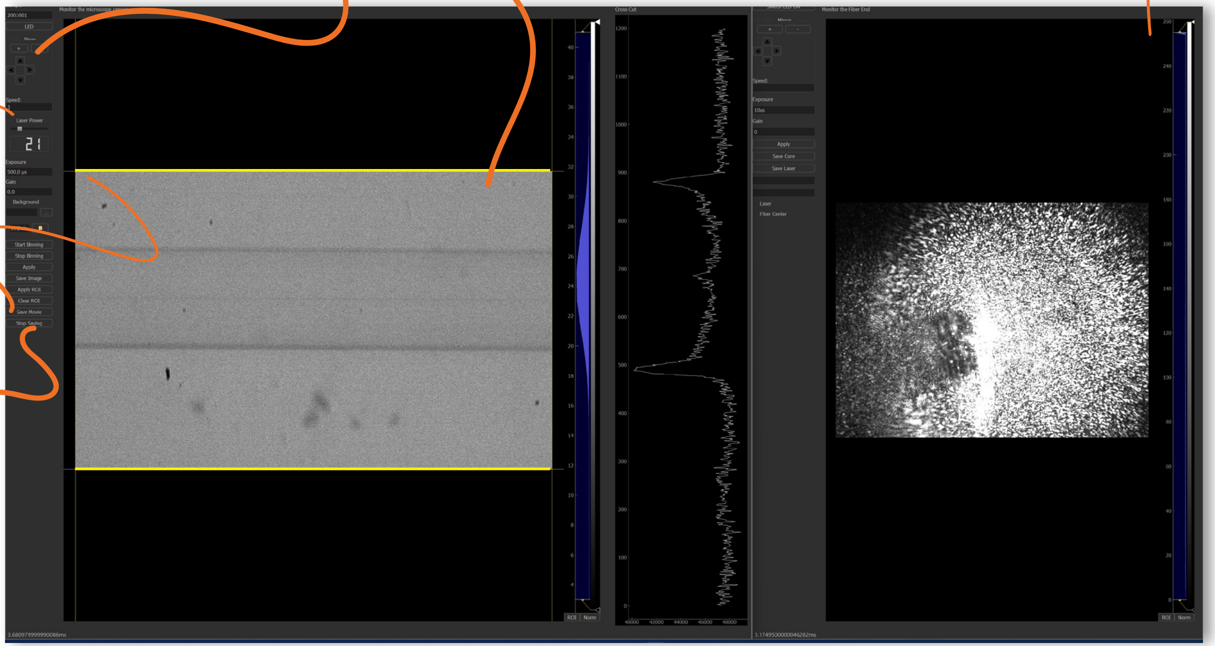


Figure 5. Split screens of Software 1 (left) and the camera view (right).

The current workflow consists of many steps requiring going back and forth between the device and Software 1. Some elements are already automatic, like aligning the laser, in contrast to the separate camera view and Software 1. Moreover, the language used within Software 1 to give instructions (e.g. 'Save movie' and 'Stop saving') is inconsequent and can therefore be perceived as confusing. Furthermore, the lid needs to be opened twice within one measurement.

1.3 Product stakeholders: who influences and is influenced by the product?

There are three stakeholders involved with the NanoCET, see figure 6. First, there is Dispertech, the supplier of the NanoCET.
Second, there are two groups of users conducting measurements: technicians and researchers. Researchers include PhD candidates and postdocs. Besides conducting measurements, technicians are in charge of instructing other users and maintaining the device.
Lastly, there are purchasers; people who buy the product for the user groups. These purchasers are principal investigators who are often professors or research institutions who buy the product for research purposes with the help of funding.

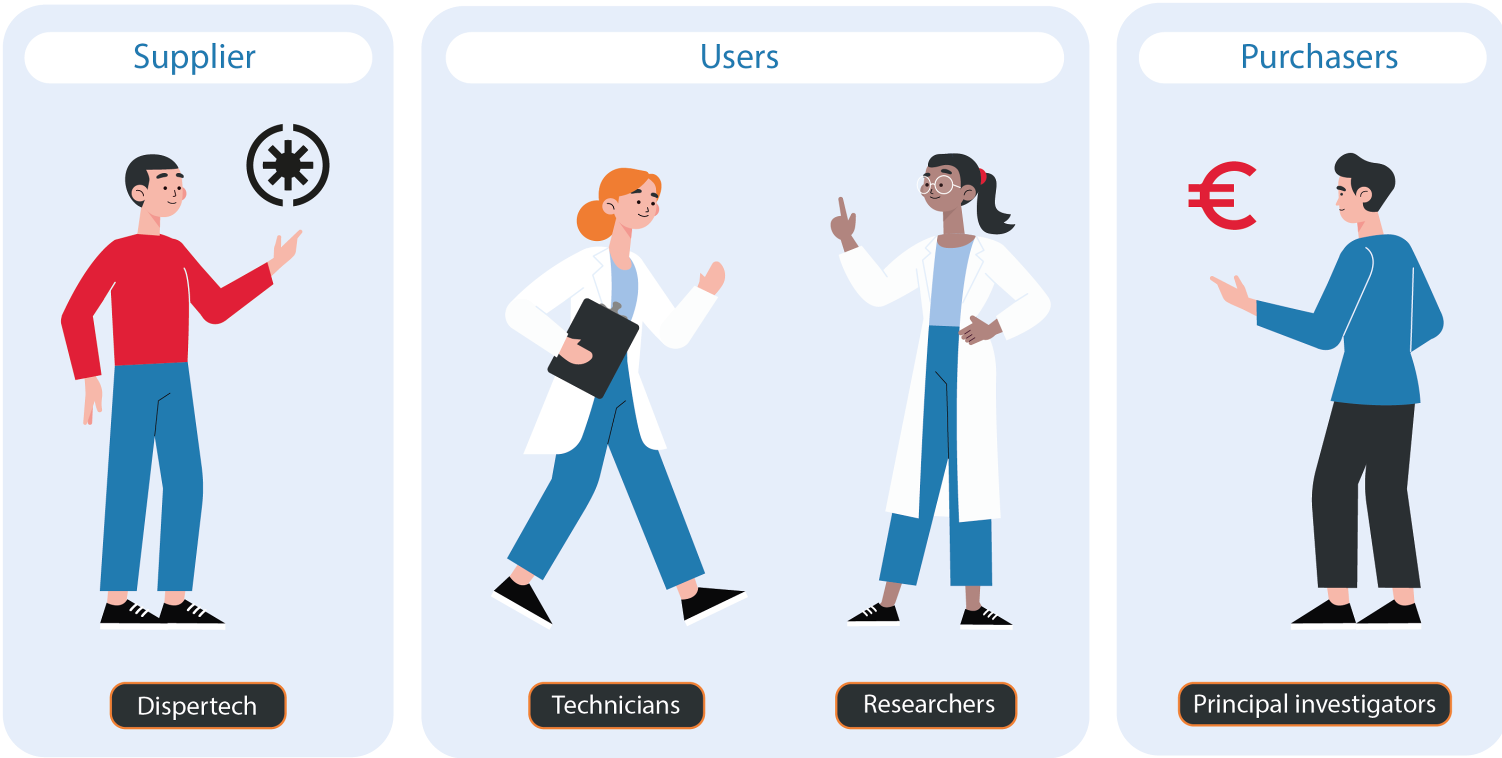


Figure 6. Stakeholders of the NanoCET.

Technician: *'I perform measurements for others when they don't dare to put their hands in the device. Or when they don't like to do it, they just want results.'*

1.4 The project: optimising the usability of the Dispertech NanoCET

1.4.1 Initial problem statement

Up to now, Dispertech focused on the proof of concept of the NanoCET. They developed the internal and external configurations of their device. Now that the technique is working, Dispertech decided to create the opportunity to focus on the user, wishing to enable users to independently operate the NanoCET. Currently, it is difficult to insert the cartridge into the device, and users experience a disconnection between the physical and digital user interface. Furthermore, Dispertech is not sure which operating tasks they can require of the user. They like to know if the current NanoCET fits the use scenarios happening in the context. These reasons lead to the following initial problem statement:

Users are unable to independently operate Dispertechs technical prototype of the NanoCET, because of the under-developed user interface/user experience (UI/UX), which can cause harmful or inconvenient situations (like operating mistakes made by users).

In this project, I look into the current prototype of the NanoCET, competitor devices, the product context, and the user group, to design a more user-friendly interaction with the NanoCET. See appendix C for the original project brief.

Figure 7. Logo of Delft University of Technology.

Figure 8. Logo of Dispertech.

1.4.2 Project context

This project is a graduation project for the master's Design for Interaction at Delft University of Technology. The project is tailored to the start-up Dispertech, located at the Science Park in Amsterdam. Dispertech has three full-time employees and two investors that are involved as well. The company started in 2019, based on a technology discovered by two professors of Utrecht University in 2015.

1.4.3 Project approach

This design project uses the Human-Centered Design approach (ISO, 1999). This approach is focused on taking human factors like capabilities, skills, and needs into account while designing to improve working conditions and performance. In this project, Human-Centered Design is executed following the Double Diamond structure (Intracto, 2021), see figure 9. This structure provides two diamonds each consisting of two phases: diverging and converging. The first diamond is about discovering the product and context by doing (user) research and defining insights based on that research. The second diamond is about developing ideas and delivering a final design. In this second diamond, the design matures in iterative loops from sketches to concept directions, to an experience prototype of a design proposal, to end up with a final design.

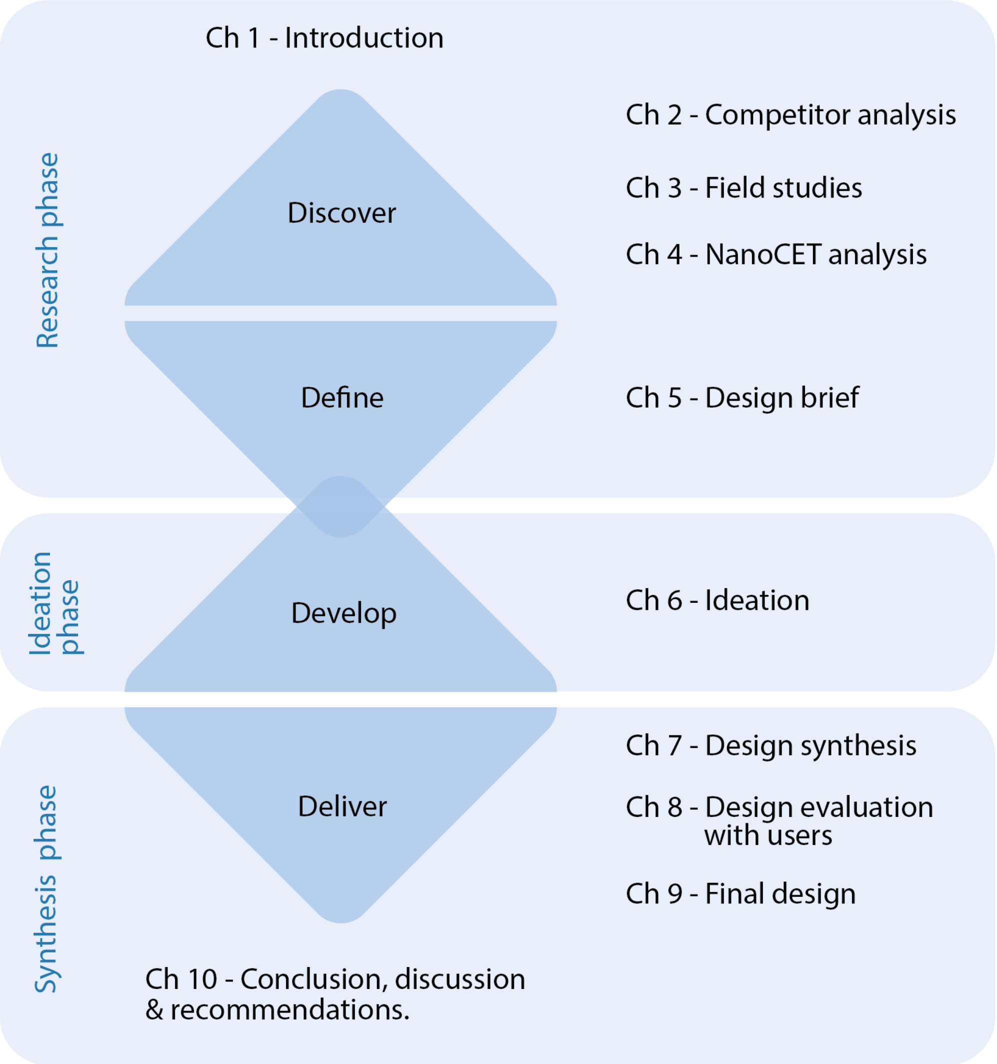


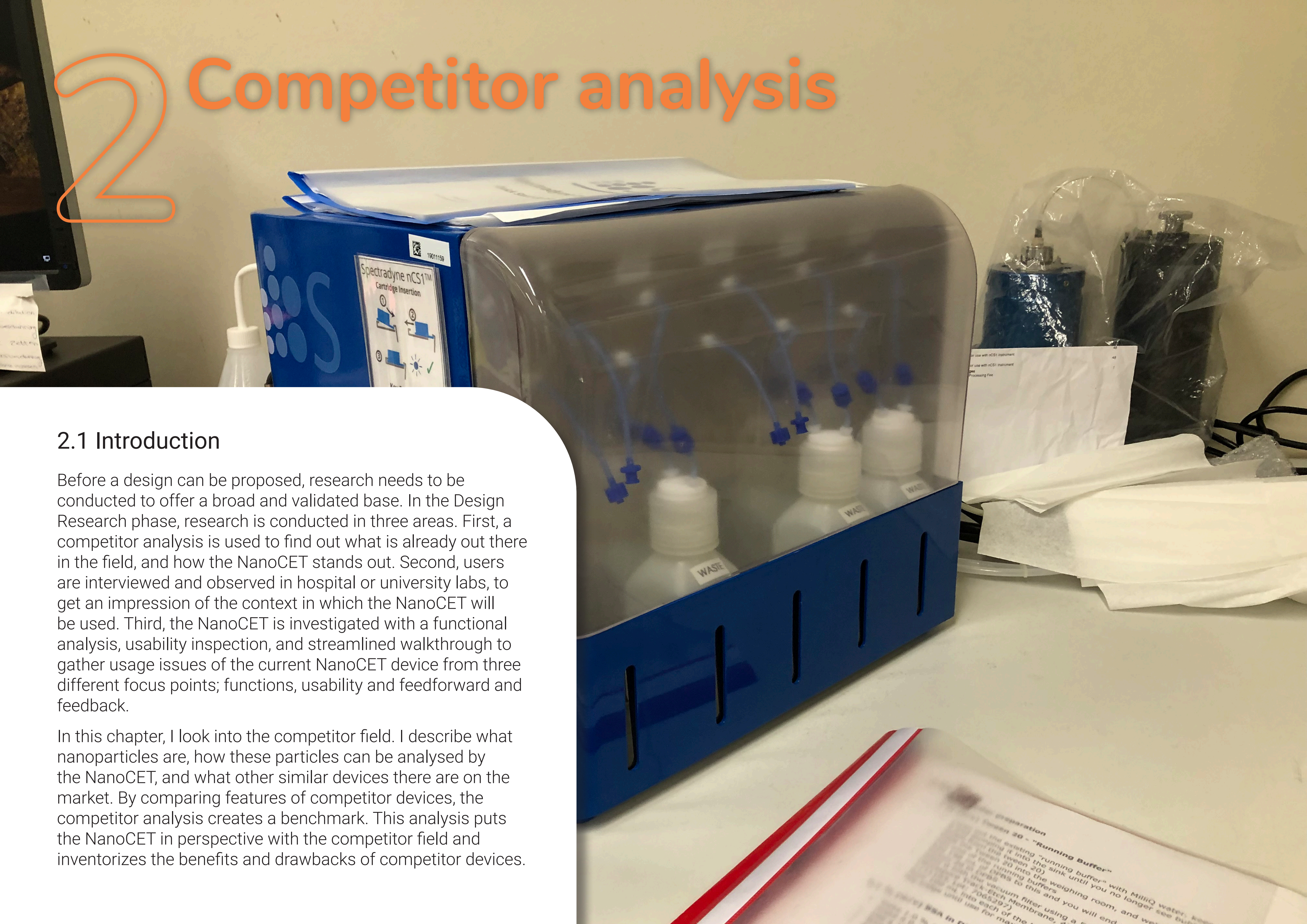
Figure 9. Reading guide of the double diamond process.

1.4.4 Project process & reading guide

After introducing the topic, context, stakeholders, and the current NanoCET design with its workflow, the project takes off with the Design Research phase. This phase consists of three diverging chapters and one converging chapter. Chapter 2 investigates competitor devices of the NanoCET. Chapter 3 dives into the context with users, where competitor devices are used. Chapter 4 analyses the NanoCET itself. The Design Research phase ends when all comes together in the Design Brief in Chapter 5.

At this point, chapter 6 diverges with an ideation phase. From chapter 7 onwards the project converges with a synthesis phase. This starts with concept directions maturing to a design proposal. The design proposal is evaluated with users in chapter 8. Chapter 9 is the result of a new iteration step and presents the final design. Finally, the entire project comes together in chapter 10 with a conclusion, discussion, and final recommendations for further research and improvements.

2 Competitor analysis



2.1 Introduction

Before a design can be proposed, research needs to be conducted to offer a broad and validated base. In the Design Research phase, research is conducted in three areas. First, a competitor analysis is used to find out what is already out there in the field, and how the NanoCET stands out. Second, users are interviewed and observed in hospital or university labs, to get an impression of the context in which the NanoCET will be used. Third, the NanoCET is investigated with a functional analysis, usability inspection, and streamlined walkthrough to gather usage issues of the current NanoCET device from three different focus points; functions, usability and feedforward and feedback.

In this chapter, I look into the competitor field. I describe what nanoparticles are, how these particles can be analysed by the NanoCET, and what other similar devices there are on the market. By comparing features of competitor devices, the competitor analysis creates a benchmark. This analysis puts the NanoCET in perspective with the competitor field and inventorizes the benefits and drawbacks of competitor devices.

2.2 Nanoparticle analysis methods

Dispertech works with a specific type of nanoparticles called Extracellular Vesicles (EVs). EV is a collective name for three particles named ***microvesicles, apoptotic bodies***, and ***exosomes***. These EVs are non-replicable nanoparticles, which are naturally released by any kind of human cell (Doyle & Wang, 2019), see figure 10 (Biogenesis of extracellular vesicle (EV) subtypes 2020).

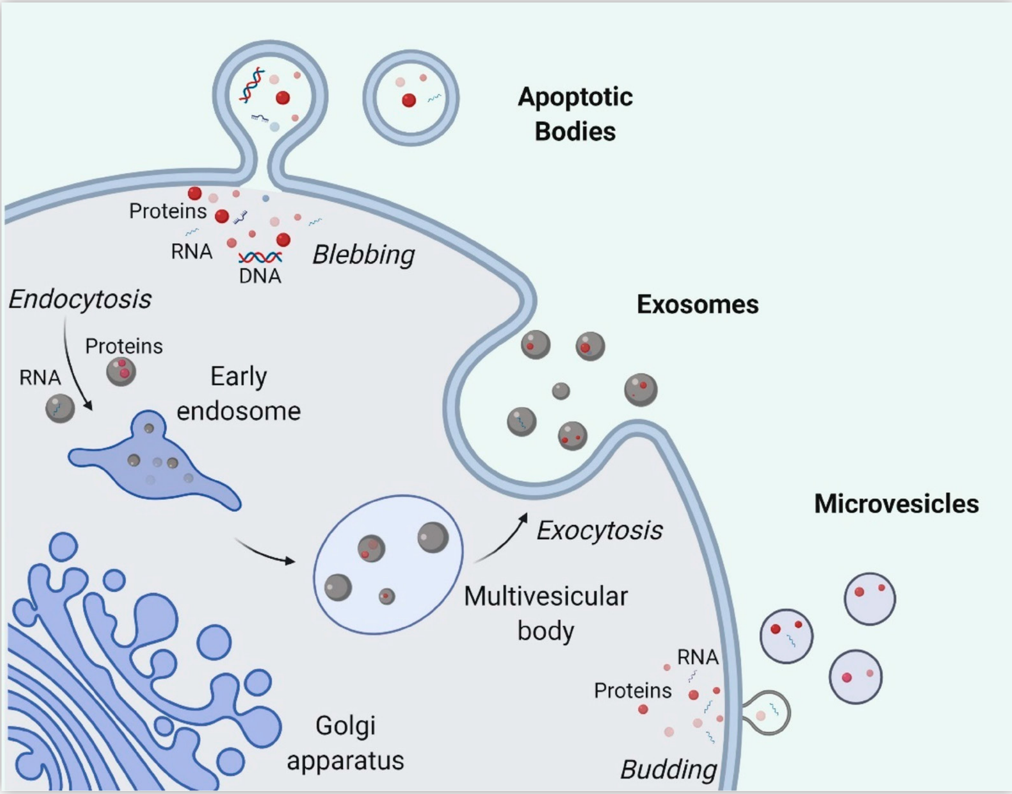


Figure 10. Extracellular vesicles of a human cell (Biogenesis of extracellular vesicle (EV) subtypes 2020).

An EV sample needed for a measurement can be taken from biofluids like urine and blood plasma, as most human cells release EVs. Once a sample is collected, it can be analysed through different techniques.

There are five well-established methods: Dynamic Light Scattering (DLS), Flow Cytometry (FC), Tunable Resistive Pulse Sensing (tRPS), Electron Microscopy (EM) and there is Nanoparticle Tracking Analysis (NTA). The NTA is the technique Dispertech applies. There are other companies that developed devices to analyse EVs using these techniques.

To put Dispertechs NanoCET in perspective, a competitor analysis is conducted to review features like price, size, and data generation.

2.3 Results & findings competitor analysis

Table 1 gives an overview of competitor devices applying some of the techniques mentioned previously.

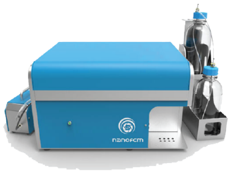
Competitor overview								
Company	Malvern	Particle Metrix	Nanoview	Nanofcm	IZON		Spectradyne	Dispertech
Device name	Nano sight	Zeta view	ExoView	NanoFCM	Exoid	qNano Gold	nCS1	NanoCET
Aesthetics								
Method	NTA	NTA	SP-IRIS	Flow cytometry	tRPS	tRPS	tRPS	NTA
Data	Size distribution & concentration	Size, concentration, surface charge	Size, amount, phenotype, characteristics	Size, concentration, phenotyping	Size & concentration	Size distribution & concentration	Size distribution	Size distribution & concentration
Size (in mm)	400x250x400	~ 400x250x400	~ 400x250x400		350x350x320	~175x175x320	330x330x380	250x277x170
Price (in €)	~ 70 K	~ 70 K		150 K	40 K	25 K		60 K

Table 1. Competitor analysis table.

Uses cartridges · Able to track individual particles

Findings based on competitor analysis:

- The NanoCET is the smallest device available as the qNano Gold is not for sale anymore. It is replaced by a newer version; the Exoid.
- The NanoCET fits into the relative price range.
- The NanoCET is unique in using (optical) fibers.
- The Nano sight and Exoid are the only ones with polished software interfaces (see appendix D for an example). The interfaces of the other devices resemble the interface of the NanoCET.
- The Nano sight can measure the smallest particles: down to 10 nm. However, the Nano sight cannot measure individual particles.
- The ExoView is the only device in table 1 that can measure multiple (nine) samples simultaneously.
- The NanoFCM requires significant maintenance, needs to be aligned by users, and is meant for bigger particles like entire cells.
- The Exoid, qNano Gold, and nCS1 struggle with accuracy as of calibration issues.
- All devices provide data on particle size, either size or size distribution, indicating that size (distribution) is an important parameter in the field of EVs.
- 3 out of 8 devices make use of cartridges.
- 5 out of 8 devices can measure individual particles.
- 4 out of 8 devices are blue or have blue accents.
- All devices are box-shaped, only IZON stands out with devices shaped differently.

2.4 Key insights competitors

- All competitors apply different techniques and focus on different parameters of nanoparticles. There is only one thing they all focus on; the size (or size distribution) of particles.
- The NanoCET is not the only device lacking a sophisticated digital software interface.
- The NanoCET;
  - fits into the price range compared to competitors.
  - is unique in using (optical) fibers.
  - has a usability advantage in aligning automatically.
  - stands out in not using blue.
  - is the smallest device available.
  - can measure the smallest particles individually.

2.5 Conclusion

Nanoparticles called extracellular vesicles can be analysed with different techniques leading to different devices by a range of companies. All these companies focus on the size (or size distribution) of EVs.

The NanoCET stands out in the competitor field as it is the smallest device currently available, because it can measure the smallest individual particles and because the device is black with orange accents. In addition to using cartridges, automatic laser alignment, and using optical fibers, its size is what makes the NanoCET a unique device.

In the next chapter, some of the competitor devices are showed in action, during the research of the current context field.

3 Field studies

3.1 Introduction

As the Design Research phase continues, I research the current context of use of the NanoCET: hospital and university labs. First, I explain the field research method and introduce the participants. After this, a visual impression of the field visits is given. The field studies lead to insights about users, their environment, and the devices they are currently using. This helps to create a better understanding of the context the NanoCET will be in when it comes on the market.

