Interactive installation for an Educational Ethics Lab

Willem van Dijk[1]

[1]**Student BSc. Creative Technology, University of Twente, Drienerlolaan 5, 7522 NB Enschede, the Netherlands**

ABSTRACT

This report dives into the implementation of ethics in technology teaching in higher education. It goes into the specific difficulties that arise when teaching this ambiguous and very culturally dependent subject. It explores the application of an ethics lab in teaching this subject, possibly with the use of interactive installations. To find out how people can be stimulated to take ethical aspects into consideration and how effective an interactive installation could be to teach such ethical reflection it first explores some different examples of classic ethical dilemmas. A concrete example of such an interactive installation was built and tested in a small case study with a group of minor students. This found some possible validity for the use of such interactive installations. The field is very broad and has many challenges, there is a broad opportunity for further research into such adaptations of interactive installations used in ethics in technology teaching.

Keywords: Ethics in Technology [EIT], Interactive installations, Constant flux, Creative Technology, Ethics education, methods for higher education

PRE-FACE

This report provides an overview of an assignment set out by the research group on Ethics and Technology of Saxion as a completion of the bachelor study Creative Technology.

ACKNOWLEDGEMENTS

During this project I was guided by Wouter Eggink, I want to thank him for his great advice and for all the time he put into proofreading reports. The project itself was set out by the ethics group of Saxion, this was represented by Steven Dorrestijn and later by Egbert Siebrand, I want to thank both of them for this opportunity and for the few occasions where we could spar about different dilemmas or the implications of different implementations.

Furthermore, I received awesome assistance from my friends, especially during the construction and assembly stage. I want to thank Allard, Mór, Lucas, Erik and Radhika for their time and skillful support.

CONTENTS

1 INTRODUCTION

The research group on Ethics and Technology of the university of applied sciences, Saxion, is setting out to build an interactive ethics lab. Conveying the importance of ethics and teaching basic ethical frameworks to students is not an easy task, and this group is inspired by the Design Lab project of the university of Twente to build an interactive and engaging environment where students can more easily get involved in ethical theory.

Ethics in Technology (EIT) is an important aspect of our lives and should be incorporated in every design process thought to students. As discussed by Mathur and Corley (2014) who gathered reasons why EIT should be part of a schools curriculum, and concluded that there is a need to establish ethical decision making in schools. This is further exemplified by Kiran and Verbeek (2010) who state that EIT not only is needed because technologies can pose a variety of risks but also to give students, or designers, a deeper grasp on concepts like trust, which they can use to further gauge possible ethical impacts of technologies. Therefore, EIT seems integral to higher education, yet studies like the one performed by Valentine et al. (2020) found that for most engineering students ethics as a subject comes across as boring or uninteresting, Valentine et al. state that encouraging students to engage more with the content will likely help students to understand the role of ethics within engineering.

The aim of the ethics lab is to try to convey design ethics using a more hands-on approach. A hands-on approach is a more focused and experience-based teaching method where more emphasis is put on reflection and actual real-world implications and the use cases of a technology. While many variations of teaching in ethics have been tried out, like Challenge based learning (CBL) and Co-creation which do also offer a more hands-on approach, the added benefit of an ethics lab as a stimulating environment might prove useful. The ethics lab will focus on design students who can benefit from EIT by including ethical considerations in their design processes. The room can be filled with thought exercises and installations that can either inform someone about ethics theory or strike a conversation about a given topic or dilemma. Two students have already made an installation aimed at this ethics lab, an interactive installation centred around the concept of Plato's cave and the panopticon by Jeremy Bentham respectively (Schreurs (2023) , Nap (2023)). These installations are great example of how the interior of this ethics lab is envisioned. The hope is that approaching EIT education in this way, using interactive installations, the students become more interested in the subject matter and therefore gain a deeper understanding of the discussed theories, the hands-on experience can also make the step to implementing actual ethical reflection easier. This project aims to answer the following research questions:

- How can people be stimulated to take ethical aspects into consideration?,
- How effective is an interactive installation based on an ethical subject in stimulating ethical reflection?.

In order to answer these questions an attempt will be made to create such an interactive installation that can convey ethical thinking by stimulating reflection on ethical theories or strike a conversation about an ethical dilemma. A focus group will give insight in the thought processes involved and on what stimulates and what doesn't stimulate designers when working on ethical considerations for their design process. The installation will be tested with engineering and design students who are also the envisioned end users of such an ethics lab.

2 BACKGROUND RESEARCH

Classes on engineering ethics or design ethics have been incorporated into a large number of technical studies. With many universities putting an emphasis on the importance of ethical considerations within engineering jobs. Even though almost every university has incorporated ethics education there is still a lot of difference between the curricula. There has not been one generalized approach to this topic and the actual usage or effect of these curricula in the real world are still not completely clear.

Teaching EIT can greatly improve and there could be a move to reflect on the outcomes of these courses more often. Therefore, it could be a good step to first analyse existing teaching methods and outcomes. A more hands-on approach can be very interesting to better transfer EIT reflective skills. But some different teaching methods have already been tried. EIT is not a new field, there are many examples of engineers failing to see ethical consequences in history. These examples are often used, and many universities have incorporated some sort of ethics class. Research done by Stavrakakis et al. (2022) found that many European universities already incorporate some form of EIT teaching. This research was focused on computer science education and found that almost all technical universities that took part in the survey offered EIT teaching and 63% of the universities that did not yet offer EIT considered teaching EIT as important. An analysis by Antes et al. (2009), where they reviewed 26 previous EIT evaluation studies, found that the effectiveness of this EIT education depends considerably on the chosen teaching method, the classical instruction method might not be the most effective choice. EIT is widely considered to be a good addition to engineering courses but to effectively convey EIT new teaching methods should be researched.

Co-creation is a good example of a more hands-on teaching approach that has already been tried. In this approach the students and teachers share responsibility over the course content, delivery and/or assessment methods. A good example of this is the test done by Meinking and Hall (2022) they organized a Co-creation based class at Elon University (North Carolina, US). Meinking and Hall adopted a strategy called 'the democratic classroom' in which students were responsible to not only steer the course content by setting their learning goals but also to make decisions about the course structure. The students reacted mostly positive, and Meinking and Hall found that this Co-creation approach was effective in encouraging students to engage and focus more on the course and learning process. This specific course was on classical studies and neuroscience, but the method Co-creation does seem like a good fit for EIT teaching, as EIT can benefit from the extra reflection that comes with the deeper engagement of the students.

Co-creation does seem to engage students on a higher level although more empirical research could be done to prove this further. Another factor to consider is how feasible it is to implement such a method on larger scales. Co-creation makes a course more flexible, but this also adds a higher workload for the lecturer. Bovill (2019) and Meinking and Hall already stated that they see a challenge in implementing Co-creation for larger classes. While Co-creation does show considerable promise, more research on the large-scale implementation and feasibility should be done.

Next to Co-creation, Challenge Based Learning (CBL) is also emerging. This method is still loosely defined and in a very experimental phase. CBL is an active teaching method that tries to call on a student's own initiative and discipline to think of a solution for a real-world problem. A slight variation of CBL (PBL, Project Based Learning) is also used. This method is not solely focused on finding a solution but, in addition, counts on the students learning through the process itself (van den Beemt et al. (2022)). A collaborative approach like CBL could be highly suitable for EIT classes as these lend themselves well for multidisciplinary case studies or challenges.

Many lecturers have already tried various implementations of CBL in practice. Some limited experimentation has also been done with this, as can be seen in Bombaerts et al. (2021) where an experiment on the efficacy of CBL has been carried out using a comparison between CBL and a more traditional 'detached' teaching method in an EIT course. Yang et al. (2018) evaluated the effect of CBL and found that "[CBL] may [give students the ability..] to transfer their creativity and innovation into something useful, practical and valuable". Considering this the use and results of using CBL in EIT teaching could be further examined as CBL is showing good potential of being a very effective method for this field.

Next to teaching EIT is also very challenging to evaluate or grade, due to its ambiguous nature and the social impact that someone's background might have on what they think is ethical, it is not easy to make a simple test or exam to evaluate someone's ethical performance. This yet to be solved challenge might lead to some less favourable circumstances. Keefer et al. (2014) even claim that the rapid increase of required EIT courses might have caused harm to the quality of EIT education as there was not sufficient time to properly evaluate and structure each course.

Most theoretical subjects are being thought using a lecturing style of teaching. For ethics education specifically Stavrakakis et al. (2022) found that many EIT courses use a hybrid form of lectures about ethical codes of conduct and working through case studies. These courses are often evaluated by a written test that can be based on a (inter-) national standardised test or be made to specifically fit the course content by the lecturer. That this approach has some caveats can be concluded from Sporre (2019) research where she does a deep dive on the Swedish national standardised test for ethics education and finds that "it is reasonable to conclude that it is a disadvantage for ethics education to be tested in such a way." Sporre (2019). As ubiquitous as evaluation using standardised testing might seem there is also a different very broadly applied evaluation method.

The second most common evaluation method in western EIT courses is the use of reflection reports. With reflection reports the students get assigned a specific case for which they then need to perform some ethical consideration and evaluation, gauging the given scenario based on different ethical structures and moral guidelines. In an attempt to improve upon the quality of EIT evaluation Savulescu et al. (1999) set up an instrument for evaluating students' performance solely based on handing in a paper, in their study there was however, no significant benefit found stating that: "We believe that the instrument is a useful, relevant formal assessment of ethical thinking skills. However, an alternative interpretation of the data is that the instrument is redundant: it performs similarly to the naive rater's global assessment" Savulescu et al. (1999). Many more studies followed and a contemporary literature review by Avci (2017) concluded that case-based learning is considered to be effective and beneficial. Next to these examples of regional or course specific evaluations there have also been some moves to establish an internationally standardised framework with which all EIT teaching could be evaluated.

