Tinkering with Technology

How Experiential Engineering Ethics Pedagogy Can Accommodate Neurodivergent Students and Expose Ableist Assumptions

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Chapter 16
Tinkering with Technology: How Experiential Engineering Ethics Pedagogy Can Accommodate Neurodivergent Students and Expose Ableist Assumptions

Janna van Grunsven, Trijsje Franssen, Andrea Gammon, and Lavinia Marin

Abstract The guiding premise of this chapter is that we, as teachers in higher education, must consider how the content and form of our teaching can foster inclusivity through a responsiveness to neurodiverse learning styles. A narrow pedagogical focus on lectures, textual engagement, and essay-writing threatens to exclude neurodivergent students whose ways of learning and making sense of the world may not be best supported through these traditional forms of pedagogy. As we discuss in this chapter, we, as engineering ethics educators, designed and implemented a new engineering ethics exercise with which we aimed to promote inclusivity *at the levels of form and content*. At the *content* level, students were invited to critically engage with inclusivity-undermining ableist assumptions in technology development. This took shape, at the *form* level, through a hands-on 'material tinkering' workshop in which students collaboratively and creatively altered (or 'hacked') artifacts used in contexts of disability and healthcare, so as to operationalize values of inclusivity and accessibility. Our hunch was that this hands-on tinkering workshop would simultaneously encourage a meaningful way of engagement with these ethical issues and values, while also enacting a more inclusive learning environment by enriching the range of pedagogical activities and learning formats available to our students.

As we aim to show in this chapter, we believe this hunch largely panned out – though there are clear areas for future improvement pertaining to the pilot exercise itself and the research we conducted on the exercise. We begin by offering a description of our tinkering exercise. We discuss the exercise's source of inspiration (Sect. 16.2.1) and its implementation (Sect. 16.2.2), which is visually captured via

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photographic documentation. We then discuss (Sect. 16.3) how we utilized a triangulated research method to assess the pedagogical value of the exercise. After we discuss our findings, we conclude by identifying areas for future improvement (Sect. 16.4).

Keywords Neurodiversity · Ableism · Engineering ethics education · Tinkering · Inclusivity

16.1 Introduction

The Ethics and Philosophy of Technology department at Delft University of Technology has a long history of teaching engineering ethics to its large body of engineering students. This history reflects a commitment to combining traditional pedagogical approaches (lecturing, reading ethical theory, writing essays) with less traditional exercises that call on students to engage with ethical issues in a more embodied interactive manner (Doorn and Kroesen 2013; Van Grunsven et al. 2021). Our guiding assumption has been that active learning through interactive embodied exercises, such as role-play, makes the ethical issues at stake in engineering contexts more experiential to engineering students and that this helps foster important ethical competencies such as moral sensitivity, imagination, and reflection.

While examining this assumption in a 4-year research project (link to the project), we have become increasingly preoccupied with the idea that the embedding of non-traditional embodied interactive exercises is warranted not only from a pedagogical perspective but also from a perspective of social justice and inclusivity. On a conservative estimate, 10% of TU Delft's student population studies with a disability. Since this number is based on students who self-identify and voluntarily report as disabled, it may, in fact, be more reasonable to assume that up to 30% of students in higher education study with a disability.[1] With ADHD, autism, and dyslexia making up a large portion of these disabilities, this means that our student body is emphatically neurodiverse. Indeed, "Evidence … shows that in engineering degrees neurodiverse students are overrepresented" (Saunders-Smits and van den Bogaard 2019). Neurodiversity refers to the idea that people experience, understand, and interact with the world in many different ways and that those differences ought to be *valued* rather than labeled as *deficient* deviations from an assumed norm of typicality (Cf. Van Grunsven 2020).[2]

[1] See Expertisecentrum Handicap + Studie (Dutch Expertise Centre on Studying with a Disability) https://www.ecio.nl/wp-content/uploads/sites/2/2019/09/70jaarhandicapstudie-min.pdf, p.35 Accessed April 20th 2022.

[2] See Chapman (2020) for a discussion of why the concept of 'neurodiversity' is best understood as a 'moving target'.

Like many other universities across the globe, TU Delft has signed the United Nations Convention on the Rights of Persons with Disabilities, thereby committing itself to actively valuing neurodiversity and promoting an inclusive learning environment. However, such an explicit commitment is, of course, just a first step in the realization of more inclusive, equitable education. Among other things, we as teachers in higher education must consider how the content and form of our teaching can foster inclusivity by being responsive to neurodiverse learning styles. The question is how we can develop "pedagogy … that addresses multiple ways of thinking?" (The National Association for Multicultural Education 2021). How can we "make education maximally accessible," providing "different ways for students to gain knowledge and formulate what they know" (Shmulsky et al. 2021b)?

A narrow pedagogical focus on lectures, textual engagement, and essay-writing threatens to exclude neurodivergent students whose ways of learning and making sense of the world may not be best supported through these traditional forms of pedagogy (Gardner 2000; Armstrong 2009). Research suggests that many dyslexic and a significant portion of autistic students are more likely to thrive in educational settings that encourage the use of visual–spatial talents (Cf. Davis 1997; Grandin 2009, 2023) Similarly, many students with ADHD would seem to benefit from pedagogy that requires "creative divergent thinking" which is "the ability to generate multiple ideas or solutions to a problem;" for instance identifying unexpected new uses for everyday use objects (White and Shah 2006). Against this backdrop, we designed and implemented a new engineering ethics exercise with which we aimed to promote accessibility and inclusivity *at the levels of form and content*.[3] At the *content* level, students were invited to critically engage with inclusivity-undermining ableist assumptions in technology development. This took shape, at the *formal* level, through a hands-on 'material tinkering' workshop in which students collaboratively and creatively altered (or 'hacked') artifacts used in contexts of disability and healthcare, so as to operationalize values of inclusivity and accessibility. Our hunch was that this hands-on tinkering workshop would simultaneously encourage a meaningful way of engagement with these ethical issues and values, while also enacting a more inclusive learning environment, enriching the range of pedagogical activities and learning formats available to our students.