3.2 Method & participants

Going into the field, I wanted to get an impression of how other devices are used, how different the contexts are, and how the user group performs their work. To achieve this, I combined interviewing and observing. I had questions prepared which were supplemented by questions inspired by the context of the interview. This way, I took an interview guide approach accompanied by an informal conversational interview (Patton, 2002). More specifically, the leading method includes a topic guide (Merkus, 2021). With a topic guide, questions are structured per topic, so you can easily hop between topics and write down what you hear or observe on a certain topic. This way, I combined interview questions easily with observations perceived during the lab visits. My topic guide covered the following topics: user experience, measurement, device(s), looks, cartridges, environment, and inclusivity. Some of these main topics have sub-topics like the topic user experience contains the subtopics; current device(s), new devices/technologies, interaction, and sustainability. Appendix E shows a full overview of the questions per (sub)topic.

Five field studies are conducted, all on a different location. Table 2 gives an overview of the participants:

Participants	Gender	Role	Location	Interview depth	Task with device (s)	Left/right handed
Participant 1	Female	Researcher (PhD candidate)	Hospital lab Amsterdam UMC	Extended	Particle analysis with nCS1 (& qNano Gold)	Right
Participant 2	Female	Researcher (PhD candidate)	University lab Utrecht University	Extended	Particle analysis with NanoCET set-up	Right
Participant 3	Male	Technician	University lab Delft University of Technology	Brief	Tour showing different microscopes.	Right
Participant 4	Female	Guiding tour	Training facility Leiden University	Brief	Tour showing different kinds of labs.	-
Participant 5	Female	Technician	Hospital lab Cancer Centre Amsterdam	Extended	Isolation method* with IZON products.	Left

Table 2. Overview of participants in field studies.

*A preparation step of EV analysis: in some methods, EVs must be isolated before they can be analysed with a device.

3.3 Impression field studies

On the next pages follows an overview of the field studies to get an impression of the individual field studies, see figure 11.

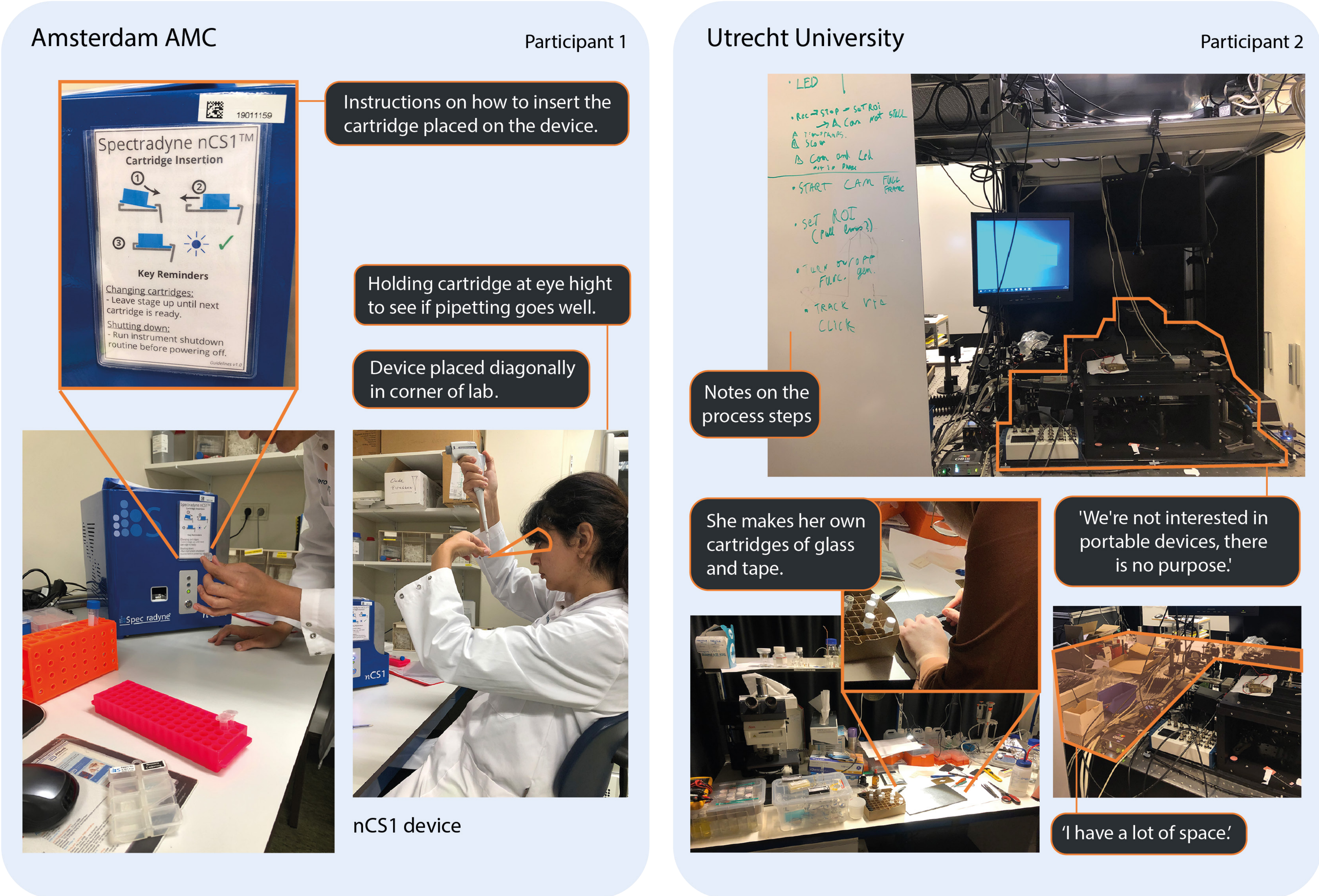
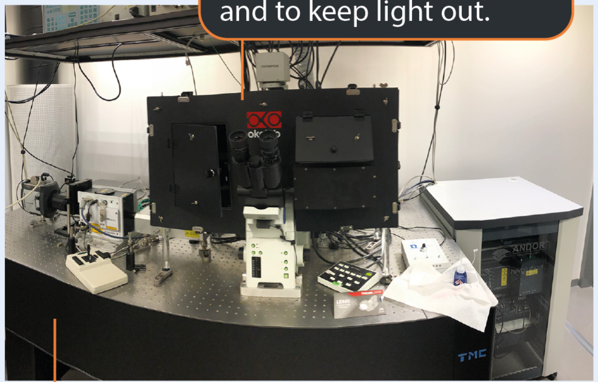


Figure 11. Impression of the five field studies.

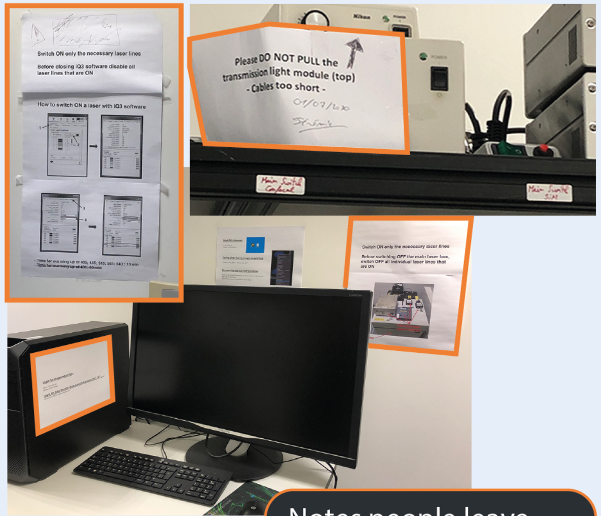
TU Delft

Participant 3

Black boxes around microscopes for protection and to keep light out.



All microscopes placed on optical tables.



Notes people leave on/around the set-ups to instruct other users.

Leiden University

Participant 4

Neat, clean lab.

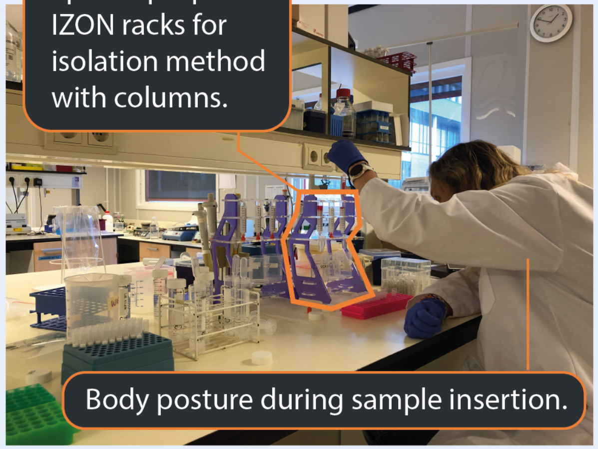
Some devices/machines have a lot of loose cables.

Protocols and instructions laying around.

Amsterdam CCA

Participant 5

Special purple IZON racks for isolation method with columns.



Body posture during sample insertion.

'If it looks too cool, I doubt: but does it work?'

Shiney lights: gimicky device with touch screen.

AFC device of IZON

3.4 General findings field studies

Below an overview of findings is presented, based on the field studies conducted. A detailed description of each field study can be found in appendix F. An overview of the raw data can be found in the data analysis table in appendix G.

Figure 12. Cartridge Zetaziser.

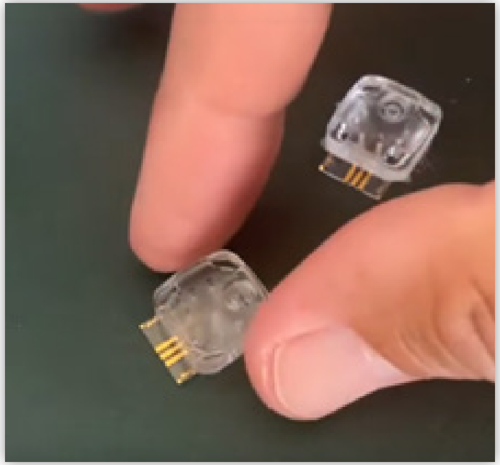


Figure 13. Cartridge nCS1.

Context:

- All labs have strict safety regulations, but it depends per context on how strict they are followed.
  Participant 1: *'With a biological sample it's better to wear gloves, but we don't really do it here.'*

- There is no need for a portable device, labs have all devices already set up on lab tables spread over different labs.
  Participant 2: *'We're not interested in portable devices, there is no need.'*

- There are a lot of disposables in a lab context like pipet tips, gloves, sample tubes, cartridges, etc.
  Participant 5: *'Science isn't friendly for the environment, there are a lot of disposables in a lab.'*

- Labs have multiple devices/set-ups that perform similar tasks. The difference between these devices/set-ups is the capacity and quality of the results. Sometimes labs have newer versions of the same device or a device of a competitor, to be able to compare results between devices.

Devices:

- Cartridges are a known medium to insert a sample in a device: other devices use cartridges as well, see figures 12 and 13.
  Participant 1: *'I'm quite happy with cartridges.'*

- The aesthetics of lab devices differ quite a lot, but that does not matter to users:
  Participant 5: *'I prefer functionality over aesthetics.'*
  Participant 1: *'It doesn't stand in your kitchen, so it doesn't matter.'*

- There is a difference in devices for research (lab) purposes and devices for companies. Devices for companies need to meet more requirements. Also, devices for diagnostics are bound to more (safety) regulations.
  Participant 5: *'Because it's research you've got more freedom than in diagnostics or with companies.'*

- Instructions on (new) devices are given in person. When a device is new, someone from the company visits to give instructions on how to use a device. When a device is already in the lab and someone new wants to use the device, a technician instructs the user on how to work with the device. Either way, instructions are not provided via a manual or instruction video, but through speech.

Users:

- All devices can be operated with standard lab skills, like pipetting. The user only needs specialised knowledge on how to operate that device specifically to work with it, like referred to with the instructions under the device insights.

- Some participants have different backgrounds than (nano)biology. I have come across participants that have backgrounds in engineering, microscopy, or physics.

- Working in a lab is an active job: users walk around a lot to collect props in different labs or because certain devices/set-ups are clustered in another lab (group).

- Lots of labs do not have fresh air available (no windows that can be opened). Sometimes this is a safety regulation, so no random elements from outside can come into the lab, but sometimes it is just a practical issue as certain labs are dark labs. No availability of fresh air often causes lab workers to suffer from headaches.

- A lot of people working in labs are female.

Workflow:

- Generally a measurement takes a lot of preparation steps, whereas during the actual measurement the device does the work. Preparation can take a whole day during which a sample goes through other processes like an isolation method. Furthermore, samples are often kept at minus 80 degrees Celsius, so they need to defreeze before they can be analysed with a device. Other preparations include centrifuging the sample and preparing buffer liquids for the device.

- Lab workers are supposed to keep a lab journal, but I have not seen any of the participants use any. Sometimes they make notes or calculations on Post-its.

- Users determine the end of a measurement themselves and therefore there is no set time for the amount of time of a measurement. Devices analysing EV samples need to be manually stopped when the user estimates enough data has been acquired.

- The data analysis part happens at a different moment or even a different day. Analysing the data does not happen inside the lab, but behind a user's office desk and can include different software than the one used for generating data.

3.5 Key insights field studies

- There is no strict time planning possible on the day of a lab worker as it is not certain how long preparation steps or measurements take. If anything goes wrong or if the user thinks something goes wrong, they start over.
  Participant 1: *'I'm always really careful. When I'm hesitating, I redo it, even if it takes a lot of time.'*

- Lab environments differ in light/dark, chaotic/structured, general/ personal/, experimental/strict with protocols, and in the level of cleanness, like seen in the impression collages of the field research (section 3.3).

- Users often put the NanoCET on low desks where they have to sit down, so users might find it hard to get a proper look at the front panel and seeing the communicative LEDs.

- As the NanoCET set-up in Utrecht is most comparable to the NanoCET product of Dispertech, it is remarkable that the workflow with the NanoCET set-up is more fluent than the workflow with the NanoCET device. This is because the NanoCET device has a housing and a lid, which cause extra actions and interactions compared to the open NanoCET set-up, see figure 14.

- Researchers and technicians have trouble trusting the claims of a company by default: they want to see proof for themselves. Gaining trust in a device/company takes time and proof.
  Participant 1: *'You notice the protocol is developed by the company and not by the customer.'*
  Participant 5: *'I trust a device when I can validate: when it's easy to compare the old device with the new one and the results are the same or even better. And then when it shows that 2/3 times.'*

- (Un)intentional sound can be used as a communicative element. The nCS1 device makes a sound when the measurement clogs, which is used by participant 1 as an indication that she needs to press a button for the measurement to continue.

- Researchers stick around after the measurement starts, to see if everything goes well.
  Participant 1: *'During a 50-minute measurement, I don't do anything and wait, because if something clogs, I need to push a button.'*

- Devices are used by many different users within the same lab. Next to that, users often conduct measurements for other people.

- Disposing a lot is prioritised above sustainability. Users need to be sure a sample/measurement is not contaminated.
  Participant 1: *'If you reuse a cartridge, you always have contamination doubts and you don't want that because you want to be sure.'*
  Participant 5: *'It needs to stay clean, so you don't doubt your results.'*

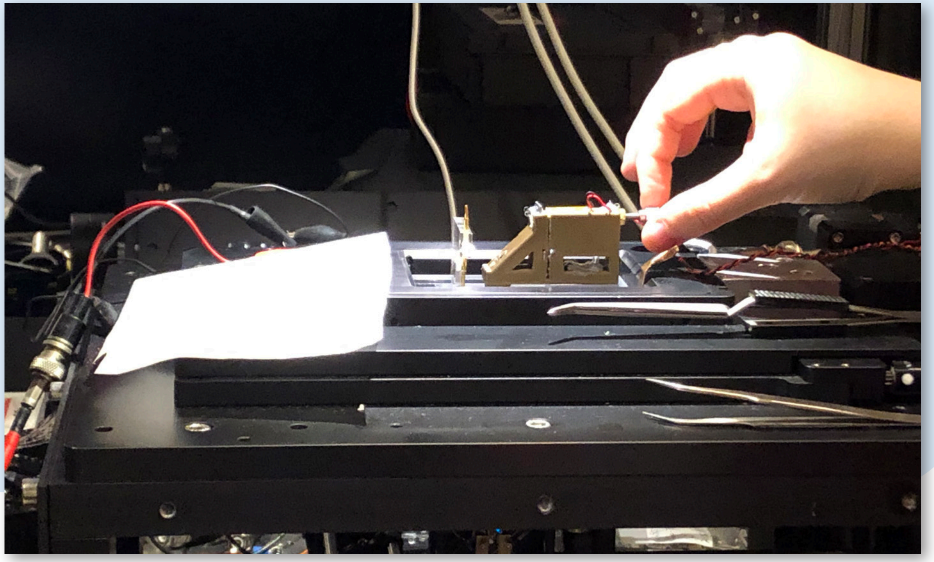


Figure 14. Open NanoCET set-up.

3.6 Conclusion

The field studies investigated users, their environment, and their interaction with devices in that context. After visiting five different university/hospital labs in different cities, a few things became apparent. First, trying to look for similarities between labs, I found them to be in very different environmental circumstances. Second, several users are using the same device and users often conduct measurements for other people. Third, there seems to be a reluctance in trusting a company or its device: users want to experience a working collaboration with a device/company. Fourth, if users would have a NanoCET device in their labs, they would often place it on a low, desk-like table within a lab, which can obscure the view on the seeing the communicative LEDs on the front panel.

This means the design proposal should be: flexible to different environments, able to be operated by different users, trustworthy, and able to communicate with the user from every working and viewing angle.

Furthermore, a few key things came forward during measurements;

- the user interacts more fluently with an open set-up.
- users stick around when a measurement starts to see if everything goes well.
- users would rather be sure about not contaminating their measurement than be sustainable.
- the user uses the sound of a device to extract information about the measurement.
- users are unable to make a clear schedule of their day because it is impossible to know how long steps will take in a measurement process because of possible mistakes.

After looking into other devices, the following chapter researches the usage issues of the NanoCET.

4 NanoCET analysis

4.1 Introduction

With the competitors and field studies conducted, the Design Research phase now focuses on the NanoCET. This chapter investigates its functions and usage issues to create an overview of elements that can be addressed in the design proposal.

4.2 Methods

The NanoCETs usage issues are analysed through three methods: the functional analysis, usability inspection, and streamlined walkthrough.

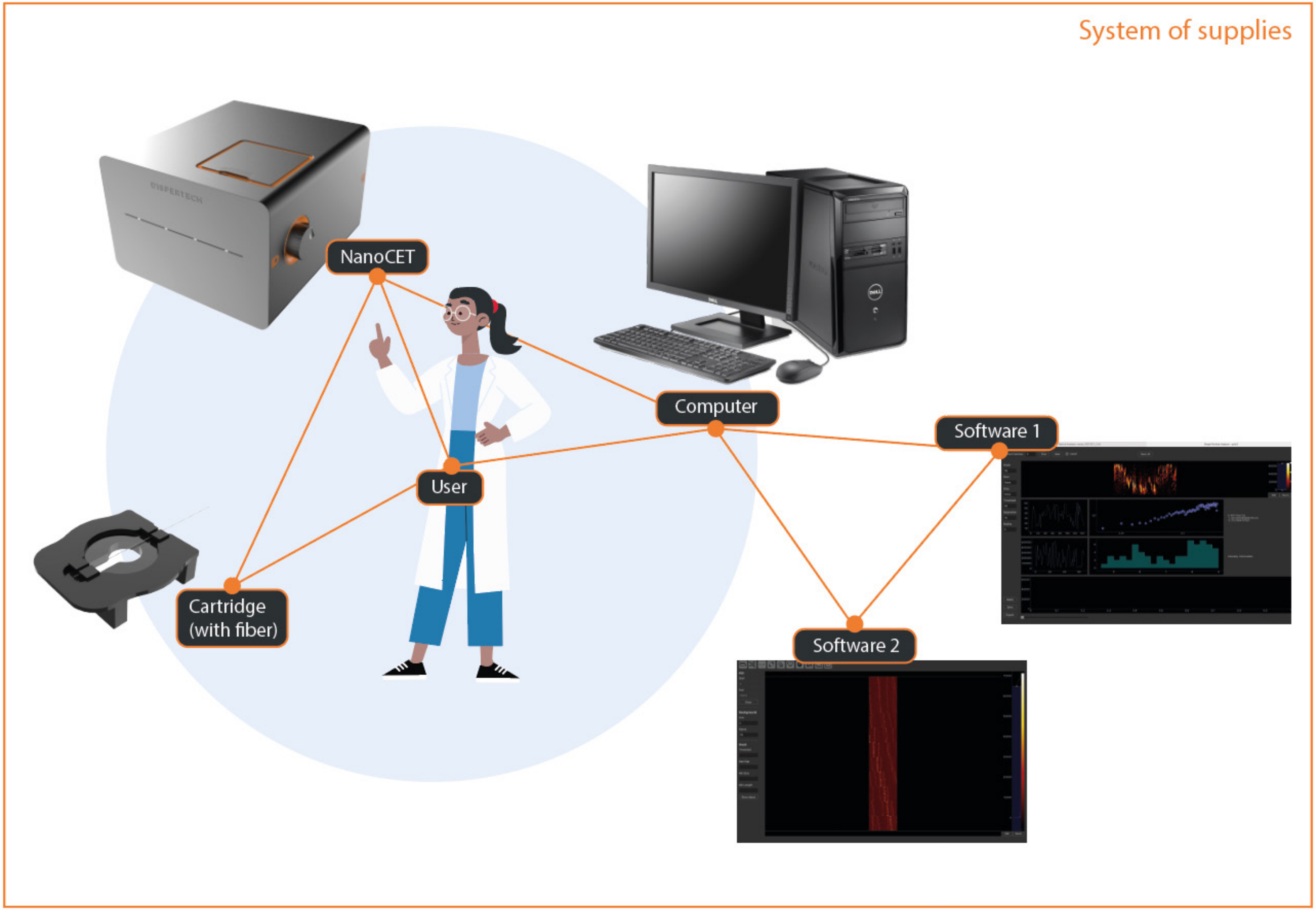


Figure 15. System of supplies.

Functional analysis

A functional analysis (Roozenburg & Eekels, 1998, pp. 215-218) is applied to the system of supplies, see figure 15. The system of supplies only shows elements that are part of the interaction with the NanoCET. Appendix H depicts the full ecosystem of the NanoCET.
The functional analysis method separates each element of the system of supplies and looks at the function of that element. It makes sure the element is lifted to a more abstract level by adding the word 'thing' behind the function. In this way, every part becomes just 'a thing' that fulfils a function. This enables you to get an insight into what element fulfils what function. Appendix I shows the full results of the functional analysis in which the same functions are highlighted with the same colour.

Usability inspection

In a usability inspection (van Kuijk, 2021e), you go through the whole interaction with a device yourself and capture relevant information like the task, the touchpoint with the system of supplies, the pain points, and the positive or negative emotion experienced during a task. By applying this method myself on the NanoCET, I was able to analyse the experience much deeper than with the functional analysis. A graph of the full results is shown in appendix J.

Streamlined walkthrough

A streamlined walkthrough ('How to Conduct a Cognitive Walkthrough', 2021) makes you zoom in on every step of an interaction needed for a measurement. For each step, you analyse the feedforward and the feedback of the product. The executor of the walkthrough empathises with the user. This method will lead to results in the form of learnability problems, design ideas, design gaps, and problems in intended usage descriptions. This method is again executed by me. The extended results can be found in appendix K.

A streamlined walkthrough is conducted as follows:

First, for each step in the scenario, you look at the feedforward of the elements in the system of supplies and ask yourself: will the user know what to do at this step?

Then you look at the feedback of the system of supplies and ask yourself: if the user did the right thing;
- do they know they did it right?
- is the user making progress towards their (end) goal?

4.3 Results and findings

Figure 16 shows the most important usage issues found in all three methods combined.