A few frameworks were developed and only a small number of those were widely tested and discussed. The most used and well-regarded framework being the Defining Issues Test (DIT) of moral judgment, introduced by Rest et al. (1974) in the nineteen-seventies, which they later expended upon by forming the DIT2 (Rest et al. (2000)) in the early two-thousands. The DIT and DIT2 are written tests that aim to gauge ethical competence, the test takes around 45 minutes. The original DIT test was heavily based on the works of American psychologist L. Kohlberg, the revision of the test steered the method more towards the modern era. The DIT is a standardised test that can be used to gauge students' moral judgement and development, especially after its revision and restructuring in 2000 and it is widely used to measure potential impact of new EIT teaching methods. This was found and mentioned by Keefer et al. (2014) who formulated that the DIT2 is the most common example of a formal measure in EIT. This however does not mean that DIT2 is the only form of standardised EIT test that was developed since the original DIT in 1974 (Rest et al. (1974)) a good example, of an alternative test that follows a very similar structure, would be the "SMARTS" method as defined by Curzer et al. (2014) in their paper on the effectiveness and successfulness of current day EIT implementations. Due to the long testing time and poor repeatability of the test the DIT will not be used in the methodology of this study. Additionally, the DIT is a standardised test that has been around for decades now, so it is not often used to provide grades in actual education scenarios, as cheating by preparing your answers would be very easy.

This is relevant in two ways, first of all we now see that effectively teaching and grading EIT is still very challenging, and the ambiguity and social variance of EIT also makes it very challenging to gauge ethical development in an easy and standardized way. This makes it hard to design a simple case study for evaluating different methods or even teaching techniques that could for example include interactive installations. Another thing that can be taken away from this is that there is an obvious cause for the inclusion of more activating work forms like CBL of co-creation, these form a promising perspective for EIT teaching as they involve more of the complete process or project into the grading part of a course. Small workshops that combine these or indeed an immersive environment like the envisioned ethics lab might fill a role here.

3 STATE OF THE ART

Next to these teaching methods more physical artefacts of ethics in technology have also emerged. To give a better context for this project it is valuable to first take a look at the state of the art in teaching EIT. This context includes the landscape of similar projects and products that have already been made, and that have a focus on teaching ethics or inspiring ethical reflection within designers.

In the classroom there have been some examples of hands-on workshops or other activating hands-on or project-based methods, but none really use a physical-interactive installation. For close parables art installations like the installation "the Follower" by artist Dries Depoorter (Depoorter (2022)), who has many projects where he uses AI as foundation for an installation, can be reviewed. This installation is a piece of software that uses open cameras and images that it scraped from Instagram to locate the real location and time of capture of Instagram posts and show a second perspective of the moment the picture was taken. A side by side comparison of such an Instagram post and a capture from an open camera can be seen in Figure 1. Similar to this is another artefact on the topic of algorithms and artificial intelligence is the Dutch website "versealgoritmes.nl" by Vera van de Seyp and Roos Groothuizen (van de Seyp and Groothuizen (2023)). This is also an interesting installation that is trying to educate its users on the basic principles of artificial intelligence and online privacy. Both these examples are not directly suited for ethics courses in higher education as they were not designed with this target in mind, but they do form an interesting basis.

In higher education props (artefacts) and games are occasionally used for ethics teaching. Next to the already discussed hands-on variations of normal teaching, interesting concepts are also appearing where a lesson is based around an artefact (which could be an installation) or game. The wonderberry workshop, a workshop where students get to design packaging for a wonderberry pill that shifts our taste using a natural ingredient from a miracle berry, from "Wijs met techniek" by Eggink et al. (2022) is an excellent example of this.

Another interesting approach is the incorporation of games in ethics courses. There are plenty of examples of small review exercises or reflecting on something in groups but with the word "game" in this context a physical game is meant. There are fully developed examples like the board game "privacy by design" described by Shilton et al. (2020) that also uses simulation to engage students in the learning, that is mostly focused on computer

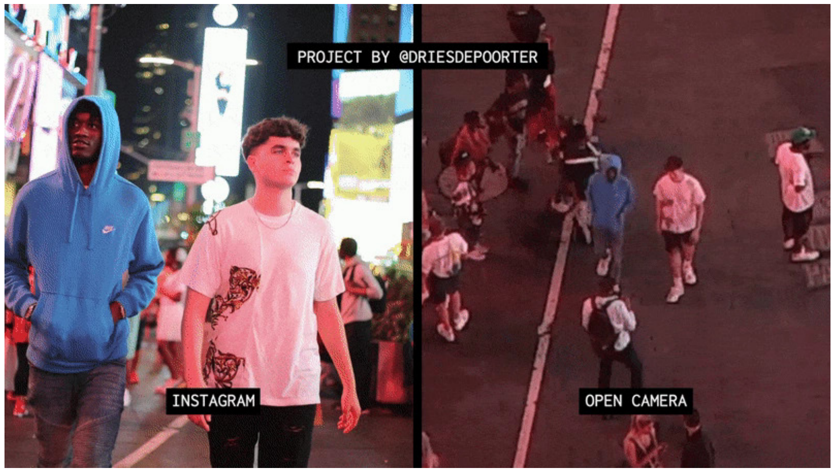

Figure 1. An excerpt showing ”the Follower” by Dries Depoorter

ethics. Alternatively, the card game described by Gordon et al. (2020) seems promising but could use a better reflection as that seems to be missing in their paper. A good example of a somewhat similar card/board-based game that was reflected upon by the author is the game from Rodriguez (2020) that in its own paper reflects:” Many of the responses appreciated how, as the scenarios reflected actual or everyday scenarios that could occur, this enabled them to apply what they learned in class to real-life situations.”

All in all, game based forms of ethical teaching might be interesting for further research, but even though some authors did inquire into what level the methods were engaging a solid research or framework to the effectiveness of these methods has not yet been done.

With a solid research framework in place studies could be done into the overall effectiveness of these approaches. If these approaches prove to be effective they could fit perfectly in course structures like CBL or they could be integrated in an environment like the ethics lab where the games or artefacts could be included in a set of small workshops that were aimed to exercise and gauge a specific subset of ethical thinking.

4 CONCEPT GENERATION

This chapter will go into the ideation phase, and later the more detailed concept generation, it will discuss all the background that was used as a basis and all the considerations and deliberations that were made to end up at the final design of an interactive installation.

To focus or guide the ethical content of the ethics lab the research group was already leaning heavily towards using classical ethical dilemmas. The dilemmas are thought experiments, ethical challenges or a well discussed visualisation (can be in writing or verbal) of an ethical theory. A good example of this is the trolley problem by Philippa Foot, the term was coined by Judith Jarvis Thomson. In this well-known example the exercise is that you envision a train on a railway speeding towards a junction, on both arms of the junction is some sort of individual or group who would be run over and killed by the train if the train continues that way, the player or the challenged person has to decide if they flip the switch for the junction and thus has to decide who to kill and who will stay alive. The trolley dilemma is just an example of such a dilemma but there are many more, in total we discussed 26 different dilemmas.

4.1 Selection of interesting dilemmas

After some exploring a preliminary discussion with the client was scheduled, here the explored concepts and the different ideas for interactive installations were laid out. We talked about the possible implications and we had some back and forth about the relevance and implementations of the different dilemmas. A few dilemmas were chosen to look further into, the client expressed a preference for some of the dilemmas but left the choice up to me. The following section will give a compact summary and overview of the dilemmas that were discussed next to the previously described trolley problem.

The first dilemma is a classical example, namely: Zeno’s paradox introduced by Zeno of Elea. The notion that a hare can never overtake a turtle in a race as the hare halves the distance to the turtle every time unit, so it will get closer and closer to the turtle but never overtake it. This is an example of a dilemma that is relatively well known, this example has more relation to mathematics but the fact that it makes us doubt if our view of the world is correct links it to ethics.

Another interesting example is the knowledge argument by Frank Jackson, this thought experiment (also referred to as "Mary's room") consists of visualizing a girl called Mary who grew up in and is still stuck in an enclosed room where everything is black and white, she does have access to study materials and is now a neuroscientist. Through reading she knows that roses are red and she knows the theory of light wavelengths and how humans perceive and register those as colours. If she would see a red rose or the first time, is that a new experience for her, will she learn anything from seeing this, or did she already know all the theory and does the addition of the real experience not matter anymore? This dilemma can be a spark to light a conversation about the definition of knowledge and if "knowing" is even possible.

Additionally, the Chinese room experiment by John Searle was investigated. In this dilemma you envision someone stuck in a room with an unlimited number of books containing instructions. This person gets a message on a piece of paper that slides under the door, the message is in mandarin (using mandarin characters) which this person does not speak or comprehend, but the books provide him with very clear instructions (if this input then answer that output) so the person can copy the answer from a book and slide that back under the door. This person can maintain entire conversations this way in a language he does not comprehend. Now we can argue to what degree this person understands Chinese, Searle divided this into two degrees, one where you really understand something and one where you are simulating an understanding. This thought experiment can easily be adopted to ai and computer programmes as this is the way that many computer programmes function.