As we aim to show in this chapter, we believe this hunch largely panned out – though there are clear areas for future improvement pertaining to the pilot exercise itself and the research we conducted on the exercise. We begin by offering a description of our tinkering exercise. We discuss the exercise's source of inspiration (Sect.

[3] There are discussions within critical disability studies and crip technoscience about the difference between and the limits of the concepts of 'inclusivity' and 'accessibility.' Both concepts, it is argued, can have assimilatory undertones. Though we believe these conceptual disputes matter (and can have practical implications), it is beyond the scope of this chapter to delve into them here. For our current purposes, we treat inclusivity and accessibility as broadly the same and we understand them as concepts that capture a need to recognize, value and accommodate the various forms of diversity among human beings. For a critical discussion of the concept 'accessibility' see (Hamraie and Fritsch 2019). For a discussion of the difference between the concepts of 'inclusivity' and 'accessibility' see (Van Grunsven and IJsselsteijn 2023).

16.2.1) and its implementation (Sect. 16.2.2), which is visually captured via photographic documentation. We then discuss (Sect. 16.3) how we utilized a triangulated research method to assess the pedagogical value of the exercise. Drawing on data gathered through (Sect. 16.1) a survey, (Sect. 16.2) open-ended interviews, and (Sect. 16.3) ethnographic and instructor observations, two of the questions that we aimed to answer through triangulation were:

Research question 1 [RQ1]: Did our collaborative tinkering exercise offer an alternative form of engineering ethics pedagogy, capable of contributing to a more inclusive learning environment?

Research question 2 [RQ2]: Did our collaborative tinkering exercise stimulate moral sensitivity regarding issues of ableism, inclusivity, and accessibility in contexts of technology development?[4]

After we discuss our findings, which largely affirmed RQ1 and partially confirmed RQ2, we conclude by identifying areas for future improvement (Sect. 16.4).

16.2 The Exercise

16.2.1 Inspiration Behind the Exercise

The source of inspiration behind the tinkering exercise was a TED talk by artist and disability rights activist Sue Austin. In the talk entitled "Deep sea diving …. in a Wheelchair," Austin powerfully captures her multi-layered experience of becoming a wheelchair user, or, as she prefers, a 'powerchair' user. Austin recollects how, on the one hand, the chair was instantly empowering, a source of joy. After an extended period of illness, the artifact expanded Austin's access to the world in a spatial and bodily sense, allowing her to race down the streets and feel the wind blowing through her hair. However, in a social sense, she felt instantly excluded, as others seemed to see her primarily in terms of loss and deficiency. To challenge this image, reclaim her visibility in social space, and articulate the empowering joy-providing experiences that her wheelchair had brought her, Austin began transforming the artifact into a deep-sea diving device, making video recordings of herself floating along the ocean's corals. As she explains in her TED talk, when people watch her videos, they are "seeing an object they have no frame of reference for" such that "they have to think in a completely new way."

> For me, this means that they are seeing *the value of difference*, the joy it brings, when instead of focusing on loss or limitation, we see and discover the power and joy of seeing the world from exciting new perspectives. For me the wheelchair becomes a vehicle of transformation. … Because nobody's seen or heard of an underwater wheelchair before …

[4] Another question that we raised, and that we discuss in a different paper that is currently under review, is to whatextent and in what ways the exercise enlivened the moral imagination of our students.

> creating this spectacle is about creating new ways of seeing, being and knowing. (Austin 2012, our italics)

A Similar attempt to alter pernicious yet commonplace ways of seeing disabled people is offered by non-speaking autistic blogger Mel Baggs. In their widely viewed short video "In My Language,"[5] Baggs challenges viewers' assumptions about the idiosyncratic ways in which many autistic people behave and engage with their environment. Where these behaviors and engagements are often dismissed as pathological and problematic, Baggs invites us to see them as deeply communicative and meaningful. In doing so, they confront us with the pervasiveness of ableism. As many disability rights activists and scholars have shown, ableism is a pernicious value-system that gets materialized into the world through a wide range of technological artifacts (Shew 2020). From lecterns expressing norms about stature and traffic signals timed for fast-moving pedestrians to communication devices designed in accordance with neurotypical communication norms, the world is built with a certain kind of body-mind in mind (Hendren 2020; Van Grunsven and Roeser 2022). At the same time, Austin's artwork wagers that it is also through the tweaking, tinkering with, and disrupting of technological artifacts that entrenched ableist ways of seeing and imagining disabled people can be called into question.

At the theoretical level, this idea is emphatically put forth in the field of *Crip Technoscience* (Hamraie and Fritsch 2019). Crip Technoscience situates itself as an emancipatory alternative to what it calls "disability technoscience." Disability technoscience frames the lives of disabled people as marked by loss and deficiency, which ought to then be overcome via technology. Operating from within this perspective, well-intending (usually 'able-bodied') engineers tend to view themselves as self-proclaimed problem-solvers offering technological interventions to disabled people, who, in turn, are framed as the passive non-agential recipients of (allegedly much-needed) support (Hamraie and Fritsch 2019; Shew 2020). Crip Technoscience resists this perspective on disabled people and their relation to technology. It draws attention to the numerous ways in which disabled people have always actively hacked and tinkered with their material-technological environment, claiming access to the world as skilled, knowledgeable agents of world-making, instead of waiting to be invited as the mere beneficiaries of technological assistance.

