

Electrical Engineering Demonstrator

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Abstract

This bachelor thesis presents the research and development of an interactive learning demonstrator for the study of electrical engineering at the University of Twente open days. Initially, research was conducted to identify core principles suitable for an interactive learning tool that would promote engagement, excitement, and accuracy. This involved a literature review and a state-of-the-art analysis. The research indicated that power principles could efficiently be explained using an analogy related to physical human effort, to facilitate engagement. Using this information, a prototype was created to allow users to discover information through interaction and observation, linking physical effort to power generation. Participants could cycle to generate wattage which was then related to common household appliances. Through the utilisation of user tests the prototype was finalised demonstrating its potential to inspire potential first-year electrical engineering students. Nonetheless there are improvements to be made for future iterations.

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1. Introduction

During open days it can be difficult for high school students to make a clear distinction between the different types of Engineering studies at the University of Twente (UT), e.g: Mechanical Engineering (ME), Advanced Technology (AT) and Electrical Engineering (EE). Because other engineering studies have interactive demonstrators available during the open days, these studies are perceived more interesting by a lot of potential first-years, because they allow the students to playfully learn the key principles and highlights of the offered education. EE does have projects which could arguably be a demonstrator but lacks a dedicated interactive installation and this results in a possible skewed image of EE, which is unfortunate since this is a relevant subject to partake in.

The goal of this project is to build an interactive demonstrator for EE to use during open days to excite potential first year students, explain core EE principles and reflect the EE course. This will all be achieved through interactive learning, where through own interactions core EE principles will be explained.

The interactive demonstrator should be easy to transport and store, since it will only be used on occasions during a year. The process of building the demonstrator itself should be well documented, allowing for easy possible repairs when necessary and the entire project should be made with accessibility in mind. Meaning that it will be made with readily available components. In order to best understand what makes a good interactive demonstration, background research will be conducted, to discover what already exists, what works and what does not.

1.1 Research Questions

In order to build an effective interactive demonstrator for Electrical Engineering open days, a set of research questions has been created, with a main research question and 4 sub-research questions.

Main research question:

- What is the most effective use of a demonstrator for Electrical Engineering to display and explain key principles during the open days in an engaging fashion to students?

Sub-research questions

- What are key principles and concepts within Electrical Engineering that are both fundamental and tangible to high school students?
- How can an interactive demonstrator provide more excitement regarding Electrical Engineering?
- What is an effective method to measure the impact of an interactive demonstrator on a student's understanding of Electrical Engineering?
- What successful aspects can be identified in interactive demonstrators across different fields or contexts
- What are simpler, more accessible ways of conveying information during open days?

Combining the answers of all these questions should allow for a clear strategy to build an interactive demonstrator for Electrical Engineering.

1.2 Outline

The following steps will be followed to answer the research questions and design an end product.

- Chapter 2: Background research
This chapter has a description of the performed background research including a reflection on the relevance findings
- Chapter 3: Method and technique
This chapter will include a description and argumentation of the method and techniques.
- Chapter 4: Ideation
This chapter includes a stakeholder identification & analysis, preliminary requirements, description of developed concepts, and argumentation of the preferred concept. With all these discussed, a final concept will be chosen
- Chapter 5: Specification
This chapter will specify the scope and requirements of the project. With these final requirements a concept will be generated which will be created during the thesis.
- Chapter 6: Realisation
This chapter will describe the implementation of the design. This includes the hardware, software and documentation
- Chapter 7: User evaluation
This chapter contains the performed user evaluation, outcome and consequences of the feedback.
- Chapter 8: Discussion and conclusion.
This chapter is an overview of the performed research and the relevance of the work is outlined.
- Chapter 9: Future work
This chapter will reflect on the performed work and list recommendations for possible future research

2. Background Research

In this chapter background research of interactive demonstrators will be discussed, first a literature research will be conducted to discover what knowledge is available and how this might relate to this project. Second the current field will be explored through state of the art research, discovering where modern interactive demonstrators are used and what is successful.

2.1 literature research

In order to find the best possible approach on how to build a demonstrator for the open days, literature research has been conducted using the research questions. This gives insight as to what has worked in other fields, and how that could be applied in this project.

Visualising concepts in electrical engineering

The demonstrator will be used during the open days of the University of Twente with the goal being exciting potential first year students, therefore the concepts presented must be within their grasp, while still facilitating a fun interaction. This means that the subject can not be too advanced or the installation risks being ineffective, because the subject is too difficult. Research must be conducted to discover what principles are tangible and interesting to students. Sani[1] reflects on a one week summer academy course teaching electrical engineering. In this paper it is found that although not applicable to everyone, the hands-on courses were a great success with a lot of students enjoying the course. It was also found that students best enjoy activities with moving parts and loud noises. Taber *et al*[2], take a more theoretical approach for explaining concepts of electricity, but does state that the use of analogies is greatly effective for younger students to learn about key concepts and principles of electrical engineering, by relating it to something that is already known to them. The best way to achieve this according to Taber[2] is oversimplification, there is no need to go in depth and explain concepts perfectly 1:1. This will only make subjects more vague and less tangible, which is the opposite of the goal. Hussain *et al* [3] discovers the use of simulations as a way to visualise difficult or intangible concepts and concludes that the use of simulations as visualisation can be very effective in learning basic electronic circuits. This also links to Sani[1] and Taber *et al*[2] who also maintain that by having a relatable and tangible experience, concepts that first seemed abstract are now visualised and therefore easier to grasp. This is relevant to this research because by understanding that concepts do not necessarily have to be simple, if they can be visualised, interacted and played with. This could open up more possibilities for the demonstrator.

Successful aspects

With interactive demonstrators being used in a lot of fields to easily educate people, there are different successful aspects which can be identified. Not all aspects are relevant to Electrical Engineering but by identifying what works and what does not can be learned how to best use these practices for the EE demonstrator. It is difficult to find studies related to EE specifically, but demonstrators for educational purposes are common. Therefore it is possible to relate the findings from education to EE.

With the demonstrator, it is important that people can freely interact with it without needing any background knowledge. Pallud[4] maintains the best learning experience is achieved when a demonstrator in a museum is intuitive. Meaning that the installation should be self explanatory. When people interact, they should discover the explanation by interaction, this leads to increased cognitive engagement which helps with learning and remembering what the demonstrator was about[4]. Ibrahim[5] has found that participation is key to remembering, or knowledge retention, which is desirable in the case of this project. Discovering information through interaction is also suggested by Hung *et al*[6], after comparing static vs dynamic installation it was discovered that dynamic installation were perceived as better, since the information display would be adaptable and therefore more in the interest of the user[6]. When using dynamic installations engagement automatically goes up, because people have to actively participate in order to interact with the installation, which is not possible with static installations. If this interaction and participation is achieved in an intuitive manner, cognitive engagement could also be boosted. DiPaola[7] adds that with interactive installations, the setting should be informal. By using informal learning settings, the responsibility of paying attention lies with the user and it is up to them if they are interested. This could boost engagement and participation because people will only interact if they feel interested in the installation.

Generating excitement in education

Exploring how to translate successful aspects of interactive learning into an engaging demonstrator for electrical engineering presents a unique challenge, particularly because direct similarities in the field are sparse. The challenge being that there are limited articles specific to electrical engineering, but other fields can be analysed to extrapolate how interactive installations facilitate excitement. It is important that the installation will be fun and exciting to use during the open days because that will be positive for EE. Abykanova *et al*[8] finds that a friendly and supporting environment is important, because this will improve motivation amongst students, even if they are ill-prepared. Mladenov *et al*[9] suggests after researching demonstration as a way to boost engagement that the best way of use is as a break during difficult and potentially boring topics. short (<15 min) in class activities helps with keeping the attention and interest of the students[9]. This could relate to Abykanova *et al*[8], who also states that by keeping the workload light and by working in groups everybody feels comfortable working with the subject, even if they are not confident individually. This can be useful for the demonstrator for EE because some people might feel intimidated by the subject. It is therefore important that to keep excitement high during the open days, the interaction needs to be short, keep attention, and the topics presented need to be realistic and accessible, as to keep motivation of everybody willing to participate high.

Measuring impact

To effectively gauge the success and reception of the demonstrator, an appropriate method to measure its impact with its target audience is important. In order to do this effectively a correct method of measuring the impact of interactive demonstrators is crucial. There are different ways of collecting data with interactive installations. Three different methods can be defined in acquiring

the data: Surveys, test score and monitoring. Ibrahim[5] emphasises on monitoring students during their interaction because this gives the most accurate insight. Pallud[4], Hung *et al*[6] and van Dijk *et al*[10] argue for the use of questionnaires as means to measure performance of an installation. This results in feedback that is of interest and it is a time efficient method of gathering data. Mladenov *et al*[9] stipulates the use of a test as a way to determine effectiveness of an installation, this is however not applicable in the case of a demonstrator during the open days. During the open days real time monitoring could be used since the faculty of EE will be present at the demonstrator regardless. Also they can provide further excitement or information regarding electrical engineering.

Conclusion

After carefully examining all papers it can be concluded that the most effective way of demonstrating key principles in an interactive fashion will be by restricting the complexity of the installation to something tangible that people can relate to. This should be achieved in an informal setting with presentation of information being achieved through user interaction, with the individual interaction being short as a way to keep engagement and participation high. This will also benefit the motivation to interact with the installation.

2.2 State of the art

When researching interactive learning demonstrators, it can quickly be concluded that there are two fields that use interactive learning the most; musea and education. Through a state of the art research successful aspects can be identified and preliminary suggestions could be achieved for the electrical engineering demonstrator.

2.2.1 Interactive demonstrators in museums

To better grab and keep the attention of visitors, museums make great use of demonstrations or demonstrators to explain otherwise boring or difficult topics. Musea that relate most to a demonstrator used for open days would be technical museums, since these have the same goal of explaining core principles in an interesting and tangible fashion. Two technical museums have been visited as orientation for this project.