The constant flux dilemma was also included, this ancient dilemma, introduced by Heraclitus states that one can never step into the same river twice. This because the water is always flowing so you are not stepping into the same water you are stepping into new water that just arrived and immediately flows further downstream. Now this is just a visualization, but Heraclitus went further by claiming that everything is constantly changing and that the world therefore is in constant flux.

4.2 Ideation based on ethical dilemmas

For each of these dilemmas an outline of a possible interactive installation around that dilemma is formulated, these course concepts were also discussed with the client and this eventually led me to choose the dilemma that was going to be physicalized into an interactive installation. At this point in the ideation these concepts were not fully worked out yet, but it does give a good idea of how someone might incorporate a dilemma in an interactive installation, the four half-concepts that were not chosen will be described in the coming paragraphs.

The first half-concept was based around the trolley problem. Already quite some games and website exist that challenge users with more and more difficult trolley switching problems. The idea would be to do a basic physicalization of one of these, bringing the experience into the real world. Here you can think of a box or a sizable suitcase that could unfold, inside would be a scale model of a railway with of course the famed switch. The switch allows the player (or "spectator") to choose which of the two tracks the train will go onto. On the two tracks would be a screen or a different media interface that would allow the installation to show the player ever more difficult choices. Then the player would choose, the train would drive, and maybe some sort of dramatic effect would happen (lights and sounds) to symbolize the impactful and maybe even horrific choice that was just made. The installation could be made portable so that the ethics group could use it in lectures and workshops as well as in the physical ethics lab.

Another half-concept was based on Zeno's paradox, this previously described dilemma is a semi-mathematical thought experiment where the outcome is that a hare can never overtake a turtle in a race. This idea would be virtual based, so the installation would consist mostly of a screen. The user would either get assigned or get the option to choose an animal or object (racecar, hot air balloon, hare, turtle, scooter etc.), they would then get to draw this object on a drawing tablet (or on paper underneath a camera). This object would then race something else (either a different player or maybe some pre-determined object/animal) on the big screen, the perspective would zoom in on the difference between the two objects, this space would become smaller and smaller but of course the player's object would never overtake the leading object. This installation is relatively simple to implement, has a semi interactive element and could be a fun addition to something like the ethics lab.

The next half-concept was based on the knowledge argument, which is most commonly known under the name of "Mary's room", this dilemma is also previously described. The idea would be a sort of game, the player would be prompted with three definitions (or keywords) of something, they would then have to draw this object on a drawing tablet. After they had finished they would be shown what the mystery object really was, then it would of course be interesting if they ended up drawing something completely different from what the source object originally was. In addition, the installation could collect images of interesting combinations, and show the player how previous players did in drawing their mystery objects based on the three word input.

Another half-worked-out concept was centred around the already discussed Chinese room dilemma from John Searle. This installation would take the form of a somewhat competitive game, where two spectators (or players) would be needed to properly interact with the installation. It would also lend itself really well to be observed from a third perspective, perhaps an audience would best get the chance to see the intended effect of the installation. The two players would be on opposite ends of the installation, each having a screen in front of them that the other player could not see. Player one would see a chat and would be chatting with someone (perhaps with some incentive like "get to know this and that about the other chatter"). Player two would be wearing noise-cancelling headphones and would be playing a quiz or some comparable simple to implement game that takes quite some user input. The input or "choices" that player two would be making would secretly be effecting the chat answers that player one would receive (through the implementation of a chatbot). The audience would be able to see what was going on (perhaps on a third screen) and could see that player two was secretly just picking the answers to player one's chat prompts, unknowingly keeping the conversation going. Then it would of course be very interesting to see how long the two players would keep playing this and if they ever would discover on their own what was happening while they interacted with the installation.

These are some of the projects that were discussed with the client and that could maybe have been worked out to full interactive installations, but the idea that was eventually chosen is slightly different. The next paragraph will go into the chosen dilemma and cover the ideation phase of creating an installation that has to do with this installation.

4.3 The chosen dilemma

After discussing these concepts with the client the preference went to the constant flux dilemma, so this concept was refined into a functional specification and outline of an interactive installation.The constant flux dilemma was interesting because it is a lesser known example but still a very approachable problem, it was also a practical fit for the ethics lab as it differed in experience from the two installations and dilemmas the other two students had picked and developed (see Schreurs (2023) and Nap (2023)). These installations were aimed at solo-interaction, one person would interact with the installation at a time while the proposed installation could be used by a big group at once through vicarious interaction. The installation is also a lot more abstract than the two installations that have already been placed in the ethics lab, taking a different approach with the same aim, to hopefully make it, so people have to take a moment to think about the installation which might prove useful as the goal is to stimulate reflection.

The chosen concept is an interactive installation with many moving arms, these arms are in constant motions, and this makes it so the installation constantly morphs into something else. The audience can take selfies or pictures with the installation that can then be displayed on an array of monitors behind the moving arms, of course none of these pictures are the same as the installation constantly looks different.

The aim was to express constant change and unpredictability to the spectators, so the design ended up being moving arms. The further ideation started with thinking of ways to make moving waves like the river in the anecdote. But the aim was to avoid spectators noticing patterns in the installation, or at least thinking they noticed patterns. Humans easily think they see a pattern if something has a slight aspect of repetition, so in the end the project moved away from waves and moving arms were chosen instead. The idea here was that the arms could cross each other's paths making the total installation a messy and difficult to follow clutter of multiple arms, this would hopefully make it less likely for a spectator to notice a pattern as the final result would look more chaotic. In Figure 2 a visualization can be seen that was generated using DALL-E, this of course is not the finished product, and it is also not entirely what I have in mind. But after sculpting the input and picking the best result out of the generated images Figure 2 comes closest to the planned build. This image was striking to me because the arms look like they are in motion, the installation also feels borderless because the tentacles of lights run away from the pedestal and connect to the walls and surrounding objects. This is an interesting effect but it is not certain if this is also to be included in the installation.

Figure 2 was one of the most gripping images that Dall-E generated, for this image the prompt:

Figure 2. A possible visualization of the installation (generated by DALL-E)

> a single artpiece on a pedestal, the artpiece has 8 moving robot arms (about 40cm long each) that never stand still and are constantly changing, this is all being controlled by an arduino and some electronics. behind this artpiece you see an array of monitors.

was used, in total about 30 different prompts (becoming more and more specific) were tried, and the description ended up being such a long-winded one. Dall-e definitely did not do the design work for me, but it did give some feedback on how you could conceive my descriptions, and it provided me with a good image to use when trying to convey my idea to others.

This concept is not yet fully defined, but further reflection and refining will improve upon the concept. The idea is to build the installation and then do a small trial with it with several different groups of students, each group will have a different level of explanation that accompanies the installation. After interacting with the installation, the students can convey in a focus group if they think they can use anything of this experience to improve the ethical reflection in their own design processes.

5 FUNCTIONAL SPECIFICATION

After deciding to visualize Heraclitus' constant flux theory it became time to formulate a plan for a feasible interactive installation. In order to get a better idea of common pitfalls in this stage of the project an expert interview was held with Volkert van der Wijk ,an experienced artist at comparable moving sculptures, the notes of which can be found in the appendix.

The idea is to make a collection of moving arms that not only are in constant motion but of which the total installation is also never the same. Extra attention was given to making sure that likely recurrence of a pattern was as little as possible, meaning that the machine would not repeat a pattern for as long as possible. This combination of constant motion and aiming to not repeat itself symbolizes the constant flux that Heraclitus described. The arms should also move enough and in a nice enough motion (like dancing) to grab the spectators' attention.

5.1 Specification

So in order to land on a suitable design a few design specifications had to be formulated, these can function as a guideline for the more detailed construction plan.

- A physical installation that can symbolize Heraclitus' constant flux dilemma.
- The installation should have moving arms.
- The interactive element should be accessible and keep in mind privacy and safety guidelines/laws.
- The installation should be durable enough so that it doesn't break itself and can withstand transport and some human interference.
- The installation should be somewhat portable and relocating it between rooms or even between buildings should not be too much of a problem.
- The installation should be easy to use, a lecturer or employee of the ethics lab should be easily able to operate it with minimal instructions.
- The installation should be sufficiently documented and accessible, a theoretical future student should have no problem continuing on the design.
- The installation should be safe, it cannot be strong enough to hurt humans and it should be designed with some fire safety in mind.

The goal of the installation is to make design students reflect on their products/projects by hopefully including Heraclitus' constant flux theory. This project and case study will form just a small trial with the hopes of answering the question of how effective an interactive installation based on an ethical subject can be in achieving this.

As was mentioned, the plans were discussed with an expert in this field, Volkert van der Wijk. A full reflection on the interview notes can be found in the appendix, but to summarize Volkert does believe that an interactive installation can have the potential to influence behaviour and stimulate reflection, but he is certainly not considering this an easy goal. Volkert had most success by first starting to gather and visualize what people think of when they think about your subject, the installation should be rooted in a primary feeling or reference that is grounded in the spectators' perception.

Volkert also had interesting experience with vicarious interaction, he found that the effect of interaction also worked on spectators who were not even interacting with the installation but were merely watching someone else interact with it. This effect of vicarious interaction within interactive installations could be looked at further as it could be an interesting solution to the scalability problem of EIT teaching with interactive installation.

5.2 Construction

Careful thought was put into the design of the installation, continuing on the ideation process and trying to visualize the constant motion. To realize this 6 arms were made which each have two joints, the arms themselves are constructed out of 3d printed PLA parts and aluminium square tube. And are directly driven by a mg996r servo, the hinge is made using a turned axle (made out of an m6 bolt) and a turned nylon bushing.