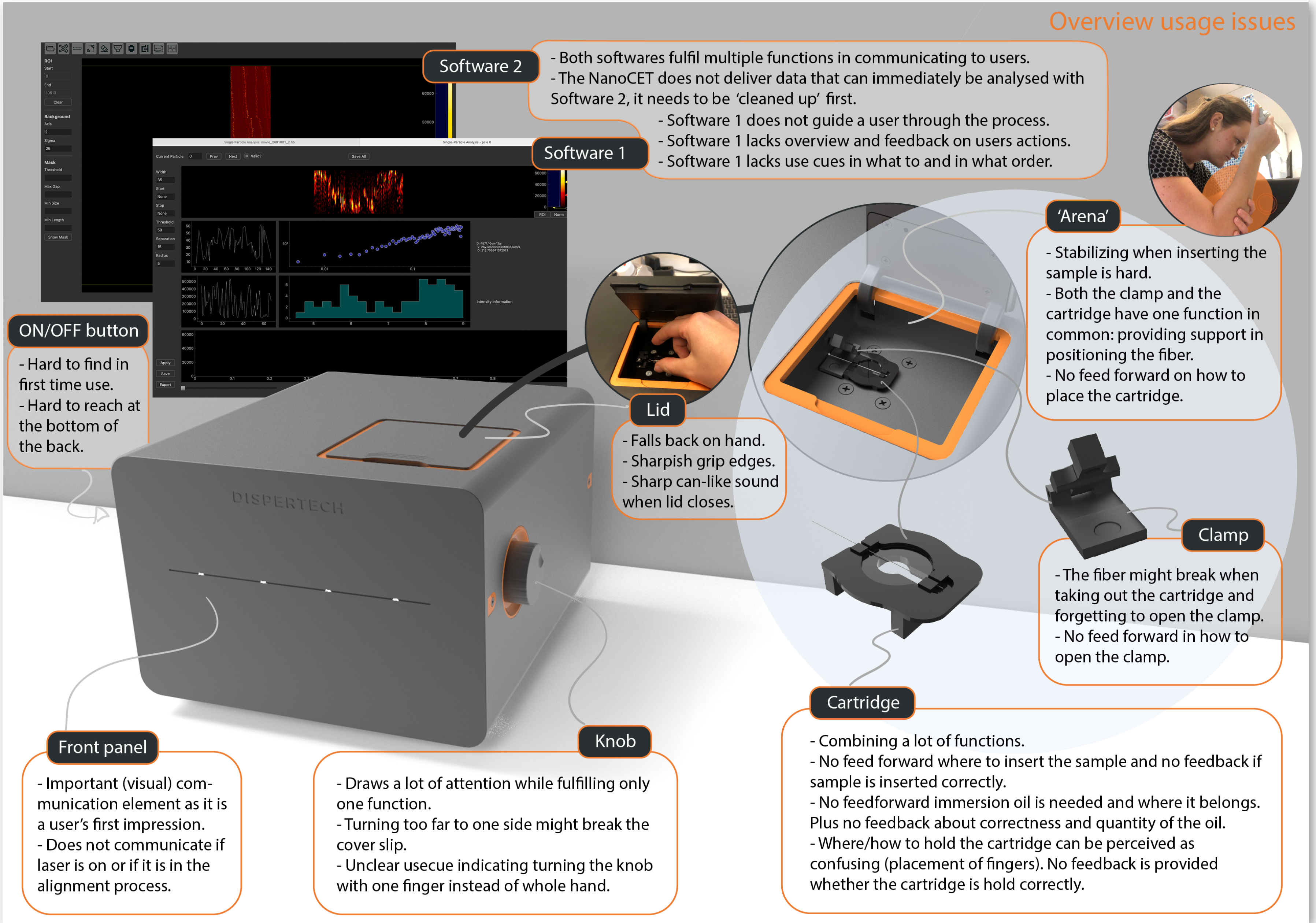


Figure 16*. usage problems NanoCET found with functional analysis, usability inspection, and streamlined walkthrough.
*Dispertech is constantly developing the NanoCET as they are still a start-up, so problems might have been tackled in the meantime.

4.4 Key insights NanoCET analysis

Workflow

- The workflow is experienced negatively when multiple touchpoints of different elements of the system of supplies come together.
- The communication of the NanoCET can be experienced as confusing, because the device does not communicate everything, like the laser status.

Software

- Both Software 1 & 2 are underdeveloped in terms of feedforward, feedback, and process guidance, compared to the rest of the NanoCET. Software 2 is not fully developed yet and therefore cannot properly be judged on usability. Furthermore, it is not yet known what the desired data is to work with for users. Thereby, Software 2 is about data analysis and my project is focused on measurements and sample/cartridge placement with the NanoCET. Because of these reasons Software 2 is left out of the scope of this project. Consequently, from now on, if only 'software' is mentioned it refers to Software 1.

Found with:

- Functional analysis
- Usability inspection
- Streamlined walkthrough

Device

- Some of the elements are physically out of proportion compared to the number of functions they fulfil: the knob is dominant and the LEDs on the front panel are subtle.
- The cartridge is an essential element to combine functions. Thereby a cartridge eliminates complex steps of preparing the optical fiber needed for a measurement.
- Although the cartridge is an essential way to combine functions and eliminate steps, the interaction touchpoints with the cartridge are experienced negatively and therefore deserve attention. Even if you zoom out and look at multiple touchpoints; problems occur inside the 'arena' with the clamp and inserting the sample as well.
- The placement or shape of both physical knobs (the tuning knob and the ON/OFF button) lead to inconvenience or misinterpretation. **Participant 5:** ***'It's preferred if the ON/OFF button is easy to reach, so you don't have to bend over the table.'***
- The lid of the NanoCET lacks comfort in interaction, sound, and tangibility.
- The 'arena' is lacking feedforward in opening the clamp, placing the cartridge, inserting immersion oil, and inserting the sample.
- The 'arena' is lacking feedback in inserting immersion oil and inserting the sample.
- Holding the cartridge is not foolproof, especially since you are not supposed to touch the coverslip or the fiber.

4.5 Conclusion

Inspecting usage issues of the NanoCET pointed out that one of the main problem areas is the ‘arena’, as multiple touchpoints and elements come together. More specifically, one of the main points of attention inside the ‘arena’, is the cartridge interaction: holding it, placing it, and inserting elements onto it.

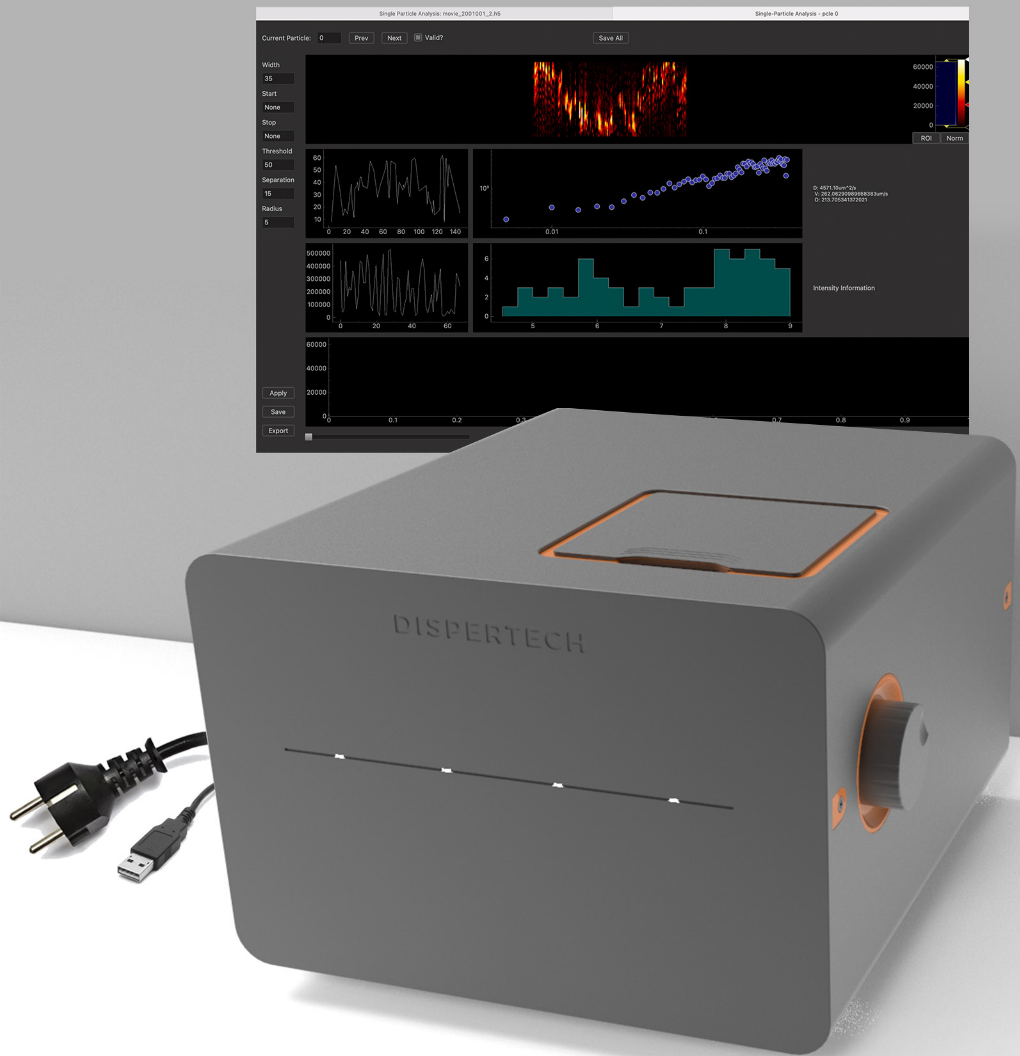
Next to the cartridge, other elements of the ‘arena’ lack feedforward and feedback as well.

While most importantly, Software 1 lacks guidance, use cues, feedback, and overview, so there is a lot to gain in the digital part. Both Software 1 & 2 need development, yet Software 2 is left out of scope because of its infancy state, unknown application, and my focus on measurements and sample/cartridge placement.

Furthermore, some physical elements cause discomfort or confusion, like the lid and physical buttons. Likewise for the communication of the NanoCET about the laser (alignment).

The Design Research phase now comes to an end with a Design Brief, which is presented in the next chapter.

Design brief 5



5.1 Introduction

In the Design Research phase the competitors, context, user group, and NanoCET are analysed. In the Design Brief, all of this comes together to round off the research phase and to create a starting point to continue with in the design phase. The Design Brief includes the current situation with the problem statement and the desired situation with the design goal, interaction vision, design focus, design criteria, and personas.

5.2 Current situation

Problem statement

Seen from the current context situations in chapter 3, users are reluctant to trust the outcomes of a device and therefore what the company claims or promotes. This is because users do not experience the NanoCET as trustworthy and if the NanoCET is not experienced as trustworthy, it can lead to issues in the adaptation process towards working with a NanoCET in labs. Seen from the usage issues described in chapter 4, most interaction problems occur while preparing a measurement. Users experience these problems because they are sent back and forth between the device and the computer (disrupted workflow) and because (elements of) the device and the software miss guidance, feedforward, and feedback throughout the interaction. This creates opportunities for errors during (the preparations of) a measurement, which will influence the number of materials and samples used and the amount of time spent. All of this together leads to the following problem statement:

Researchers and technicians working in labs have difficulty setting up and using the NanoCET device and software when conducting a measurement on the size distribution and concentration of nanoparticles. This leads to failed measurements and therefore a waste of time, materials, and samples. As a result of these issues, it is difficult for researchers to trust Dispertech and their NanoCET.

5.3 Desired situation

5.3.1 Design goal

To turn the current situation into a desired situation, the following design goal is formulated:

Let researchers and technicians working in labs experience a fluent and efficient workflow and feel guided by the NanoCET device and software when researching nanoparticles down to 20 nm, so they will make fewer mistakes and will trust Dispertech and their NanoCET.

5.3.2 Interaction vision

The interactions in my design should be like walking with a guide dog; clear, fluent, and guided, see figure 17.
As a result of interacting with the design, researchers and executors experience the NanoCET as trustworthy. Users should feel the NanoCET is there to help them get trustworthy results.

Figure 17. Interaction Vision: walking with a guide dog.

5.3.3 Areas of attention

Being more specific about the design goal, there are three areas of attention: the software, the ‘arena’ with the cartridge, and the physical configuration of the NanoCET. Combining these areas of attention should lead to an efficient, fluent, and guided workflow, see figure 18. The primary focus is on the software, as there is a lot of usability to gain in the digital part. The secondary focus is on the ‘arena’ and the cartridge to improve the interaction between these two elements. Last but not least, the design focuses on the physical configuration of the NanoCET to provide better communication.

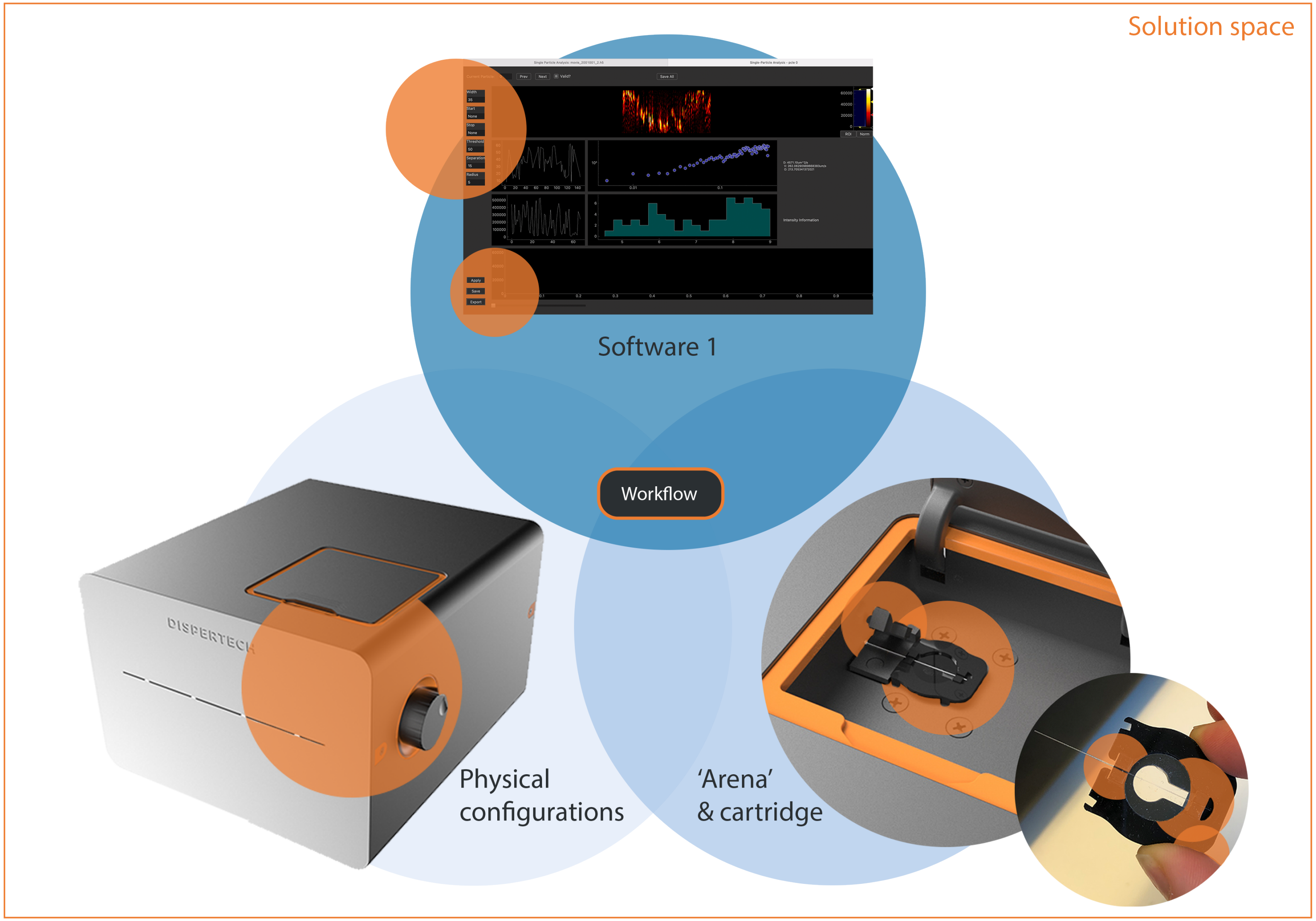


Figure 18. Solution space of design focus.

5.3.4 Design criteria

Design criteria will help to select the most suitable concept (direction). Therefore, the design proposal should have:

- Grouped steps, so users do not need to go back and forth between the NanoCET device and software to experience a disrupted workflow.
- Least possibilities for errors, so users do not waste time, materials, and samples.
- An efficient workflow to not waste time.
- Clear feedforward and feedback on interaction steps with the device and software, so users feel guided and experience the device as worthy of delivering results they can trust.
- A flexible design, as Dispertech is still a start-up and design decisions may be influenced by new insights along the development way.
- Developmental perspective for the future when the NanoCET reaches a scale-up phase.
- A trustworthy reputation, so users can build on Dispertech and the NanoCET.
- A feasible, desirable, and viable prospect, so the NanoCET can be produced and sold.

5.3.5 Personas

For the desired situation, personas (Zijlstra et al., 2020, p. 115) are created to specify the role of all stakeholders that interact with the NanoCET, see figure 19. Personas describe a stakeholders' job to be done (Laubheimer, 2017), situation, and their needs, wants, and desires. The main difference with the stakeholder description earlier described in section 1.1.4, is for Dispertech. They need to create a new function: the instructor. The instructor instructs new users or labs on how to operate the NanoCET, like all competitor products and companies do as well.

Participant 3 (technician): *'I like to make the microscopes available for everyone to do their own experiment.'*

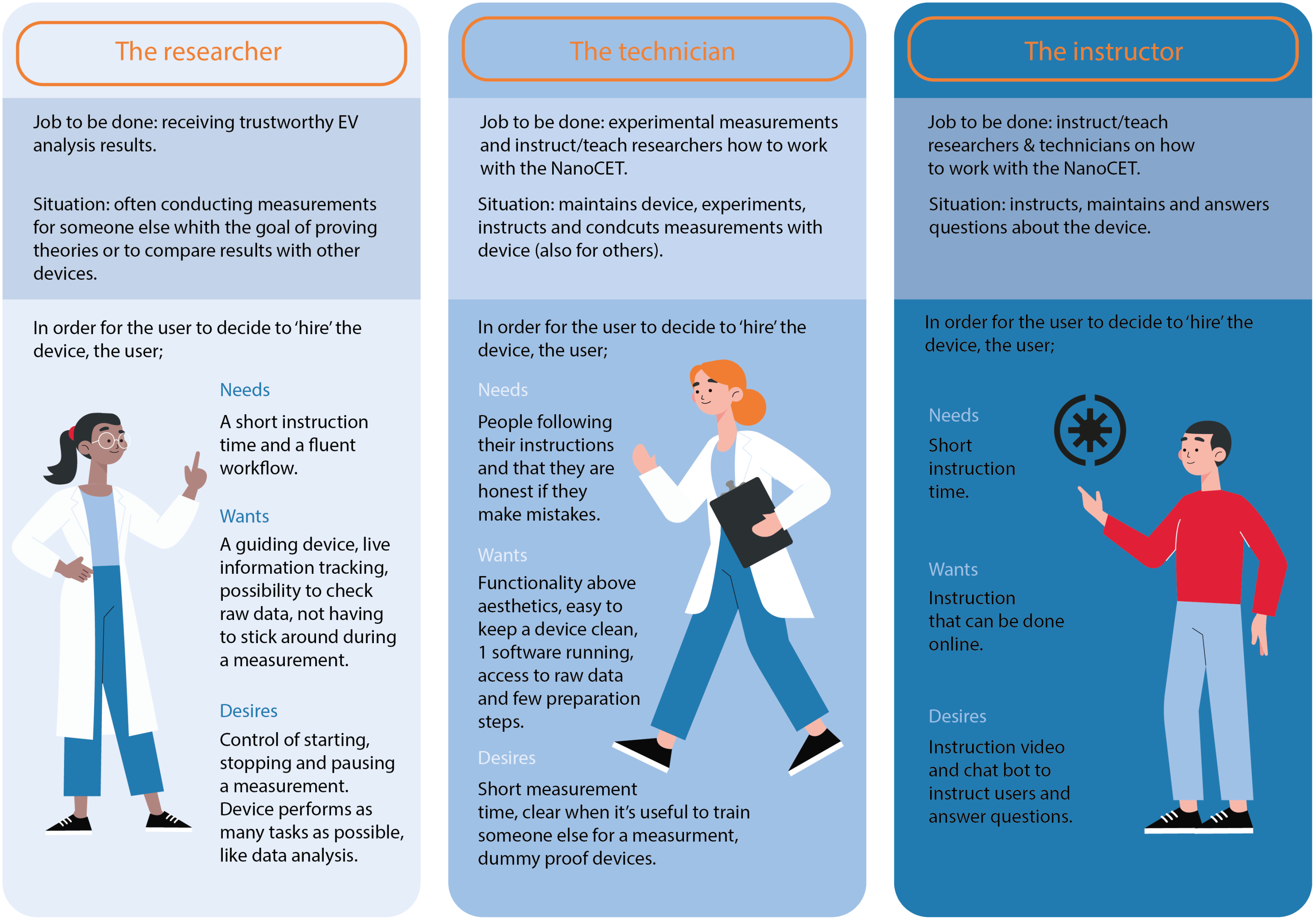


Figure 19. Stakeholder personas in the desired situation.

5.4 Conclusion

This chapter concluded the Design Research phase with a design brief, in which the following problem statement is formulated: Researchers and technicians working in labs, will have difficulty setting up and using the NanoCET device and software when conducting a measurement on the size distribution and concentration of nanoparticles, leading to failed measurements and therefore wasted time, materials and samples.
As a result of the issues, researchers will have trust issues with Dispertech and their NanoCET.

The design goal that I have set to turn this current situation into the desired situation is as follows: let researchers and technicians working in labs experience a fluent and efficient workflow and feel guided by the NanoCET device and software when researching nanoparticles down to 20 nm, so they will make fewer mistakes and will trust Dispertech and their NanoCET.
This will be achieved by integrating the digital part (Software 1) and the physical part (device, 'arena' and cartridge) into a fluent and guided workflow.
To help select a concept (direction) design criteria are lined up.

Furthermore, the researcher, the technician, and the instructor persona are created to specify a stakeholder's role.

The next chapter starts addressing the design goal with ideation.

Ideation 6

6.1 Introduction

Arriving at the Ideation phase, I look into the solution space mentioned in the Design Brief. The goal of the Ideation phase is to explore options and directions for the design proposal. To this end, I combined individual brainstorming, consisting of a lot of associative sketching, and using methods with two creative sessions: one with peers and one with Dispertech. This leads to a divergence of ideas.

6.2 Brainstorming

As shown in figure 20 and 21, I started sketching ideas throughout the Design Research phase. Brainstorming does not start in the Ideation phase. However, when sketching in the Ideation phase, the knowledge and insights of the Design Brief contribute significantly to the process. Nevertheless, it does not hold me back to diverge ideas and explore beyond the limitations of reality during this phase of the process.

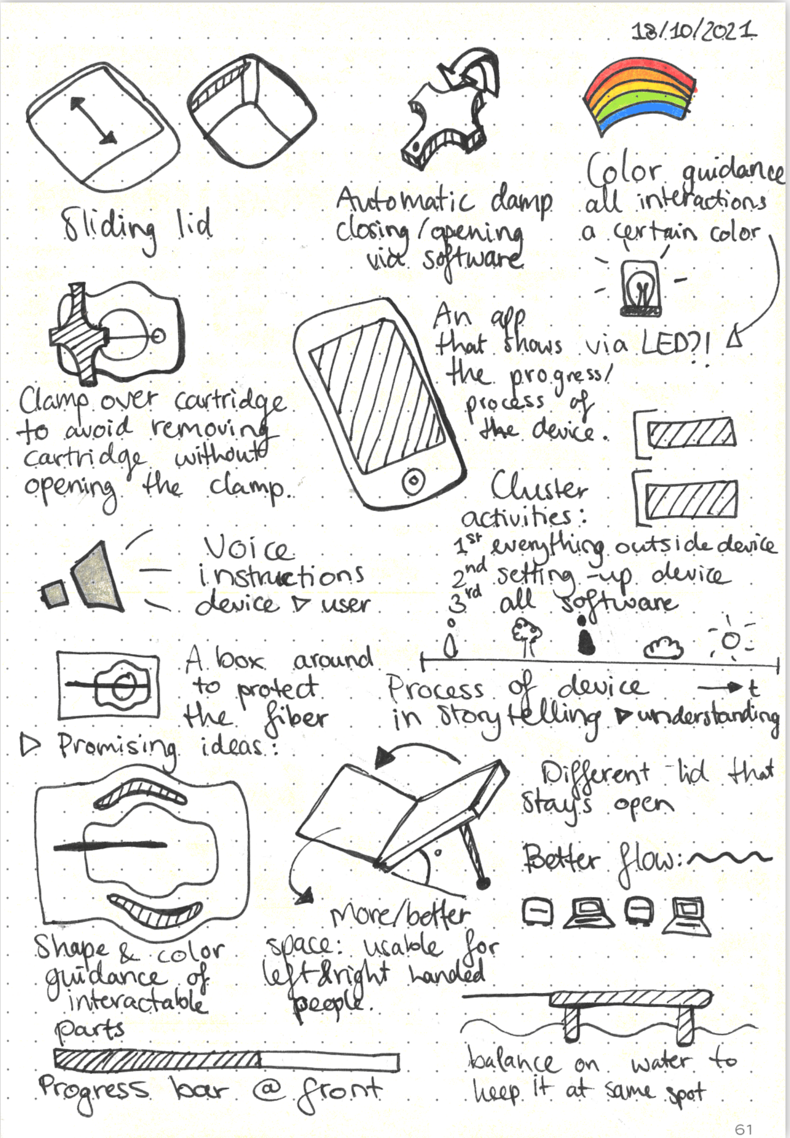


Figure 20. Sketches during the Design Research phase.