Visits to RedDot and Technik museum

To get the best understanding of interacting with installation, the Reddot museum in Essen and the Technik museum in Berlin were visited. The Reddot design museum displayed all products that have received a “Reddot design award”(this is a design award given to everyday devices for exceptional design) and visitors are allowed to touch and interact with all of them(see figure 1). This is fun and allows for a great user interaction and experience, but the museum explains nothing in terms of manufacturing, only design. The “technik museum” in Berlin is better in this regard, this museum is massive in size and features everything from aviation to chemistry. The museum featured many interactive installations, explaining everything from different manufacturing options to the complexity of the internet and how it works. What best can be learned from this museum is

the choices available to the visitors, nothing is mandatory, everything is optional and information in the demonstrators is presented by interacting. This is good because this results in people interacting to discover what they are interested in. Every installation also had signs explaining more in-depth information, for people who were not interested in interaction or did not want to wait for the demonstrator. Both these aspects were useful to see and can be useful to the installation for the open days.



Figure 1: Different feel of buttons at RedDot

2.2.3 Interactive demonstrators in electrical engineering education

Interactive demonstrators are used in the educational field for many reasons, with the main one being the exploration of important or difficult subjects in a playful manner. A good way to achieve this in the context of electrical engineering is the use of analogies. The concept of electricity is rather intangible, but the use of analogies in a different domain could serve to help explain. A study from 1993 regarding analogies for scientific concepts suggested that analogies worked especially well as an introductory way of getting started with a subject or concept [14]. This is very applicable in this case. An often used analogy for electricity is using the hydraulic equivalent.

Electricity is like a water hose

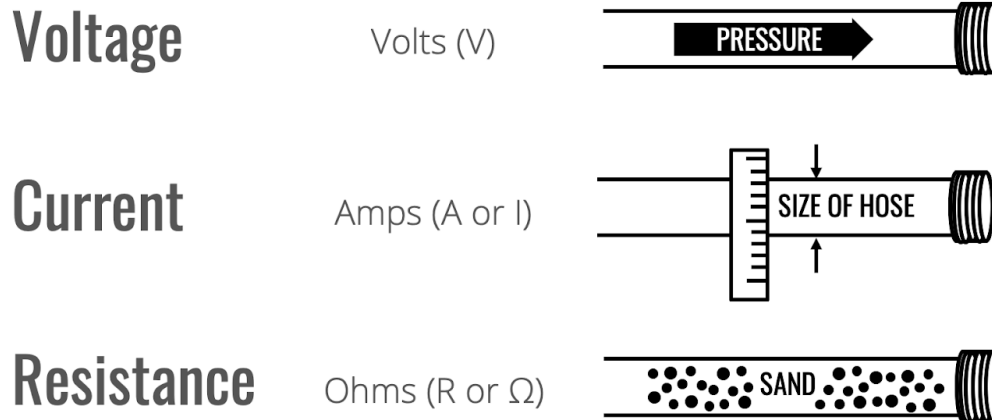


Figure 2: Using water as an analogy for electricity [11]

As seen in the image it is possible to quickly explain core principles of electricity by using water. It is certainly not perfect and has some shortcomings, for example Alternating Current (AC) or Direct Current (DC) is impossible to explain this way, and principles like common flow or common effort with series and parallel connections do not work in the water domain because of gravity and backpressure in pipes, the same is true for resistance, pipe diameter in load since in the water domain these parameters are affected by much more. But nevertheless it offers a great way to demonstrate and allows for playful interaction which is useful.

A different popular example that came to light was the “afm cantilever”, this device is quite complicated but the core is easy to explain and it is a great example for what electrical engineering is all about.

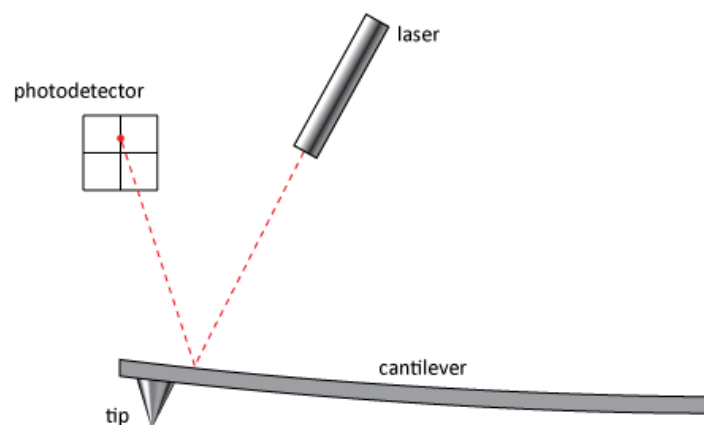


Figure 3: Sketch of the afm cantilever [12]

The cantilever works by moving an incredibly small tip on a spring across a surface, on an almost molecular level it traces the shape of this surface. By reflecting a laser to a photodetector it is

possible to easily and accurately measure the vertical movement, resulting in an incredibly precise map of the surface [13].

Applications or physical installations

A difference between digital applications and physical installations can also be identified both in museums or educational fields. The main benefit of digital applications is the accessibility. Almost anybody can participate with smartphone apps, or simply just watching a video. These digital ways of converging information also works for the open days, where a video could be displayed showcasing electrical engineering as a subject or an app could be created with information. Physical installations on the other hand, offer more interaction and can be more memorable by gamifying a subject. Therefore although digital applications are easier to create and distribute, a physical approach will be preferred for this project since it will be easier to create excitement and engagement for electrical engineering.

2.2.3 Construction possibilities

With the idea of a physical installation in mind, where users can freely interact with the demonstrator, an idea of the construction requirements can be created. Some constraints that are fixed are the dimensions, here the main limit is the size. It should be easily store-able within an office, so it can not take up too much space when stored. Also the installation should strive to use off the shelf components, allowing for easy repair if necessary. This means that if 3d printing is used, the documentation should be comprehensive and include the files. The same applies to the microcontroller that will power the installation and what code this runs. There is a lot of freedom in the project but everything should be well documented.

2.3 Reflection and conclusion

Combining the findings of the literature research and the state of the art observations, the EE demonstrator for the open days should embody simplicity, interactivity and tangibility. This can best be achieved by employing intuitive analogies fostered by engagement and centred around core principles of the subject. From the museum visits can be concluded that the best way to present information in an engaging way is to discover it through interaction since this facilitates the highest engagement. It is also possible for the interaction to be optional and that the installation is clear simply by observing. The discovery from the state of the art research is that the use of analogies or tangible relations are an accessible and interesting way to explain core principles.

3. Method and Techniques

The method that is chosen for this project is the design process for creative technology by A. Mader and W. Eggink [15]. This method splits the design process into four parts: Ideation, specification, realisation and evaluation. All phases are related to each other via a flow graph. This allows for reviewing and possible reverting to an earlier phase, which is of use for this project since changes can be made at any time based on feedback provided by the stakeholder connected with the installation.

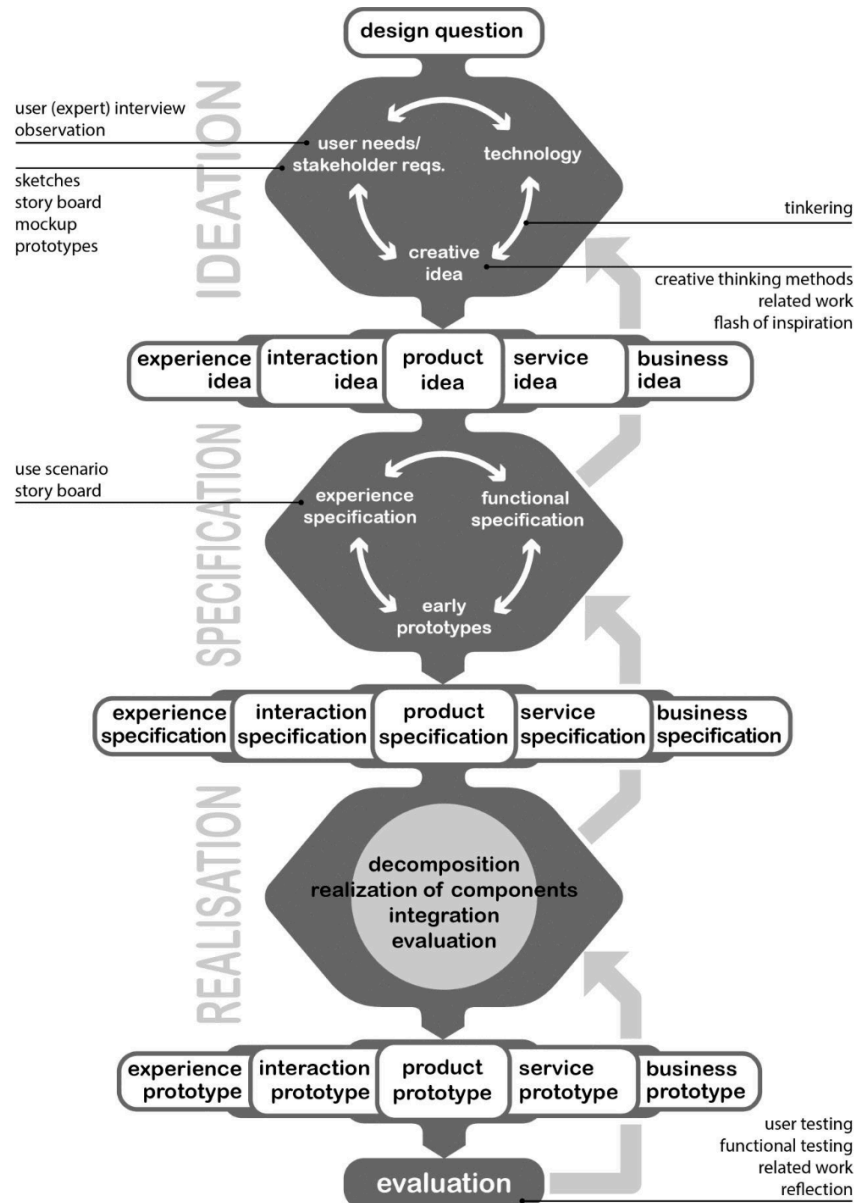


Figure 4: The Creative Technology design process [15]

3.1 Ideation

The first step in the creative technology design cycle is ideation, the goal of this phase is to generate multiple different ideas or concepts. This begins with an analysis of the field and creating an understanding of the field that is being worked in. This can be done by conducting literature research trying to get preliminary answers to the research questions. This will create an understanding of the field of interactive demonstrations and possible successful applications and aspects. Literature will also be used throughout this project when necessary. The next step in the ideation phase is stakeholder analysis and possible stakeholder interviews. The stakeholders that are relevant for this project are: potential first year students attending the open days, professor / lecturers of electrical engineering and the electrical engineering module coordinators. By interviewing these stakeholders a good understanding of the requirements, desires and ideas for the demonstrators will be achieved. By obtaining an understanding of the field and interviewing stakeholders, eventually a creative idea can be generated. It will then be possible to reflect back and see how this idea would interact with the field and stakeholders.