The centre to centre distance of the arm-segments is 200 mm, of which 115 mm is aluminium. The servos are mounted between two aluminium plates which are clamped together using four m4 bolts. These arms are mounted on a wooden frame. The servos will be powered at 5-7V, the exact voltage will depend on the torque needed to make the arms work smoothly. An Arduino and a 12-bit 16-channel PWM controller will be used to drive them all.

The idea is to have a computer generate the desired angles of the servos using a simulation in the programming language Processing, this simulation would calculate random angles but keep into account the possible collisions between different arms and the physical limitations of the servos (they for example can not rotate more than 180°). When the computer has a safe angle for every servo it will send these to the Arduino using a serial link, the Arduino will then drive the servos to the desired angles.

After having written this Processing code the resulting functions and used mathematical formulas were adapted to run directly on an Arduino. Of course the Arduino could not render a visual representation (something the Processing code could do) but for the bare functionality this was not a necessity. This process was optimized and simplified for the Arduino and the Processing code was used to validate the angles that the Arduino generated. The Arduino ended up using a simplified 2D environment for the arms, which could mostly be reduced to simple trigonometry. This was done as a test but it turned out that the Arduino could generate angles fast enough to run as a stand-alone installation. Taking only about 9 milliseconds to generate a set of angles and these angles are possible about 95% of the time. The sets of angles that are not possible are filtered out by the Arduino itself using some basic tests.

This makes the Processing code no longer a functional part of the installation, it was used as a tool in creating the project and later on as a validation tool for the Arduino code. But the Processing code will not be delivered with the final installation and it was therefore also not worked on further, it could be optimized some more, the graphical representation could be significantly improved and some more functions could be added. For a better overview of what this Processing sketch is and what it does, see the included overview in the appendix.

As one of the aims of the installation was to have it be always different and never repeating itself some different solutions to try to achieve this were considered. For example having a set database of angles which the arms would go through or just having a few joints picking angles from an array and then deleting those angles. All of this was to try and get the statistical chance of recurrence of a given combination as unlikely as possible. In section 6.4 more about the confidence of recurrence is explained.

Figure 3. A picture of the fully assembled installation

6 REALIZATION

Here the hardware and software will be discussed as they ended up, some parts went through multiple iterations before ending up at the working state that they are now.

6.1 Electronics

The electronics for this project ended up being straightforward, this is due to the installation not requiring a separate computer to generate the angles and also due to the fact that an off the shelf PWM controller was chosen.

Figure 5 shows a schematic overview of the electric setup. The system also includes a current sensor to monitor the consumed power, this feature was used during testing to detect when one of the servos was not powerful enough for its task and thus stalled. different supply voltages were tested as these servos support a voltage of up to 7 Volt, in the end a supply voltage of 5V was chosen as the extra torque that higher voltages could provide was not needed for the installation to function and the lower speed at 5V is actually nicer. The arms have a tendency to move too fast, so the code also includes a feature to limit the speed at which they change angle.

In Figure 4 the final electronics can be seen, from left to right: A power supply, a current sensor, an Arduino and the 16-channel PWM controller.

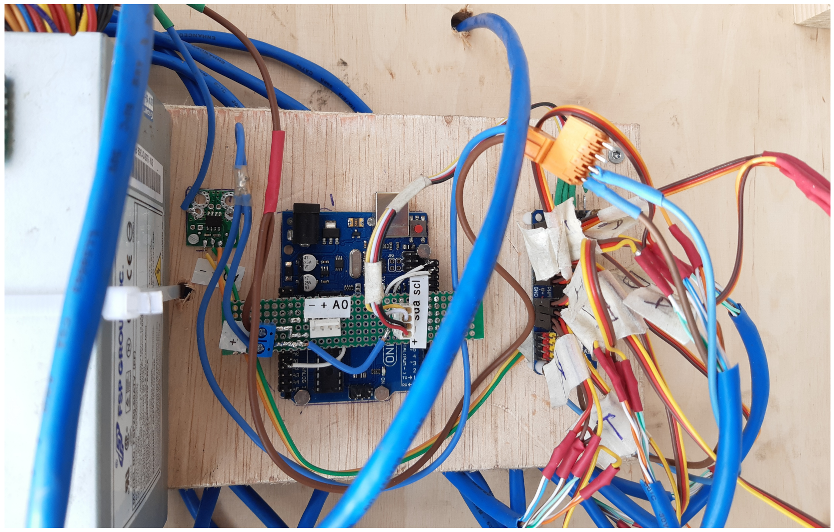

Figure 4. A picture of the electronics

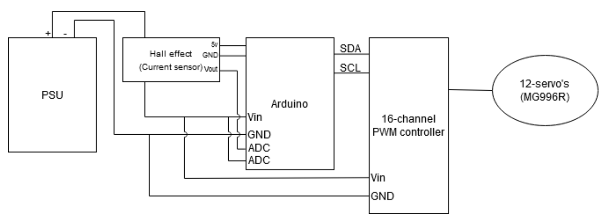

Figure 5. A schematic overview of the used electronics

6.2 Code

The installation runs entirely on the logic of the simple Arduino Uno, Figure 6 shows a schematic overview of the methods and functions in the Arduino code. The original Processing code relied heavily on the use of classes and objects but in the end this was mostly stripped from the Arduino code in order to improve efficiency. This does mean that some functions are calling on themselves in order to function, this does introduce the risk of a stack overflow but as the physical positioning of the joints is used the Arduino is sufficiently powerful for the aforementioned use-case, meaning it has enough memory to circumvent this happening.

The code now even includes a maximum rate of change for the motor angles in order to prevent the arms moving too quick and breaking themselves in this process.

6.3 Assembly

Now it became time to repeat the assembly process twelve times, to produce 14 sets (2 backups) of all the required parts. Figure 7a shows an overview of all the parts required for one arm joint, the nylon bushing and the axle had to be machined on a lathe and the aluminium plates were hand drilled and shaped using an angle grinder and a file, the rest of the parts were 3d printed.

The joints had to be assembled in their home (90°) position, as the servos can only move 180 degrees, so software calibration was very limited. After all the joints were assembled they were wired up and tested.

6.4 Statistical analysis

The joints are driven with a 12-bit driver, the average calibrated duty cycle for 0°'s is 23%, for 180°'s this is only 4%. This gives a range of 19%, for a 12-bit system (2^{12}) 19% is 778 steps. The code only supports change

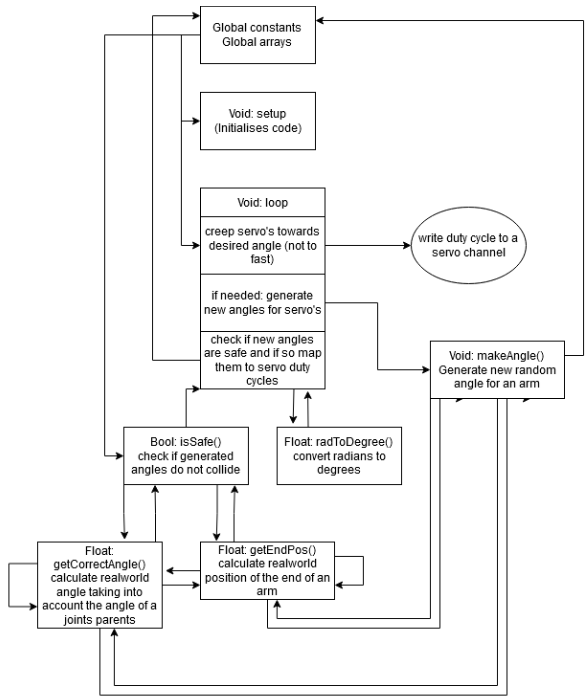

Figure 6. A code diagram of the final Arduino code

in step sizes of 2 so that leaves (778/2) 389 steps. This means the servos can be controlled with a step size of 180/389=0.46°'s.

The range of the servo's is hard limited between 20°and 160°and there is a dynamic limit to keep the arms from crashing into each other. For the bottom joints (the "anchor points") this limit is calculated by taking the arm length and the set limit to calculate the minimum allowed angle of the arm. $cos(12/20) * (180/\pi)$ this gives about 50°, as the current setup is symmetric the maximum allowed angle will be 180-50=130°. Resulting in a total of $((130-50)/0.46 = 173.9$ steps (rounded down is 173 steps), for calculations this amount of steps is assumed for all the joints. Later on an error factor will be used to filter out the fact that the upper joints behave differently as their allowed range is dependent on the angle of their parent joint.

A theoretical amount of different possible angle-combinations of the installation can be calculated with these approximations. That would be $173^{12} = 7.2 * 10^{26}$, applying an error factor of 0.7 to compensate for the previously ignored dynamic range gives: $7.2 * 10^{26} * 0.7 = 5.0 * 10^{26}$ possible combinations. The code (as can be seen in the appendix) picks a new combination every 1.5 seconds.

For the N_{th} draw the chance of that generated angle being a new angle (one that the installation hasn't had before) is $\frac{5.0*10^{26}-N}{5.0*10^{26}}$. So in total for the N_{th} draw the accumulated chance of not having a repetition is $\prod_{i=1}^{N} \frac{5.0*10^{26}-i}{5.0*10^{26}}$.