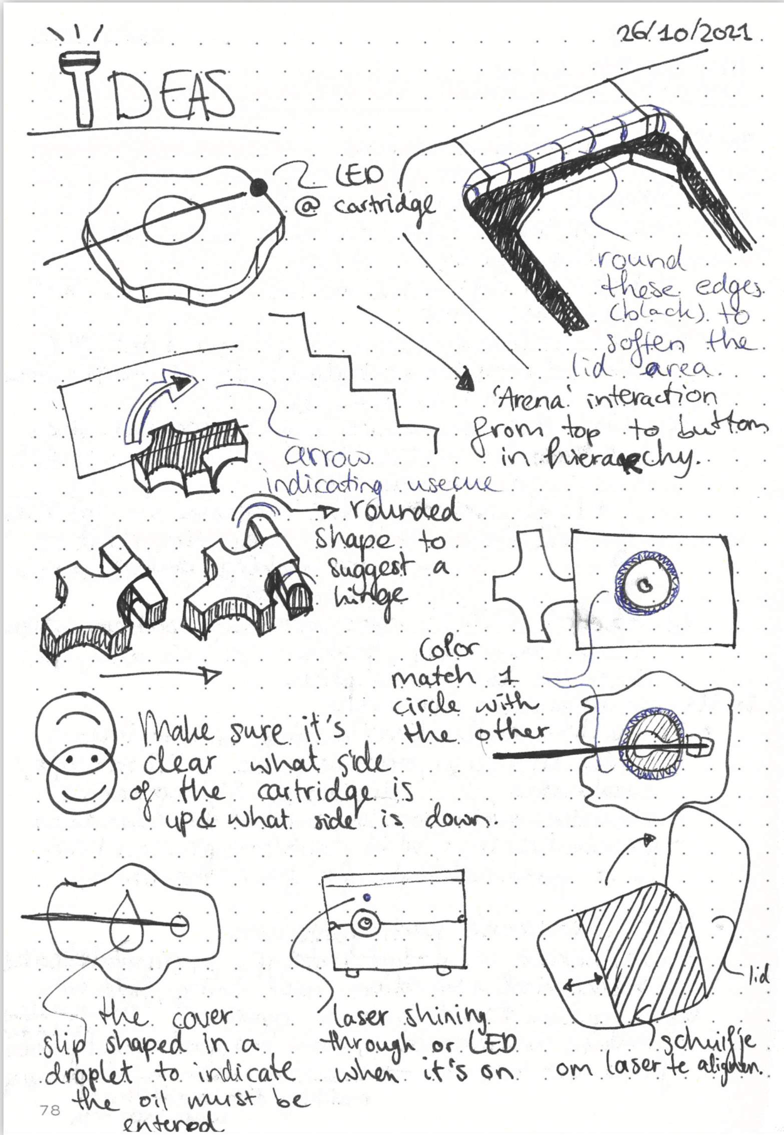


Figure 21. Sketches during the Design Research phase.

To brainstorm on my own in this individual project, I build on, associate, and sketch further on the earlier sketches made during the Design Research phase, see figure 22.

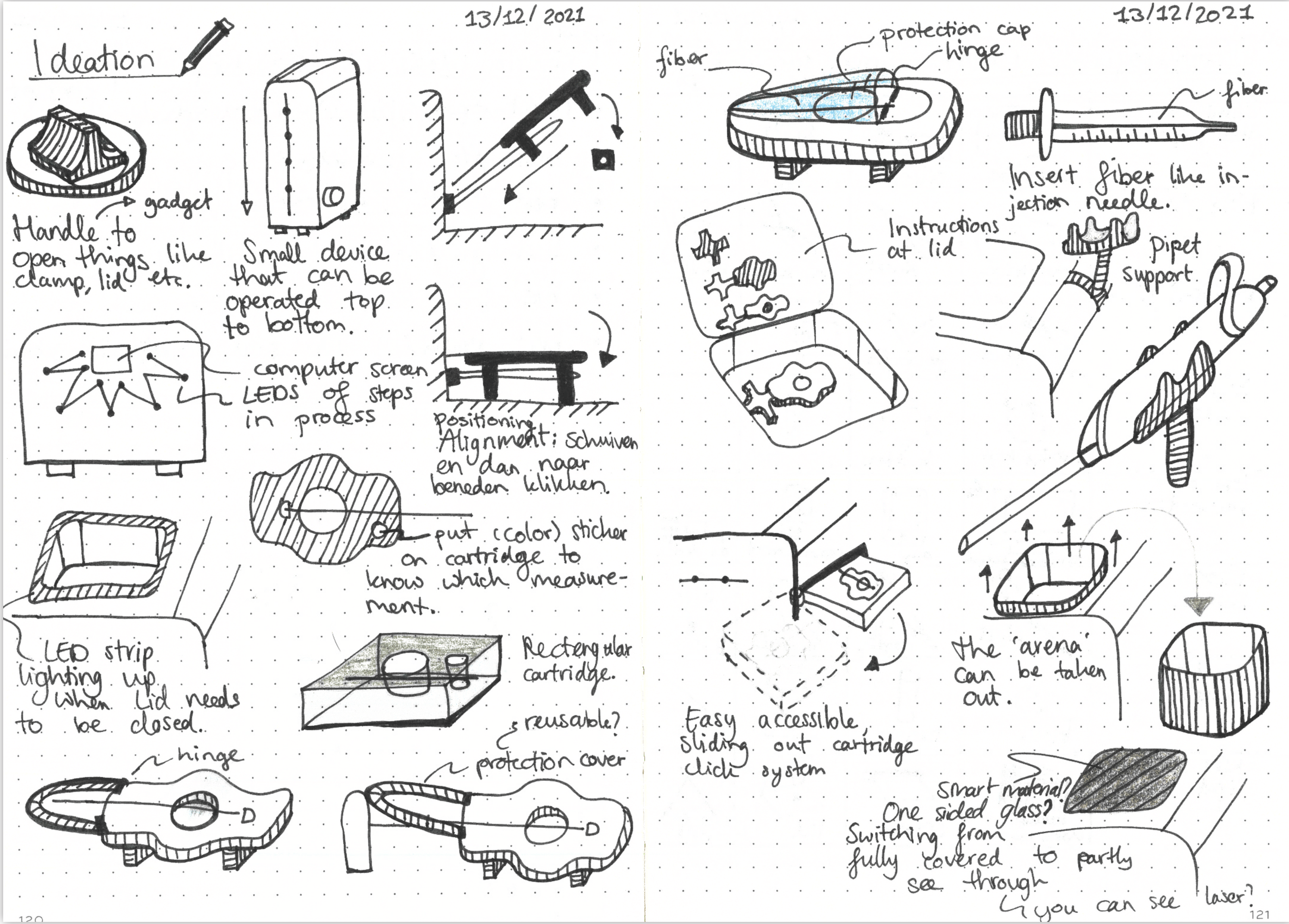


Figure 22. Sketches Ideation phase.

Furthermore, I used methods like SCAMPER and a morphological chart (Zijlstra et al., 2020, pp. 170-173). SCAMPER helps to diverge from a current product in the following categories: Substitute, Combine, Adapt, Modify, Put to another use, Eliminate and Reverse. The morphological chart is based on the NanoCET's functions of the functional analysis in section 4.2 and appendix I. In a morphological chart, you separate each function and look for possible solutions. These separate solutions can then be combined into ideas or concepts. Figure 23 shows a morphological chart with solutions for current functions of the NanoCET and figure 24 shows a chart with solutions for desired functions of the NanoCET.

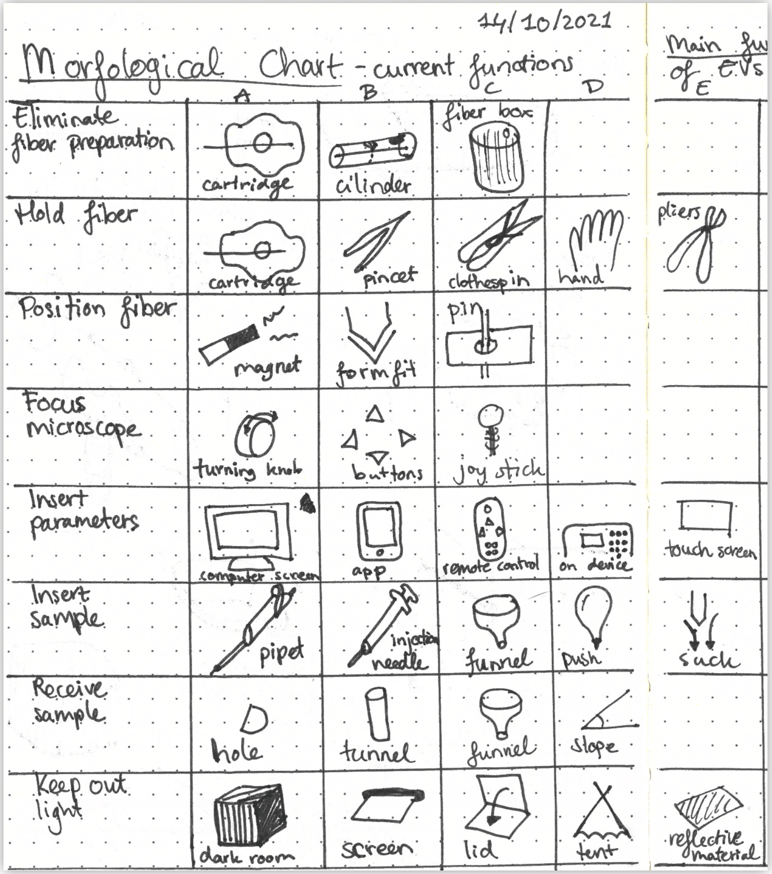


Figure 23. Morphological chart current functions NanoCET.

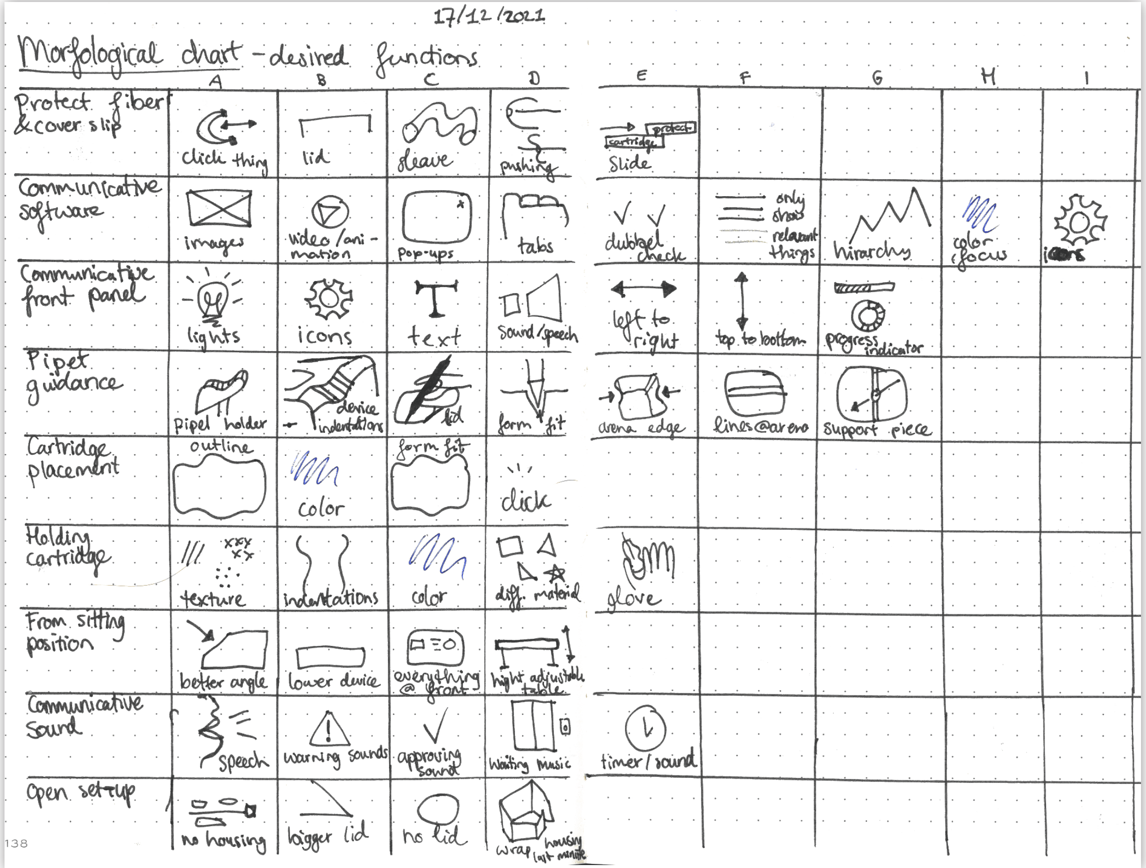
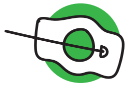


Figure 24. Morphological chart desired functions NanoCET.

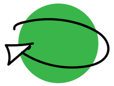
The most interesting results of the individual brainstorming are:



Change the shape of the cartridge to provide use cues on where to insert the oil/sample and how to hold the cartridge.

Show information on the device on a different spot. For instance, like on/around the lid.

Position the cartridge differently: sliding, magnets, screwing.



Split the lid into a lid for laser alignment and a lid for a measurement.

Communicate differently on the front panel. For instance with icons or a digital screen.

- Ideas for software
- Ideas for physical configuration
- Ideas for workflow

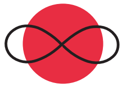
6.3 Creative sessions

To not only brainstorm on my own and get input from others, I have set up two creative sessions. Both sessions have the same goal: diverging; creating as many ideas as possible.

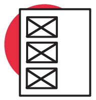
The first session was with two other Design for Interaction master graduation students, see figures 25 and 26. This first creative session started with a short introduction about my project to create an understanding of the context among the participants. Then, we discussed the question 'What is a good workflow?'. After that, we brainstormed on 13 How to's (see appendix L1). How to (Zijlstra et al., 2020, p.175) is a method in which you break bigger issues down into smaller, more concrete questions. All these questions start with the words 'How to...'. The How to's are divided into rounds: each round contains three How to's. In one round, each participant first gets one and a half minutes per How to and then slides the paper on to the next person, so you can build on each other's ideas. Once everyone brainstormed on the How to's in that round, you got one minute to read each other's ideas and add extra associations.

The most interesting results of this creative session are the following:

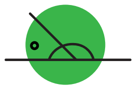
Create instructions like an IKEA instruction manual.



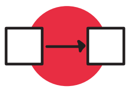
Create the same experience when using the NanoCET for the first or 100th time.



Create a visual protocol.



Cues that can be seen from every angle.



Make use of relay: one thing can only happen if something else is finished.

Appendix L2 shows the full results of the creative session.

Figure 25. Explaining the project during creative session 1.

Figure 26. Brainstorming on how to's

The second session was with five people of Dispertech of which two were joining remotely, see figures 27 and 28. The second creative session started with explaining the rules of brainstorming to get everyone on the same page and create a safe space to brainstorm. The session consisted of a couple of general questions and again How to's of which some are the same as in the first session. Appendix M1 shows an overview of the questions and the How to's. This time, the questions and How to's are discussed all together, one by one. Everyone mentioned ideas out loud so others can hitchhike on each other's ideas.

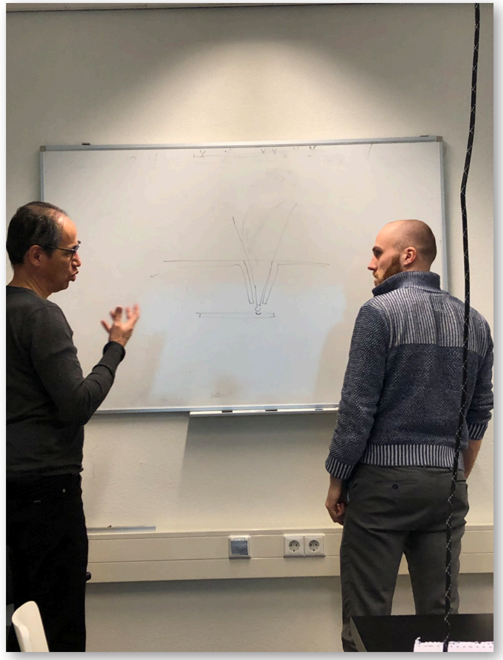
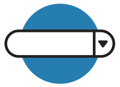
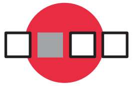


Figure 27. Creative session 2 with Dispertech.

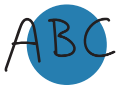
The most interesting results of this creative session are the following:



Add presets: reduce the amount of effort for users.



Block out wrong steps: avoid errors.



Different modes within the software for different options.

Demo mode/ guiding tour when software is used for the first time.

Question mark button at software providing information.

Providing extra help after a long idle time.

Create pipet support to make inserting the sample easier.

Figure 28. Discussing sketches during creative session 2.

Appendix M2 shows the full results of this creative session.

6.4 Conclusion

Divergent ideation with brainstorming and creative sessions resulted in fruitful input like a different communication way between the device and the software, adding use cues to the cartridge, adding pipet guidance/support, providing clear (visual) walkthrough instructions on the device and/or software that can only be followed in one way/order, and reducing the input needed from the user.

The individual brainstorming mostly led to physical ideas to improve the NanoCET device, the first creative session gave insight into workflow ideas, and the second creative session mostly resulted in software ideas.

The next chapter converges this broad collection of ideas and merges the idea categories into concept directions and a design proposal.

Design synthesis 7

7.1 Introduction

During this stage, the broad idea generation of the previous phase is narrowed down to arrive at a design proposal. Taking off with explorative prototyping to evaluate the NanoCETs configuration and workflow. After that, three concept directions are proposed of which one is selected and turned into a concept. This concept is further developed into a design proposal, presented at the end of this chapter.

7.2 Explorative prototyping

An explorative prototype (van Kuijk, 2021b) is a quick simulation of an idea or question to try out if something will work. The goal of this explorative prototype is to get the user's input on the NanoCET configuration and to examine the current workflow of the NanoCET.

The explorative prototype is tested with one user that I visited during field research in an earlier stage (Participant 1 of section 3.3). The participant is given a clean box that represents the NanoCET. All its elements are made out of paper and foam. The software is simulated with a Word document, see appendix N. The explorative prototyping user test consists of four steps: placing the elements on the box in the desired configuration (figure 29), acting out the measurement steps (figure 30), reflecting on the configuration, and trying another configuration (figure 31). The full results can be found in appendix O.

Reflecting on conducting a measurement with the configuration of figure 29:
'If it's not a box shape it's unusual.'
'The colour of the LEDs, that each LED has a different colour like the nCS1.'
'Maybe when I align the laser, I can also crop the ROI.'

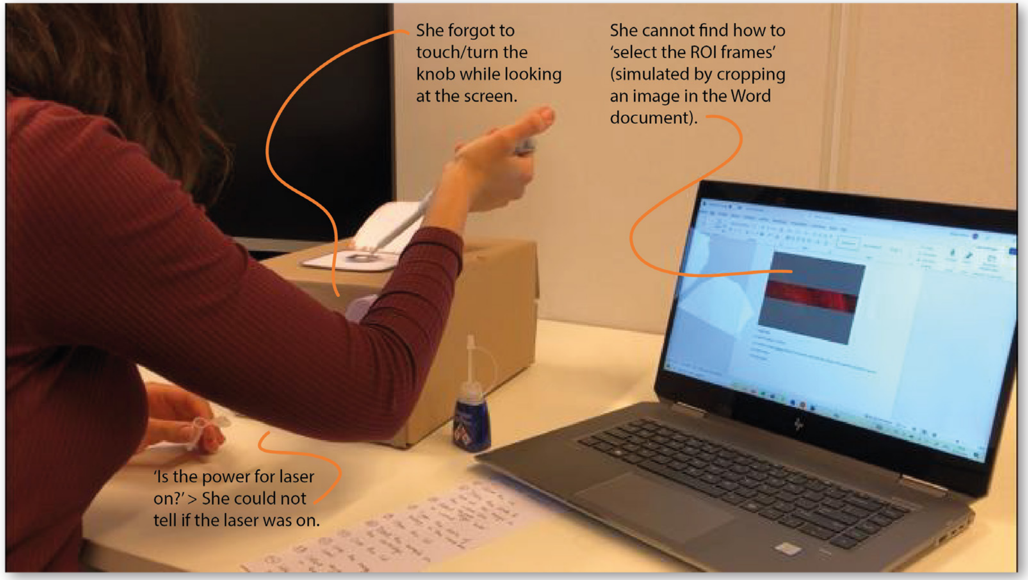


Figure 30. User interacting with explorative prototype.

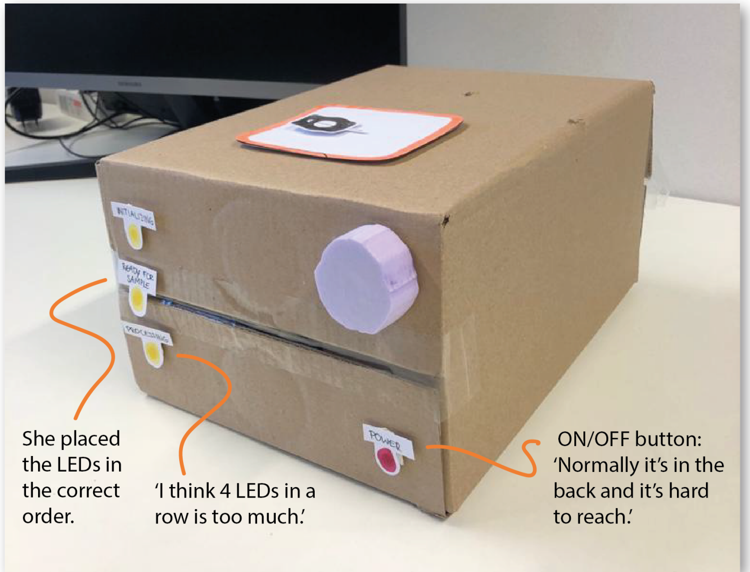


Figure 29. Configuration created by explorative prototype user.

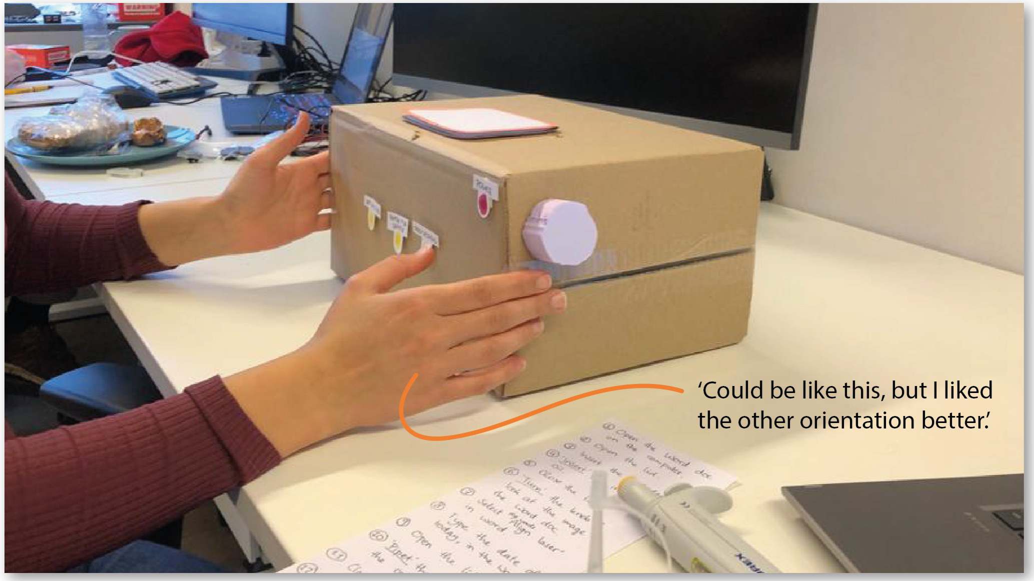


Figure 31. User putting the device in a different orientation.

7.3 Concept synthesis

7.3.1 Concept directions

Converging ideas of Chapter 6 together with the insights of explorative prototyping, resulted in three concept directions:

Concept direction 1: focus on software, with the device on the side.

In this first concept direction, users get instructions and guidance of the software with the support of the device. Figure 32 shows an overview of different ways in which this can be done, for instance with a timeline, pop-ups, a carousel, or pagination. The device is clean it does not need many buttons and provides enough space for branding. The ON/OFF button can get a more prominent place, for instance on the front panel.