3.2 Specification

The second step is the specification phase. This phase is all about prototyping and scope definition. With the information gathered in the ideation phase it is possible to use a number of prototypes to explore the design space, where each time a short evaluation and feedback loop is applied. The functionality changes the user experience and the demands of the user experience may change with the functionality. These causalities are evaluated with the prototypes with the user, or designer self. Prototypes are subsequently discarded, improved or (partially) merged into new prototypes [15]. This will result in an accurate product description with a good understanding of what is desired and possible for the final prototype.

3.3 Realisation

The third step is the realisation phase. With the product specification it is possible to start working towards the final prototype. Decomposition can be used here, where all components necessary for the final prototype are analysed individually, like communication, microcontroller, sensors, actuators et cetera. Realising the components by ordering or buying what is necessary is also part of this phase. When the prototype is complete or near completion, functional testing is also possible in this phase.

3.4 Evaluation

The final step is the evaluation phase. In this phase there will be evaluated if all the original requirements set in the ideation phase are met. This can best be done by user testing [15] with the target stakeholders. In the case of this project, testing with potential first year students would be preferred since these are the target for which a demonstrator will be built. All reflections obtained here will contribute to a potential upgrade or second version.

4. Ideation

This chapter will start shaping the possible solutions for the interactive demonstrator for electrical engineering. First all possible stakeholders will be described and analysed in order to understand what problems and interests are present with each group. Second, the constraints are constructed to confirm the scope and limitations of the project. With these parameters set it is possible to start ideating designs.

4.1 Stakeholder Analysis

This project knows multiple stakeholders, in this paragraph each stakeholder will be analysed. The stakeholders are: Potential first year students attending the open days, the faculty of EE, open days staff and visitors. The analysis includes Potential problems, interest and desires per stakeholder.

Potential first year students

The key stakeholders of this project are the potential first year students attending the open days. It is the goal of this project to inform and excite them about the subject of electrical engineering in a truthful yet interesting manner. The challenge of this stakeholder is fair representation of the subject of EE. If the installation is as exciting and interesting as possible, it should still reflect EE in a realistic way, and inform them transparently. The demonstrator should also achieve this while displaying concepts tangible to potential first year students. The interests of this stakeholder are to be informed, and to be excited.

Faculty of electrical engineering

The stakeholders of the faculty of electrical engineering consist of people closely related to the subject, these are professors, module coordinators and students. It is in their interest to gain new first year students for next year, because this will generate more revenue for the faculty of EE. A high rate of student interaction is therefore desired by this stakeholder. The interest of this stakeholder is also in truthful representation, because if new students sign up having different expectations, it is possible that they quit, which benefits no-one. When the installation is not used it is stored somewhere at the faculty of EE. It is therefore in the interest of this stakeholder that the installation is robust, portable and storable.

Open days staff

The staff of the open days are also an important stakeholder, this mainly refers to the working students responsible for offering additional information regarding EE. The role of the working students is also to offer additional explanation with the demonstrator, therefore it is in their interest that the installation is tangible for somebody who studies EE. A second role of this stakeholder is maintenance, if something were to happen to the installation this stakeholder should be capable of resetting the demonstrator. Because of this reason it is also important that the demonstrator is easy to work with / self explanatory.

Visitors

The final stakeholder are the general visitors simply attending the open days. These are regular visitors or parents accompanying their child. Although the project is not aimed at this group, the demonstrator should still offer some clarity or new information to this group.

4.2 Constraints

Before concept generalisation can begin, it is important to understand the scope and constraints of the project. There is a lot of freedom and flexibility with this project, as long as the end product is informative and engaging. The only constraint that is defining is size. The demonstrator will only be used a couple of times per year, and therefore spend most of its time in storage, possibly inside an office. This means that the demonstrator must be compact and easy to transport. Compactness could mean that the installation will be foldable, however this usually adds fragility and then the ease of transport suffers. Dividing the installation in multiple easy to transport modules could possibly work better.

A second point is the use of components, which are in the interest of the faculty of EE. For this stakeholder it is important that the installation will be relatively easy to repair when necessary. This means that common components must be used, such as accessible micro controllers like Arduino or ESP32 and off the shelf components, readily available at the University.

Apart from these two constraints the design and interaction of the installation is completely free. This leads us to concept generation.

4.3 Concept generation

To generate ideas, a mind map was used to note all the knowledge collected so far, providing an overview of what might work and what might not. The main sections of the mind map are: Research, Problem Analysis, and Excitement. This method allowed for a quick and informal way to link the core problem to potential solutions and to relate these solutions to the research findings. In the mindmap(see figure 5), background research findings were noted in the top left, to set some parameters for the ideation. This could in term relate to possible ideas using analogies, differentiating between mechanical, hydraulic or electrical installations. The problem was analysed in the bottom left, here the challenges and constraints were noted, to make the parameters more concrete. How these problems relate to solutions was achieved by drawing long lines, referring back to other points or ideas. This is linked to the heading “cool / exciting”. Here was discovered what is interesting, relevant or fun about electrical engineering and how this could possibly result in a demonstration.

By brainstorming small ideas in this manner, new areas and activities of potential interest could be quickly identified. Although, the findings from this mind map were too broad. Nevertheless, it helped pinpoint what would be both interesting and exciting: the installation needed to be physical, incorporate dynamic user interaction, and display an electrical analogy.

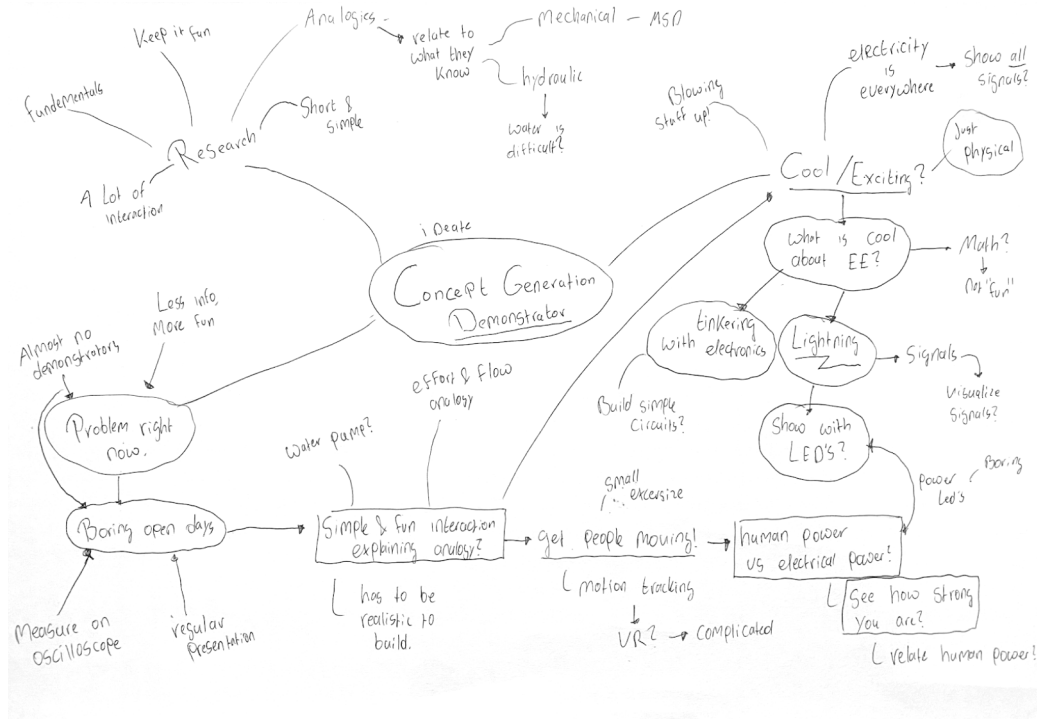


Figure 5: Mind Map relating research, problem analysis and excitement

With the three parameters set it is possible to take the global ideas and areas and work towards something more elaborate and tangible(see figure 6). Using the three previously discovered pillars: physical, interaction and analogy.

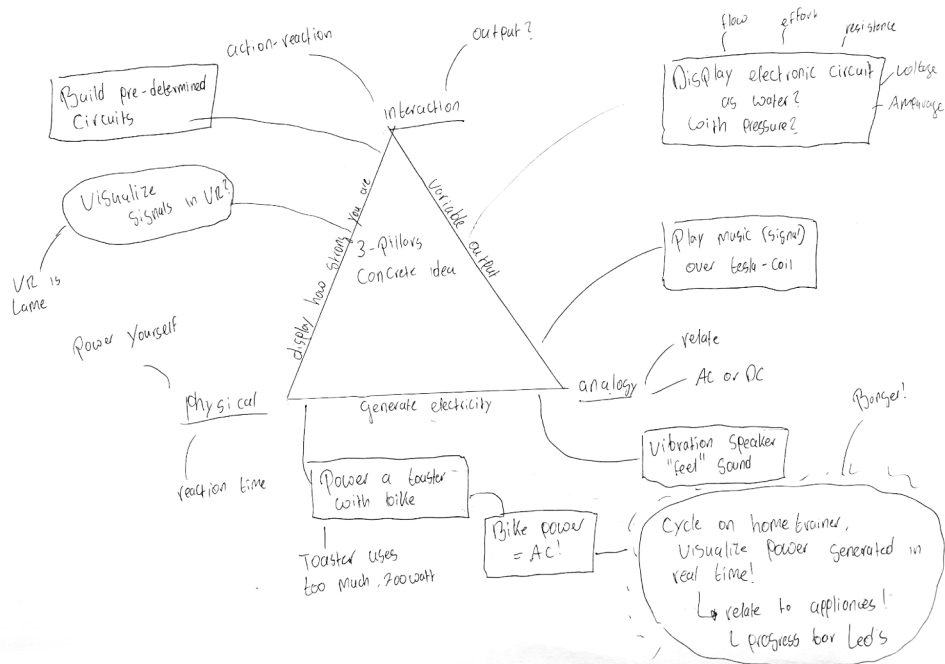


Figure 6: Triangle ideation

Through ideating with this technique multiple ideas are quickly created which can then be judged on their relevance to the project. Figure 6 has multiple ideas, however not all of them consist of the right criteria or were deemed not exciting enough. Eventually a preliminary idea was constructed which consisted of all three criteria. This idea can be taken as a base and worked out.