Viewing disabled people as world-making agents of change and as crucial experience experts is also part of the *Warm Technology* framework. This perspective has recently emerged in the field of human-computer interaction, applied within the context of Alzheimer's disease (IJsselsteijn et al. 2020). Much like Sue Austin and the representatives of Crip Technoscience, Warm Technologists resist the typical emphasis on deficiency and loss that so often guides engineering projects in healthcare technology: "Warm Technology is born from an emancipatory view of living with dementia. It is to de-emphasize disease and deficiency, and instead focus on the unique identity of the person, on the myriad of ways in which the person inhabits their world as a place of familiarity"(Van Grunsven and IJsselstein 2023). It aims to

[5] https://www.youtube.com/watch?v=JnylM1hI2jc.

design technology capable of "affirming old age – enabling people to remain open and attached to the world and to other people" (IJsselstein et al. 2020, 33).

These emancipatory perspectives on disability, technology, and inclusivity were offered to the students in a variety of formats. Following the inclusive principles of universal design for learning, students had access to video materials, written academic articles, personal testimonials, as well as in-person and pre-recorded subtitled video lectures.[6] This set up the theoretical backdrop against which our tinkering workshop took place.

16.2.2 Implementation

Austin's work exposed us, as engineering ethics educators, to the possibility that hands-on tinkering with artifacts can stimulate critical reflection on ableist biases, opening up an experiential engagement with the ways in which ethical values such as inclusivity and accessibility can be promoted (or thwarted) through material design choices. This prompted us to develop our hands-on tinkering workshop, during which students would work together in small groups to transform artifacts used in disability, illness, and rehabilitation contexts. These transformations had to be value-oriented. That is, students would have to consider how concrete material changes to the artifact could expose ableist assumptions and/or improve (or undermine) the values of accessibility and inclusivity for relevant stakeholders.

We received funding from our department to purchase scrap materials used for tinkering (see Image 16.1) and 15 artifacts, including a tricycle walker, a dressing stick, a foldable walking cane, hearing aids, and a picture memory phone designed for people with dementia (see Image 16.2). We should note that students were not restricted to these purchased artifacts. Using a suggestion from *Student Onbeperkt* – TU Delft's student-run organization for students with a disability – we

Image 16.1 An overview of tinkering material

[6] https://udlguidelines.cast.org/.

Image 16.2 An overview of the artifacts used in the exercise

gave students the option to select a personal artifact, thereby aligning ourselves with the view "that students and their life histories and experiences should be placed at the center of the teaching and learning process" (The National Association for Multicultural Education). Interestingly, none of the approximately 200 students who participated in the exercise opted for a personal artifact. We revisit this point in Sect. 16.4.1.

In collaboration with several other members of our department, we embedded the exercise in three different courses in the fall semester of 2021.[7] These courses were: the ethics of healthcare technologies, introduction to responsible innovation, and philosophy and history of science and technology. While they differ in a number of respects (see Table 16.1), these courses share an emphasis on ethical issues in engineering and design contexts. Some of the instructors involved in these courses explicitly presented the workshop to the students as an effort to value neurodiversity in our pedagogy. Such explication can signal to students who identify as neurodiverse that "they belong," while normalizing the idea that learning and knowledge-acquisition takes on many different shapes (Shmulsky et al. 2021a). As a form of consciousness-raising, the latter can be particularly important for students who do

[7] During the early developmental phase of the exercise, Samantha Copeland made significant contributions. In ordering the artifacts and tinkering materials as well as teaching the exercise, Cristina Richie was involved.

Table 16.1 Description of the three courses

Course name	Introduction to Responsible Innovation	Ethics of Healthcare Technologies	Philosophy and History of Science and Technology
Level	Bachelor (Second year)	Master	Bachelor (Second year)
Student background	Interdisciplinary: Engineering, design, humanities & (social) sciences)	Different engineering & design backgrounds (strong representation of biomedical engineering)	Clinical technology
Number of students	65	24	105
Preparation before the workshop	Austin's video Lecture & literature on Crip Technoscience & warm technology Artifact selection Preparatory questions	Lecture on crip technologies; Literature on crip technology	Austin's video Literature on Crip technology Artifact selection Preparatory questions
Student presentations on the workshop	10 min, 1 week after the workshop	5 min at the end of workshop	5 min at the end of workshop

not yet recognize their own mind as neurodivergent, but who would benefit from such acknowledgment.[8]

Within each of these three courses, a three-hour workshop took place, during which students worked in groups of 4–6 to tinker with their chosen artifact.[9] In the two BSc courses, the groups already selected their artifact several weeks prior to the workshop. This gave them time to brainstorm and to meet the requirement of consulting relevant stakeholders by reading testimonials on blogs, talking to friends and family who might count as a stakeholder, watching documentaries, etc. The extent to which students utilized this opportunity differed widely between groups, but many groups did little stakeholder research beforehand. We discuss this further, and why it is particularly problematic in the context of this exercise, in Sects. 16.3.2 and 16.4.1.

The workshop was divided into two 'rounds.' **Round one**: After examining their selected artifact by touching it, walking around it, discussing it, and in some instances using it in different indoor and outdoor settings – each student group started with a first 'redesign' or iteration of the artifact. A walking cane, a hearing device for children, and a stoma were aestheticized, transforming the 'medical look' of these devices into a more eye-pleasing one; a picture memory phone was visually simplified and enriched with tactile elements; a walker was motorized to facilitate

[8] See also https://www.nicole-brown.co.uk/invisible-disabilities-academia/.

[9] The workshop held in the ethics of health care technologies course was restricted to 90 min due to scheduling constraints.