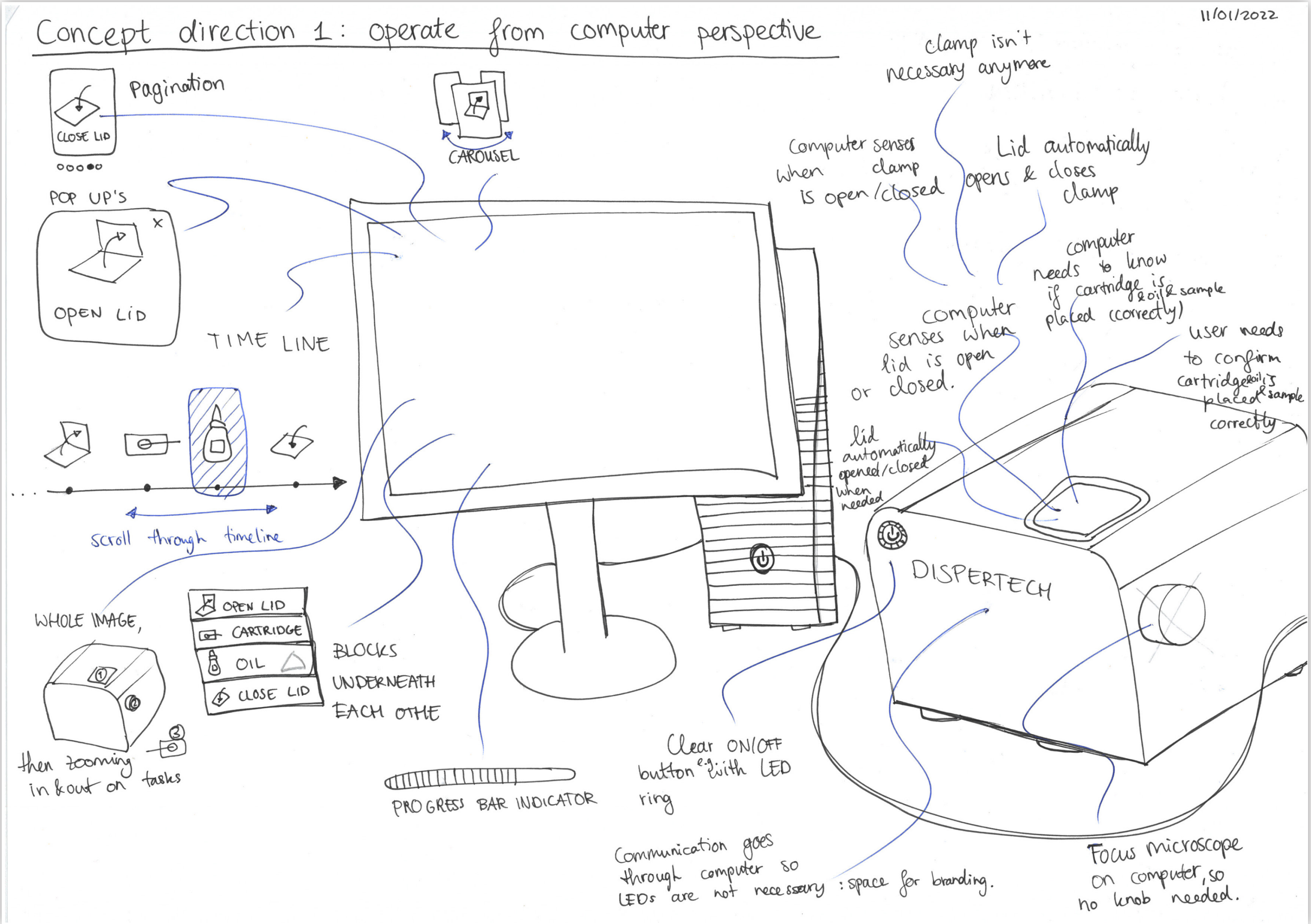


Figure 32. Concept direction 1: focus on software, with the device on the side.

Concept direction 2: focus on the device, with the software on the side.

The second concept direction is the other way around: users get instructions and guidance of the NanoCET with the support of the software. Figure 33 shows an overview of different ways this can be achieved like using a (touch) screen, physical knobs, a pause/play button, or icons indicating the scenario steps. This leaves hardly any functions for the software, just showing the camera view and the power of the computer to collect data.

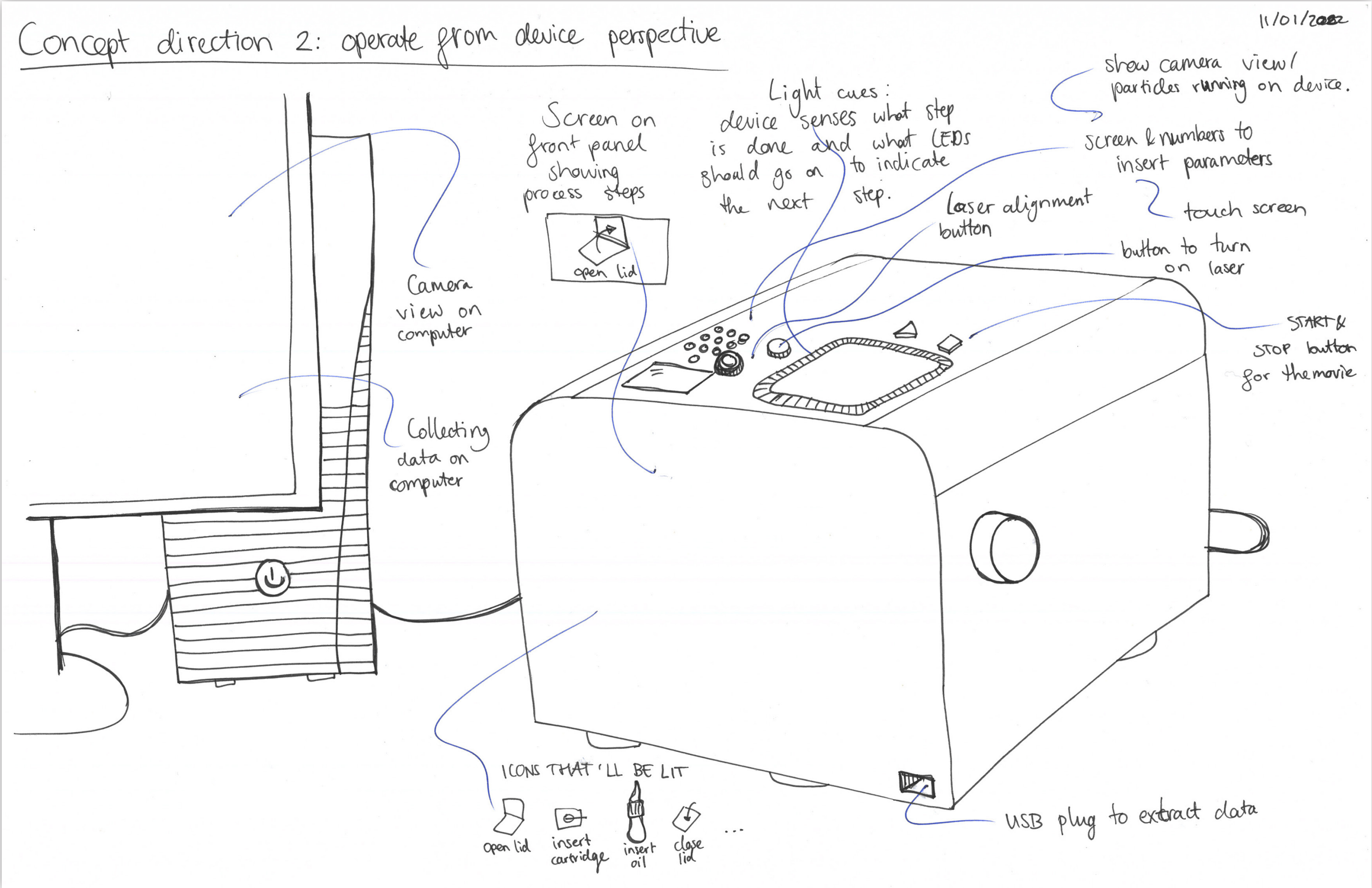


Figure 33. Concept direction 2: focus on the device, with the software on the side.

Concept direction 3: radically different from current NanoCET.

The last concept direction is focused on radical adjustments in the physical configuration of the NanoCET. Figure 34 shows an overview of different ideas on how this can be done. For instance, sliding a part out or lifting the 'arena' out of the device to insert the elements like the cartridge and oil.

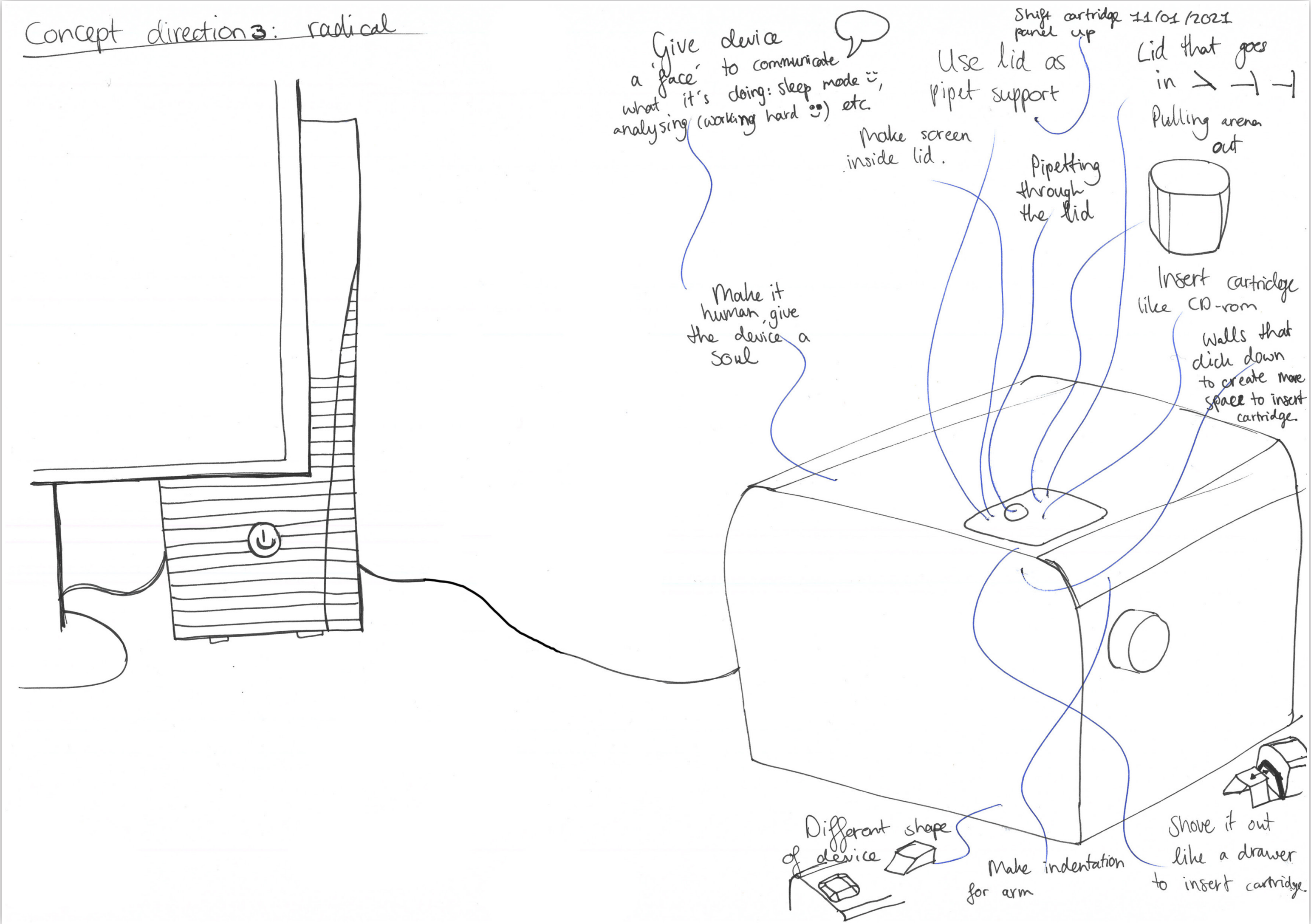


Figure 34. Concept direction 3: radically different from current NanoCET.

7.3.2 Concept direction selection

To select a concept direction to continue with, a risk analysis (Rosencrance, 2021) was performed. In this risk analysis, the benefit of the concept direction is evaluated, considering the amount of effort in time and costs it will take. Next to that, the design criteria mentioned in the Design Brief are evaluated per concept direction.

Building on this, the 10 arguments below are used to select concept direction 1 as direction to continue with. A visual representation of the concept direction choice that supports these arguments is shown in figure 35 in the form of a Harris Profile (Zijlstra et al., 2020, p.177). The Harris Profile uses design criteria in order of importance, so the most important criteria are mentioned at the top. The numbers on the right of figure 35 refer to the arguments below.

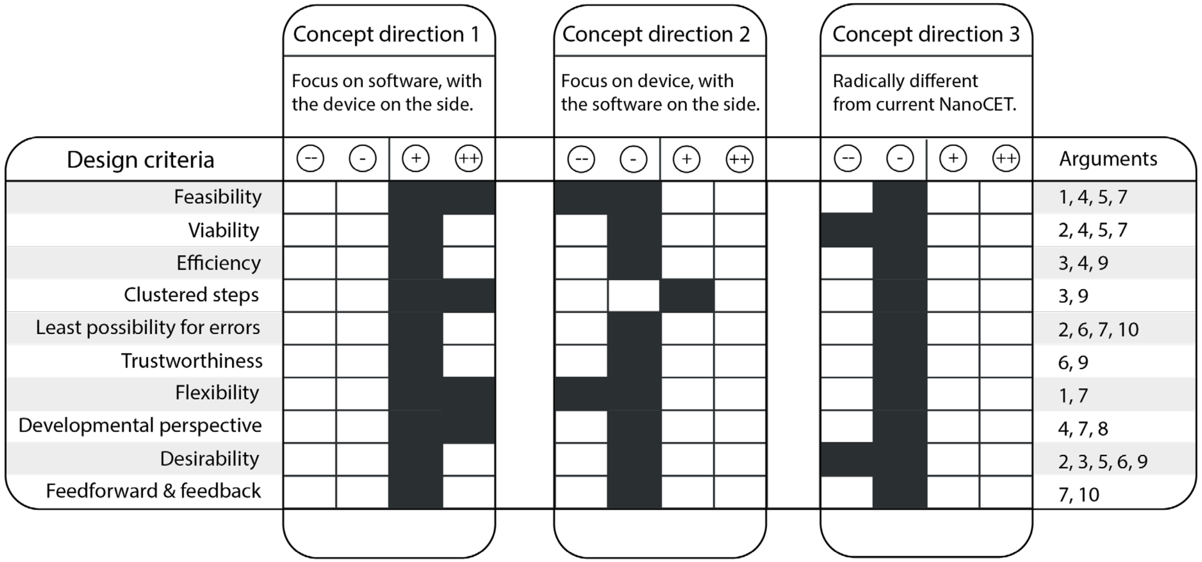


Figure 35. Harris profile concept directions.

1) Aesthetic physical buttons in small volumes are expensive to produce and Dispertech currently does not have dozens of NanoCET devices in the production pipeline.

2) Touchscreens are complicated as users mostly wear gloves when conducting a measurement.

3) In direction 1, most interactions happen on the computer. This means the body posture remains in a similar position, compared to the time lifting elements and pressing physical buttons in the other two directions.

4) Turning the knob might eventually become an overrated function in the process of a measurement, so the number of physical interactions is more likely to decrease. Therefore it is counterintuitive to increase the number of physical interactions with direction 2 or 3.

5) Especially direction 3 would cost a lot more effort to implement than it would benefit the workflow and usability issues encountered in sections 4.3 and 4.4.

6) Clicking physical buttons can give users a feeling of messing up the alignment of the device, therefore, touching the NanoCET as least as possible is desired, like in direction 1.

7) Software is flexible with updates compared to physical buttons or configurations like in concept direction 2 or 3. Mechanical changes are harder and more complicated than digital adjustments. This is convenient as start-up Dispertech still re-evaluates design and technical decisions.

8) Direction 1 is most future-proof: the software could be turned into a screen on the device or even an application that goes along with the NanoCET.

9) In concept directions 2 & 3, the computer becomes almost overrated in terms of interaction, but the power of the computer is still needed for the device to work. So making use of the computer by emphasizing it in direction 1 is more in line with the workflow of the device.

10) Direction 1 can make use of the fact that the software runs on a computer, so mouse hovering feedforward can be used.

7.3.3 Concept development

Selected concept direction 1 is developed and detailed further into a concept, see figure 36. This is done by discussing the options within the concept direction with Dispertech. The concept includes adjustments in the physical configuration of the housing and inside the 'arena'. The cartridge and its packaging contain newly designed features as well. But overall, the major change is in the digital part. Figure 36 shows a list of elements on the computer screen that form the ingredients of the software.

Wireframing is used to develop the software. Appendix P1 shows how the listed ingredients of figure 36 are converted into sketched screens. By increasing the fidelity, the wireframes of appendix P2 are created. These wireframes are evaluated with five peers by asking them how they interpret features and what parts they think are clickable and which parts are not. Incorporating their feedback led to the wireframes in appendix P3 that form the basis of the software of the design proposal.

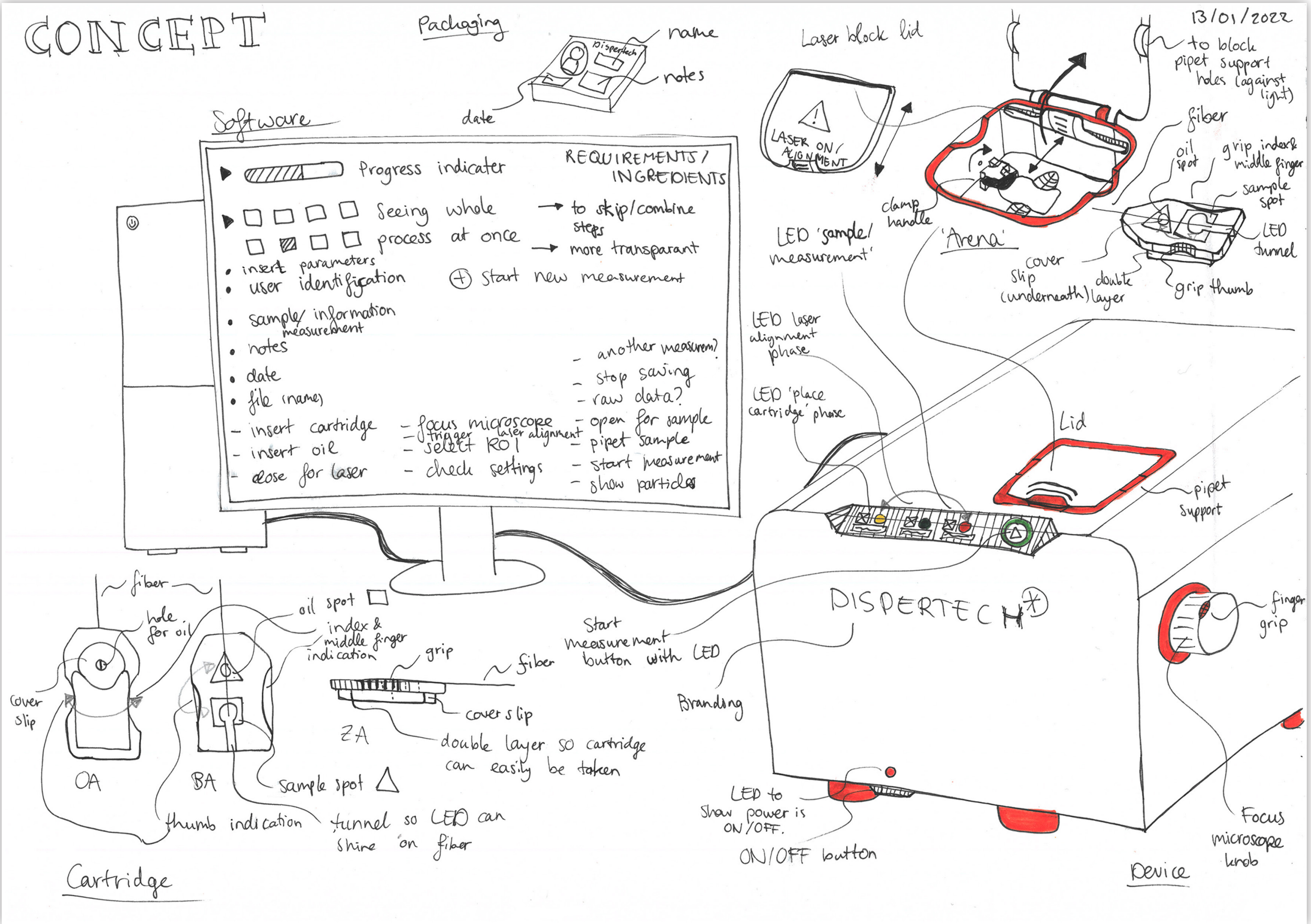


Figure 36. Concept based on direction 1.

7.4 Design proposal

The concept shown in section 7.3.3 is further refined into the design proposal as presented in figure 37.

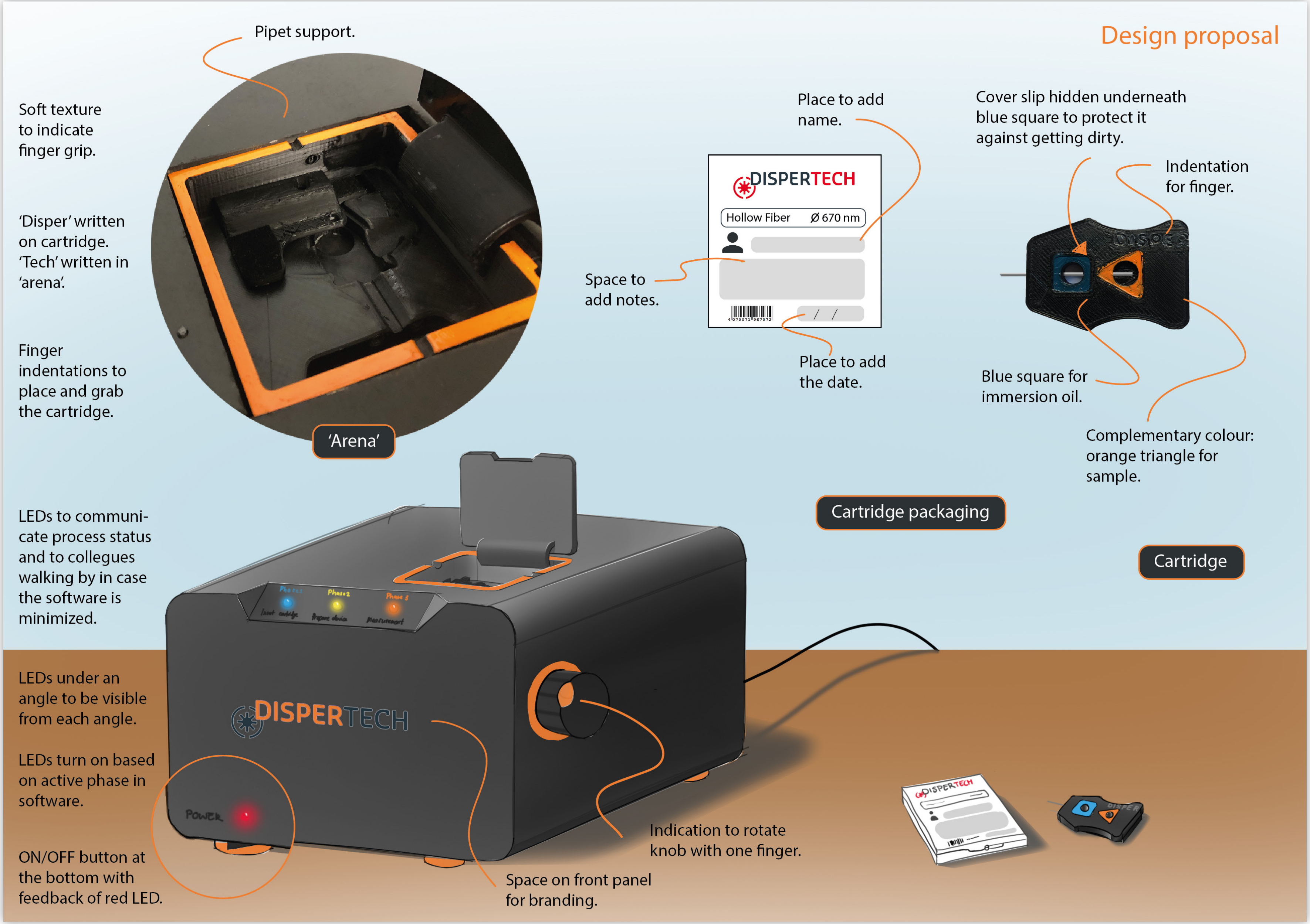


Figure 37. Design proposal.

Figure 38 presents the workflow of the design proposal.