This cumulative product function with an input as high as 10^{26} is not easily solved, but could be approximated. The resulting amount of cycles where the confidence would be 98% will be very large. Without solving this cumulative sum function it is already apparent that the N will be large, as just obtaining a non-time dependent probability value of 99.98% will already take an i of around $1 * 10^{23}$ meaning around $1 * 10^{23} * 1.5 seconds = 1.5 * 10^{23}$ seconds so already more than a trillion years. (This is not the correct way to calculate this, and it does not mean that there is a 99.98% confidence that the installation will not repeat in a trillion years.) The actual expected amount of repetitions that the installation can do with a 98% confidence factor is found by solving the following formula:

$p(N) = \prod_{i=1}^{N} \frac{5.0*10^{26}-i}{5.0*10^{26}} = 0.98$ gives N=....

7 USER EVALUATION

Nine students of the minor "AI, Safety and Security" were interviewed, they gave insight in what they thought the installation visualized and on the possible applications of installations in EIT education.

(a) The individual parts of one arm joint **(b)** An arm joint almost fully assembled

Figure 7. The arm assembly

7.1 The plan

This test was done at Saxion in Apeldoorn, where the students had a guest lecture on EIT and I joined this guest lecture and interviewed the students in the break. The installation had fully working arms, so constant motion and a minimal change on recurrence. The possible interactive element was not yet implemented, and in the end this also wouldn't have been correctly tested as the interview was done as a plenary session. Meaning there was no opportunity for the students to individually interact with the installation.

The aim of this test was to find out if the end users (the students) thought an approach to EIT teaching like this interactive installation could be beneficial to their learning process. Meaning if they thought an installation could be more effective at communicating or inspiring ethical reflections skills or ethical dilemmas then a straightforward lecture would be. This is inline with research question 2:

- How effective is an interactive installation based on an ethical subject in stimulating ethical reflection.

The concrete plan was to set up the installation in a room of Saxion and have a few small groups of students interact with it. These groups of around 3-5 students would first answer some questions to gauge their pre-existing knowledge and opinions on the subject and would then interact with the installation. They would receive some explanation of what was going on and what they were seeing in order to make the process go smoother, the amount and extensiveness of this explanation would be varied (between about 3 different levels). This in order to see if the installation would become more or less effective dependent on the amount of information given around it.

The test users would be students from the minor "AI, Safety and Security", this is an example of the possible end users that the ethics lab's target audience consists of, so this would give a good idea of the possible uses of an installation like this. In the end the situation differed from what was expected so a slight variation on this research plan was executed.

7.2 The execution

The actual execution of the study went slightly different, this Saxion location did not have the option to set up the installation in a separate room thus the installation was forced to be placed in the lecture hall itself. This also took away the opportunity for doing multiple user-interaction sessions as the whole group would see the installation all at once, so the installation was shown to the entire class at once. The next unforeseen problem was that this minor was quite small, the class consisted of only 10 students of which 9 were willing to participate in the study so even if individual interaction had been possible, group sizes of 3-5 students would not have been feasible.

So the study was pivoted to consists of an online questionnaire with first some orientation questions, then a class-wide showing of the installation and then some further questions about the perceived effect and message of the installation, and about the possible use cases of interactive installations like these in EIT education.

In the end nine students filled out the questionnaire which consisted of two gauges on a Likert scale, two yes/no questions and five open questions. The students chose to answer the open questions in Dutch so for this report a translation will be used. An overview of the direct answers and their translations can be found in the appendix. What was also notable is that not all students had a technical background, some students studied for example integral safety science, human resource management, archaeology, or law. Due to the relatively small test size the Likert scale answers will be used mostly as individual opinion gauges and not as quantitative data sources, the findings will be mostly based on the qualitative insight that the open questions gave into the perspectives of the students.

An example of the qualitative insight that this data can provide is the following answer that one of the students gave to the question ”What do you think this is? (or what do you think it visualizes?)[about the interactive installation]”:

> *Reflection of society/groups. Everyone moves differently.*

In part from these answers a couple of interesting patterns can be concluded, For example, it can be seen that the students picked up on the message of movement, they specifically name movement and that movement differs from person to person. It can also be seen that even the tougher message of the higher meaning of the dilemma and therefore the installation got picked up on, as the students mention reflection and that is precisely what the installation was meant to stimulate.

7.3 The findings

All in all the interviews gave interesting insight to process. To the question if EIT has a relevance within their studies the participants answered that this is somewhat the case, only one outlier answered that they did not see a relevance in EIT, the rest of the participants indicated that they did see a use for EIT education being there. What was also interesting was the answers to the question ”Can you elaborate (why does/doesn’t ethics fit your study?)”, here some of the answers showed a compelling contradiction:

> *-Without it, development will be able to go faster. With ethics one will develop boundaries rather than with certain thoughts.*
> *-Technology is often at the forefront of social/political change, so ethical issues must be addressed during the development of the technology.*

If we use open coding (the first step of a grounded theory analysis as also described by Sosa-Díaz and Valverde-Berrocoso (2022)) on the answers to the question ”What do you think this is? (or what do you think it visualizes?)” we get a table like Table 1. This shows that the key values of the installation were mostly communicated effectively. The test users got the point that the installation was meant to symbolize change and motion, giving a hopeful foresight to RQ2 which was about the effectiveness of installations like this in EIT teaching and in stimulating ethical reflection.

keyword	occurrence
differences	3
movement	3
respond to each other	2
change	2
communication	1
random	1
signals	1
adaptation	1
reflection of society	1
learning	1
learning to walk	1

Table 1. Open coding result on answers to the question ”What do you think this is? (or what do you think it visualizes?)”

What is especially interesting in table 1 is that we can see that the key-words “differences”, “movement” and “change” come back. These of course describe a key-value of what I was trying to convey with the installation, and the students did pick up on this before I explained what it was they were looking at. This is a clear indication that at least some of the desired effect has been reached.

As another form of user evaluation the installation was presented to the client. A big part of the ethics research group was present, and the presentation was a success. A nice observation of this presentation was the amount of discussion that the installation caused. As there is not yet a decisive implementation plan on how to integrate the installation in a classroom environment some discussion around different approaches arose, one of the lecturers started brainstorming on different tips that could be mounted to the arms (hands, fists, heads, puppets). Another discussed topic was the idea to put 10 people in a room with the installation and note or record what they are saying, the research group seemed very curious to what the conversation would steer, and how it would differ from run to run with different people.

All in all the research group seemed happy with the installation and even though they don't have any concrete plans for implementation they did seem interested on further testing in this topic area

8 DISCUSSION AND CONCLUSION

Ethics in Technology is an interesting field, the many attempts to applying different teaching methods and work forms next to the widely discussed ambiguity and great influence of perspective of the subject show that reform or innovation in the applied teaching methods would be a very interesting development. This is amplified by the social and academic relevance of EIT as a field, and including more activating working methods like the discussed CBL or co-creation does show a promising future.

This installation could be included in a CBL or Co-creation work form, within Co-creation the set out assignment could for example be to make a workshop that is centred around the installation and that uses the installation to stimulate ethical reflection in the students, during the process of designing this workshop the students could learn a lot in the field of ethical reflection. Combining the installation with pre-existing work forms like the above-mentioned CBL and Co-Creation could prove beneficial and would give interesting research opportunities.

The installation is now an artefact within EIT that complements the other artefacts found in the State-of-the-Art chapter. It differs from many as it is more abstract and partly due to this it could be adapted for a specifically designed workshop around the installation or for a course using CBL where the installation can be the artefact that poses the challenge. The students could for example be given the challenge to improve upon the installation, by working together and setting a goal they could learn a lot during the CBL process of modifying or adapting the installation.

A factor that limits what can be done with the obtained data in the user study is that the group size was relatively small, with only 9 participants the effect could still be seen, but a larger group would have allowed for a better testing structure and just generally more data points to base conclusions on. If the group had been bigger small groups of students would have been able to interact with the installation individually, as it was designed to be used. This would have also allowed for tweaking in small parameters like the amount of background information given to the spectators.That would have meant that the study could give better insight into how to shape an interactive installation to obtain the best results when it comes to stimulating ethical reflection.

As this case study was performed on a group of students who all chose to do this minor (which has to do with ethics) the group of interviewees is possibly skewing the positive result of the test. In this case, this does not necessarily form a practical limitation here though, as the target audience of the ethics lab is Saxion students and the use case of the installation is to be used as an educational example or topic starter in an ethics course. So the tested group is a nice representation of the eventual target audience of the project.

Furthermore, the phrasing of research question 2 posses a challenge, research question 2 states: "How effective is an interactive installation based on an ethical subject in stimulating ethical reflection?". It is very difficult to attach a decisive conclusion to this question as the question is very wide.

For example, the subject "an interactive installation" might point to a number of different implementations and artefacts around an ethical dilemma, depending on your definitions this description could also include common teaching tools like an online quiz or puzzle. In my opinion the installation part of the sentence does delimit the subject to physical machines or real-world artefacts that a user interacts with, but this of course is still very broad. During ideation the concept for the arm installation was formulated and such this study focused on this installation specifically.

The same argument can be made for the "ethical subject" part of the question, the impact, implementation and result of the applied ethical subject can be wildly different. Of course this study picked the constant flux dilemma and focused on that. Not to mention of course the cultural and context dependence of this, it is already broadly found that EIT teaching and ethical theory itself differ from region to region, and this certainly would also be the case for the resulting interactive installation.

The consensus is that teaching and grading EIT is a very challenging undertaking, new and experimental teaching methods like Co-creation or highly integrated workshops are being posed as possible aids in the further improvement of EIT education. Tests like the DIT2 or some national-level implementations of standardized test mainly show how hard it is to properly gauge ethics as a skill, yet development of better teaching methods is very difficult without a broad framework to measure ethical competence with.