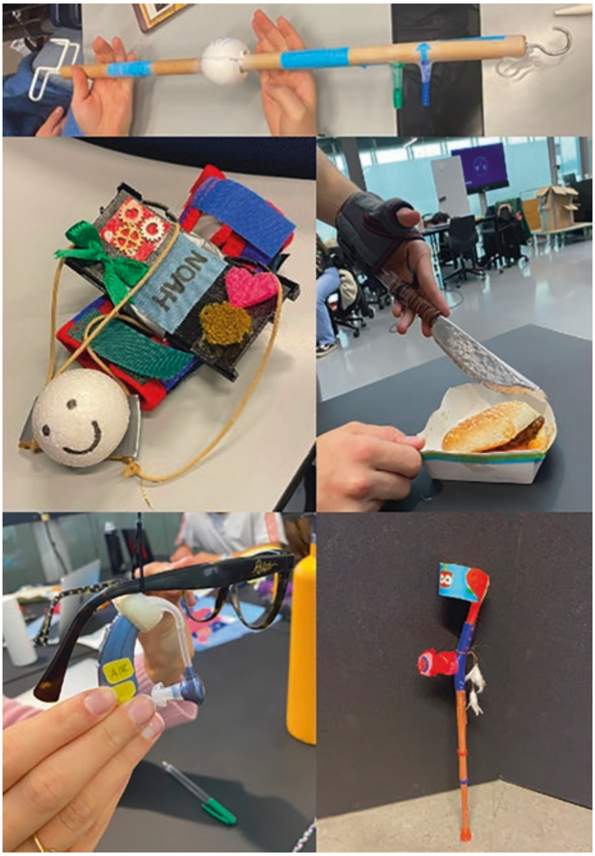

Image 16.3 sample of artifacts after second iteration

up-hill mobility, etc. This process took 45 min and was photographically recorded by the students (Image 16.3).

After this initial design round, student groups were paired up and asked to observe and constructively comment on each other's redesign. To encourage targeted feedback, a selection of constructive questions was provided to the BSc students in advance (see Image 16.4).

Round 2 In the second round, students made another iteration of the same artifact, taking the other group's feedback into account. At the end, they took additional pictures of their artifact, so that later iterations could be compared and reflected upon in ensuing in-class presentations.

During the workshop, the instructors walked around to observe and ask open questions to stimulate discussion and creativity. To avoid steering students in a certain direction and to leave sufficient space for them to come up with their own ideas, we deliberately chose not to provide feedback that would have included concrete

Feedback questions/recommendations (pick one)

1) Have you considered incorporating another value in your design as well, namely value X, for instance by making change Y?
2) Have you considered how your artefact could be improved to accommodate a very particular stakeholder (for instance, a parent who may have young children, a teenager who cares a lot about looking cool, an aging person who is feeling cut off from their social environment). Here is one way you could maybe do that ___________
3) Have you thought about adding an additional functionality to the artefact (such as a snow-plowing or deep see diving functionality to a wheelchair)? Which functionality would you add and what purpose would this serve (for instance, would it serve a practical purpose? Perhaps a practical service catered towards a specific stakeholder? Or would it serve a more critical reflection-promoting purpose, encouraging people to reflect on their own ableist assumptions about the artefact? Or would it serve both those purposes at once?). We were thinking functionality X could be interesting to consider, because ____
4) In line with Crip Technoscience, have you considered changing your artefact so that it encourages critical reflection on ableism, for instance by……
5) In line with Warm Technology, have you considered changing your artefact so that it includes several of its five elements (see below), for instance by …..

Image 16.4 Critical feedback questions students were asked to use to propose design recommendations to one other group

suggestions or solutions. The interviews conducted after the workshop indicated that students appreciated this open hands-off approach.

After the workshop, students were asked to reflect on their product and the tinkering process itself in the form of a final presentation and ensuing Q&A.

16.3 Assessing the Tinkering Exercise Through Triangulation

As stated in the introduction, two of the research questions motivating our tinkering exercise were:

RQ1: Did our collaborative tinkering exercise offer an alternative form of engineering ethics pedagogy capable of contributing to a more inclusive learning environment?

RQ2: Did our collaborative tinkering exercise stimulate moral sensitivity regarding issues of ableism, inclusivity, and accessibility in contexts of technology development?

In order to answer these questions, we opted for a triangulated method. Triangulation combines different sources of information or methods to gain a more comprehensive understanding of the subject under investigation (Jick 1979). Commonly used in mixed-methods research, the general idea behind triangulation is an epistemological one: as Moran-Ellis et al. (2006) remark, triangulation amounts to a claim about “what more can be known”(47) by combining methods in particular ways. Turner and Turner (2009) observe that triangulation is often employed “when the field of study is difficult, demanding or contentious” (171) because it can complement findings with additional data or analysis, provide supplemental corroborating evidence, and even challenge or test findings. It is frequently used in education research (Cohen et al. 2007; Altricher et al. 2005) as well as in other fields (e.g., nursing), where single methods for assessing interventions fall short. In our case, we adopt a version of triangulation to gain multiple (student, observer, and teacher) perspectives on the same activity to assess the activity based on how it achieves the educational goals referred to in our research questions. Our triangulation scheme used data collected through: (1) a participant survey (of students); (2) semi-structured interviews (with students); and (3) ethnographic observations (conducted by Marin and Franssen 2022), combined with reflections from the instructors involved in the course.[10] Two of these instructors were also involved in the research (Franssen & Van Grunsven). One was disconnected from the research project (Cristina Richie). This version of triangulation does not try to validate or confirm findings but instead puts these complementary data sources together to evaluate a pilot exercise.

Immediately after each workshop was completed, students received an email with a link to an anonymous survey which consisted of 10 questions.[11] Out of a total of 194 students taking part in the exercise, 54 of them voluntarily filled in the survey. By soliciting responses from a swath of students, the participant survey provided an important initial data source with which we gauged general student response to the exercise and learned from a large number of students what specifically they experienced as valuable.

To delve deeper behind the initial findings provided by the survey, we conducted semi-structured one-on-one interviews (30–40 min) with three participants from the workshops. During these interviews, we asked the students to reflect upon their experience during the workshop, and for suggestions on how to improve the exercise.[12] The interviewer was not involved in teaching the interviewees’ course. Thus there was no possibility that the students’ answers would be influenced by extraneous factors such as grading concerns.