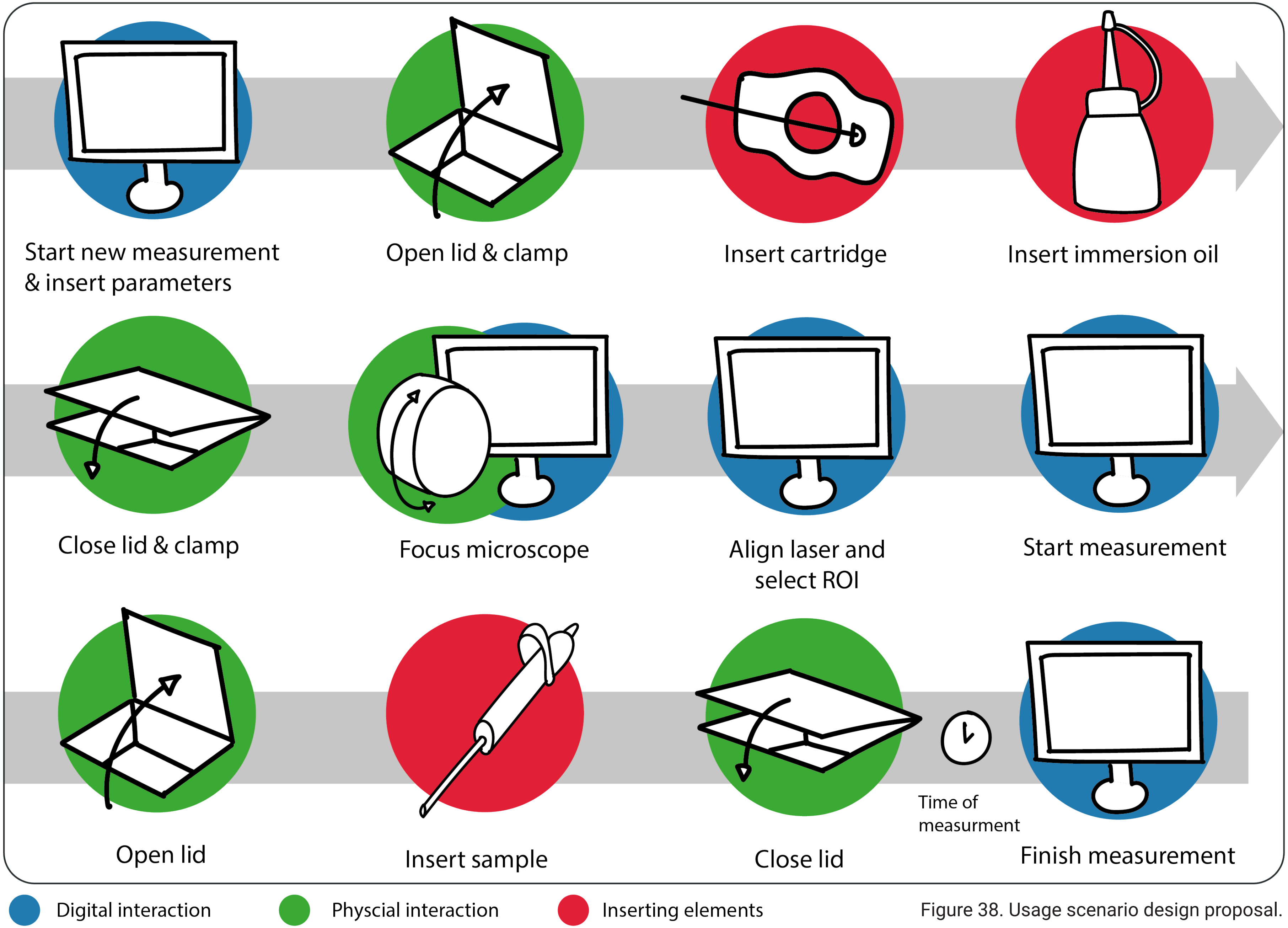


Figure 38. Usage scenario design proposal.

7.4.1 Software design proposal

This section shows and explains the software of the design proposal, see figures 39-41.

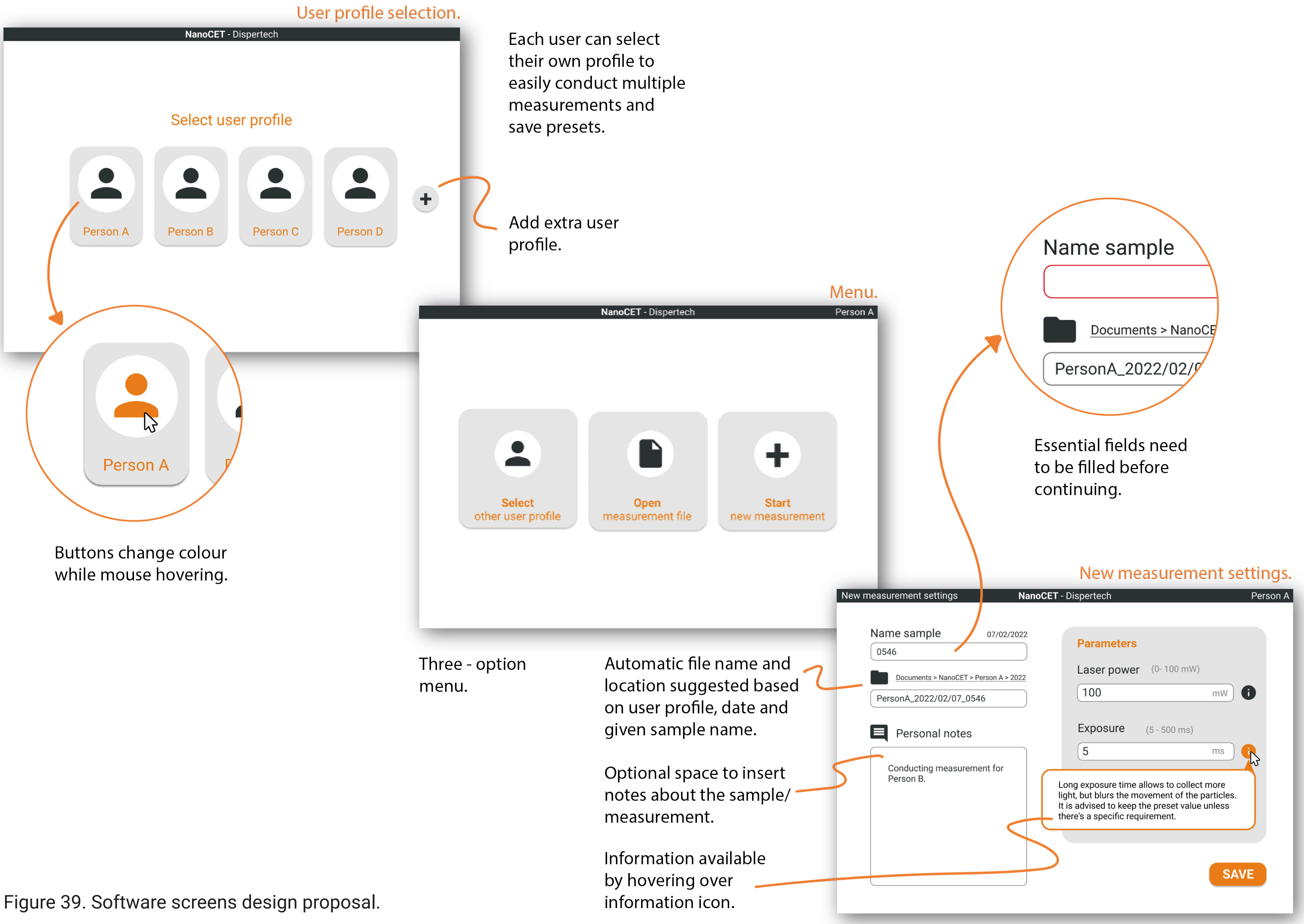


Figure 39. Software screens design proposal.

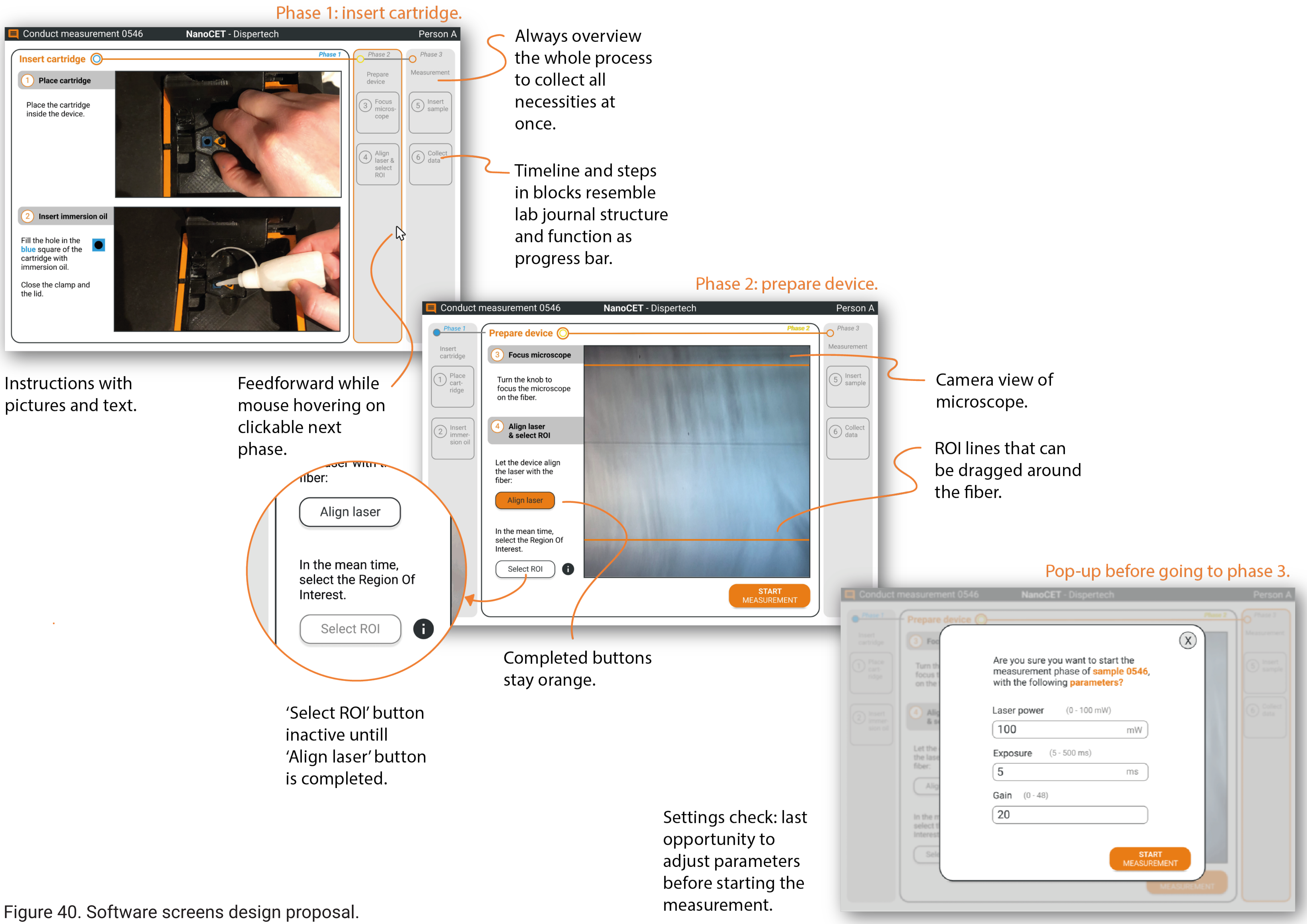


Figure 40. Software screens design proposal.

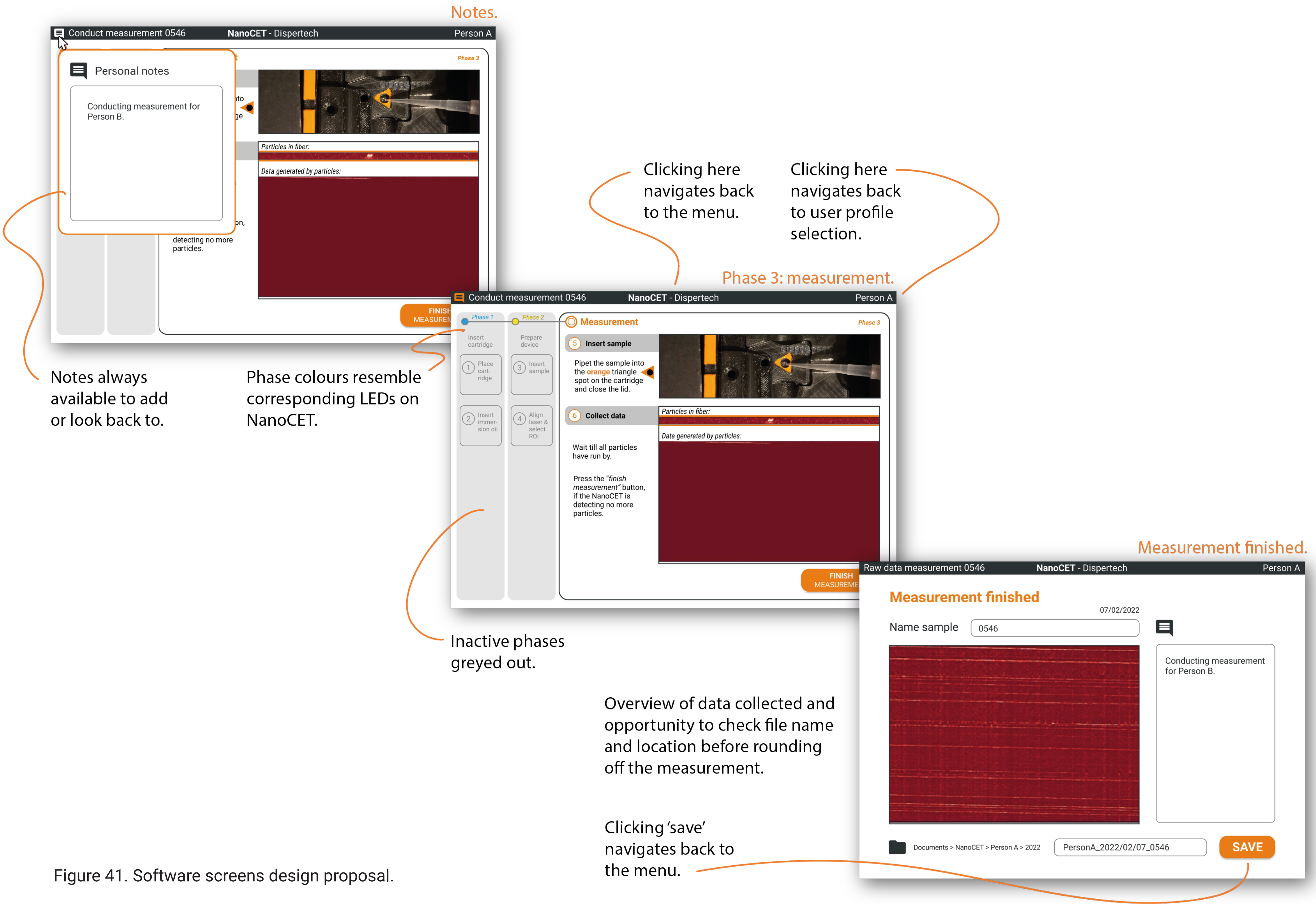


Figure 41. Software screens design proposal.

7.5 Conclusion

The most important insights found during the user test with the explorative prototype include; performing the laser alignment at the same time as selecting the Region of Interest, separating the power LED from the other communicative LEDs, and giving each individual LED a different colour. Furthermore, a reachable ON/OFF button is preferred, process steps should be clear and essential steps cannot be skipped.

The following three concept directions were proposed:
1) Focus on software with the device on the side.
2) Focus on a device with the software on the side.
3) Radically different from current NanoCET.

A risk analysis and the design criteria of the Design Brief are used to select concept direction 1 to continue with, because this direction is most feasible, viable, efficient, and contains clustered steps compared to the other two directions, as software is flexible and can easily be updated. By using wireframing, the concept out of direction 1 is further shaped and developed into a proposed design.

The next chapter evaluates the design proposal through user testing.

8 Design evaluation with users

8.1 Introduction

In this chapter, the design proposal is evaluated with users in the context. To achieve this, an experience prototype of the design proposal is created along with a user test plan. Conducting user tests leads to insights on how to improve the design, and recommendations that can be further researched.

8.2 Method

8.2.1 Experience prototype

The experience prototype of the design proposal consists of a digital part: the software, and a physical part: the device. The prototype of the software is made tin Figma and simulates the breadth and depth of all the steps needed to conduct a measurement, see figure 42. The prototype of the device is made of wood and (spray) painted black and orange to resemble the current NanoCET of which the 'arena', lid, and knob are 3D printed, see figure 43. Furthermore, the prototype contains electronics to mimic the communication between the device and software.

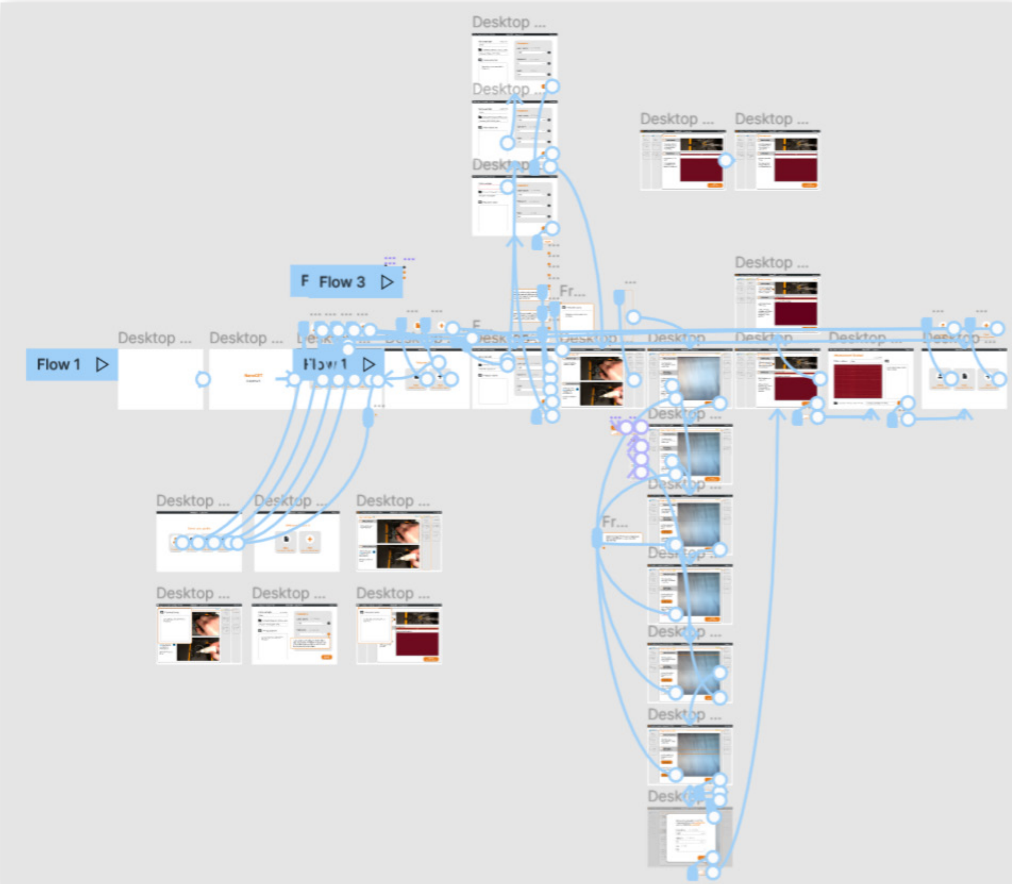


Figure 42. Digital prototype in Figma.

Figure 43. Physical prototype made of wood.

8.2.2 User test plan

The user testing has two goals: to get an impression of the quality of the interaction and to improve the design further. To reach these goals, the following research questions are lined up:

- How do users interact with and experience the software (plus the incorporated workflow), and the device?
- To which extent does the workflow align with the (preferred) way of working for users?
- Which usability and user experience issues arise?
- Is the device experienced as trustworthy?

These main research questions are transcribed into interview questions that can be found in appendix Q. These questions are asked in an interview after each user test. To get a summative result out of the user tests, the System Usability Scale (SUS) according to the Assistant Secretary for Public Affairs (n.d.), is used. A SUS consists of 10 statements which can be rated on a 1-5 scale (strongly disagree to strongly agree). Participants filled out these statements themselves at the end of the interview. A SUS score delivers a number on a validated scale, with each number coupled to a usability level ('worst imaginable' up to 'best imaginable'). This score puts the design proposal's usability in perspective.

Participants

Table 3 shows the users that participated in user testing the experience prototype of the design proposal. Participants are selected based on the ability to pipet, their gender (to create balance), whether they are left- or right-handed, in which stakeholder category they fall, and whether they work(ed) in the context or can work in the context of hospital/university labs.

Participants	Gender	Role	Location	Left/right handed
Participant 1	Male	Researcher	Science Park, Amsterdam	Right
Participant 2	Male	Researcher	Science Park, Amsterdam	Right
Participant 3	Female	Researcher	Science Park, Amsterdam	Right
Participant 4	Female	Researcher	Amsterdam UMC	Right
Participant 5	Male	Intern	Amsterdam UMC	Right
Participant 6	Female	Technician	Cancer Centre Amsterdam	Right
Participant 7	Female	Researcher	Utrecht University	Left
Participant 8	Male	MSc graduation student	Utrecht University	Right

Table 3. Participants user testing the experience prototype of the design proposal.

Test set-up

The test set-up is sketched in figure 44. My laptop filmed the participant's face to record facial expressions and it run the software. A mouse is connected to the laptop. The prototype of the NanoCET is placed on the left side of the participant. (In case a participant is left-handed the device is placed on the right side). With my phone on a tripod, see figure 45, I filmed over the shoulder of the participant, so I had my hands free to make notes and click the remote control to operate the LEDs according to a participant clicking the software phase. Half of the supplies were on the main desk of the test, the rest is in a cabinet as these supplies needed to be collected during the user test, see figure 46.

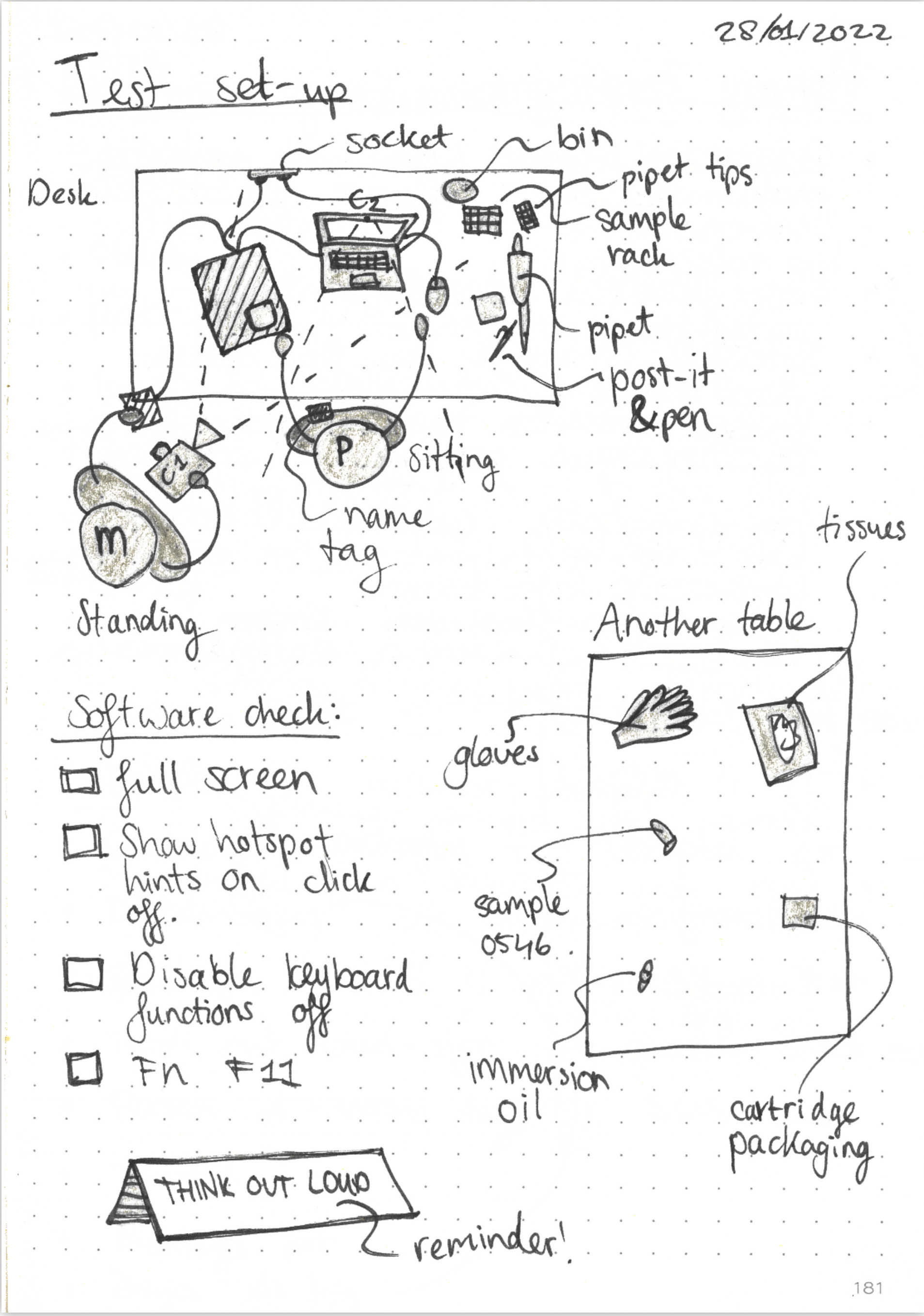


Figure 44. Sketch test set-up.

Figure 45. Test set-up in real life.

Figure 46. Test set-up: cabinet with supplies.

Structure of user test

Once the user test is introduced to the participants and formalities like consent forms are handled, the assignment is explained. During the user tests, participants are asked to conduct a measurement with the experience prototype of the NanoCET. This way, users interact with the full breadth of the physical and digital prototype and experience using all additional necessities on the device, like the pipet and immersion oil. After a user test, I interviewed participants on how they experienced the NanoCET prototype. Then, participants gave feedback on the workflow by having the possibility to shift steps around in the workflow, see figure 47 for an example. Up next, there were practical questions about performance and desires. The interview finished with filling out the SUS scale statements and three other scale statements. Appendix R shows further details of the user test plan.

Figure 47. Example of participant puzzling his/her optimal workflow.

8.3 Results user tests

Figure 48 shows an overview of the most relevant results of the user tests. Note that P1 for example resembles participant 1, etc.

Figure 48. Results of user testing with the experience prototype of the design proposal.