There are also examples of artefacts that have been made around ethical questions but the proper implementation of these in an education environment is not wide-spread, and would be assisted by the establishment of such a described framework to measure EIT competence with.

The project still shows a promising result, even tough the full proposed interactive element of the installation was not implemented. Meaning that the final installation did not have the screens or the signs to stimulate taking selfies with the installation, but the lack of these does improve the installation's ability to be used by bigger groups at once. This functionality would have given an interesting opportunity to look into the effect that such interaction can have on the spectators.

The user study with 9 students gave interesting results as a qualitative test, but I suspect this is just touching the surface of possible implications that techniques like this can have. The interview answers show interesting takes on the installation and can help understand the thought process of the target audience better, but a large scale quantitative study could give more decisive statistical evidence around the presence/absence of the desired effect.

This gives a context from which it can be concluded that innovative teaching methods for EIT are a welcome addition as the subject is already difficult to teach and evaluate. Interactive installations and designed immersive environments like the discussed ethics lab might prove to be a useful tool for improving the quality of EIT education but due to the broad sense of the subject and the discussed limitations it is not possible to conclusively prove or disprove this with the data at hand.

9 FUTURE WORK

All in all this project did show some interesting facades of the use of interactive installations in EIT teaching. Further research into the effect of a combined environment could be done, as the goal of the ethics research group is to establish an ethics lab where multiple interactive installations can be displayed and used the possible reinforcing or overloading effect that such an environment might have can very well be significant and is therefore very suitable for a broader test.

It might also prove fruitful to do a project continuing on this installation but with a better testing methodology, a controlled testing environment and better separated user groups might lead to some more results. Of course the interactive element can then also be further developed and examined.

As the ethics research group progresses with the ethics lab it will become more and more reliable to test the possible effect of installations on ethics teaching. As of now the observed range of possible implementations is quite small but with a more fleshed out ethics lab a better study could be setup to test the real impact of a concept like installation-based teaching.

REFERENCES

Antes, A. L., Murphy, S. T., Waples, E. P., Mumford, M. D., Brown, R. P., Connelly, S., and Devenport, L. D. (2009). A meta-analysis of ethics instruction effectiveness in the sciences. *ETHICS BEHAVIOR*.

Avci, E. (2017). Learning from experiences to determine quality in ethics education. *International Journal of Ethics Education*.

Bombaerts, G., Doulougeri, K., Tsui, S., Laes, E., Spahn, A., and Martin, D. A. (2021). Engineering students as co-creators in an ethics of technology course. *science and Engineering Ethics*.

Bovill, C. (2019). Co-creation in learning and teaching: the case for a whole-class approach in higher education. *The Int. Journal of Higher Education Research*.

Curzer, H. J., Sattler, S., DuPree, D. G., and Smith-Genthôs, K. R. (2014). Do ethics classes teach ethics? *Theory and Research in Education*.

Depoorter, D. (2022). the follower.

Eggink, W., van der Heijden, K., Dorrestijn, S., and Ouwens, I. (2022). Tool-based ethics education for engineers; wonderberries and wisdom tiles. *Proceedings of the 24th International Conference on Engineering and Product Design Education*.

Gordon, D., O'Sullivan, D., Stavrakakis, I., and Curley, A. (2020). Homo ludens moralis: Designing and developing a board game to teach ethics for ict education. *international conference on the ethical and social impacts of ict*.

Keefer, M. W., Wilson, S. E., Dankowicz, H., and Loui, M. C. (2014). The importance of formative assessment in science and engineering ethics education: Some evidence and practical advice. *Science and Engineering Ethics*.

Kiran, A. H. and Verbeek, P.-P. (2010). Trusting our selves to technology. *Knowledge, Technology Policy*.

Mathur, S. R. and Corley, K. M. (2014). Bringing ethics into the classroom: Making a case for frameworks, multiple perspectives and narrative sharing. *International Education Studies*.

Meinking, K. A. and Hall, E. E. (2022). Co-creation in the classroom: Challenge, community, and collaboration. *College Teaching*.

Nap, T. E. (2023). Interactive installation for an educational ethics lab.

Rest, J., C., D., C., R., M., J., and A., D. (1974). Judging the important issues in moral dilemmas: An objective measure of development. *Developmental Psychology*.

Rest, J. R., Narvaez, D., Thoma, S. J., and Bebeau, M. J. (2000). A neo-kohlbergian approach to morality research. *Journal of Moral Education*.

Rodriguez, S. B. (2020). Using a game for undergraduate global health students in the united states to practice applying ethical research principles. *Learning and Teaching*.

Savulescu, J., Crisp, R., Fulford, K. W. M., and Hope, T. (1999). Evaluating ethics competence in medical education. *Journal of Medical Ethics*, 25(5):367–374.

Schreurs, M. (2023). Interactive installation for an educational ethics lab.

Shilton, K., Heidenblad, D., Porter, A., Winter, S., and Kendig, M. (2020). Role-playing computer ethics: Designing and evaluating the privacy by design (pbd) simulation. *Science and Engineering Ethics*.

Sosa-Díaz, M.-J. and Valverde-Berrocoso, J. (2022). Grounded theory as a research methodology in educational technology. *International Journal of Qualitative Methods*.

Sporre, K. (2019). Assessing ethics education through national tests–an advantage or not? *Journal of Curriculum Studies*.

Stavrakakis, I., Gordon, D., Tierney, B., Becevel, A., Murphy, E., Dodig-Crnkovic, G., Dobrin, R., Schiaffonati, V., Pereira, C., Tikhonenko, S., Gibson, J. P., Maag, S., Agresta, F., Curley, A., Collins, M., and O'Sullivan, D. (2022). The teaching of computer ethics on computer science and related degree programmes. a european survey. *International Journal of Ethics Education*.

Valentine, A., Lowenhoff, S., Marinelli, M., Male, S., and Hassan, G. M. (2020). Building students' nascent understanding of ethics in engineering practice. *European Journal of Engineering Education*.

van de Seyp, V. and Groothuizen, R. (2021-2023). verse algoritmes.

van den Beemt, A., van de Watering, G., and Bots, M. (2022). Conceptualising variety in challenge-based learning in higher education: the cbl-compass. *European Journal of Engineering Education*.

Yang, Z., Zhou, Y., Chung, J. W., Tang, Q., Jiang, L., and Wong, T. K. (2018). Challenge based learning nurtures creative thinking: An evaluative study. *Nurse Education Today*.

10 APPENDIX A: EXPERT INTERVIEW

Notes expertinterview with Volkert van der Wijk

Dr. Ir. Volkert van der Wijk is an assistant professor at the TU Delft and an artist who focuses on dynamically balanced moving sculptures. He made many of these moving sculptures of which many are available online via www.kineticart.nl

On Tuesday the 16th of May I called him to discuss my project and ask for his input on the subject. We had previously agreed upon this time via email and Volkert could spare the time because he was driving at that moment.

I asked him how he designs an installation with a specific feeling/message/goal in mind, he explained that it is very important to start the ideation journey from the viewpoint of the spectator. It is important to let your ideas run wild without linking things to physically feasible installations.

So for my specific project it would be a good idea to first think deeply about the word “random”, or “change”. How can we visualize this word? And what feeling/object/anecdote do people think of when they really focus on this word? If I would start with really shaping this thought, I could later think of a way to incorporate this finding in an interactive installation.

I asked him if he has a guideline for the amount and the type of motion a installation needs to capture the spectators attention. He explained that it is enormously difficult for an installation to cover more than one goal at once, you draw the spectator’s attention to one thing, and you can give direction in what that one thing is. But switching between or being focused on two things at once will in general have a negative effect on the installation.

He also went into the power of interaction for capturing the spectator’s attention, people are drawn to buttons and switches and like to explore how they can be in control of an installation. In Volkert’s experience interaction doesn’t even seem to be limited to one spectator. As vicarious interaction seems to also work very well at capturing people’s interest.

After talking a little about my plans for an installation he also recommended that I look into an art project called “De Spullenmannen”, a collective in the Dutch town of Amersfoort that uses reused stuff (“Spullen”) to build theatrical installations and environments. This collective has been active for quite some time and has made many interesting installations over the years that I could use to draw inspiration from. What especially draws me to this project is that they also specifically aim to search for the best way to convey a single topic, then per project they vary the subject.

We also talked about the potential for interactive installations to teach spectators new theories or to influence their behavior in such a way that it could stimulate incorporating ethical reflection in their own design process and we are convinced that installations can definitely have an impact on their spectators. But it is difficult to say that they are suitable for teaching new theories and the goal of influencing people’s behavior is an ambitious one.

In the end I think that I took away quite some useful input from this conversation and I am grateful for Volkert’s time in this.

11 APPENDIX B: PROCESSING SKETCH

An overview of the Processing arm simulation code

In order to control the arms of the installation I started with a simple Processing sketch to simulate the arms. This sketch could validate where the arms would end up at different angles and warn if certain angles would cause collisions.

Processing is a simple coding language based on Java that is specifically developed to be used as an introduction to coding in classroom environments, that is also how I got to know this language. Processing is versatile and can easily be used for a wide range of different coding projects. In this case I chose to use Processing as I have a lot of experience with the software (both in my bachelor courses and in my minor as a high school computer science teacher), and had also already made projects where Processing and an Arduino worked together before.

