From Trash to Treasure: Experiences from Building Tangible Artifacts out of Discarded Components

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ABSTRACT

Prototyping interactive hardware artifacts is an iterative process that can produce significant amounts of waste. This problem becomes particularly apparent in teaching, when multiple students build the same artifact as an exercise and components can break when used improperly. In the context of a university course on tangible interaction, we explored how material found in the trash could be used as a resource for prototyping interactive artifacts. We could source interesting components and found that a bottom-up prototyping approach based on those components opened up new design spaces. Furthermore, as we relied on trash as a resource, we were able to considerably reduce waste during the course.

KEYWORDS

Upcycling, Sustainable Interaction Design, Sustainable Human-Computer Interaction, Prototyping

1 INTRODUCTION

Designing interactive systems is oftentimes an iterative process that requires building prototypes and evaluating them in user studies to gather insights for the next design iteration [1]. If designed artifacts include hardware components, such as electronics or structuring material, waste tends to be produced at multiple points during the design and development process. This problem can be avoided to some degree by disassembling previous prototypes, but this is not always possible as materials could get destroyed during disassembly (e.g. when glued in place), or it might be uneconomic.

When teaching designing and prototyping physical artifacts, for example in a university context, the problem of produced waste can become even more apparent. Hands-on exercises require building materials and components for each student. Additionally, students will make mistakes while learning basic skills and thus, some amount of material and components will get destroyed. In several years of teaching the basics of electronics, microcontroller programming, and prototyping in an undergraduate university course [12], we observed the problem of accumulating waste during our courses. Therefore, used one of our courses to explore to which degree salvaging and upcycling components and material from trash could reduce waste produced during the course. Additionally, we were interested in how the material-driven approach of "working with what you can find" would influence students' design mindsets.

Due to the ever increasing awareness of ecological, economical and social sustainability in today's society, new paradigms such as Sustainable Interaction Design (SID) [2, 3] and Sustainable Human-Computer Interaction [4, 7, 8] have emerged. SID introduces the factor of sustainability into interaction design and promotes principles such as longevity of use, repairability, and modularity for easier salvaging and recycling of components.

Upcycling material from waste can be a promising way to make physical prototyping more sustainable, as even in the worst case, no new waste is generated. Ideally, a new purpose for seemingly useless components can be found and new artifacts can be built while reducing the amount of overall waste. For example, Kovacs et al. [11] utilized plastic bottles and 3D printed connectors to fabricate large structures, such as furniture, domes, and bridges. In later work [10], they extended those structures with moving parts such as pistons and moving joints to allow for moving parts. Choi and Ishii [5] describe a new method to create inflatables from plastic bags. They use the heated extruder of a 3D printer to fuse the layers of plastics to create seams. Similar to our work, Dew and Rosner [6], together with students, explored how waste could be used in design. They followed a material-centered approach by examining biological and chemical properties of waste such as discarded 3D printer filament and packaging material. Finally, ethnographic studies investigated how sustainability and upcycling were implemented in DIY culture and maker spaces [9, 13]. Vyas and Vines [13] conducted a field study at a non-profit organization that built a whole infrastructure for repurposing discarded batteries out of salvaged material. Houston et al. [9] compared four repair sites located in the USA, Uganda, and Bangladesh. They conclude that the value of repairing is not limited to technological aspects, but includes social factors such as collaboration and mutual learning.

With this pictorial, we expand the existing body of research by sharing our experiences from prototyping tangible prototypes with undergrad media informatics students, using material we found in the trash. We describe our course's structure (Section 2), the process of acquiring trash and sourcing material (Section 3), the components we found useful for prototyping interactive artifacts (Fig. 3), and give an overview of the prototypes students built during the course (Fig. 4 and 5).

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Figure 1: Impressions from the university course. Students learned the basics of electronics, microcontroller programming, and prototyping. They brainstormed and presented ideas for their final project and worked on their interactive prototypes.