8.4 Insights user tests

As seen in figure 48, a clear result is a System Usability Scale score of 85,3 out of 100. This score represents an ‘excellent’ system (device and software) (Alathas, 2018). Even with a standard deviation of 9.1 the lowest SUS score would be 76,2 which still represents ‘good’, see appendix S for the full data and calculated results.
The user test results led to many more insights, which are sorted out in the following categories: remarkable elements, first-time use, workflow, software, and device. At the end of this section, improvements in the design proposal are listed.

Remarkable elements of the user tests

- 2 out of 8 participants are standing during the user test.
- Participant 1 does not dare to click ‘save’ at the parameter screen and/or feels thus guided by the device that he conducts the measurement preparation steps before finding the instructions of the software.
- Participant 1 interprets the blue square on the cartridge as a logical connection with the blue packaging of the immersion oil.
  Participant 1: *‘Since the oil is blue and the spot on the cartridge is blue, I’m reassured where to put it.’*
- Participant 1 is less careful when conducting a measurement for someone else.
  Participant 1: *‘I will care less for someone else’s measurement.’*
- The initial reaction of participant 4 is to look for the manual or to search on the internet.
  Participant 4: *‘I need some kind of manual because I have no clue how to start with the device.’*
- Participant 7 is right-handed but uses the computer mouse with her left hand because she is wearing a glove on her right hand and does not want to make the glove dirty.
- Participant 7 often walks up and down to the cabinet, although the route is inconvenient. One time she even does not return with any supplies.

Insights first-time use

- Users have trouble finding the ON/OFF button.
  Participant 4: *‘Had to look for the ON/OFF button, but luckily it was close to the power LED.’*
- Users have trouble figuring out how to open the clamp inside the ‘arena’.
  Participant 1: *‘I was struggling to recognize the clamp.’*

Insights workflow

- Users prefer the design proposal of the NanoCET over the device they are currently working with.
  Participant 4: *‘I had less problems with handling this one than the nCS1, and for that, I had a manual.’*
  Participant 5: *‘More easy to use than the Osrom I’m currently using.’*
  Participant 6: *‘It’s quicker than my Exoid.’*
- Users do not understand why certain steps are in a certain order. Therefore, the workflow sometimes does not make sense to them. This is caused by a lack of experience with the NanoCET and the fact users are not fully instructed about the device beforehand.
  Participant 2: *‘I would keep the lid open the whole time and then insert the sample.’*
- 2 out of 8 participants think the moment of inserting the parameters can be done later.
  Participant 7: *‘Could parameters go later?’*
- Users feel like they can operate the NanoCET on their own.
  Participant 4: *‘I have the feeling I can handle this myself, even if it’s once in a couple of months.’*
- Users appreciate elements that just have one function.
  Participant 7: *‘The knob on the side just to focus, really convenient.’*
- 6 out of 8 participants want to first insert the sample and then start recording the data of a measurement.
  Participant 1: *‘You definitely want to start after entering the sample.’*
  Participant 3: *‘I would have expected to place the sample and then click somewhere to start it.’*
  Participant 4: *‘Start measurement for me feels like the sample should already be in there.’*
  Participant 5: *‘I’m a bit confused because I thought I should enter the sample first.’*

- All participants insert the right liquid in the right place. Even participant 1 did it correctly, although he did not follow the guidance of the software.
- Participants do leave the clamp down when inserting the sample.
- Not all users realize the cartridges are disposable.
- Users can complete a measurement while wearing gloves.
- 2 out of 8 participants use just one glove during the user test.
  Participant 3: *'I'm doing one-handed gloving because I'm a chemist, it's what we do.'*
  Participant 4: *'Actually, we normally have a one-handed glove policy.'*

Insights software

- 3 out of 8 participants experience the file name and location as repetitive.
  Participant 3: *'As long as I have to fill it once, it's fine.'*
  But not all participants agree: Participant 7: 'Reassurance of folder and sample is really nice.'
- Users compare their situation with the instruction images, so if the image does not resemble their situation, users feel like they missed an instruction.
  Participant 3: *'I'm kind of weirded out by the fact that in the photo I see this plastic part [clamp], so I think I just have to slide it under.'*
- 6 out of 8 users think the cartridge needs to be slid into the device instead of pushed down.
  Participant 8: *'Sliding it in feels more natural.'*
  Participant 4: *'Just squeeze it underneath?!'*
- Having an overview of all steps in the software, visible at all times, works well: users collect multiple necessities at the same time from the cabinet and use the overview to look forward on what steps are coming or to look back on what steps are completed.
- 7 out of 8 users want to know the amount of sample they need to pipet on the cartridge. And half of the participants wants to know exactly how much immersion oil should be applied.
- The exact wording of the instructions is very important as users follow them literally.
  Participant 3: *'So, I'm just going to fill the hole, it said 'fill', so I'm just going to continue pouring.'*
  Participant 4: *'I can save this* [parameter screen] *and save doesn't mean measure, so I'm not starting the measurement right away.'*
- Paradoxically, because of the instruction images in the software, the text instructions are not always read carefully.
  Participant 3: *'Because there is an image, I barely read the instructions, but I see now that it says close clamp and lid.'*
- 3 out of 8 participants specifically mention they like the information buttons.
- 2 out of 8 participants reset the device themselves by discarding the cartridge, even if resetting is not mentioned in the user test assignment.
  Participant 6: *'What to do after? Clean it?'*
  Participant 1: *'I think the next person would like it if I clean up.'*
  Participant 3: *'And I suppose I would take a new glove and take this [cartridge] out.'*
- Users want to navigate back and forth between phases.
  Participant 3: *'Oh no, I clicked phase 2 already, just because I thought, can I do that?'*
- Users want every step to be written out, even the small steps like opening/closing the clamp/lid.
  Participant 8: *'I guess this one* [clamp] *can open, can it?'*
  Participant 2: *'First step seems to be missing: open the clamp.'*
  Participant 6: *'It's missing one step, if you want to make it dummy-proof: add open lid, open clamp.'*
  Participant 2: *'Maybe too obvious, but I would still like to see 'open lid' first.'*

Insights device

- Multiple users do not know the word for the clamp.
  Participant 3: *'Close the small thing.'*
- Because there is a hole above the clamp (meant to let an LED inside the 'arena' enlighten the fiber for focusing), it is physically possible to pour immersion oil through the clamp which can lead to confusion by users.
- Protecting the fiber is still an unsolved usage issue.
  Participant 1: *'I'm very afraid I'll break the fiber.'*
- The pipetting support is not used nor recognized and therefore an overrated element of the design proposal. Users have their way of managing to pipet the sample in the cartridge.
  Participant 7 about pipetting support: *'If you are used to pipetting, they won't be used.'*
  Nevertheless, the usability issue of inserting the sample is solved by enlarging the sample spot (orange triangle on cartridge).
  Participant 6 about inserting the sample: *'Very easy, it was a very big surface.'*
  Participant 3: *'I pipet a lot and in pipetting terms this spot you need to hit is huge.'*
- The descriptions on the device next to LEDs might be too guiding and in the way of the guidance, the software provides: 2/8 participants are guided or confused by the guidance of the device.
  Participant 1: *'Maybe I was guided by the device too much, so I didn't see software.'*
  Participant 3: *'Expected to see yellow led: 'prepare device' off during phase 3.'*
- Half of the participants think the device can deliver trustworthy results and the other half is not sure as they did not conduct an actual measurement.
- The device is usable for both left- and right-handed users according to the only left-handed participant. Nevertheless, she still places the sample with her right hand.
  Participant 6: *'Easily accessible for left and right-handed.'*

Improvements design proposal

These insights lead to the following desired improvements on the design proposal;

- Leave out the pipet support.
- Switch the workflow steps of 'start measurement' and 'insert sample'.
- Add instruction steps of opening/closing the clamp/lid and an instruction step to take the cartridge out.
- Add use cues for opening the clamp inside the 'arena'.
- Add the following buttons: continue-button in Phase 1, reject/retry-button in Phase 3.
- Specify the wording of the instructions given in the software.
- Add the possibility to go back to earlier phases.
- Reduce the input and repetition in the software.
- Manage expectations that instructions will follow.
- Finding the ON/OFF during first-time use.

8.5 Conclusion

With a SUS score of 85,3/100, the eight user tests conducted show the design proposal to be ‘excellent’. The extended software guides users fluently through the process of conducting a measurement.

Next to that, the use cues of the cartridge and ‘arena’ help users to place the cartridge correctly.

Thereby, half of the users consider the design proposal as trustworthy, as far as users think they can judge on an experience prototype.

Naturally, issues arose as well. Summarizing the main elements; for the workflow, the steps of starting a measurement and inserting the sample should be switched around.

For the physical configuration, it is hard to open the clamp, to find the ON/OFF button and the pipet support can be abandoned as it turned out it is not used.

For the software, the issues can be solved by mentioning explicit steps like opening/closing the clamp/lid, more explicitly facilitating to go back and forth between phases by for instance adding buttons, reducing the input and repetition of information needed, making clear that instructions are incorporated in the software and details like words used in the instructions.

In the next chapter, the improvements are incorporated into a proposed final design.

Final Design 9

9.1 Introduction

Based on the insights of the user tests, the design proposal is iterated towards a final design. As it is the next version of the design proposal, a final design would be ready for the next round of user tests. The final design is presented in this chapter, and includes design specifications like the physical configuration, software, and workflow in the form of a picture scenario.

9.2 Final design

Figure 49 presents the iteration of the design proposal: the final design.

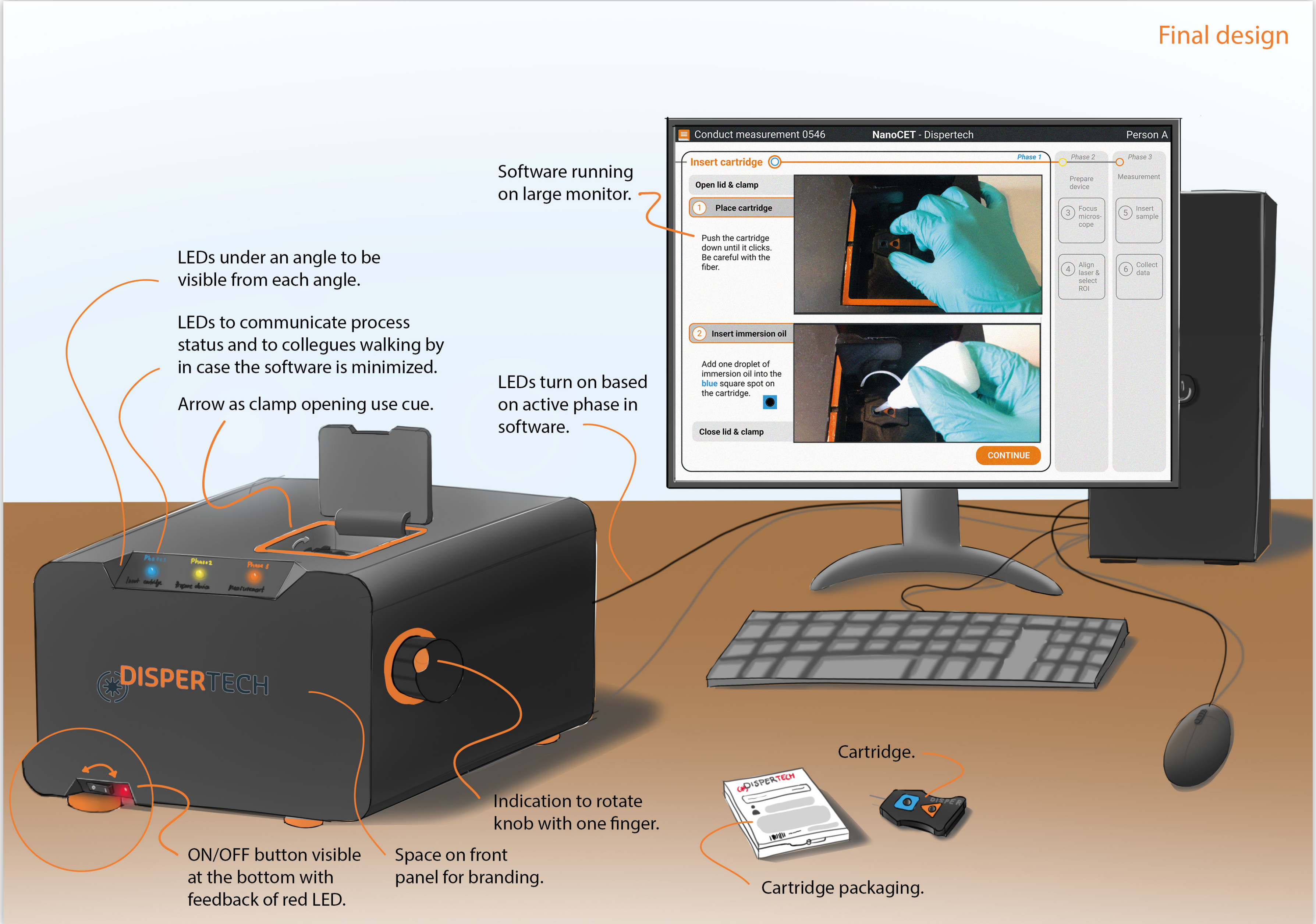


Figure 49. Final design of NanoCET.

The cartridge and cartridge packaging design remained the same as shown in figure 37 in section 7.4. For the 'arena' there are adjustments as shown in figure 50. Figure 51-53 explain the software of the final design.

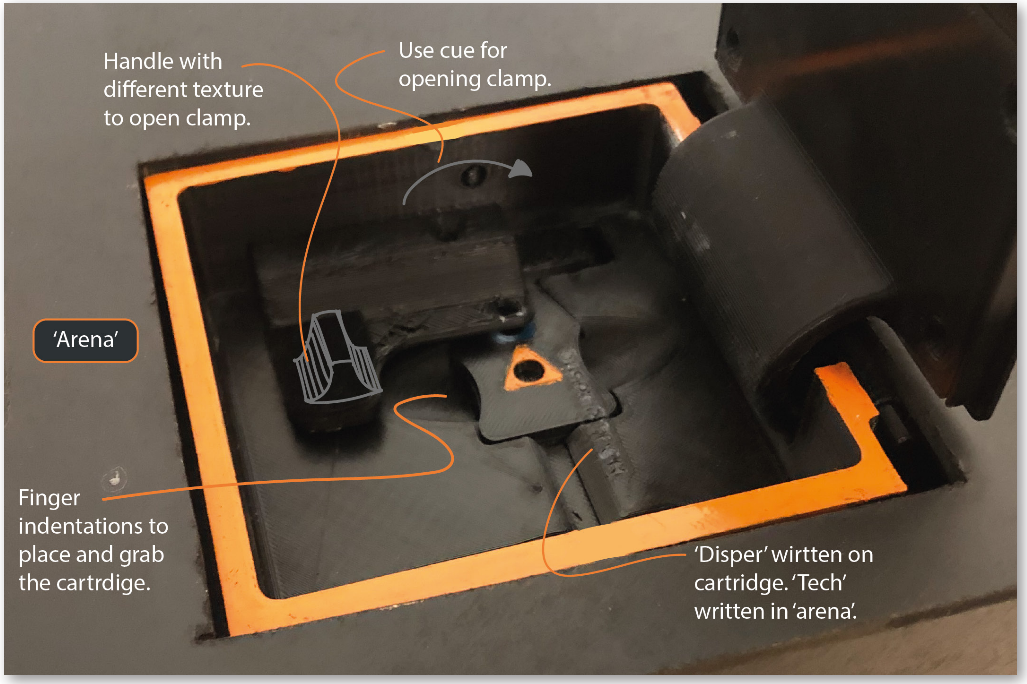


Figure 50. 'Arena' design of final design.

Participant 6: *'No way it'll work it'd be upside down.'*

Participant 4: *'Looking at shapes of container and cartridge helped.'*

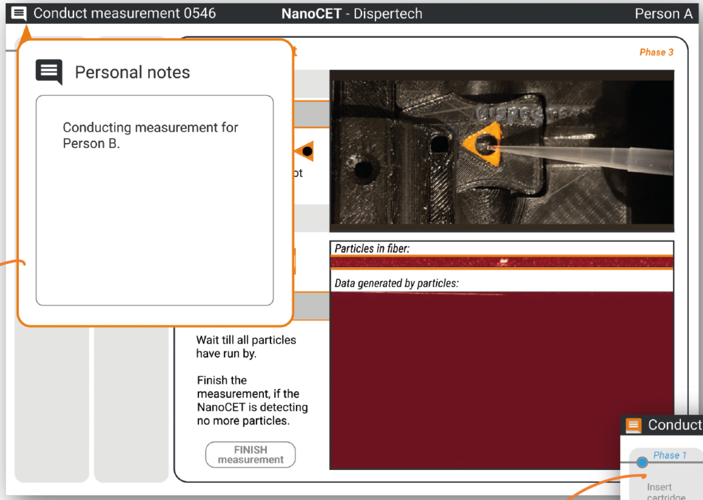
Participant 1: *'Because of the holes here, it's very clear it should be inserted in this orientation. The structure [of the 'arena'] also makes it clear how to position it.'*

Figure 51. Software screens final design.

Three - option menu.

Figure 52. Software screens final design.

Notes.



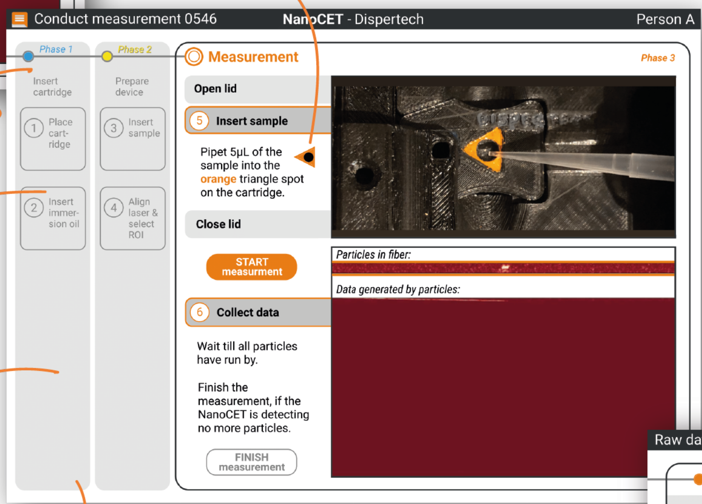
Notes always available to add or look back to.

Specific written instructions, like sample volume.

Clicking here navigates back to the menu.

Clicking here navigates back to user profile selection.

Phase 3: measurement.



Phase colours resemble corresponding LEDs on NanoCET.

Always overview the whole process to collect all necessities at once.

Timeline and steps in blocks resemble lab journal structure and function as progress bar.

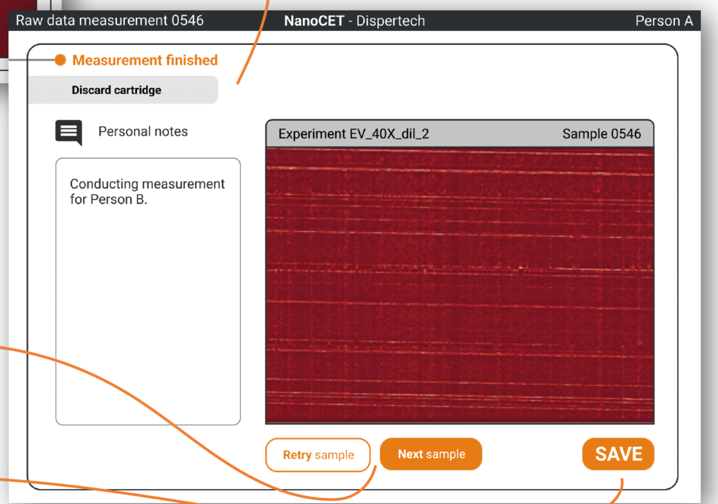
Inactive phases greyed out, but you can navigate back to a previous phase by clicking on it or by using the keyboard arrows.

P5: 'Workflow was really good, mainly because of the software. Clear what steps to take and what's next.'

Instructing to reset the NanoCET after use.

Overview of data collected and opportunity to check file name and location before rounding off the measurement.

Measurement finished.



'Retry sample' gives the opportunity to try different parameters for the same sample.

'Next sample' gives the opportunity to measure the next sample within the same experiment and parameters.

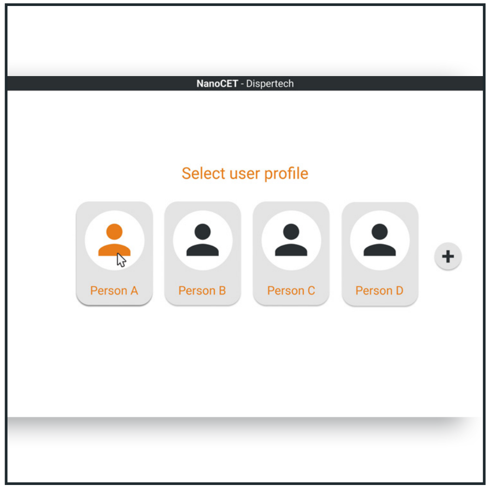
Clicking 'save' navigates back to the menu.

Figure 53. Software screens final design.

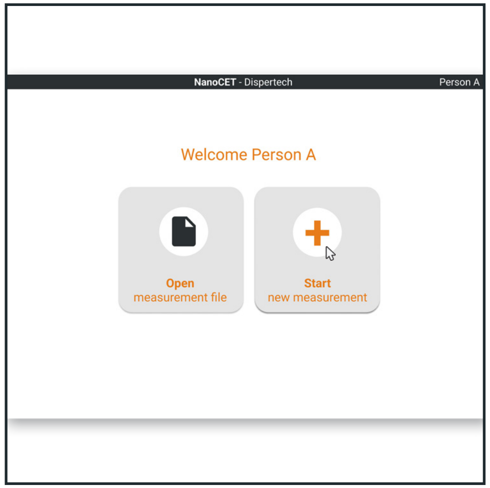
9.3 Usage scenario of the final design

This section shows the workflow of the final design in a scenario. Note that some of the pictures of the physical device may not exactly look like the final design as drawn in figure 49, since the scenario is made with the prototype of the design proposal.

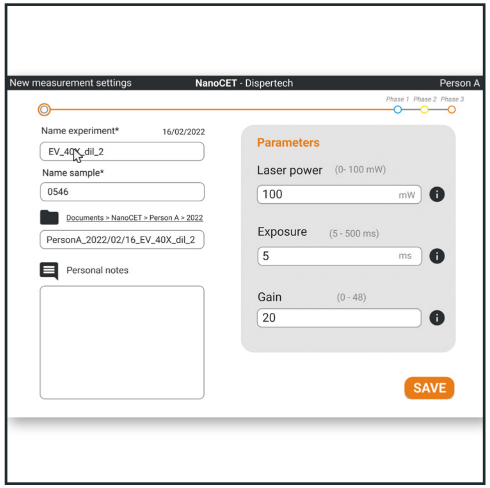
1). Switch on the NanoCET and start the software.



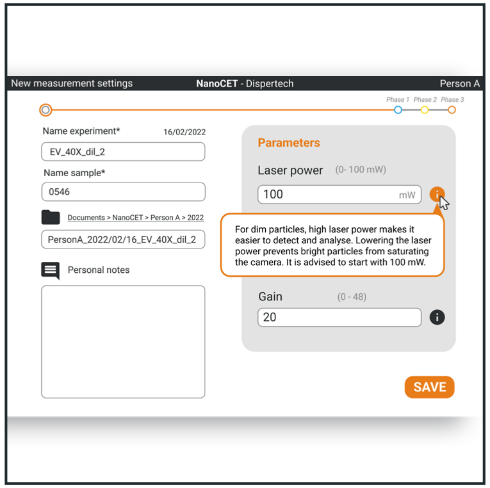
2). Select user profile.



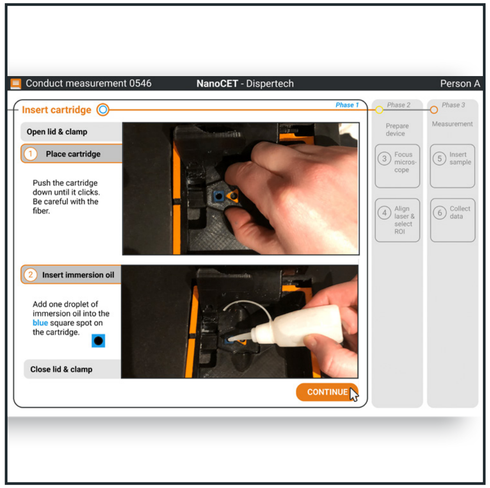
3). Start a new measurement (or open an old one).



4). Insert experiment and sample name. Option to add notes.



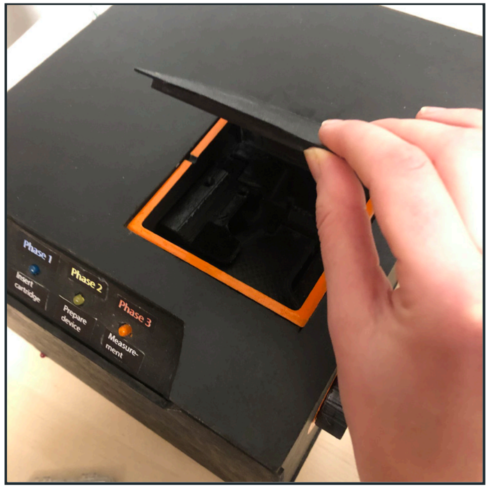
5). Insert parameters.