4.3.1 Preliminary idea

The preliminary idea is that the installation will visualise power generation / consumption through a score board. This scoreboard will be interactive and output a different score based on user performance. This performance is cycling power. People interact with the installation by cycling and their watts generated (revolutions per minute / intensity) will be displayed via a LED progress bar. This bar will be rated from 0 watts (no input) to 500 watt (a strong challenge). The harder that is being cycled, the more LEDs will light up. Along the LED bar will also be checkpoints, in the form points of recognition. These will be devices that anybody recognises and this will offer an analogy and insight into how much power is required for everyday devices. The range could be:

Wattage	Device
1 watt	Phone camera flash
5-10 watts	phone charger
20 watts	Wi-Fi Router
50-100 watts	Laptop
100-150 watts	Flatscreen TV
200-400 watts	Refrigerator
500+ watts	Small toaster

Table 1: Power usage household appliances [16]

By relating something often overlooked and intangible like power to human exercise, it can be visualised and felt how much strength is needed to power everything around us. This shows the importance of electricity and the sheer power and convenience that it brings, because powering everything by hand would be impossible.

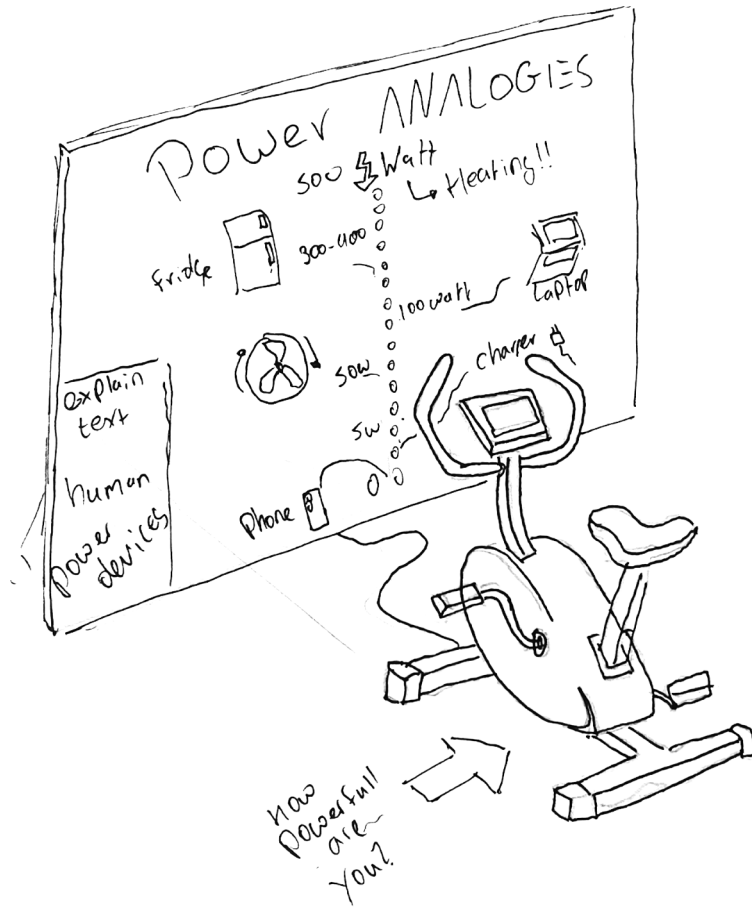


Figure 7: Sketch of preliminary idea ; a hometrainer relating physical effort to power generation.

The sketch (figure 7) shows a possible design of the idea. It serves more as an explanation to the idea than the actual design since this would be too large. This design will be elaborated further.

5. Specification

5.1 Final requirements

For the final installation some requirements need to be constructed to indicate the scope of this project.

- Easy to build and maintain
- Foldable design for storage
- Fun and memorable interaction
- Short interaction
- Clear documentation including software

The Demonstrator will mostly be used during the open days and spend a large portion of the year in storage. The installation will be set up and operated by faculty members of electrical engineering including students, repairs will also be conducted by them. It is therefore important that readily available components are used. The interaction for the visitors must be fun and short, allowing most people participation. The construction must be well documented which will allow for easy repairs in the future. This also includes the software.

5.2 Final concept

After ideation and discussion with key stakeholders from the faculty of EE, a final design concept was selected. The concept is similar to the ideation sketch (figure 7), meaning that the user will cycle on either a bicycle or a hometrainer and the power generated will be displayed on the live display board, indicating what household appliances could be powered with this energy. These will be the main 2 components of the installation.

5.2.1 Hardware

Display Board

The display board will be the main piece that visitors will look at. It will be made by laser cutting wood, this results in a very clean look and also displays the use of laser cutting technology to the visitors of the open days showing that advanced technology like this is accessible at the University of Twente. The board will be large to allow for bigger fonts which increases readability from a distance since it can be busy during open days.

The scale from electronic devices that are presented on the board will range from 0 watt to 500 watt. This range was selected because it is realistic for most people to cycle with 500 watt of power, but keeping this up for longer durations is difficult. The goal is to help people understand the intensity of power consumption of common devices around them. The devices chosen for display are a phone charger, Wi-Fi router, laptop, LCD television, refrigerator, and toaster. These were selected because most people have interacted with them, yet are often unaware of their respective power consumption.

Microcontroller

The microcontroller that will be used will be on the arduino platform[17]. Arduino was selected because of the many free online libraries available which can be particularly useful with the LCD display and neopixel LEDs. Arduino has been used multiple times throughout the creative technology bachelor and therefore some additional experience is also present. This can be helpful with troubleshooting.

The arduino will act as the brains of the installation, running the code and offering the platform for all other electronics to connect to. The built in power rails are a useful addition to quickly powering small electronics. An external power supply is therefore not necessary which will reduce the weight of the installation.

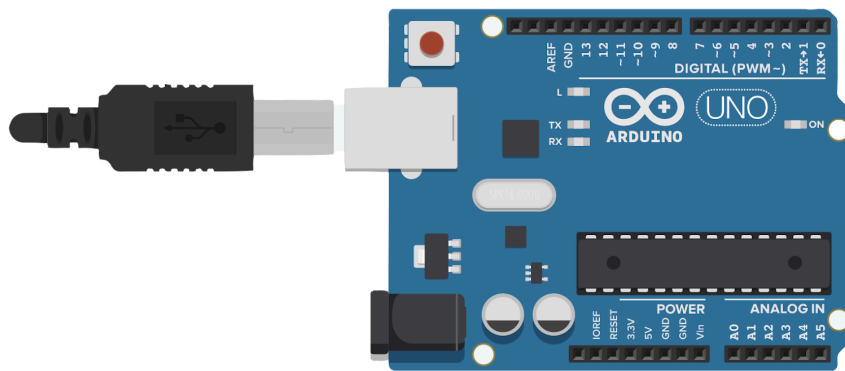


Figure 9: Arduino Uno [20]

Electronics

For the specification of the electronics some constraints can be identified. The LEDs will be neopixel w28 series with a density of 30 LEDs / metre. This density was selected because this allows for the diffusion of the brightness by shining through sanded acrylic which results in a soft glow. W28 type LED's are selected because they can easily be individually addressed through the use of the 'FastLed' library[18]. The LCD display facilitates a live power generated number which reflects a more accurate view of the live power generated by the user. LCD displays can be integrated in arduino using the 'LiquidCrystal' library[19] which allows for direct text output to the display without the need of defining all pixels individually. The electronics in the hometrainer will be the generator present. This generator provides a load / speed measurement. This measurement is then sent to the built-in computer on the trainer. This signal can be read by using an oscilloscope to identify the right signal, which can then be routed to the arduino and processed.

The readability and use of this signal is critical to the function of the installation, therefore a backup plan is also in place. This plan relies on the use of hall effect (magnetic) sensors to manually calculate the velocity of the bicycle and determine a wattage based on this. This is less accurate and unsophisticated solution but serves as a backup in case of unreadable signals on the hometrainer.

Bicycle

The final physical aspect of the installation is the bicycle itself. This is the platform which the users will interact by trying to bike as hard as they can in order to generate as much power, represented as watts. The bicycle will be a hometrainer since hometrainers are robust, relatively portable and affordable.

In case of the hometrainer malfunctioning or breaking, a backup rolling road is present. This will make the installation less complete since there is no longer an electronic hometrainer, but by using hall effect sensors a velocity readout should still be possible. Resulting in a functional installation.

5.2.2 Software

The software or code on the installation will be C++, and uploaded to the microcontroller via the arduinoIDE export. The software will be well documented in case it should ever be re-uploaded on the arduino. The Fastled and LiquidCrystal libraries will also be exported using the arduinoIDE, which offers integrated library support.

5.2.3 Documentation

In order to make the entire installation as future proof as possible, a google drive repository will be created. This hub will contain all necessary documentation necessary to build a copy of the demonstrator, or can be used as a guidebook when repairs need to be made.

The repository will have a build log with pictures of the building process, list of the parts necessary and what components go where.

All necessary files will also be present on the drive repository including the software files, vector files for the laser cut parts and schematics of the electronics. A QR code on the back of the installation will link to the drive repository which makes it more accessible.

Software used to access some documents will be the ArduinoIDE, vector edit software (pdf) and fritzing for the schematics.