2 COURSE

We used the undergraduate media informatics course "Sketching with Hardware" as a base for our upcycling experiment. The course is a two-week block. In the first week, students learn the basics of electronics, soldering, Arduino programming, and interaction design. Then, a general theme for the final projects is revealed, students form groups of two, and brainstorm ideas. Based on those ideas, each group builds an interactive hardware prototype as a final project for the entire second week. Details about the course's general curriculum have been published in earlier work [12] and material can be found on our Github repository[1]. Ten students from the second bachelor's semester up to the second master's semester attended the course. Among them, seven students needed the grade and three participated voluntarily out of interest.

The general theme for final projects was "Upcycling and Sustainability". After revealing this theme, we went to our university's garbage collection site and searched for useful materials and components in electronic waste.

One major difference the upcycling aspect brought to the course was the ideation process for the final projects. Our common method is to reveal the general theme, followed by a brainstorming phase where each group of students creates a poster with three ideas. Those first ideas disregard all technical aspects and focus solely on interaction concepts. This process was not suitable for the upcycling theme, as we did not know what we would find in the trash beforehand. Therefore, the ideation phase was conducted after we inspected and salvaged material from the trash (as described in the following section). This seemingly minor change had a significant impact on the students' design mindset. Many ideas heavily focused on specific components students deemed interesting or wanted to work with. Thus, we could observe a bottom-up and component-centered design approach in many cases, thinking about affordances and use cases for components instead of working out which components could be useful to solve a specific problem.

While some groups followed this material-centered approach and tried to make use of as many salvaged components as possible, others focused more on the sustainability side of the course theme and decided to build interactive prototypes that raise awareness for sustainability, or help people to live more sustainably.

[1]https://github.com/UniRegensburg/SWH

3 SOURCING MATERIAL FROM TRASH

We sourced material to build interactive prototypes for the course's final project from the central garbage collection site of our university. To find out whether we could find usable material and components there and to ask for permission to access the trash, we visited the site several weeks before the course. During a tour of the site, a staff member provided us with background information about the university's waste management system and problems that occur during daily business. For example, it is very common for unauthorized persons (*"bipedal rodents"*, according to our guide) to enter the site and either look for valuable items and materials (especially copper), or to discard their own waste (e.g. car tires) to avoid disposal fees.

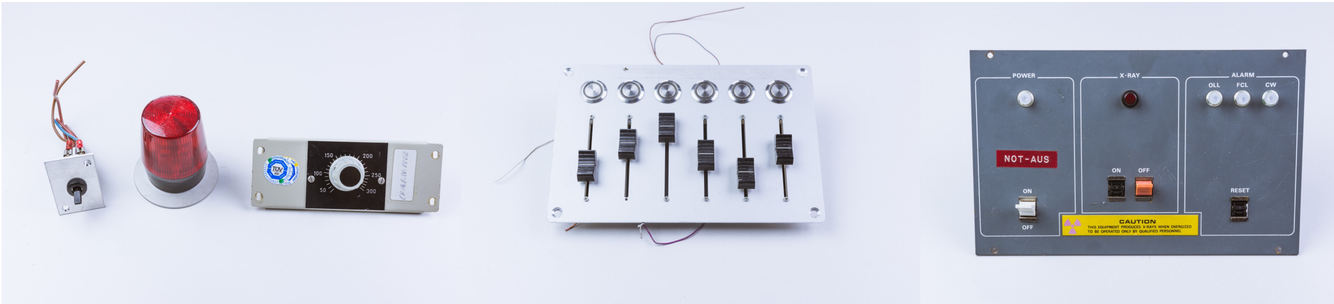
The garbage collection site has multiple containers with different types of trash. Some types of trash, for example glass or bulky waste, were not suitable for building interactive prototypes. Furthermore, we were not allowed to access others for safety reasons, for example the steel container with many sharp and pointy objects. The most promising material for our purpose could be found in the electronics waste. It was already roughly sorted into separate containers for computers, household appliances, laboratory equipment, and miscellaneous small devices.

At the end of the first course week, we visited the garbage collection site together with the course's participants. We brought a cart and several containers for the things we wanted to salvage from the trash. We introduced our students to the general theme of the final projects ("Upcycling and Sustainability") and our plan to salvage material from electronics waste only just before we arrived at the site. This way, students were able to develop ideas with a fresh mindset while investigating the trash.