In this project, both the participant survey and the in-depth interviews are prone to the same potential sampling bias in that the group of students reflected in both groups were self-selecting. For this reason, including further information in the form of ethnographic observations and teacher insights is essential. The

[10] The ethnographic reports can be found in the 4TU.Data repository, DOI https://doi.org/10.4121/20115983.

[11] A significant proportion of these students were from the Introduction to Responsible Innovation course. Survey answers can be found in the 4TU.Data repository, DOI https://doi.org/10.4121/20115971.

[12] Interviews are uploaded in the 4TU.Data repository and are available with a restricted license, upon request: Franssen, Trijsje (2022): Interviews about the educational exercise tinkering with technology. 4TU.ResearchData. Dataset. https://doi.org/10.4121/20020154.v1.

combination of student feedback and teacher responses/evaluation is a typical way of assessing education. We also included ethnographic observations to provide an additional source of insight into student learning and to answer our research questions. While observing, the ethnographers were not involved in teaching that class, enabling a detailed and more detached perspective on how the exercise unfolded. The ethnographic reports reflect the researcher's point of view, how they experienced the educational setting and what struck them.

Below, we will discuss how each of the methods we used interacted with each other to shed light on our research questions (Image 16.5).

16.3.1 A Triangulated Answer to RQ1

RQ1: Did our collaborative tinkering exercise offer an alternative form of engineering ethics pedagogy capable of contributing to a more inclusive learning environment?

The question on the survey that addresses RQ1 most directly is the one displayed below in Image 16.5. In this question, students were asked to rank four aspects of the workshop "from the most valuable aspect of the workshop to the least valuable" These aspects were articulated in the following four statements:

Note that options 1 and 3 either highlight or reference the *collaborative* dimension of the exercise. The other two statements emphasize the exercise's non-traditional hands-on form, with statement 4 explicitly contrasting this form with more traditional pedagogical learning formats. To be sure, many students expressed appreciation for the opportunity to collaborate with others during the workshop, both anecdotally as well as in the in-depth interviews:

Interviewee 1: if you're on your own .. doing something like this, like, having an artifact and fool around with something like that. I don't think it's going to work. … if you have people that had these ideas and you can come up with your

#	Field	Minimum	Maximum	Mean	Std Deviation	Variance	Count
1	Tinkering with the artefact in a collaborative manner - deciding on changes to the artefact together	1.00	4.00	2.81	1.00	1.00	52
2	The fact that it encouraged a creative approach to the ethical dimensions of technological artefacts	1.00	4.00	2.35	1.14	1.30	52
3	The combination of creatively playing with the artefact and collaborating with my group	1.00	4.00	2.88	1.07	1.14	52
4	The fact that it provided an assignment that wasn't focused on reading or writing but that encouraged learning through a hands-on interactive exercise	1.00	4.00	1.96	1.00	1.00	52

Image 16.5 Survey Questions and Responses

own view on it, that's much more exciting than just being on your own. It's not the same. You don't get motivated. [1.14]

Interviewee 2: It was a good chance to have a good brainstorming session. That was a really nice thing to do with this project. … a lot of ideas came from the brainstorming and discussion [Interviewee 2.14]

Interviewee 3: I did really enjoy the collaborative part. It was challenging but it was something that I enjoyed and that was really important [3.78]

In the same spirit, the instructors and ethnographic researchers who were present during the workshops all noted that many students "were clearly very engaged" (Marin and Franssen 2022) in their interactions; that "they were very vibrant during the tinkering" (Cristina Richie, via private email conversation). Particularly in the wake of several COVID-19 related lockdowns, students seemed eager to engage in in-person collaborative interaction.

This makes it all the more telling that students ultimately placed the collaborative dimension of the exercise at the bottom in terms of what made it valuable. Instead, the most frequently prioritized reason for valuing the exercise was that it "wasn't focused on reading or writing" but "encouraged learning through a hands-on interactive exercise." The second most valued aspect of the course was the exercise's creative dimension. Combined, this leads us to wager that there is a need among students for alternative, non-textual engineering ethics exercises; exercises capable of accommodating learning styles not frequently accounted for in traditional forms of pedagogy. The survey offers a first indication that this exercise was able to meet this need, with a significant majority of survey respondents seeing the tinkering workshop as "the most memorable part of the course." This was reiterated in the interviews:

Interviewee 1: … "I think it's a really great concept of teaching. [...] Some teachers know a lot about their own subject and they can talk about it for hours and hours. But sometimes that doesn't really land to the students. Things like this really help [especially when you are introduced to a subject. It really helps] to gain interest and to find your own perspective on it. In my opinion it's better than just listening to someone." [1.64]

Interviewee 2: "*It was a really good project to see how a tool is developed and how it can be further improved based on all the things you have learned." [2.60] "The project was really useful. I think it was the most fun part of the whole course." [2.84]*

Interviewee 3: most useful was … just the idea that you're doing something practical and creative with the group, it's something that we just don't have a lot of opportunities to do so it was. … this mix between creativity and practical [3.75; 3.78; 3.80]

One might wonder whether students valued the exercise's creative, hands-on, non-traditional form because it is simply more entertaining. Perhaps it provided a reprieve from more 'genuine' educational activities, where the tinkering workshop offered time for play but lacked pedagogical value. Establishing if the exercise can appeal to different learning styles while having genuine merit as a form of engineering ethics pedagogy is key to RQ1. At first glance, the survey suggests that students were broadly divided over the following statement: "The workshop was fun but it wasn't of any added educational worth (I would have engaged with the course's concepts and theories in just the same way if the workshop would not have been embedded in the course)." When asked about this in the follow-up interviews, the interviewees described the activity as simultaneously fun, challenging, and interesting. Interviewee 1, for instance, describes the exercise as "really confronting and it's fun to do" [1.66]. Interviewee 2 recounts how the activity "was fun but challenging, from what I saw from other teams as well. [...] what was challenging …. was coming up with the ideas" [2.64]. They specified that "The interesting part was the whole process that we went through to develop the ideas and implement them and associate it with the values. And the fun part was the practical part where we got to use the tools, and try to mix them up, and develop the product, and the video's and pictures. [2.68]. Interviewee 3 described the workshop as "quite challenging … there is this reflection process of what values come out of this modification and is that really what we want and achieve with that?" [3.66].