Of course I started with simple 2D representations and logic, after having the basics laid out I transitioned to using P3D renderer, an integrated renderer in Processing that allows you to render and work with 3D objects. The original idea of the project was to have a laptop running Processing generate sets of angles for the motors that would set the arms in possible positions (no crashes or collisions). After having written the Processing code that generates random angles (within physical limitations) I translated this code to work directly on an Arduino, and after some small changes and optimizations (I for example chose to make the code a straight script instead of an object-oriented program that used classes) I decided to let the Arduino handle the generation of new angles.

There are two big difference between the Arduino and the Processing implementation. The first big difference is that the Processing code uses a class “Arms” and a different object for each joint (a joint is either an “Anchor” (bottom joint) or an “arm” (one of the joints that follow the Anchor)), the Arduino implementation does not do this but instead stores all the necessary information in a global array called “arms”. The second big difference is that the Processing code implements the PVector library, this library offers the direct implementation of vectors in Processing, including basic vector transformations like multiplications, headings and the normalization of vectors, the Arduino code does not do this but instead uses basic trigonometry to reach the same result.

Making the Arduino generate angles reliably could of course not be done without testing, so I let the Arduino generate 100 different sets of angles and imported those into the Processing sketch to check them for collisions and possible other problems. Now that there are basically no problems that this code can detect any more (problems related to inertia and torque are for example not simulated but can be avoided by giving the joints a relatively low maximum speed) the Arduino is trusted on its own, making the Processing code redundant.

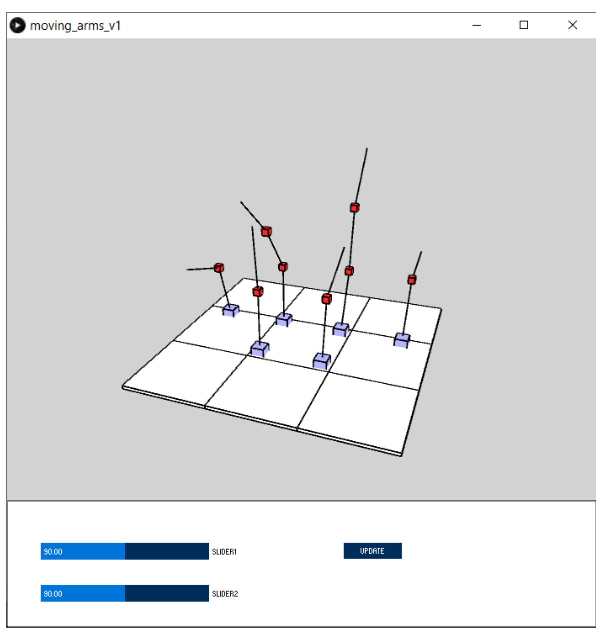

Figure 8. Visualization of the arms, generated with Processing

12 APPENDIX C: ARDUINO CODE

The Arduino code as it was at the user study.

```
/*
  Code for controlling up to 16 servo's using the adafruit PCA9685 servo driver.
  The arduino calculates random servo angles that are still physically possible.
  Willem van Dijk, 9-6-2023

  Using a "16-kanaals I2C PWM-Servo Aansturing - PCA9685"
  Arduino, servo driver
  SCL  -> SCL
  SDA  -> SDA
  5V   -> VCC (make sure you don't use V+ as there is a difference between these)
  GND  -> GND

     alu is 115mm

*/
#include <Wire.h>
#include <Adafruit_PWMServoDriver.h>

const int stepTime = 12; //in ms how long does taking a step of +-
const int stepSize = 2; //max step size that can be done in stepTime
const int generationTime = 1500; //ms between generating new angles
unsigned long nextGenTime = millis() + generationTime;

const float boundingSize = 12; //horizontal cm to each side from the centre point in which the arm is allowed to be
const float errorFactor = 0.7; //1=full trust, 0=no trust
const float servoRange[] = {0.349, 2.793}; //between 20 and 160 degrees

/* joints (servos) arranged in a grid
         -------------------------
         | A-B | C-D | F-G | I-J |
         |     | E   | H   |     |
         -------------------------
         |     | K-L | M-N |     |
         |     |     |  !  |     |
         -------------------------
*/
//array that holds all the arm data: structure:armID,angle(inRad),type(1=anchor),armLength,parentId.
#define N_ARMS 14
float arms[N_ARMS][5] = {
  {0, 1.57, 1, 20, 0}, {1, 1.57, 0, 20, 0},
  {2, 1.57, 1, 20, 0}, {3, 1.57, 0, 20, 2}, {4, 1.57, 1, 20, 0},//arm ingekort dus armId 4 is niet meer
  {5, 1.57, 1, 20, 0}, {6, 1.57, 0, 20, 5}, {7, 1.57, 0, 20, 4},
  {8, 1.57, 1, 20, 0}, {9, 1.57, 0, 20, 8},
  {10, 1.57, 1, 20, 0}, {11, 1.57, 0, 20, 10},
  {12, 1.57, 1, 20, 0}, {13, 1.57, 0, 20, 12}
};

int servos[][5] = {
  //calibration of servo angles (in length (ms)), 0 degrees, 90 degrees, 180 degrees
  //servos[3-4]= currentPulseLength, desiredPulseLength
  {970, 615, 213, 600, 615}, //servo A
  {970, 601, 225, 586, 601},
  {952, 567, 200, 552, 567}, //servo C
  {978, 595, 215, 580, 595}, //servo D
  {937, 550, 170, 535, 550}, //servo E er uit gehaald
  {945, 550, 185, 535, 550}, //servo F - loopt wat stroef
  {940, 560, 170, 545, 560},
  {940, 570, 180, 550, 570},
  {933, 550, 177, 535, 550},
  {1020, 580, 175, 551, 566}, //servo J
  {945, 563, 185, 548, 563}, //servo K
  {931, 551, 166, 536, 551},
  {955, 576, 166, 561, 576},
  {932, 560, 192, 545, 560}
};


Adafruit_PWMServoDriver pwm = Adafruit_PWMServoDriver(); //initialise the board at adres 0x40
int pulseLength = 0; //pulse length count, so how long is the signal on...


void setup() {
  Serial.begin(9600);
  delay(200);
  Serial.println("Started");

  pwm.begin();
  //Possible problem: the oscillator of this board is not calibrated by default, so if the system acts weird it might come down to this calibration.
  pwm.setPWMFreq(100); //setting pwm frequency to 100Hz.
  delay(40);
}

void loop() {
  //set the servos to angles:
  for (int servo = 0; servo < 15; servo++) {
    int desiredPulseLength = servos[servo][4];
    int pulseLength = servos[servo][3];
    if (pulseLength != desiredPulseLength) {// if currentPulseLength != desiredPulseLength
      int difference = desiredPulseLength - pulseLength;
      if (difference > stepSize) {
        difference = stepSize;
      }
      if (difference < -stepSize) {
        difference = -stepSize;
      }
      pulseLength += difference;
      servos[servo][3] = pulseLength;
      pwm.setPWM(servo, 0, pulseLength);
    }

  }
  delay(stepTime); //wait stepTime ms

  //check if we should generate new angles:
  if (nextGenTime <= millis()) {
```

```
    //calculate possible angles:
    int started = millis();
    for (int i = 0; i < N_ARMS; i++) {
      makeAngle(i);
    }
    int ended = millis();
    Serial.println("Generation took " + String((ended - started)) + " milliSeconds");
    nextGenTime = millis() + generationTime;

    //set the angles to the servos:
    if (isSafe()) {//if these angles are save:
      for (int servo = 0; servo < 15; servo++) {
        if ((arms[servo][1] >= servoRange[0] ) && (arms[servo][1] <= servoRange[1] )) {
          //set the pulselength to the corresponding ammount based on the angle and the calibrated values per servo
          pulseLength = map(int(radToDegree(arms[servo][1])), 0, 180, servos[servo][0], servos[servo][2]);
        } else {
          pulseLength = servos[servo][1];//the 90 degree setting of this servo
        }
        servos[servo][4] = pulseLength;
      }
    } else {
      Serial.println("isSafe() failed, averted a possible crash");
    }
  }
}

bool isSafe() {//function for checking if the calculated angles are possible (to avoid a crash)
  bool possible = true;
  bool posProblem = false;
  bool angProblem = false;

  float positions[N_ARMS];
  for (int i = 0; i < N_ARMS; i++) {
    positions[i] = getEndPos(i);
    if (positions[i] < -boundingSize || positions[i] > boundingSize) {
      possible = false;
      posProblem = true;
    }
    if ((arms[i][1] <= servoRange[0]) || (arms[i][1] >= servoRange[1])) {
      possible = false;
      angProblem = true;
    }
  }
  //  if (!possible) {
  //    Serial.print("\tNOT possible:");
  //    if(posProblem){Serial.print("position problem! ");}
  //    if(angProblem){Serial.print("angle problem! ");}
  //    Serial.print("\n\tpos:[");
  //    for (int i = 0; i < N_ARMS; i++) {
  //      Serial.print(positions[i]);
  //      Serial.print(",");
  //    }
  //    Serial.print("]\n\tang:[");
  //    for (int i = 0; i < N_ARMS; i++) {
  //      Serial.print(radToDegree(arms[i][1]));
  //      Serial.print(",");
  //    }
  //    Serial.println("]\n");
  //  }
  return possible;
}

float radToDegree(float rad) { //function for converting radians to degrees
  return rad * (180 / PI);
}

float getCorrectAngle(int armId) { //calculate the real-world angle of a point (taking into account the angles of all the parrents)
  float tempAngle = 0;
  if (int(arms[armId][2]) == 0) { //if this is an arm not an anchor.
    tempAngle = arms[armId][1] + getCorrectAngle(int(arms[armId][4])) - (0.5 * PI);
  } else {
    tempAngle = arms[armId][1];
  }
  return tempAngle;
}

float getEndPos(int armId) { //calculate the real-world position (x) of a point (taking into account the angles of all the parrents)
  float tempPos = 0;
  if (int(arms[armId][2]) == 0) { //arm:
    tempPos = (cos(getCorrectAngle(armId)) * arms[armId][3]) + getEndPos(arms[armId][4]); // position is cos(angle)*armLength+positionParent
  } else { //anchor:
    tempPos = cos(getCorrectAngle(armId)) * arms[armId][3]; //an achor is always in the middle of the axis system
  }
  return tempPos;
}

void makeAngle(int armId) { //generate a random angle for an arm (taking into account restrictions)
  float minAngle;
  float maxAngle;

  float ownArmLength = arms[armId][3];

  switch (int(arms[armId][2])) {
    case 1: //this arm is an anchor point
      minAngle = cos((boundingSize * errorFactor) / ownArmLength);
      maxAngle = PI - cos((boundingSize * errorFactor) / ownArmLength);
      arms[armId][1] = float(random(int(minAngle * 100), int(maxAngle * 100))) / float(100);
      break;
    case 0: //this is an arm (so we need to take into account the angle of the parent)
      int parentId = int(arms[armId][4]);
      float baseAngle = getCorrectAngle(parentId);
      float parentArmLength = arms[parentId][3];
      float parentEnd = getEndPos(parentId);
      float distanceRight = (boundingSize * errorFactor) - parentEnd;
      float distanceLeft = (-(boundingSize * errorFactor) - parentEnd) * -1;

      //calculate minimum angle:
      if (distanceRight >= ownArmLength) { //check if we need to calculate
        minAngle = servoRange[0];
      } else {
```

```
        minAngle = acos(distanceRight / ownArmLength);
      }
      minAngle += (0.5 * PI) - baseAngle; //account for angle of parent
      if (minAngle <= servoRange[0]) {
        minAngle = servoRange[0]; //check set limitations
      }

      //calculate maximum angle:
      if (distanceLeft >= ownArmLength) {
        maxAngle = servoRange[1];
      } else {
        maxAngle = PI - acos(distanceLeft / ownArmLength);
      }
      maxAngle += (0.5 * PI) - baseAngle; //account for angle of parent
      if (maxAngle >= servoRange[1]) {
        maxAngle = servoRange[1]; //check set limitations
      }

      //create random angle within constrictions
      arms[armId][1] = float(random(minAngle * 100, maxAngle * 100)) / float(100);

      //          if(armId==N_ARMS-1){
      //          Serial.println("data for arm"+String(armId));
      //          Serial.println("dR="+String(distanceRight)+" dL="+String(distanceLeft));
      //          Serial.println("that means acos(dL/20)="+String(degrees(PI-acos(distanceLeft/float(ownArmLength))))+"   ");
      //          Serial.println("base angle calibration: angle +="+String(degrees((0.5*PI)-baseAngle)));
      //          Serial.println("minAngle="+String(degrees(minAngle)));
      //          Serial.println("maxAngle="+String(degrees(maxAngle)));
      //          Serial.println("arm= "+String(radToDegree(arms[armId][1]))+" that was between "+String(int(radToDegree(minAngle)))+"&"+String(int(radToDegree(maxAngle)
      //          }
      break;
    default:
      Serial.println("switch in update method defaulted");
      break;
  }
}
```