6. Realisation

With the final designs selected and created, the project can now be realised, moving from design to prototype. This chapter will present an overview of the building process, explaining the design choices made and how they were implemented. It will describe the steps and features of the design and installation. In order to keep this chapter compact, a detailed description of the building process can be found on the created google drive page [22]

6.1 Hardware

The hardware aspect of the installation can be divided into three sections; The hometrainer, the display board and the electronics. The hometrainer will be the main point of interaction, here the participants will try to cycle as hard as possible in order to generate as much wattage. This output will be measured and displayed on the display board via LED's. The electronics will connect everything together

6.1.1 Bill of Materials

- 3x 1200x600mm 8mm Plywood
- 1x 140x200mm 6mm plywood
- 2x 40x150mm 4mm Plywood
- 1x Hometrainer (brand unknown)
- White primer
- Yellow paint
- 1x Arduino Uno
- 1x 16x2 LCD display
- 1x Hall effect sensor
- magnet
- 1.53m 30LED/m w2812b Neopixel (46LED's)
- Dual usb power supply
- 46x 10x10mm 6mm matte-acrylic cutouts
- Support electronics¹
- 270mm 4' x 2' Wood
- 2x Quick release hinges

¹ Additional support electronics: 'Pull up resistors', 'Pull down resistors', Potentiometers

6.1.2 Hometrainer

The hometrainer will be the one of the most important parts of the installation because this is where the participants will try to generate as much power as they can, with the goal being relating this effort necessary to power common household appliances for as long as they can. This means that the hometrainer needs to be robust, since unlike a normal training session this hometrainer will mostly endure the endsprints. The best solution was to buy a used hometrainer made from metal to ensure its strength, durability and low price.



Figure 10: The secondhand hometrainer

Buying a used hometrainer brings risks with it, the main potential issue being signal readout. Although all hometrainers function very similarly, the way they process signals is different for every brand and this could lead to complications. But this was an acceptable risk, because the pro's of its ensured strength outweigh the risks of signal readout.

A backup plan was created in case of signal readout issues, in this case the built in measuring method would be replaced by an own made position encoder. This would likely be less accurate, but would ensure that the installation will work.

The first step was to disassemble the hometrainer in order to properly clean it and discover the electronics present.



Figure 11: Exposed internals of the hometrainer

With the hometrainer open it was possible to take a look at the electronics present. The hometrainer functioned by rotating the fixed mass on the rear (left) axle. This was connected to a brake drum which could simulate different loads. The hometrainer could read the velocity and its respective load and calculate the wattage generated based on this. This leads to the expected problem, this signal is bundled together with other data and sent to the bike computer, meaning that this signal is overlaid with other data, making it hard to read. After this discovery it was determined that the hall effect sensors should be tried, since this would give a clear data output.



Figure 12: Prototyping with the hall effect sensor

Hall effect sensors function by sensing the presence of a magnet. When a magnet is close to the sensor, the output changes from 0 to 1. The arduino can read this signal and understand that a measurement was taken. In the case of the hometrainer, the magnet was attached to the flywheel. By calculating the times the magnet passes the hall sensor multiplied with the wheel diameter times pi it is possible to extract the velocity of the hometrainer. This velocity is multiplied with a constant to extract the generated wattage related to the velocity.



Figure 13: The brake mechanism on the hometrainer

The load of the hometrainer can be configured via an inductive brake. By tensioning a spring the load either increases or decreases. For simplicity reasons the brake was fixed at its highest setting, since the intended use case is for short sprints. This load can be adjusted, but not in real time. This is a deliberate choice to see if during user testing people might desire a lighter or heavier load, depending on this outcome the variable load could be added.

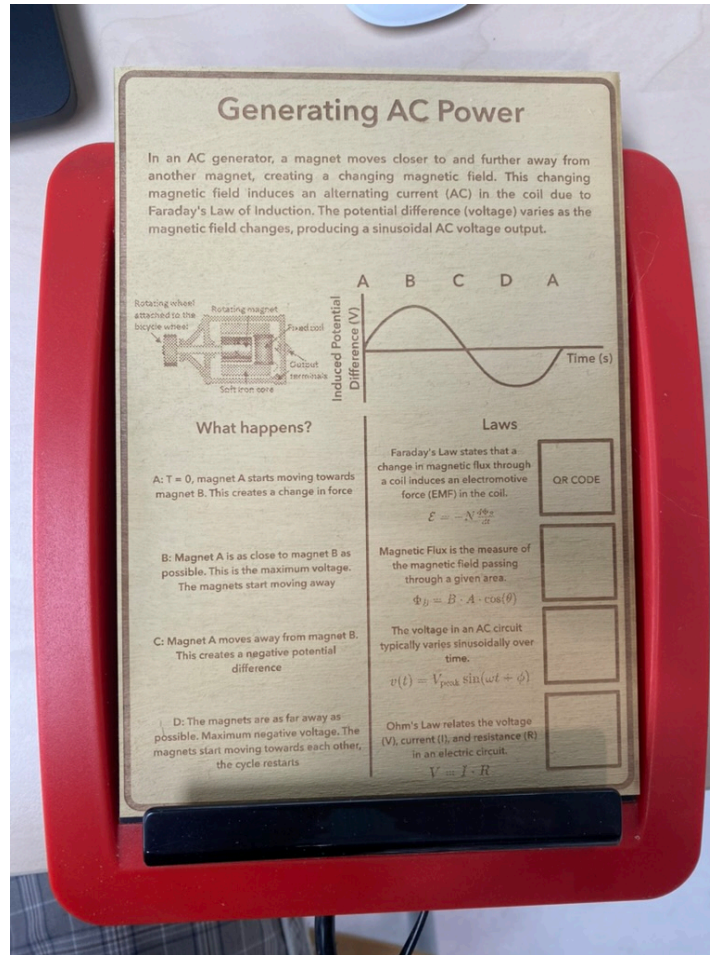


Figure 14: Additional information how the AC generator works

Additionally, there is a small information board mounted to the old interface of the hometrainer. This screen is not used anymore and therefore some extra information about how alternating current (AC) is generated. The board shows AC over time, similar to how a bicycle dynamo works. There are steps explaining what is happening at what point in time, with the accompanying laws to add some more in depth explanation. The empty squares offer a place for QR codes linking to external websites related to the represented formula.



Figure 15: The assembled hometrainer

With everything put together the hometrainer looks original again, apart from the “Electrical Engineering” branding and the information board. The wire running from the hometrainer can be detached for transportation and is 2 metres long, which gives some setup options.

6.1.3 Display Board

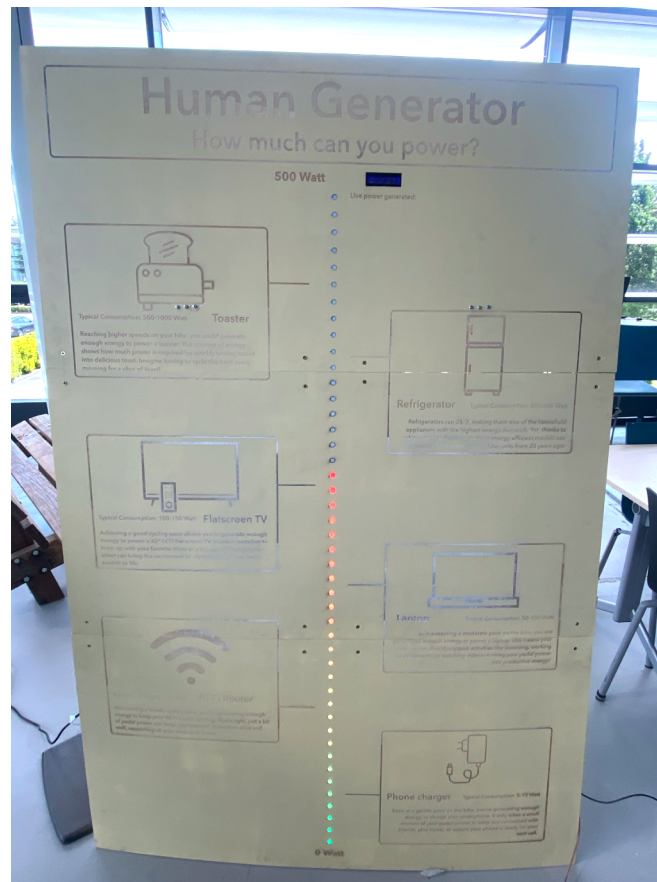


Figure 16: The display board front with powered LED and LCD screen

The display board is the main part of the demonstrator, designed to grab attention and be visible and readable from a distance. It is made from three wood sheets connected with a backplate and screws. An LED strip runs down the middle and an LCD screen shows the accurate values. The dimensions of the board are 120 x 180 cm to facilitate good readability from a distance during the open days, but because of the lightweight wood the board is not heavy.



Figure 17: The backside of the display board

The back of the board is not painted and shows the construction. The backplates are visible here and the electronics box has an acrylic top, to show the inner workings of the demonstrator. This design choice was made because some visitors could be interested in electronics and this way everything is visible. There is a poster explaining what the electronics do. The idea here is that the demonstrator should represent average university projects which also make use of laser cutting and arduino components. This is realistically reflected this way.

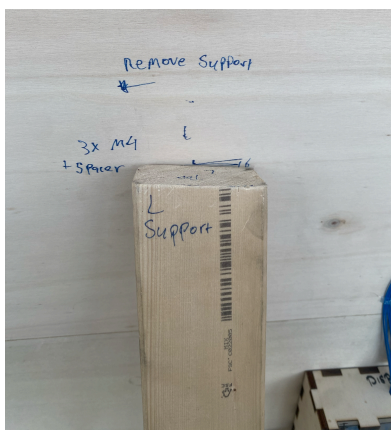


Figure 18: The detachable wood frame

The two wooden legs are 135 cm and make the board stand up right. The legs are detachable via a click-hinge system, for easier transportation.

6.1.4 Electronics

The electronics play a vital role in the functioning of the demonstrator and server as a demonstration of themselves. All electronics are visible from the back of the demonstrator. This decision was made to show how easy it could be to build projects similar to the EE demonstrator.