As we were allowed to disassemble those devices on site, we were able to quickly evaluate which devices were suitable for the projects and how hard it would be to access interesting components. In general, we avoided devices and components that could not be operated with low voltages, such as household appliances, or were too complex to control with a simple microcontroller. Instead, we were interested in devices with easily accessible standard components (e.g. motors, gears, speakers, and photoelectric barriers) or interesting exteriors (e.g. vintage knobs and buttons, analog displays, possible encasings for prototypes). Especially discarded laboratory equipment turned out to be a very good source of interesting components. Examples are old voltmeters and power supplies with analog displays and large potentiometers, an auto-sampler consisting of several stepper motors and linear rails, a small pressure tank, as well as an X-ray machine with a vintage user interface. Surprisingly, printers turned out to contain only a few usable components (two small motors and some plastic gears), with the remainder of the device consisting mainly of PCBs and the plastic housing.

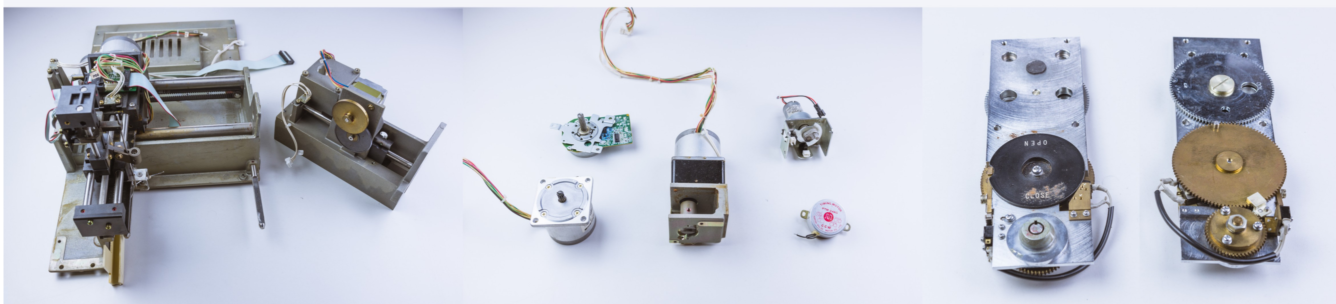
It is worth noting that some devices sparked great interest among our students. They used their phones to search the web in order to identify components or learn about the function of devices. Furthermore, some of them were interested in the original cost and secondary market value of found devices.

Figure 2: Students investigating, disassembling, and salvaging components from the trash. There were multiple containers with pre-sorted electronics waste, as well as some larger devices such as discarded laboratory equipment.



We found several useful components in our university's trash. For example, we could disassemble analog user interfaces from old laboratory equipment. On the left hand side, a switch, a lamp and a large potentiometer can be seen. Such components can be used for future prototypes.

The center and right images depict functioning control panels with switches and potentiometers. Especially the backlit switches and the linear pots are quite expensive when bought new. Such control panels could either be further disassembled, or used as a whole, for example to control lab equipment.



Laboratory equipment oftentimes contains many useful mechanical components. For instance, the disassembled auto-sampler depicted above can move along linear rails with three degrees of freedom. For this particular device, only stepper motors and photoelectric barriers were used. Therefore, controlling the system with a microcontroller is straightforward.

Furthermore, we were able to salvage stepper, servo, and DC motors from discarded devices. Some of the motors even came with gear boxes or transmissions. On the right hand side, a locking mechanism can be seen. It includes several cogwheels and an analog display - and snaps into place in a satisfying way.

We did not only focus on the functional properties of the devices we found, but also on their physical shape as well as feelings they evoke. For example, the pressure vessel at the left hand side looks very sturdy but worn down. By including it into the design of an interactive artifact, the implication of something dangerous going on could be conveyed.

The rotary phone (center) is likely unfamiliar to younger generations while still conveying clear affordances for its use. Therefore, it could be suitable as the housing for an interactive experience that works with audio. The object on the right is the prism of a projector including CMOS displays. Our students were very courious to find out what it is and explored the prism and color filters by shining light through them.

