Extended Abstract
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Experiencing Design for Repair, educating circular practitioners

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Introduction

In the bachelor program of the faculty of Industrial Design Engineering, three courses on sustainability are offered. *Sustainable Impact* focuses on the basics of sustainability like ecodesign and LCA, *Design for the Circular Economy* focuses on circular business models and future design visions, and the *Sustainable Transitions* minor focuses on sustainable systems interventions. Although these courses score "more than satisfactory" on student evaluations (EvaSys), attendance is low and decreasing over the course. Besides, coordinators of the parallel running design projects notice that students struggle with the integration of sustainability into the design solutions. To make sustainability more applicable, we developed a new master elective related to design for repair, named Repair! (ID5422, 3EC over 8 weeks). In this course we explicitly implemented the theory of productive failure by Kapur & Bielaczyc (2012) and followed the course-design model for productive failure described in Persaud & Flipsen (2023). Contrary to traditional teaching, productive failure flips the process and starts with an explorative problem which students cannot solve without the right knowledge. This is followed by an instruction explaining the missing concept and filling the knowledge gap, after which students apply their learnings on their own project. This approach engages students in active problem-solving, with the goal to increase retention of the theoretical concepts and facilitate deep learning. In the Repair course respectively 24 and 36 students participated over the past two years. Students work on client-based products, focusing on a demonstration model to show the improved fit of the product within a circular economy. In this paper, we will present the course and its content, one of the workshops explaining the productive failure approach, and finalize with an analysis of the student's learning experiences.

Course setup

This hands-on circular-design course is divided in seven weekly workshops and a final demonstration day. The course modules build upon each other, and addresses three perspectives on repair: product architecture, legislation, and human factors in design for repair. During the workshop sessions students are experiencing the weekly concepts through a weekly recurring case-study, a simple wired computer mouse, after which they are instructed on the tools and methods applied in the course. In the rest of the time, they apply their acquired knowledge to a client-based project, like a computer accessory (e.g. keyboard), kitchen appliance (e.g. blender), or multimedia device (e.g. headset, figure 1).

Figure 1. One of the results of student's product, improved on repairability (week 7).

During week 1 to 3, students analyze a product on its ease-of-disassembly covering disassembly mapping (De Fazio et al., 2021), locating priority parts and key repair obstacles using hotspot mapping (Flipsen et al., 2020), and deep dive into optimizing their project with redesign strategies. During these weeks they learn to improve the product design for repair (Flipsen, 2023; Pozo Arcros et al., 2021; Dangal et al., 2019, Dangal et al., 2022). Week 4 gives students space to continue with the disassembly mapping and come up with redesign solutions for observed hotspots using sketching and prototyping. During week 5 the design is addressed from the second perspective where the influence of legislation, directives, and repairability indicators on the design are discussed (FRI, 2022; Flipsen, et al. 2016). In week 6 the third perspective is addressed, and students learn about emotional, functional, social, epistemic, and conditional values influencing users to do repair (van den Berge et al., 2023). These three perspectives on repair result in different directions within the solution space and result in different and sometimes contradicting design changes. Week 7 and 8 is there to give students the space to finish their design and demonstrator, validate their findings, and present their solutions (figure 2).

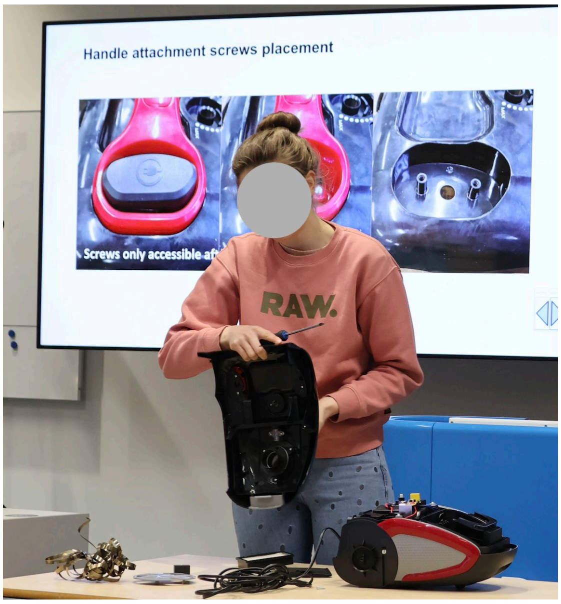

Figure 2. Demonstrating the improvements on a vacuum cleaner during demonstration day in week 8.

Productive Failure Workshop

Each week consists of a four-hour workshop, where we start with reflecting on previous weeks by means of a quiz. After the short introduction students deep dive immediately into an activity concerning the concept of that week using the recurring case-study, the simple wired computer mouse. For instance, in week 2 students are introduced to prioritizing activities and parts, where they need to rank the mouse's parts based on their own prior knowledge (figure 3). This exercise helps them to activate their brain and be involved in that week's learnings. While students fail to generate the correct solution, curiosity and a need-to-know develops. Only after a short period of failing and struggling, they are introduced to the method of hotspot mapping where it is explained to prioritize activities based on time and difficulty of the disassembly, and prioritize parts based on failure rate and its intrinsic economic and environmental value. In the following hours students are guided in applying their learnings to their own project, while during the rest of the week students implement further by designing and prototyping.