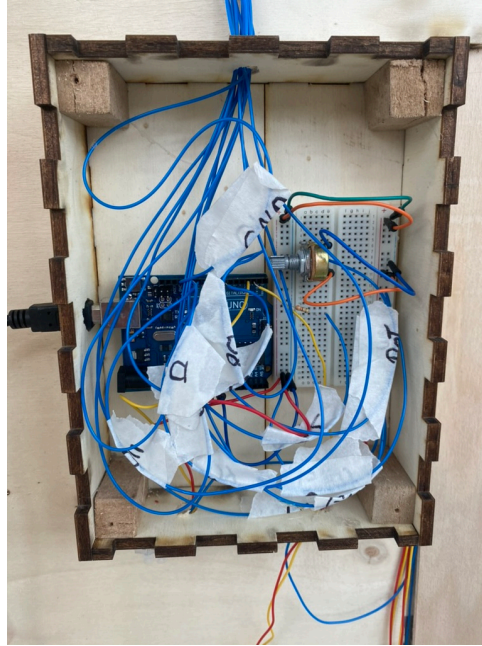


Figure 19: The electronics on the back of the demonstrator

The electronics box contains the brains of the device, which are arduino based. The lid of the box is made from acrylic, so people who are interested can see what is happening inside. A potentiometer is present to control the brightness of the LED's. Pull up and pull down resistors are also placed here for signal management. The breadboard serves as a way to allow for common ground and a +5V rail. All blue wires have a label, these are attached to the wire because the same colour makes it difficult to keep the wires apart. The choice of keeping the breadboard was made because this makes the project easier to maintain and this helps with explaining what is happening inside, opposed to just unreadable soldered wires.



Figure 20: The live power display for accurate values

For the current velocity and accurate wattage reading an LCD display is present. This LCD can also be used to temporarily store and display highscore settings.

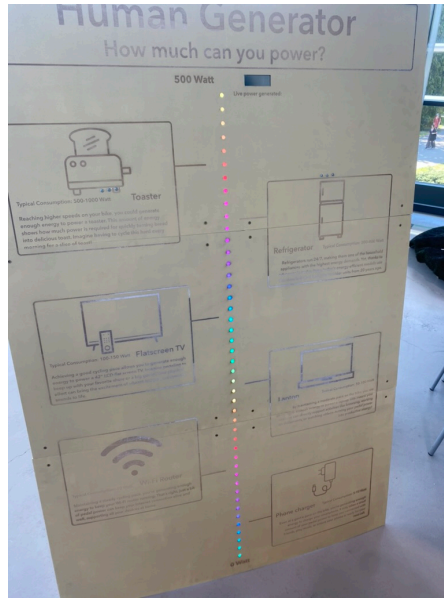


Figure 21: The full colour addressable LED strip

The LED strip runs along the height of the display board and reflects the current power generated. Multiple colours are possible and each LED is addressable allowing for many customisation options. When running at max brightness the strip consumes around 15 Watts (46 Led's * 60mA * 5v). The Led's are individually mounted behind a diffused acrylic insert, to give them a 'soft glow' look.

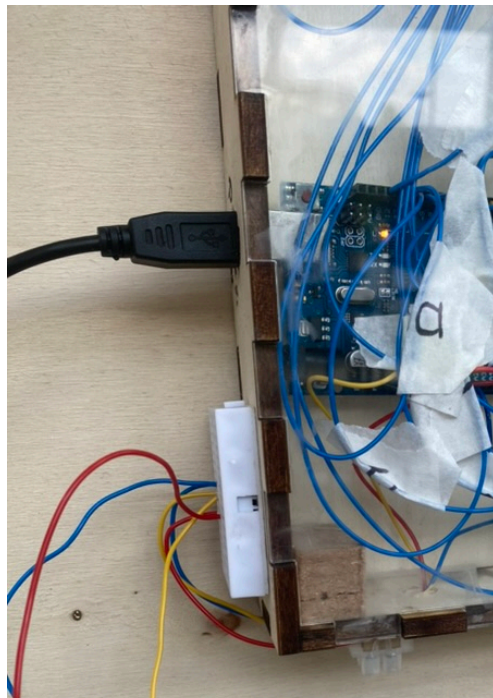


Figure 22: The permanent and quick attachment of the hometrainer

The hometrainer connects to the back of the display board. For the connection two options are available, a 'quick release' system and a more secure system. Both options work but for testing and

storing a quick release system works better since no screwdrivers are required. For the eventual open days the connection can be screwed in for a secure fit. Figure 22 shows both connections, the left breadboard is the quick release and on the bottom of the box are the screw inserts for the secure method.



Figure 23: Power supply for the demonstrator [21]

The installation is self powered by a dual usb 5v power supply unit (PSU). The two usb ports are required because one is necessary for the arduino and the other for the LED strip to achieve maximum brightness. The max power draw is 1.9 ampere for the LED's and 500mA for the Arduino therefore this PSU is suitable. This PSU was selected because it is very lightweight and compact, which helps with the portability of the demonstrator.

6.2 Software

The software ties all parts of the demonstrator together. This sub chapter describes the software used for the creation of the installation and gives some additional information how it has been used.

6.2.1 Arduino IDE

The program that was used for writing code was the default ArduinoIDE. This was chosen because it works seamlessly with the arduino used in the demonstrator, has plenty of libraries and has a massive user base which makes troubleshooting a lot easier. The code runs solely on the arduino and does not require an external computer, making the demonstrator 'plug and play' which is ideal for the open days. The code that was written for this project can be found in the appendix [D] and is present on the Google Drive hub, in case tweaks are needed or a fresh installation is required.

6.2.2 Linearity Curve

Linearity curve is a vector editing program and has been used extensively for this project. The large display board has been designed in Linearity Curve, but all smaller laser cut parts as well. It offers

true millimetre sizing which is ideal when designing parts that tightly have to fit together, like the three displayboards or the electronics box on the back of the demonstrator. All files designed in Linearity curve have also been uploaded to the drive in case they ever needed to be printed again.

6.2.3 Fritzing

Fritzing was used to create clear schematics of all electronics. This is useful to show the way the installation works but also in case something ever disconnects it would be easy to reconnect it again when looking at the schematics.

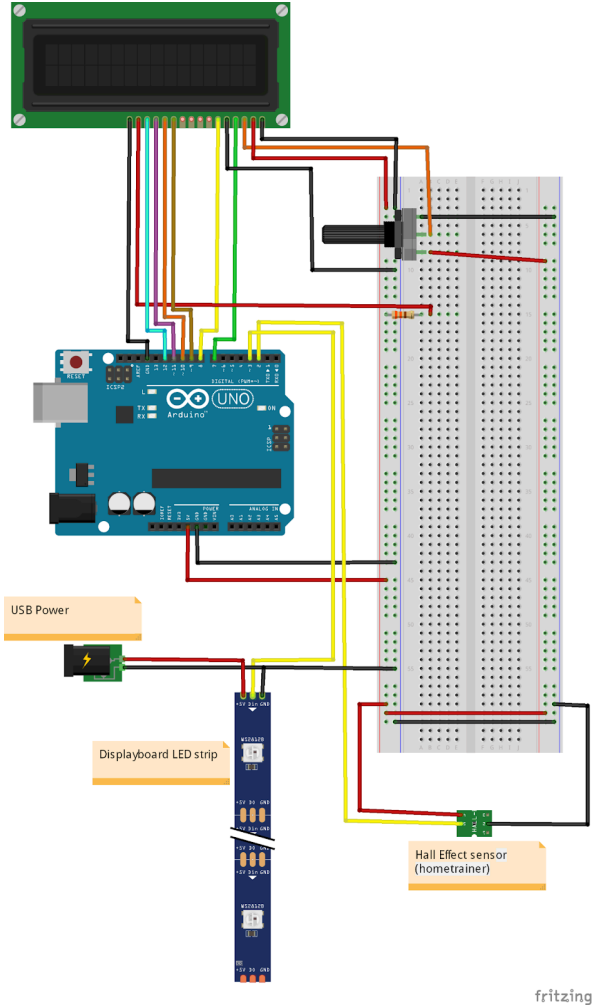


Figure 24: The schematics of all electronics connections

6.3 Documentation

6.3.1 Google Drive

In order to ensure a long life of usage with many open days, a google drive has been created with all the files related to the demonstrator[22]. This includes all PDF's for laser cutting, images for the schematics and a document describing the construction of the installation in detail. The drive is linked with a QR code on the back of the demonstrator to allow for easy access.

6.3.2 Cost overview

In order to keep track of all costs related to the demonstrator, an overview of the costs has been created. All receipts have been kept as proof of purchase.

Item	Date of purchase	Price
Hometrainer	30-4-2024	€ 27.5
linearity curve	1-5-2024	€ 15
3x 8mm plex wood	7-5-2024	€ 30
Praxis paint	6-5-2024	€ 11.97
Action Brushes	6-5-2024	€ 10.78
hall effect sensor 3x	8-5-2024	€ 2.5
270cm wood 2"*4"	13-5-2024	€ 19.78
Total	-	€ 117.53

Table 2: Cost overview of EE demonstrator

7. User evaluation

With a working prototype constructed, it is possible to start testing with potential users. The installation was not yet in its finished state but it was developed enough to get an insight in the engagement, accuracy and interaction. User testing can also provide more inspiration or feedback on features of the demonstrator, which could be implemented.

Eight user tests were conducted with peers. While this number is not particularly large, it is sufficient to observe how people interact with the installation and identify any critical oversights. The main goal of user testing was to uncover potential oversights, inaccuracies, and test the demonstrator's reliability. These tests took place at the design lab of the University of Twente. The form used for these tests can be found in Appendix C.

7.1 Strategy

The chosen strategy for the user testing was a combination of observation and interviewing users as they interacted with the installation. This was selected because questionnaires allow for quick and easy data collection while observing allows for a deep understanding.

For the testing this meant that users were first asked to fill in some pre-testing questions, which were demographics to understand from what background they came from. When the demographics were filled in they could start exploring the demonstrator. Users were deliberately given no information regarding the installation, since this would also be the case during the open days. They would have to discover everything themselves by reading and interacting with the device. During this stage their comments were noted when they interacted with the demonstrator. Once they felt they had discovered enough they stopped and filled in the post-testing questionnaire. This hybrid approach resulted in plenty of data and insight regarding the interaction and installation in general.

7.2 Relevant Questions

This subchapter will describe the questions and discuss why they were asked.

7.2.1 Pre testing questions

What is your name?

What is your age?

What is your gender?

What is your occupation / study?

These questions were asked to get an insight in the background of the participants and relate how accurate / relevant their experiences with the demonstrator would be.