13 APPENDIX D: ETHICAL DILEMMAS

An overview of the dilemmas and possible subjects that were originally posed by and discussed with the ethics group

- Falsifiability (Black swans) Karl Popper or white raven (Carl Gustav Hempel)
- Zeno's Paradox (turtle and the hare) Zeno of Elea
- Eternal recurrence (no decision, always the same) old but revived by Nietzsche
- Plato's cave (projection of reality without knowing) Plato
- Theseus's ship (replace all parts, which one is real?) [Mythology/legend]
- Trolley dilemma (weighing decisions) Philippa Foot, term coined by Judith Jarvis Thomson
- The Chinese Room (what is intelligence or conscious?) John Searle
- Brain in a vat (how do we know things for certain?) René Descartes adapted by Gilbert Harman and Hillary Putnam
- Constant flux (can you step into the same river twice?) Heraclitus
- The knowledge argument (aka Mary's room, is knowing the same as knowing?) Frank Jackson
- What is it like to be a bat? Thomas Nagel.
- Panopticon, Bentham-Foucault
- Veil of ignorance, John Rawls
- Denkgereedschappen (Paul Wouters, filosofische methoden uitgelegd aan de hand van een gereedschap als: hamer, wig, etc)
- Turing test (linked to the Chinese room dilemma)
- Agora (Greek), A dedicated place for joint discussion.
- Nietzsche's hammer
- Product impact tool [https://productimpacttool.org/en/applications/]
- Necker kubus (Don Ihde), What do you see in such an optical illusion, multi stable. Only in practice do you know for sure.
- The Milgram experiment (authority, electric shocks)
- Cartesian theatre (Daniel Dennett)
- Kierkegaard's existential philosophy
- Experience machine (Robert Nozick) (Would you enter an eternal happiness machine?)
- The Parliament of Things (Latour)
- The scale (or libra) of lady justice

14 APPENDIX E: INTERVIEW ANSWERS

An overview of the different answers to the open questions, including their freely translated English meaning.

Can you elaborate (why does/doesn't ethics fit your study?)	
Zonder zal de ontwikkeling sneller kunnen gaan. Met ethiek zal men eerder grenzen dan wel met bepaalde gedachten ontwikkelen.	Without the development can go faster. With ethics, people will develop boundaries rather than with certain thoughts.
Aan techniek zitten vraagstukken	There are issues connected to technology
Omdat we in de lessen hiermee te maken hebben gehad.	Because we have had to deal with this in the lessons.
Omdat techniek veel dilemma's met zich mee brengen waar	Because technology entails many dilemmas
Technologie ligt vaak aan het begin van sociale/politieke veranderingen, ethische kwesties moeten dus worden behandeld tijdens de ontwikkeling van de technologie.	Technology is often at the start of social/political changes, ethical issues must therefore be treated during the development of technology.
Ethiek speelt zeker een rol in de minor die ik volg. Het gaat vooral om de vraag waar een ethische hacker moet stoppen met hacken	Ethics certainly plays a role in the minor that I follow. It is mainly about the question of where an ethical hacker should stop hacking
Het past wel bij mijn minor. Je kan ethiek namelijk in meerdere opzichten zien	It fits my minor. You can see ethics in several ways
Ehtiek heeft een groot aandeel tijdens een technische studie, bijvoorbeeld het verwerken van gegevens en cybercriminaliteit	Ethics has a large share during a technical study, for example the processing of data and cyber crime
Ik denk dat technologie en ethiek altijd hand in hand moet gaan om tot een goede oplossing kunt komen	I think that technology and ethics should always go hand in hand to come to a good solution

Table 2. Interview answers to the question "Can you elaborate (why does/doesn't ethics fit your study?)", with English translation

What do you think this is? (or what do you think it visualizes?)	
Stokjes die op elkaar reageren Geen idee	Sticks that respond to each other No idea
Ik denk dat het een actie-reactie is.	I think it's an action-reaction.
De verschillende meningen van mensen die de hele tijd veranderen aan de hand van de informatie die ze hebben over een bepaald onderwerp. Deze meningen kunnen veranderen door men andere mensen te spreken (de armen die de hele tijd heen en weer bewegen)	The different opinions of people who change all the time on the basis of the information they have about a certain subject. These opinions can change by speaking other people (the arms that move back and forth all the time)
Weerspiegeling van de maatschappij/ groepen. Iedereen beweegt anders.	Reflection of society/ groups. Everyone moves differently.
Iets wat te maken heeft met het doorgeven van signalen in een machine.	Something that has to do with passing on signals in a machine.
Dat iets elke keer verandert, dus nooit hetzelfde is.	That something changes every time, so is never the same.
Random bewegingen. Constant anders.	Random movements. Constantly different.
Reinforcement learning: om een computer te leren lopen? Constant aanpassen aan de omgeving	Reinforcement Learning: To learn a computer how to walk? Constantly adjust to the environment

Table 3. Interview answers to the question "What do you think this is? (or what do you think it visualizes?)", with English translation

How could you use the constant flux theory to make better products?	
Naar verschillende scenarios kijken	Look at different scenarios
Om dit moment zij we bezig met een onderzoek. Vanuit dit onderzoek kijken bekijken we meerdere kanten over het onderwerp. Denk daan voor en nadelen. Meningen van anderen enz.	To this moment we are working on an investigation. From this research we look at several sides on the subject. Think for the advantages and disadvantages. Opinions of others etc.
Door bij productontwikkeling het mogelijke gebruik te analyseren op zo veel mogelijk verschillende manieren, komt men wellicht tot andere inzichten die het doel van het product voorbij streven/verbeteren/verslechteren.	By analyzing possible use in product development in as many different ways as possible, one may come to other insights that pass/improve/improve the purpose of the product.
Door een dilemma beter te overzien.	To better oversee a dilemma
Door verder te denken dan de huidige tijd	By thinking beyond the current times
Vanaf het begin, trl 1 al nadenken hoe het product geintegreerd moet worden	From the beginning, TRL 1 already think about how the product should be integrated
-	-
Vaker te testen	To test more often
Na denken of verschillende gebruikers mogelijkheden	To consider or different users options

Table 4. Interview answers to the question "How could you use the constant flux theory to make better products?", with English translation