Interestingly, most students – including some of those who attributed no additional educational value to the activity – agreed that the actual tinkering activity was integral to their grasp of the link between ethical values and technological artifacts: 85% of students who took the survey either agreed or strongly agreed that "New ideas about how our artifact should be altered emerged through the tinkering process," and 67% of students agreed or strongly agreed that "Engaging with the artifact in a hands-on way during the workshop (touching it, moving around it, altering it, looking at it from different angles) brought out new ethical considerations that I or my team hadn't reflected on prior to the workshop." The interviews underscored our hunch that an embodied interactive material exercise could provide a non-traditional format for engaging with engineering ethics issues. Firstly, the interviewees explicated how their ways of *seeing* the artifacts and of making choices about how to improve the artifact were co-determined by their bodily comportment and engagement with the materials available to them:

Interviewee 1: "what makes the workshop special in that kind of way is actually moving it around, and using it. … Feeling something and using makes it more confronting. So, you have a more specific way of looking at a certain artifact instead of just imagining it." [1.62]

Interviewee 2: "when we actually saw the tool by itself and what other tools we could use, I think the ideas just popped up way easier. Which was also a very nice thing of the project." … [Interviewee 2.20; 2.26–28]

Interviewee 3: "Just moving around with it really impacted how we made our decisions. Even seeing a group member walk around with it. I mean, you see like, 'Oh it actually doesn't make sense for it not to fold because if you sit down then where you are going to put the walking stick.' So, these kinds of considerations were really helped by moving with it around." [Interviewee 3.100]

These considerations emphasized the ethics domain and its relationship to technology. One of the questions asked during the interview was: "Do you believe that working with the artifact as you did right now in the workshop has somehow changed – what I could call – your moral sensitivity? Has it made you more sensitive to, well, the moral values that are embedded already in the artifact, and what you could change, and so on? The interviewees responded as follows:

Interviewee 1: *"Yeah, I think so. … I don't normally think about the ethical aspects of technology. You just use it and that's fine. But if you really look at it and you think about it, all the ethical issues come along. And you realize that your viewpoint is not the only viewpoint that there is. … That's when you realize that technology is not always necessarily always a solution, it can also be a problem. And that was something that was really interesting." [1.28]*

Interviewee 2: *I would say definitely yes. … we don't want to just see how a tool can help people, but we want to also see how the tools can be embedded inside the life of people to make their life easier. So, for example I didn't actually think about that before the project. I was just thinking that tools like this just to help us, but its more than that [2.60–62] … We were trying … to make the tool as ethically correct as possible. … We were trying to find a value that was missing and try to place it through the tools that we had [2.22; 2.24]*

Interviewee 3 stressed the important stage-setting work that the theories (Crip Technoscience and Warm Technology) had done: "I think learning about the theoretical background that we received before the workshop had already increased the moral sensitivity, especially when looking at an object and trying to see what kind of values are embedded into it [3.66] That said, they proceeded to add: "As valuable as the theory was, sometimes it's really hard to visualize it in practice if you don't do it yourself. So, I think there's obvious value to the exercise in doing something like this." [3.70]. A similar point about the combination of theory and practice was expressed by one of the instructors involved in the course: "the most meaningful was the workshop itself and the least "meaningful" was the literature review, although it was absolutely essential to the academic nature of the assignment" (Richie, via private email conversation)).

These are noteworthy results for engineering ethics educators, who often grapple with the challenge of getting students to engage with engineering's ethical dimensions.[13] We take these results as indicative of the tinkering exercise's value at the formal level, offering a non-traditional pedagogical format capable of (1) getting students to engage with ethical values and issues related to the use of these artifacts and (2) contributing to a more diverse learning environment that accommodates different learning styles, including those marked by visual–spatial and creative divergent thinking. We wager that embedding neurodiversity-acknowledging pedagogy

[13] We observed that this challenge was significant in a focus group conducted with engineering ethics educators from across the globe in Marin et al. (2022).

in engineering ethics education allows, at once, for pedagogy that is more socially just and effective.

16.3.2 A Triangulated Answer to RQ2

In order to arrive at an answer to RQ2, we traced how students actively appealed to and reflected upon the meaning of inclusivity, accessibility, and ableism during the activities surrounding the workshop (preparing for it, participating in it, and presenting on it). That students acquired new sensitivity towards the ethical issues at stake in this workshop was, as we just saw, agreed upon by a majority of students responding to the survey. But how and to what level of depth did this sensitivity manifest itself? Based on the interviews and ethnographic reports, the following things stood out:

Echoing some of Sue Austin's ideas, several students and groups linked the value of inclusivity to desirability, attempting to remove the stigma around a disability by making the artifact an object of desire. One such example was that of an aestheticized foldable walking stick. Crucially, and in line with Crip Technoscience and Warm Technology, the group working on the stick appealed to the desires and needs of actual users in linking the artifact's aesthetic look to the value of inclusivity. As Interviewee 3, who belonged to this group, explains:

> *"My cousin uses it … she's quite young and she really didn't want to use it because it's associated with old age. So, that was kind of one of the main issues that I wanted to bring into the group discussion." [3.6] …[With] the creative design … we hoped to kind of increase this value of … – I'm not sure – ideas of identity and …allow them to express themselves through the walking stick. [3.14]*

In addition to consulting their cousin, interviewee 3 and the rest of their group also read user-testimonial blogs and talked to aging stakeholders they knew personally. It was in doing so that they discovered that:

> *one of the main problems why people refuse to use walking sticks is that they don't want to be considered old [...]. It's not congruent to their self-identity, they don't want to be seen as old, so the decoration part was kind of targeting that". [3.56]*

Strikingly, interviewee 3 is retrospectively critical of some of their group's design choices. Specifically, they describe how, after a suggestion made in the critical feedback stage of the workshop, the group was tempted to add a voice-controlled GPS tracker to the walking stick:

> *looking back on it, it is quite easy to see – maybe we were working with some biases about older individuals. And also, … warm technology … amplifies this idea that the technology must be really easy to use. And if we were targeting older individuals then maybe voice control would not have been the best way to approach a GPS function. [3.26]*

We tentatively take the interviewee's retrospective remark about biases informing their group's choices as an indication of the workshop's potential to stimulate sustained critical reflection. The ethnographic observations also noted efforts to connect biases and obstacles to inclusivity with aesthetic design choices. Observing a group who tinkered with a hearing aid by decorating it with a pink ribbon, an ethnographer noted:

> *This group was the most reflective one, going into deep discussions. They didn't modify the artefact much, but they did notice how the hearing aid has much in common with their airpods. They wondered why stigma is associated with the hearing aid and a lifestyle choice with having airpods in your ears? They wondered how to make it less stigmatising to wear a hearing aid. Since hearing aids are associated with aging people, one idea was to make it fashionable for young people to wear them. They noticed the difference in look and design ("the case looks medical" for the hearing aids). … "the real issue is not the functionality but the stigma associated with it." But they also wondered how would the disabled people feel if everyone was wearing these?*

Another group, who tinkered with the picture memory phone, operationalized inclusivity by simplifying the design and usability of the artifact. As they stated in their final presentation:

> *We tried to reach optimal inclusivity by making the Design of the phone simple and with Easy-to-Learn functions which should enable all different kinds of people with dementia to use the phone. [...] We tried to focus on the person with dementia and their needs. People with dementia tend to be easily distracted and confused and can get a sensory overload quite quickly. So we realized they needed to have a phone that is not complex. That is why we got rid of all the unnecessary buttons. (see Image 16.6)*

The group reaffirmed this design choice, which was grounded in the Warm Technology framework, by engaging a key stakeholder of the artifact, namely a primary caretaker of people with advanced Alzheimer's disease. As the ethnographic report notes:

> *One of the most motivated groups that took the assignment very seriously; one of the students' mother worked as a nurse with people with Alzheimer. During the workshop, they called her (several times, I believe) in order to make the best design choices. Her recommendation in nutshell was to get rid of anything unnecessary.*

Image 16.6 Picture memory phone before and after modifications

Unfortunately, the perspective of a person with dementia was absent from the redesign process. Indeed, this was a recurring issue for many of the tinkering projects. The challenge of getting students to critically engage with the ethics of appropriate stakeholder inclusion is most apparent when we consider whether the tinkering exercise encouraged students to empathize with the potential users of their tinkering artifacts. In one sense, several interviewees noted this exercise's potential to encourage such empathy. For instance, a group who tinkered with a tricycle walker came up with a scenario in which an aging adult using the artifact would have to walk up a hill:

> *Interviewee 1: "You can have more empathy going on. You can think about it more. I guess it is more mind-opening, because you can sort of theatre what you're actually doing. I mean that was a whole kind of other way of looking at something like that than if you just wrote a report, for instance [1.6] … "We all were imagining how that would turn out. Like how would that person go up the hill with the tricycle and what did that person need to have a more comfortable way of using it, for using the artifact. So we eventually just, we were all thinking about that and discussing what kind of scenario would that person be in, what if it was my grandma, how would she react? [1.10].*

Two interviewees suggest that this kind of empathic perspective-taking, which decenters you from your own, often taken-for-granted, point of view, could help combat biases:

Interviewee 1: *"if you're on your own for instance and you don't have the workshop, you don't have these scenarios you can think of, you don't have the way that we work together, then you stay in your own bubble and you just think that you can just do whatever is good in your view, but you don't necessarily take into account other people's view and other people's experiences." [1.12]*

Interviewee 3: "*the object there makes it really concrete what the object would be capable of or not. And you can put yourself more into the shoes of someone who would use the object" [3.62]. […]"If you don't have an experience using these things then you also do not have the sensitivity to what actually are the necessities of the people using it." [3.100]*

However, although we believe the workshop enlivened a certain empathetic imagination for and identification with the perspectives and lives of the artifacts' (potential) users, we want to underscore that this by itself falls short of the kind of critical sensitivity we aimed to foster in our students. As discussed in Sect. 16.2.1, both Crip Technoscience and Warm Technology offer emancipatory ableism-resisting perspectives on technology and design. They adhere to the dictum "nothing about us without us," and warn against what one might call *armchair empathy* in contexts of technology development for disabled, (chronically) ill, and aging people. In this context, it is arguably just as problematic to rely upon a (well-intended) imagined understanding of the needs of one's stakeholders as it is to disregard them altogether.

Yet, despite providing students with explicit warnings against armchair empathy via Crip Technoscience and Warm Technology, many students did not catch their own engagement in such armchair empathy but only reflected on this when prompted by an instructor. Furthermore, several student groups failed to engage the end-users of the artifacts as experience experts, despite repeated reminders by the instructors of the course about the importance of doing so (and despite the fact that this was included in the grading rubric for the activity, to which students had access in advance). With respect to RQ2, we must thus critically ask to what degree the tinkering activity encouraged students to appreciate the ethical requirements and intricacies of promoting inclusivity and accessibility through technology. As Crip Technoscience warns, disability technoscience is a pervasive posture. How can the potential of the exercise de-center future engineers from their own taken-for-granted perspectives? And how can empathy with relevant stakeholders be stimulated in a manner that is critical of ableist disability technoscience tendencies? In the next and final section, we offer a few suggestions for mitigating this concern and several other possibilities for improving the exercise.