How often do you cycle?

In order to get an insight of how physically demanding the interaction would be some background information was asked regarding cycling.

Have you used a hometrainer before?

Similar question. Some questions were asked multiple times and can be seen as redundant. These questions were in the questionnaire to make sure reliable data was obtained.

How familiar are you with concepts like velocity and wattage?

This was asked because the goal of the demonstrator is generating an understanding of power usage related to physical effort. The concepts will be explained by the installation and by asking this could be determined if the installation is informative.

Would you say to have a general understanding of power consumption of general household appliances?

This question has a similar goal. Gauging the effectiveness of the demonstrator.

7.2.2 Questions during interaction

Do you need instructions to start interacting with the demonstrator?

This was asked to understand if a quick start guide should be made available, or a poster to explain how the installation works. The goal is for people to discover themselves but perhaps some things are not clear.

How easy or difficult was it to start cycling on the hometrainer?

The main interaction is cycling to generate power, the setup of the prototype was at a fixed intensity. If during testing it was discovered that this was too light or too heavy this could be tuned.

Was the velocity displayed clearly?

The LED's draw the attention to themselves by lighting up, but the display is smaller. Therefore this question was asked if people understood their current velocity.

Was the wattage generated understandable?

This also refers to the LCD screen.

Did you understand which household appliances could be powered by the wattage displayed?

The LED bar runs along some 'checkpoints' which are the devices. Understanding that the number of LEDs relates to what devices could be powered is crucial. This should be clear, but is asked to be sure.

Was the LED display showing the household appliances engaging? (eg: scoring as high as possible?)

The demonstrator should be engaging and hopefully the interaction invites people to try and generate as much wattage as possible.

Did the LED display effectively show the amount of power generated?

This is related to the reliability of the demonstrator, since it has only been used during construction in a monitored environment. The installation should be sturdy and reliable enough to last the open days and therefore all points of failure should be accounted for.

7.2.3 Post testing questions

How would you rate your overall experience?

This refers to the excitement of the installation. It is important that the interaction was fun.

What did you enjoy most about the installation?

Discover what features were experienced the best.

What did you enjoy least?

This was asked to discover downsides or oversights of the demonstrator. Things that were unexpected or undesired. It is important that these issues are addressed before the open days.

Did the installation help you understand the relationship between cycling effort, velocity, and wattage generated?

This is the goal of the demonstrator and is therefore important to discover if the installation is successful in its educational aspects. This question also helps understanding if it was clear that the effort of cycling influenced the output of the demonstrator.

Do you feel more informed about energy consumption and generation after using the installation?

Similar.

What improvements would you suggest for the hometrainer setup?

This question was asked to discover new ideas, features or address oversights.

Were there any aspects that were confusing or unclear?

These issues are important to address before release.

Do you have any ideas for additional features or information that could be included?

Discover new ideas.

7.3 Outcomes

From the user test a lot of data was obtained. Both through the questionnaire and through the additional notes. This subchapter will discuss some highlights, thoughts and takeaways from this information.

7.3.1 Outcome questionnaire

After all users had performed their user test, the obtained data could be analysed. All participants were in the age range of 19-22 which is relevant to this installation, the intended audience are potential first year students which are close to this age. The data is therefore valid to extrapolate. From the pre testing questions came that the majority of users had used a hometrainer before and were familiar with cycling.

When starting their interaction with the demonstrator 100% of users did not require instructions, this is a desirable outcome since this suggests that the demonstrator looks self-explanatory. The interaction itself was perceived as clear, with people being excited by the output of the installation. The LED bar is successful in translating physical effort to power. The LED bar was also engaging, with many users trying to cycle as hard as they could to generate the highest wattage. However the LCD screen was not clear to all participants. It was too small to be noticed and the text could be hard to read while cycling. The general output was clear but the specific data was lacking which is an oversight. 100% of the users stated to understand which household electronics could temporarily be powered by their physical effort, which was the goal of this installation.

From the post testing questions, the installation scored high when given a grade (chart 1). Many participants found the installation to be exciting and entertaining, although being short. The average interaction took around 2 minutes. Some down sides were also given, being the small screen and high physical intensity required to reach the top appliance. A cause for this high effort could be the fixed gearing of the hometrainer, if the possibility of switching gears was added this effort could be reduced. The final question was to discover the success of the installation, if the users were more informed of the power consumption of everyday electronics, which they were.

Did the installation help you understand the relationship between cycling effort, velocity, and wattage generated?

8 responses

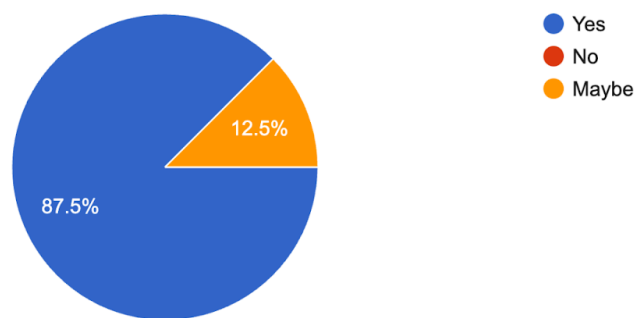


Chart 1: Outcome user testing

7.3.2 Additional notes and discoveries

With the live monitoring of the user tests, some additional notes were made. These notes were from thoughts or suggestions made by users while testing, “thinking out loud” and all comments that were added after testing had taken place.

During the first user test a suggestion was made which stated that the hometrainer obstructs the view of the display board, meaning that not all LEDs were visible since some were behind the frame of the hometrainer. A temporary solution was to put the hometrainer at a slight angle to fix the view obstruction. This slight angle can also be applied during the open days, since it does not interfere with the functionality of the demonstrator.

A suggestion was made that a highscore function would benefit the engagement. Trying to cycle as hard as possible to set a new personal highscore.

Some users expressed confusion with the concept of watt against watt hours. Because simply cycling 150 watts could power a television, but the second the cycling stops this power would be lost and the television would turn off. This unit of power vs unit of energy should be more clear.

A user expressed trouble understanding the colour of the LEDs. The LED bar has a gradient colour effect present from green to red, to appear more complex or interesting. The user stated that because the top LEDs were red it was being implied that the cycling power was insufficient, which was not the case.

7.4 Potential changes and implementation

From the user test multiple suggestions and improvements were discovered. In order to make the demonstrator as ready for the open days as possible, some changes were implemented.

7.4.1 Watt vs Watt Hour

In order to clear up the confusion present with watt vs watt hour, an additional information board was made. This was attached next to the LCD screen to also make its presentation more accessible. The information is optional and is not necessary for understanding the installation but it does offer additional insight for those who are interested or confused.

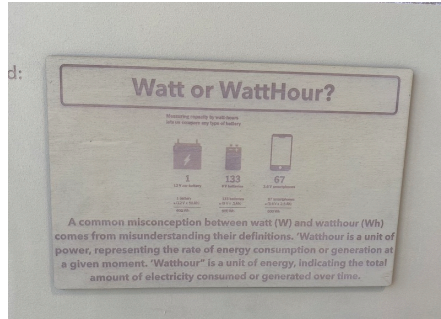


Figure 25: Additional information board

7.4.2 Code improvements

From the user testing some improvements for the software were suggested, this was a highscore function and to make the max power more engaging. These issues could be easily addressed by adding some new code. The update added a highscore function to the demonstrator which keeps track and displays the highest wattage generated per user. Also when more than 500 watts is being generated, all LEDs flash yellow to highlight the high physical effort required to cycle at this intensity.

8. Discussion and conclusion

The goal of this project was to build a demonstrator for the open days for Electrical Engineering. Reflecting back on the work and eventual prototype a discussion and conclusion of the project can be made.

8.1 Discussion

Multiple points of discussion can be raised throughout the progress of this project. The first difficulties were during the background research of the interactive learning demonstrator field. The search of finding reliable data proved to be difficult, with a lot of different technical terms being used for demonstrators, which made it difficult to consistently and efficiently find sources. A lot of research was conducted in the field of museums, but this had to be extrapolated to a scholar setting, which could be inaccurate.

Another point of discussion is the planning for constructing the physical prototype. In hindsight, the initial plan was highly inaccurate and required frequent weekly adjustments, leading to an illogical or non-chronological building process. Components often had to be removed and reattached.

Additionally, the design lab's location posed challenges, as it is an open study space. The unfinished installation was moved multiple times by third parties, occasionally causing minor damage that needed to be repaired, hindering progress.

During construction, lack of experience also occurred. When the infoboard was painted and left to dry, the wood warped in some places. Which when the wood was then put in the lasercutter for cutting and engraving, imperfections occurred. The middle wood panel is warped the most and the primer below the paint is showing, which does not look good. Knowing the wood would warp under painting could have prevented this and make the final prototype look better.

Some oversights in design are present which were unknown until the user testing. These are features which are not present on the final installation. The features are variable intensity and a larger display. Adding these proved to be outside the scope of this project since a lot needed to be changed to facilitate the update, which would take too much time.

Scope and cost in general could also be discussed, because the final prototype is large to make it readable from a distance which is preferred for open days. But this also means that it is more expensive and working on it takes longer. Therefore some compromises were made. The infoboard could look better from behind with a custom made back bracket, which would make it more rigid and robust. The detachable wooden frame is simple and a little bit fragile when setting up, also the quick connection to the hometrainer could have been made magnetic, making setting up easier. But incorporating this into the final prototype would be outside the scope of this project.

The final point of discussion is the user testing itself. This was conducted on eight students which represented pre-students. Actual user testing on potential first year students interested in EE would have been better since this is the intended audience for this project. This could also reveal new insight into the reliability of the installation.

8.2 Conclusion

The goal of this project was to research what makes an effective demonstrator for electrical engineering for the open days of the University of Twente and develop a prototype. The field was researched to discover what has already been done and what would be a good strategy to pursue when building an own installation. From the research, the core principles that best could be presented was power by using analogies. A demonstrator could most effectively be used by restricting complexity, using analogies in an intuitive fashion facilitating user interaction, which led to the user discovering information through own actions and observation.