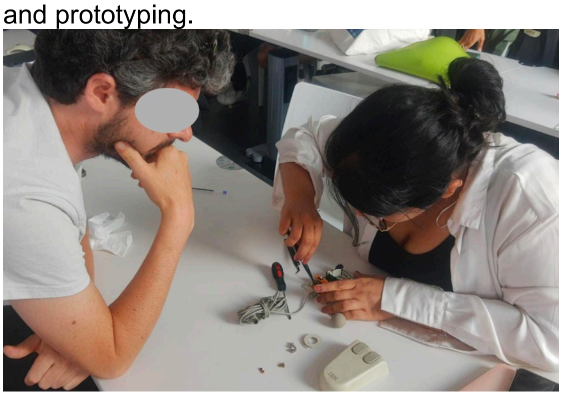

Figure 3. Dismantling a computer mouse and prioritization parts and activities (week 2).

Student experiences

For quality control of the different courses, we use EvaSys enquiries which are sent out to our students who can grade the course on delivery, feasibility in time, quality of teaching, organization, amount of challenge, and expectation for success. The results of the first student's evaluation (20 respondents) are very high and graded 8.53 out of 10, which is qualified as "very good". The course scores very high compared to other sustainability courses within our curriculum, demonstrating its effectiveness and appeal. Based on the results, students showed a high appreciation of the "quality of teaching, coaching and feedback" scoring 9.36, which refers to the didactical approach of productive failure. Furthermore, the learnings of the "practical skills in the circular economy", and the providing "students with critical design knowledge and skills" was highly appreciated by the students.

Throughout the course, students were highly engaged in making the circular economy more actionable. To get a grip on their understanding and motivation we asked both cohorts of students to reflect on their project and their own learnings. We analyzed in total 60 written reflections, using NotebookLM (Google, 2024) to generalize, group, and summarize their work. We anonymized all reflections before the data was uploaded in the online tool. The student's reflections were analyzed on (1) learnings within the course, (2) experience of the course, and (3) applicability of the course content in future work:

(1) Learnings: students gained valuable insights into the multi-faceted nature of repair, going beyond simply "making things repairable". They gained a deeper understanding of product architecture through hands-on disassembly activities. The course highlighted the importance of considering the user's perspective in repair, emphasizing the need for clear instructions, accessible designs, and available spare parts. Additionally, students learned about the influence of policy and legislation on repairability, recognizing its potential to drive systemic change.

(2) Course Experience: students consistently praised the hands-on, practical approach of the course. Disassembling and analyzing real products provided valuable learning experiences and sparked curiosity about repair. Some students found the disassembly process initially daunting but ultimately rewarding. The interactive workshops and use of tools like disassembly maps and hotspot mapping facilitated their understanding of repairability.

(3) Future Applicability in Design: students expressed a strong intention to incorporate their learnings into future design practices. They recognize the importance of designing for repairability from the start, integrating user-centered considerations, and balancing repairability with other design factors. Some students plan to explore specific areas further, such as user engagement in repair, policy implications, and the integration of repairability with other circular economy strategies.

Outlook

In the fall of 24/25, we ran the course for the third time and introduced design for recycling (Van Dolderen et al., 2024) as a new concept. Students are introduced to Recycling mapping and explore the discrepancies between design-for-recycling and design-for-repair.

"This course overall is very interesting, and the teaching approach does get you very involved in the project." [Anonymous, 2025]

This continuous improvement ensures the course remains relevant and impactful for future learners. The course was, again, highly appreciated by our students with a score of 8.83 out of 10.

Acknowledgments

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References

Dangal, S., Balkenende, R., Faludi, J., Eisenriegler, S., Reichl, H., Haas, J., Neumerkel, A., Wild, J., Depypere, M., & Opsomer, T. (2019). *Design for physical durability, diagnosis, maintenance, and repair*, deliverable 4.3, EU Horizon 2020, PROMPT project.

Dangal, S., Faludi, J., & Balkenende, R. (2022). Design Aspects in Repairability Scoring Systems: Comparing Their Objectivity and Completeness. *Sustainability,* volume 14.

De Fazio, F., Bakker, C., Flipsen, B., & Balkenende, R. (2021). The Disassembly Map: A new method to enhance design for product repairability. *Journal of Cleaner Production*, volume 320.

Flipsen, B., Bakker, C. & van Bohemen, G., (2016)."Developing a reparability indicator for electronic products", Electronics Goes Green 2016+ (EGG), Berlin, Germany, 2016.

Flipsen B., Bakker, C., & de Pauw, I. (2020). "Hotspot Mapping for product disassembly: A circular product assessment method," Electronics Goes Green.

Flipsen, B. (2023). *Hotspot mapping – user guide,* lecture notes for Repair (ID5422).

FRI (2022). *Instructions manual for the display and the calculation of the repairability index of electrical and electronic equipments*, Ministere de la Transition ecologique

Google (2024-Dec 1), *Notebook LM, retrieved from: https://notebooklm.google.com/*.

Kapur, M., & Bielaczyc, K. (2012). *Designing for productive failure*, Journal of the Learning Sciences*, 21*(1).

Persaud, S., & Flipsen, B., (2023). *Productive Failure Pedagogy in Engineering Mechanics*. E&PDE 2023, 7-8 sept., Elisava University, School of Design and Engineering, Barcelona.

Pozo Arcos, B., Dangal, S., Bakker, C., Faludi, J., & Balkenende, R. (2021). Faults in consumer products are difficult to diagnose, and design is to blame: A user observation study, *Journal of Cleaner Production*, volume 319.

Van den Berge, R., Magnier, L., & Mugge, R. (2023). Sparking the Repair “Can-Do” Attitude: Enhancing Users' Willingness to Repair through Design Support in Fault Diagnostics. *International Journal of Design*, 17:3.

Van Dolderen, D.C., Aghaeian S., Bakker, C.A., & Balkenende, R. (2024). *Design for Recycling of Electronics: The Urgent Need for Better Methods*, Electronics Goes Green 2024+ (EGG), Berlin, Germany, June 18-20.