16.4 Areas for Improvement

In this final section, we discuss several areas for improving the exercise itself, as well as limitations to the research conducted about the exercise.

16.4.1 Improving the Tinkering Exercise

In light of the abovementioned worry, the primary area that needs improving concerns avoiding armchair empathy. Two key steps towards this are: (1) ensuring genuine engagement with primary stakeholders and (2) facilitating critical reflection on students' own biases and the degree to which they align with disability technoscience.

One option is to explicitly build in stakeholder engagement prior to the workshop. In the pilot, students were required to consult testimonial material (blogs, videos, personally conducted interviews). Curiously, as mentioned, many students seemed unaware of this requirement. Interviewee 1, for instance, suggested that: "you can also, for instance, make [the workshop] even more empathetic, for example. … [Adding] some way of interviewing, or whatever" [1.32]. This might be because, as interviewee 2 acknowledges, "students before the workshop don't do as much a preparation as needed, I believe" [2.56]. To ensure students engage actively in the pre-workshop requirements, such as interviewing and other forms of stakeholder engagement, we believe a separate class should be dedicated to shared reflection on the gathered testimonial material. As interviewee 3 rightfully pointed out:

> *there was maybe not enough structured time to think about these biases, and these values, and what exactly we could do with it. [3.30] Just in terms of the span of the activity. It was all in one day and we did have instructions to prepare for it, but it wasn't structured time. And I think it would've been more useful to have this initial brainstorming within a structured setting. [3.32]*

These reflections should be presented in class to deepen the student's engagement with the importance as well as the challenges of genuinely incorporating the perspectives of stakeholders. In doing so, students should be encouraged to reflect on how these testimonials challenged their own biases, mapping their findings onto disability vs. crip technoscientific and Warm Technology outlooks. These reflective presentations should be graded on the quality of the acquired material and the critical depth of their reflections.

Another route towards avoiding armchair empathy is to work solely with artifacts derived from students' own lives. Two of the interviewees suggested ideas along these lines:

Interviewee 1: *"I would personally just give the students two weeks or something to figure out what kind of artifact they want to use and just give them complete freedom of it. … just have them to say like, "What kind of instrument/artifact do you think is lacking stuff and how can it be more useful or ethical or responsible." And I personally believe that if you give them that freedom then a lot of creativity can exist." [1.70]*

Interviewee 2: *"if we had to come up with an artifact ourselves, then I think that would actually make us investigate more. So, I think that's a good idea to also make us do our own research before coming to the workshop. [2.56] … Perhaps, if we let students just bring their experiences on the table and try to develop an artifact through that, instead of doing it other way around, I think more interesting ideas will come to the project." [2.80]*

Although selecting their own artifact was given as an option to the students, it is possible that students opted for the purchased artifacts because it can seem like a safer choice, especially at the beginning of a course when student groups are just getting to know each other. By removing the choice altogether and building the assignment around an artifact of their own, students are less tempted by armchair empathy because the artifact either belongs to themselves or one of their direct group members. We recommend that, in much the same way as the previous option, this approach should still build in an additional class prior to the workshop, in which students use the theoretical concepts of disability vs. crip technoscience and Warm Technology to reflect on how the artifact they have selected might reflect ableist biases and support or undermine accessibility and inclusivity.

Additional areas of attention, noted in the ethnographic reports and by the interviewees, concerned the role played by the physical environment and the material artifacts themselves. In one course, the ethnographer notes that "the room was not conducive to group work – a lecture hall, they had no common table to gather the group around." Additionally, they observe that "Several artifacts seemed too small or simple to keep students busy for the entire workshop." This was echoed in the interviews, underscoring the potential to improve the exercise by asking students to select their own artifacts. One could argue that the critical epistemic, pedagogical role played by interactive, embodied, spatial engagements with the artifacts was revealed in a negative sense, when conditions for learning through the tinkering were sub-optimal.

16.4.2 Limitations of the Research

By using a triangulation method, we were able to develop a robust examination of our pilot exercise. In virtue of triangulating between sources, we were, for instance, able to see that *despite* finding the embodied practice of the tinkering exercise valuable, and despite seeing the exercise as encouraging empathic engagement with stakeholders, many students still failed to appreciate the central implications of Crip technoscience and disability studies that center disabled bodies and perspectives in design. The combination of information from student feedback from surveys and interviews, with instructor and observer analysis, yields this complex finding, enabling us to identify important steps for improving the exercise.

That said, our research method also had its limitations, two of which we will touch on. Firstly, we did not work with a control group of students who were taught the same content but did not participate in the exercise. This could be an effective additional way of confirming the exercise's pedagogical value. Secondly, a more in-depth answer to RQ1 would require that we interview students who identify as neuro-divergent. When researching the next iteration of the exercise, we intend to incorporate these areas of improvement.

16.5 Conclusion

In this chapter, we discussed a pilot engineering ethics education exercise. The exercise aimed to promote inclusivity at the levels of form and content. At the *content* level, students were invited to critically engage with inclusivity-undermining ableist assumptions in technology development. This took shape, at the *formal* level, through a hands-on 'material tinkering' workshop in which students collaboratively and creatively altered (or 'hacked') artifacts used in contexts of disability and healthcare, so as to operationalize values of inclusivity and accessibility. Our hunch was that this hands-on tinkering workshop would simultaneously encourage meaningful engagement with these ethical issues and values while also enacting a more inclusive learning environment, enriching the range of pedagogical activities and learning formats available to our students. As we showed in this chapter, this hunch largely panned out, particularly regarding RQ1. There are clear areas for improvement pertaining to RQ2, particularly concerning the worry of students engaging in mere armchair empathy. Two recommendations for mitigating this worry and two areas for improving our research on the exercise were identified. This will inform the next iteration of what we see as a promising new exercise in inclusive experiential engineering ethics education.

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