This information was used as a guideline to design a new interactive demonstrator for EE. The final design presented the use of a human power analogy related to the power requirements of regular household appliances. Creating an understanding of the relationship between physical effort and the electricity that could be generated and what devices this could power was the goal. The idea was participants had to cycle on a hometrainer, and their live power output would be presented and related on a board in front of them.

The board was laser cut from wood, painted and engraved, a hometrainer was purchased and modified to output the necessary data, additional information boards were created to offer additional insight, LEDs were added and a LCD display for accurate readings. The entire construction process was documented and made available to ensure easy repairability or future modifications.

The user tests were conducted on eight students who were observed interacting with the installation and were asked to fill in a questionnaire after their experience. This method of data collecting was suggested through the performed background research since this offered the best of two worlds. The feedback from the user test was positive but also suggested multiple improvements. A bigger screen, the possibility to switch gears and making the relationship between watt & watt hour more clear.

Reflecting on the main research question: "What is the most effective use of a demonstrator for electrical engineering to display and explain key principles during the open days in an engaging fashion to students?" The answer proposed by this paper would be by building an interactive demonstrator that presents an analogy between physical effort and power generation. To make people aware of the presence of electricity everywhere around them and thus highlight the importance of electrical engineers to design and build the infrastructure.

9. Future work

While the goal of this project was to research and develop an interactive learning demonstrator for the open days, there are several areas that still require further investigation. Firstly the project was limited by its scope, timeframe and budget. These limitations meant that there were compromises in the quality of building materials and number of features present on the demonstrator. Future research could investigate the area's of shortcomings and develop additional features to the installation or alter its functionality.

Additional functionality: From the user testing occurred the feedback that the options of variable intensity, or changing gears was desired. The current setup of the hometrainer does allow for a variable intensity, but this could only be set lighter. Where the users suggested a heavier gear ratio would be optimal for reaching higher speeds. This means that the hometrainer fundamentally needs to be altered to facilitate a higher gear ratio. This change was outside the scope of this project, but could be developed by a third party in the future.

Altered functionality: In its current state, the demonstrator relates physical intensity to a live power output, but does not offer much more additional functionality. This could mainly be attributed to the small display present. This display could be improved to be bigger and sharper to allow for more insight into how the power is generated and improve visibility of the measured metrics.

Required reliability: The installation was developed for the open days at the University of Twente, but was only user tested for reliability on a relatively small sample of students. This could suggest that during an actual full open day new previously unknown issues could occur. These issues should then also be addressed and a potential solution should be designed to ensure the longevity of the demonstrator.

Appendices

A: Report references

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C: User feedback testing questionnaire

Pre-Test Questions

- **Demographics**
 - Age
 - Gender
 - Occupation or field of study
- **Experience with Cycling:**
 - How often do you cycle?
 - Have you used a hometrainer before?
- **Familiarity with Energy Concepts:**
 - How familiar are you with concepts like velocity and wattage?
 - Would you say to have a general understanding of power consumption of general household appliances?

During the Test

- **Ease of Use:**
 - Do you need instructions to start interacting with the demonstrator?
 - How easy or difficult was it to start cycling on the hometrainer?
- **Understanding of Display:**
 - Was the velocity displayed clearly?
 - Was the wattage generated understandable?
 - Did you understand which household appliances could be powered by the wattage displayed?
- **Feedback on LED Display:**
 - Was the LED display showing the household appliances engaging?
 - Did the LED display effectively communicate the show of power generated?

Post-Test Questions

- **User Experience itself:**
 - How would you rate your overall experience?
 - What did you enjoy most about the installation?
 - What did you enjoy least?
- **Educational Value:**
 - Did the installation help you understand the relationship between cycling effort, velocity, and wattage generated?
 - Do you feel more informed about energy consumption and generation after using the installation?
- **Suggestions for Improvement:**
 - What improvements would you suggest for the hometrainer setup?

- Were there any aspects that were confusing or unclear?
- Do you have any ideas for additional features or information that could be included?

Observational Data

- **Engagement Level:**
 - How long did users typically spend on the hometrainer?
 - How often did users check the LED display?
 - Did users interact with the display or ask questions during the test?
- **Physical Feedback:**
 - Observe users' physical effort and any signs of discomfort or ease.
 - Note the speed and consistency of cycling.
- **Reliability**
 - Did any technical issues arise during the user test?
 - Were there thoughts on the responsiveness of the LED screen?

D: Demonstrator C++ Code

```
#include <FastLED.h>
#include <LiquidCrystal.h>

#define NUM_LEDS 46
#define DATA_PIN 2 // Nieuwe pin waar de LED strip op is aangesloten
#define HALL_PIN 3 // Nieuwe pin voor de Hall-effect sensor

const float wheelDiameter = 23.0; // Diameter van het wiel in centimeters
const float wheelCircumference = wheelDiameter * PI; // Omtrek van het wiel
const float maxWattage = 500.0; // Maximale wattage voor volledige LED weergave

volatile unsigned long lastTime = 0;
volatile unsigned long currentTime = 0;
volatile bool magnetDetected = false;

CRGB leds[NUM_LEDS];

LiquidCrystal lcd(7, 8, 9, 10, 11, 12); // Initialiseer het LCD

unsigned long lastUpdate = 0;
unsigned long fadeInterval = 100; // Interval for fading out LEDs (adjust to your preference)
int currentLED = NUM_LEDS - 1;
bool fading = false;
float highscore = 0.0; // Variabele voor het bijhouden van de highscore

unsigned long lastMeasurementTime = 0; // Tijdstip van de laatste meting
const unsigned long noMeasurementThreshold = 5000; // Drempel van 5 seconden zonder meting
bool showingHighscore = false;
unsigned long highscoreStartTime = 0;

void setup() {
  Serial.begin(9600);
  pinMode(HALL_PIN, INPUT); // hall pin als input
  attachInterrupt(digitalPinToInterrupt(HALL_PIN), magnetInterrupt, FALLING); // Interrupt bij
  magneetdetectie

  FastLED.addLeds<NEOPIXEL, DATA_PIN>(leds, NUM_LEDS);
  FastLED.setBrightness(250); // lekker fel jonguh
  FastLED.clear();
  FastLED.show();

  lcd.begin(16, 2); // Start het LCD scherm
  lcd.print("Start to Cycle:"); // Start Text
}
```

```

void loop() {
  if (magnetDetected) {
    noInterrupts(); // Schakel interrupts uit om variabelen te beschermen
    unsigned long timeDifference = currentTime - lastTime; // Tijdverschil in microseconden
    magnetDetected = false;
    interrupts(); // Schakel interrupts weer in

    float timeDifferenceSec = timeDifference / 1000000.0; // Tijdverschil in seconden
    float velocity = wheelCircumference / timeDifferenceSec; // Snelheid in cm/s

    // Multipliers
    float metersSecond = velocity / 10;
    float kph = metersSecond * 2; //deze is adjusted, originele berekening niet helemaal correct
    float wattage = kph * 12;

    // Update de highscore indien nodig
    if (wattage > highscore) {
      highscore = wattage;
    }

    // Update de tijd van de laatste meting
    lastMeasurementTime = millis();

    // print voor debuggen kan uit uiteindelijk
    // Serial.print("Velocity: ");
    // Serial.print(kph);
    // Serial.println(" kph ");
    // Serial.print("Wattage: ");
    // Serial.println(wattage);

    // update LCD scherm
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("Velocity: ");
    lcd.print(kph);
    lcd.print(" kph");
    lcd.setCursor(0, 1);
    lcd.print("Wattage: ");
    lcd.print(wattage);

    // Verlicht de LED's op basis van de wattage
    updateLEDs(wattage);

    // Start de fade out animatie
    startFadeOut();

    // Roep gave flash aan wanneer Max wattage

```

```

    if (wattage >= 500) {
        flashYellowLEDs();
    }
}

if (fading) {
    fadeOutLEDs();
}

// check voor inactief dan highscore weergeven
if (millis() - lastMeasurementTime >= noMeasurementThreshold && !showingHighscore) {
    // Toon de highscore
    showingHighscore = true;
    highscoreStartTime = millis();
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("Highscore:");
    lcd.setCursor(0, 1);
    lcd.print(highscore);
}

// display terug naar default state
if (showingHighscore && millis() - highscoreStartTime >= 5000) {
    showingHighscore = false;
    highscore = 0; // Reset de highscore
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("Snelheid:");
}
}

void magnetInterrupt() {
    lastTime = currentTime;
    currentTime = micros(); // Huidige tijd in microseconden
    magnetDetected = true;
}

void updateLEDs(float wattage) {
    // getunde logschaal voor wattage.
    int numLedsToLight = pow(wattage / maxWattage, 0.4) * NUM_LEDS;

    // colour gradient
    CRGB lowColor = CRGB::Green;
    CRGB highColor = CRGB::Red;

    // Verlicht de juiste aantal LED's met een gradient van groen naar rood
    for (int i = 0; i < NUM_LEDS; i++) {

```

```

if (i < numLedsToLight) {
    // Interpoleer tussen de lowColor en highColor op basis van wattage
    float ratio = (float)i / (float)numLedsToLight;
    leds[i] = lowColor.lerp8(highColor, ratio * 255);
} else {
    leds[i] = CRGB::Black; // Zet de overige LED's uit
}
}
FastLED.show();
}

void startFadeOut() {
    fading = true;
    currentLED = NUM_LEDS - 1;
    lastUpdate = millis();
}

void fadeOutLEDs() {
    unsigned long now = millis();
    if (now - lastUpdate >= fadeInterval) { // fadeinterval bepaalt snelheid van fadeout
        if (currentLED >= 0) {
            leds[currentLED] = CRGB::Black;
            FastLED.show();
            currentLED--;
            lastUpdate = now;
        } else {
            fading = false;
        }
    }
}

//precies wat je denkt dat het doet: dubbele forloop mooie code man
void flashYellowLEDs() {
    for (int i = 0; i < 5; i++) {
        // Zet alle LED's op geel
        for (int j = 0; j < NUM_LEDS; j++) {
            leds[j] = CRGB::Yellow;
        }
        FastLED.show();
        delay(100);

        // Zet alle LED's uit
        for (int j = 0; j < NUM_LEDS; j++) {
            leds[j] = CRGB::Black;
        }
        FastLED.show();
        delay(100);
    }
}

```

}