6). Phase 1: instructions of software.

7). Collect the cartridge, immersion oil and sample from cabinet. (And gloves if needed).

8). Unpack the cartridge.

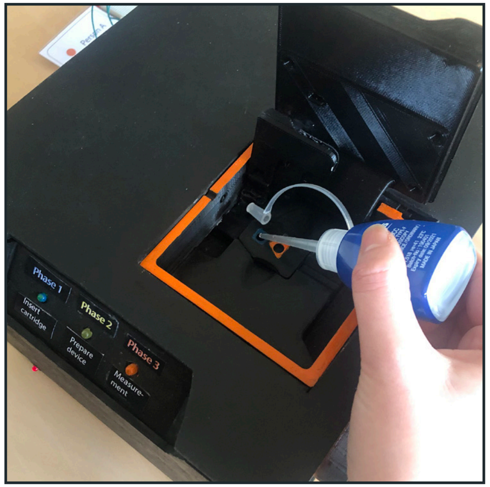


9). Open the lid of the NanoCET.

10). Open the clamp inside the 'arena'.

11). Take the cartridge out of packaging.

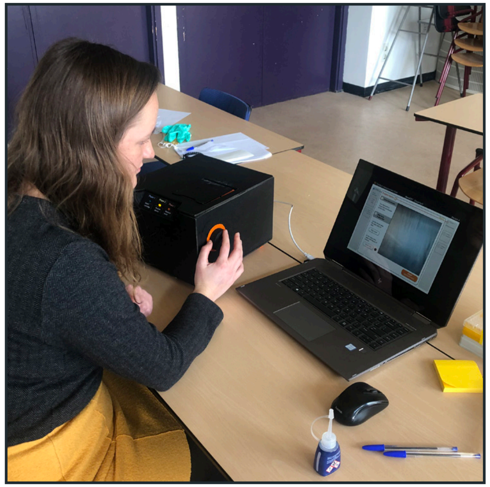
12). Place the cartridge inside the 'arena'.



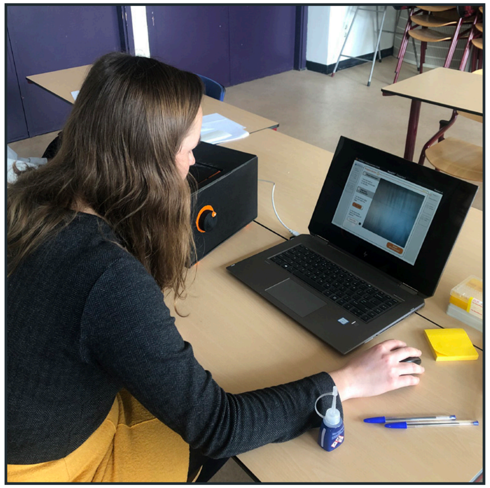
13). Insert the immersion oil on the blue square of the cartridge.

14). Close the clamp inside the 'arena'.

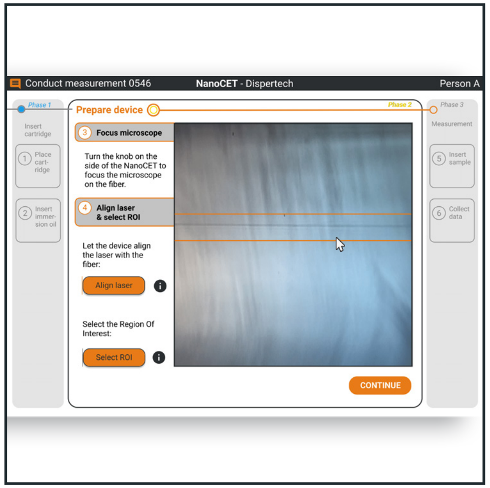
15). Close the lid of the NanoCET.



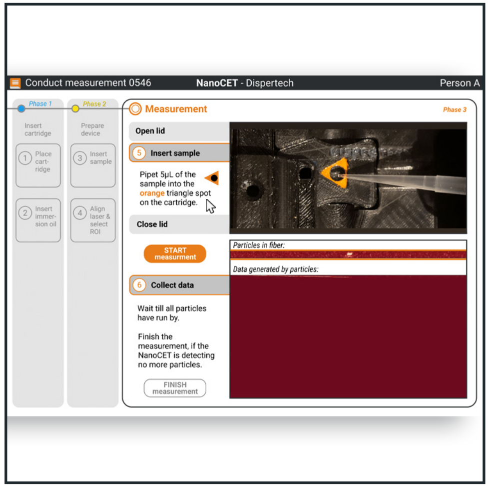
16). Phase 2: focus the microscope by looking at the camera view on the screen and turning the knob.



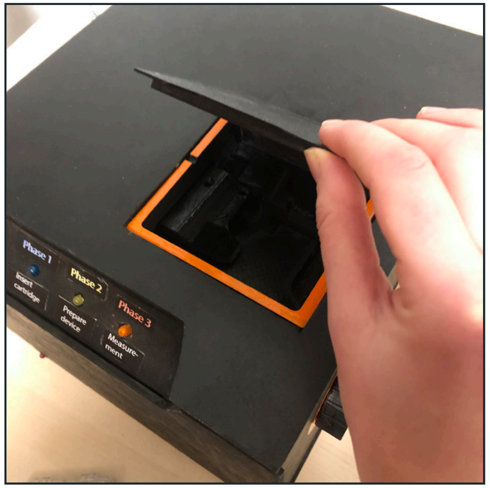
17). Align the laser by clicking a button in the software.



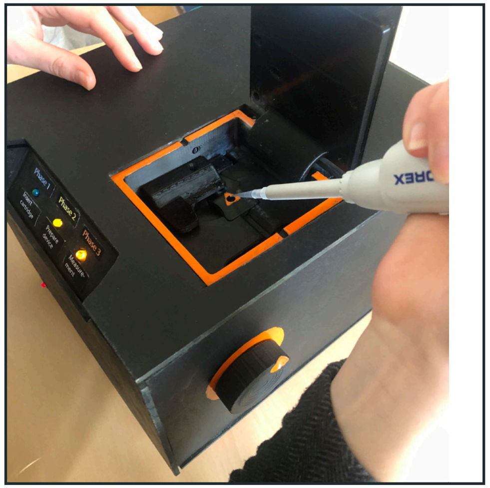
18). Select the Region Of Interest of the camera view of the fiber.



19). Phase 3: instructions of software.

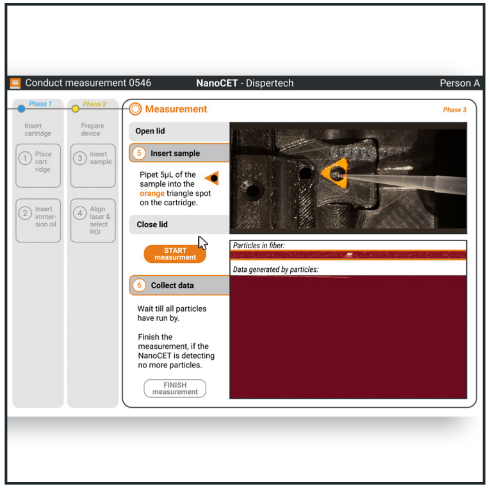


20). Open the lid of the NanoCET.

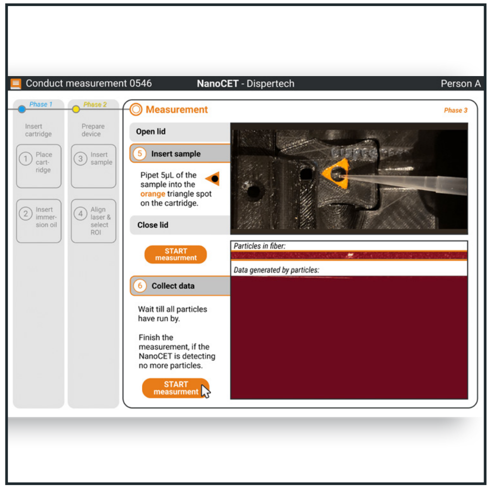


21). Pipet the sample on the orange triangle at the cartridge.

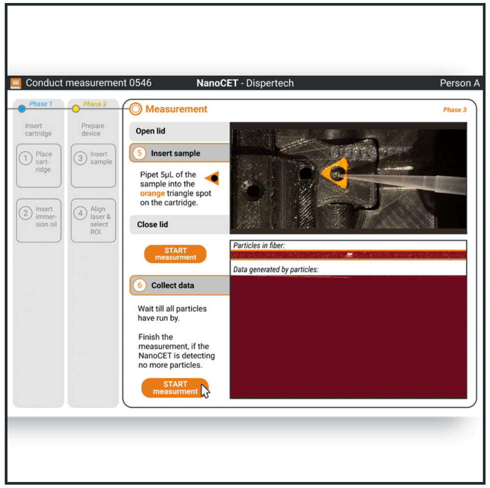
22). Close the lid of the NanoCET.



23). Click the 'start measurement' button.



24). Watch the particles run by and see the data being collected.



25). Click the 'finish measurement button' if no more particles are detected.

26). Discard the cartridge and check the collected results. Press save, next sample or retry sample.

27). Pressing save guides to the menu: start a new measurement, open a file, select another user profile or shut down the software when finished.

9.4 Conclusion

The adjustments made for the final design include more specific use cues in the physical configuration of the NanoCET, like a more visible ON/OFF button and cues for opening the clamp. Furthermore, the pipetting support is left out.

For the software, the user's expectation of the instructions is managed by an extended timeline. More specific textual instructions are added and actions like opening/closing the lid/clamp are made more explicit. Next to that, the instruction images are replaced by GIFs, so the user can mimic the interaction.

A particularly impactful change is made in the workflow: the sample needs to be inserted before the measurement can be started.

As the design process comes to an end, the next chapter concludes the whole process and suggests recommendations for further investigation to improve the final design.

10

Conclusion, Discussion & Recommendations

10.1 Conclusion

To conclude the entire design process of this project, I look back on the design brief. The process started with extensively researching the context, users, competitor devices, and the NanoCET itself, and this offered a broadly researched base with a lot of knowledge to continue on during the ideation phase. Divergent ideas and concept directions could quickly be narrowed down to a concept because of the design criteria and risk analysis. By developing the concept into a design proposal and by building this proposal in the form of an experience prototype, I was able to conduct user tests. As a result of that, the design proposal scores 'excellent' on the System Usability Scale, meaning the design proposal is definitely approved in terms of usability. Furthermore, users experienced the design proposal as easy to use, straightforward, and user-friendly with a good workflow, see quotes mentioned on the right. More specifically, with its guiding software, the final design of the NanoCET has gained an additional feature to stand out in the competitor field. Because of the improvements, it would be no longer necessary to read the manual before and during the workflow. Therefore the guiding software could be added as a unique selling point of the NanoCET. Next to that, half of the user test participants already experience the design proposal as trustworthy whereas an experience prototype cannot deliver actual results. Finally, an iteration step with the design proposal was done by proposing a final design, improving the issues found during the user tests.

In conclusion, the design goal to let lab-based researchers and technicians experience a fluent and efficient workflow and guidance by the NanoCET device and software when researching nanoparticles down to 20 nm, so they will make fewer mistakes and will trust Dispertech and their NanoCET has succeeded. The same goes for the interaction vision that the final design should be like walking with a guide dog; clear, fluent, and guided. However, there are still limitations that will be discussed in the next section, as well as further recommendations and considerations for the final design.

Quotes participants user tests

Participant 5: *'Workflow was really good, mainly because of software. Clear what steps to take and what's next.'*

Participant 3: *'I wasn't stranded, there was always a next step. Very few buttons, so few things that could go wrong.'*

Participant 6: *'Workflow is very easy. It says exactly what you should do.'*

Participant 6: *'I think, if you know how the machine works, anyone can do the measurement.'*

Participant 7: *'Very user-friendly.'*

Participant 8: *'Actually really easy to use. The hard stuff is mainly already done for you.'*

10.2 Discussion

10.2.1 Limitations

For starters, in the research phase, I researched the current NanoCET separately from the context because the NanoCET is not yet in use in hospital or university labs. To create the problem statement, the insights of the field research and the insights on the NanoCET are combined as well as possible. This however means that the implication of users experience difficulties setting up and conducting measurements with the NanoCET as mentioned in the problem statement might differ when the NanoCET is implemented in the real context.

Further, during the user tests, half of the participants mentioned not feeling able to properly rate the trustworthiness of the design proposal. A solution can be to create a technical prototype in combination with an experience prototype. This basically results in a set-up like the current NanoCET, so the (next version of the) NanoCET can be used as a prototype for user testing.
Moreover, trustworthiness as part of the design goal was challenging as it is difficult to assess this summatively, especially with an experience prototype. On the other hand, I do think that taking trustworthiness into account helped with discovering what contributes to trustworthiness in the medical field and how to implement that in the NanoCET.

User tests

The user test evaluation with the design proposal is limited by several factors. Most importantly, the test is conducted with a prototype. Participants did not expect the ON/OFF button to be an actual button, or the LEDs in the prototype to actually work. Using a prototype also means certain features are not included in the prototype, like typing in text boxes, having live camera feedback of the microscopic camera, or seeing actual particles run through the fiber during a user test. But also, not having the possibility to include the consequences when participants forget to turn on the device.

Next to that, the assignment of the user test is a fictional case, so users do not have information about or intrinsic motivation for the sample or the parameters. In this user test set-up, I deliberately choose not to instruct participants beyond the assignment. This way, users are least biased and I can get a fresh response to the design proposal. Besides, when users would have more knowledge beforehand, using the NanoCET would only go better.

Then, there are inconsistencies among the user tests. Not only are the eight user tests conducted on four different locations, but the distance, placement, and route to and from the cabinet were different as well. Likewise, in two user test cases, only one glove was available instead of two. Furthermore, between the third and the fourth user test, the carefully glued fiber on the cartridge prototype broke off, so five user tests had to be conducted with a fiberless cartridge.

10.2.2 Design process

The design process followed was suitable for this project. The double diamond served as a functional underlay, although some phases are more extended than others. Especially methods like the usability inspection to get an overview of the workflow and the streamlined walkthrough to get insight in feedforward and feedback were a good fit for this project. In addition, to combine observing and interviewing during field research, the topics guide technique was a useful approach. Furthermore, both creative sessions supported the ideation phase: it was useful to collaborate with others while brainstorming. Explorative prototyping contributed to create valuable design suggestions with a risk analysis as a clarifying method to pick a concept direction.

The conclusion in section 10.1 proves enough value contribution to continue with the final design. When continuing the design process, the next step would be to conduct user tests with the final design. The final design provides solutions for the issues mentioned during the user tests. However, to find out if the final design solves these issues, a next round of user tests will be required. In those user tests, the focus should be on evaluating the workflow as the sample is inserted before a measurement starts, the use cues in the 'arena', the ON/OFF button during first-time use, and the (textual) adjustments in the software, as these elements are developed since the previous user tests and led to hiccups during those user tests.
In the meantime, small physical configurations on the cartridge, clamp, and 'arena' could be explored using explorative prototypes, as there are multiple configuration options within the same workflow. Moreover, the results in section 8.3 show most hiccups occur with the physical elements, so the physical configuration is a point of attention. This will also be seen and suggested in the next section: recommendations.
Lastly, the third role of 'instructor' mentioned in the personas in figure 19 in section 5.3.5, should be further developed. When this function is rolled out, someone should be trained for the function. Then, when the NanoCET goes to the market, the instructor can offer the desired support.

10.3 Recommendations

To further improve the final design, recommendations are proposed in the following categories:

Workflow

- Further research is desired on the most suitable moment to insert parameters within the workflow. There could be a scenario where the parameters are inserted separately from the experiment/sample information.
- Inspect if there is a possibility to create an option to try out a measurement with something like a dummy sample, to check what parameters make sense in a measurement.

Software

- Currently, the software does not have a maintenance or settings interface that might be necessary/desired.
- Investigate whether a guiding tour in the software for first-time users is needed or would contribute to a better workflow.

Device

- Scrutinize what configuration of the cartridge can protect the fiber.
- Review being able to distinguish used cartridges.
- Investigate whether reusable cartridges are possible and desirable, taking into account that users want to be sure that samples do not get contaminated.
- Research how users interact with the packaging of a cartridge or how secure the cartridge packaging is to protect the fiber. Otherwise, a warning could be added to the packaging or the packaging can communicate that it is vulnerable.
- Find out what communication of the LEDs is desired by users: blinking LEDs, pulsing LEDs, etc.
- Try out different colours of the LEDs and phases to find out what is most sensible to users.
- Investigate what is most effective to place around the LEDs on the device: text, icons, etc. Perhaps the description around the LEDs should just be phase 1, 2, 3 without further instructions to guide users even more to the instructions within the software.

To close off, the following recommendations are to consider:

- Replace the chamfered LED surface with a screen so functions/descriptions of the LEDs can be changed easily. This contributes to the flexibility of the design, and would therefore make it more future-proof.
- Insert immersion oil outside the device, so this step can be executed over multiple cartridges at the same time when the user is measuring multiple samples. Or consider leaving out this step by including the immersion oil to the prefab cartridges.
- Mechanically connect the clamp and the lid, but in such a way that the clamp stays down after the laser is aligned and the lid is opened for the second time.
- Disable moving the knob when the laser is aligned.
- Disable the opening of the lid after pressing 'start measurement'.
- Add a preparation mode/step in the software that provides information on sample preparation/dilution.
- Add the option to insert pictures or drawings in the personal notes section in the software.

Acknowledgement

This project challenged me to put together all my skills and knowledge of the past 6,5 years. While building the experience prototype, I even refreshed skills that I had not been using since my bachelors, like soldering, electronics and working with Arduino. Designing for an actual product was a refreshing experience after so much conceptual design during my time in Delft and Loughborough, and this is something that I'd really like to take with me into my career.

Working for a start-up gave me wonderful insights in the desired flexibility and pace in which things can change. I would like to thank Dispertech and especially Aquiles for the project, the facilities, and the freedom they gave me to make it my own.

From the laboratories I would like to thank all t participants that made time to help me with my research. From Delft University of Technology, I would like to thank Jasper for his inspiration, the weekly meetings with the other graduates and his extensive constructive feedback. Last but not least, I would like to thank Arjen for his technical perspective and support in upgrading my academic writing skills.

My favourite part of the project was creating the experience prototype. It was great to put all the designed elements together and then test it with users. It really taught me how much I can achieve on my own in such a large individual project. Nonetheless, I could not have done this without my friends and family. Therefore I would like to thank Ruben, Helen, Otto, Christel, Janko, Hugo, Daniël, Tessa, Luc, Ilse, Vicky and Cenédra for their help and support throughout these months.

Sources

Adobe. (2020, March 17). The System Usability Scale & How it's Used in UX | Adobe XD. XD Ideas. Retrieved 15 February 2022, from https://xd.adobe.com/ideas/process/user-testing/sus-system-usability-scale-ux/

Alathas, H. (2018, November 19). How to Measure Product Usability with the System Usability Scale (SUS) Score. UX Planet.Org. Retrieved 17 February 2022, from https://uxplanet.org/how-to-measure-product-usability-with-the-system-usability-scale-sus-score-69f3875b858f

Assistant Secretary for Public Affairs. (n.d.). System Usability Scale (SUS). Usability.Gov. Retrieved 26 January 2022, from https://www.usability.gov/how-to-and-tools/methods/system-usability-scale.html

Boess, S. U., & Magnier, L. (2017). FACT 21 tips for IDE design coaches to help students improve form & language, argument, and coherence in their texts. Delft University of Technology.

Daw, R. (2012, April 24). Nanotechnology is ancient history. The Guardian. Retrieved 5 November 2021, from https://www.theguardian.com/nanotechnology-world/nanotechnology-is-ancient-history#top

Doyle, L. M., & Wang, M. Z. (2019, July 15). Overview of extracellular vesicles, their origin, composition, purpose, and methods for exosome isolation and analysis. National Center for Biotechnology Information. Retrieved 10 November 2021, from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6678302/

How to Conduct a Cognitive Walkthrough. (2021, April 2). The Interaction Design Foundation. Retrieved 6 February 2022, from https://www.interaction-design.org/literature/article/how-to-conduct-a-cognitive-walkthrough

Intracto. (2021, June 8). Het Double Diamond-model: een sterke strategische troef. Retrieved 18 January 2022, from https://www.intracto.com/nl-nl/blog/het-double-diamond-model-een-sterke-strategische-troef

ISO. (1999, June). Human-centered design processes for interactive systems. Online Browsing Platform. Retrieved 18 January 2022, from https://www.iso.org/obp/ui/#iso:std:iso:13407:ed-1:v1:en

Laubheimer, P. (2017, August 6). Personas vs. Jobs-to-Be-Done. Nielsen Norman Group. Retrieved 21 December 2021, from https://www.nngroup.com/articles/personas-jobs-be-done/

Merkus, J. (2021, September 27). Wat is een topiclijst voor een interview (met voorbeeld)? Scribbr. Retrieved 3 February 2022, from https://www.scribbr.nl/onderzoeksmethoden/voorbeeld-topiclijst-interview/

Patton, M. Q. (2002). Qualitative interviewing. In Qualitative Evaluation and Research Methods (pp. 312–353). SAGE Publications.

Roozenburg, N., & Eekels, J. (1998). Productontwerpen, structuur en methoden (2nd ed., Vol. 3). Uitgeverij Lemma BV.

Rosencrance, L. (2021, October 12). What is risk analysis? SearchSecurity. Retrieved 13 January 2022, from https://www.techtarget.com/searchsecurity/definition/risk-analysis

van Kuijk, J. I. (2021a, February 8). Product Analysis. Collegerama TU Delft. Retrieved 14 October 2021, from https://collegerama.tudelft.nl/Mediasite/Channel/ide-msc-dfi/watch/632ead119f954e24aab3ee166ee32cb41d

van Kuijk, J. I. (2021b, February 8). Usage evaluation approaches. Collegerama TU Delft. Retrieved 26 October 2021, from https://collegerama.tudelft.nl/Mediasite/Channel/ide-msc-dfi/watch/18c4ad11a5064fdb97333c2c90020f9e1d

van Kuijk, J. I. (2021c, February 8). Use, interaction & context. Collegerama TU Delft. Retrieved 14 October 2021, from https://collegerama.tudelft.nl/Mediasite/Channel/ide-msc-dfi/watch/e43d59c332f5466eb9ea3cd445af0aa31d

van Kuijk, J. I. (2021d, February 8). User needs & goals. Collegerama TU Delft. Retrieved 14 October 2021, from https://collegerama.tudelft.nl/Mediasite/Channel/ide-msc-dfi/watch/e43d59c332f5466eb9ea3cd445af0aa31d van Kuijk, J. I. (2021e, February 9). Usage inspection methods. Collegerama TU Delft. Retrieved 26 October 2021, from https://collegerama.tudelft.nl/Mediasite/Channel/ide-msc-dfi/watch/76421c0967eb4d138e325d179798de7d1d

van Kuijk, J. I. (2021f, February 15). User test plan. Collegerama TU Delft. Retrieved 26 January 2022, from https://collegerama.tudelft.nl/Mediasite/Channel/ide-msc-dfi/watch/b4c13a8672bf461186f10656c24296931d

van Kuijk, J. I. (2021g, February 26). Design direction & criteria. Collegerama TU Delft. Retrieved 23 November 2021, from https://collegerama.tudelft.nl/Mediasite/Channel/ide-msc-dfi/watch/079d5fce2d12475a89f9c98cb10344821d

van Kuijk, J. I. (2021h, February 26). Problem statement. Collegerama TU Delft. Retrieved 23 November 2021, from https://collegerama.tudelft.nl/Mediasite/Channel/ide-msc-dfi/watch/b16ddc3d8f26456490b69563c01da1fd1d

van Kuijk, J. I. (2021i, April 1). UI design variables. Collegerama TU Delft. Retrieved 26 January 2022, from https://collegerama.tudelft.nl/Mediasite/Channel/ide-msc-dfi/watch/b4c13a8672bf461186f10656c24296931d

van Kuijk, J. I. (2021j, April 9). Data Analysis. Collegerama TU Delft. Retrieved 1 November 2021, from https://collegerama.tudelft.nl/Mediasite/Channel/ide-msc-dfi/watch/2dc83e147a2d461487669a45b11af1d51d

van Kuijk, J. I. (2021k, April 9). Experience prototyping. Collegerama TU Delft. Retrieved 26 January 2022, from https://collegerama.tudelft.nl/Mediasite/Channel/ide-msc-dfi/watch/111213c7b44d4de8bf3097a61784db631d

What are nanoparticles? Definition, size, uses and properties. (n.d.). What Are Nanoparticles? Retrieved 23 September 2021, from https://www.twi-global.com/technical-knowledge/faqs/what-are-nanoparticles

Zijlstra, J., Daalhuizen, J., van Boeijen, A. G. C., & Zijlstra, J. J. M. (2020). Delft Design Guide (revised Edition). BISPublishers.

Image sources

The Lycurgus Cup 2016, digital photograph, The History Blog, accessed 9 November 2021, <https://www.amusingplanet.com/2016/12/lycurgus-cup-piece-of-ancient-roman.html>.

Biogenesis of extracellular vesicle (EV) subtypes 2020, figure generated with BioRender, Therapeutic Applications of Extracellular Vesicles, accessed 18 October 2021, <https://www.mdpi.com/2073-4409/9/10/2191/htm>.

List of appendices