Figure 3: Selection of interesting and useful objects we found in the trash: components to build user interfaces (top), motors and mechanical components (center), objects with interesting look and feel (bottom).

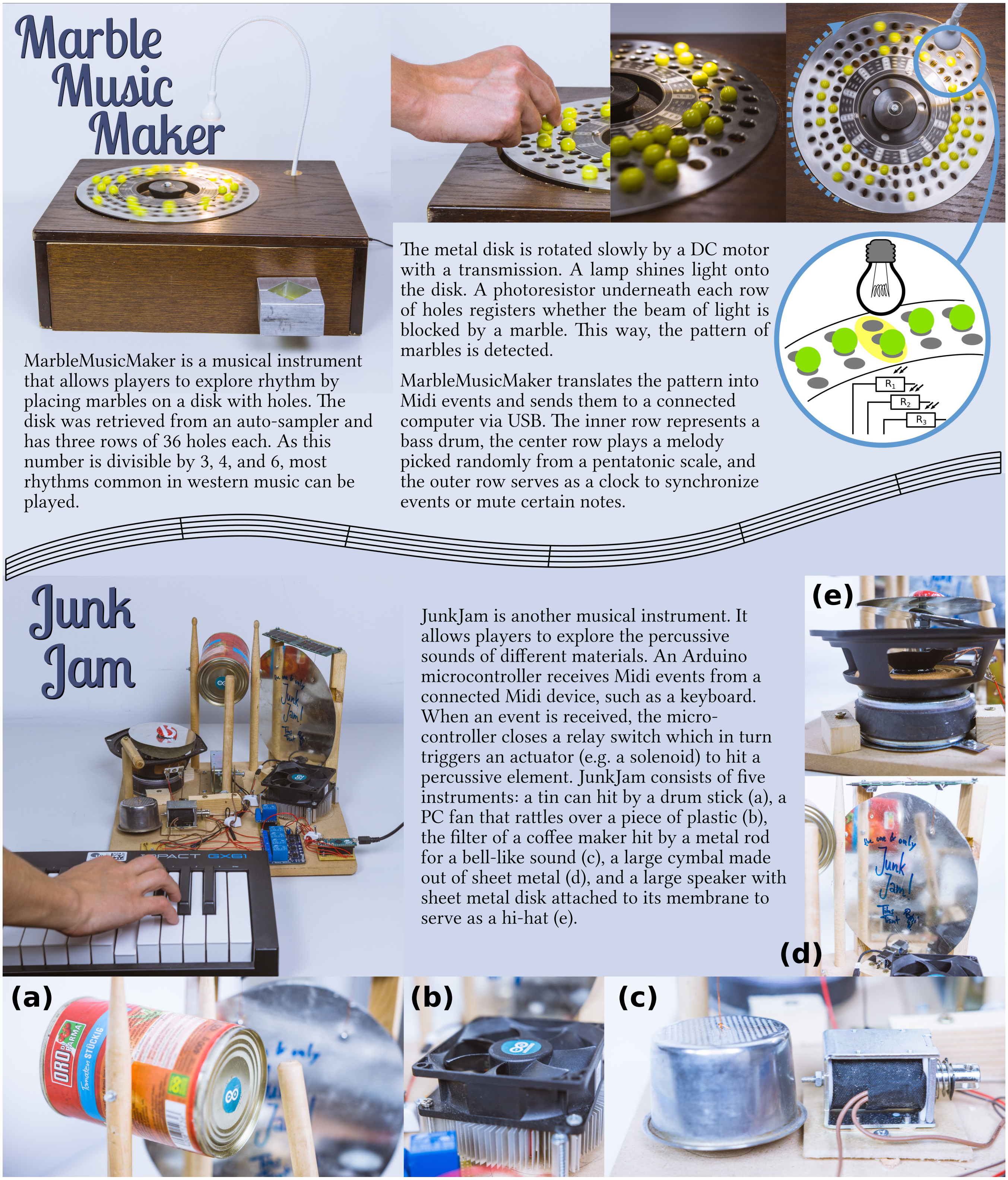
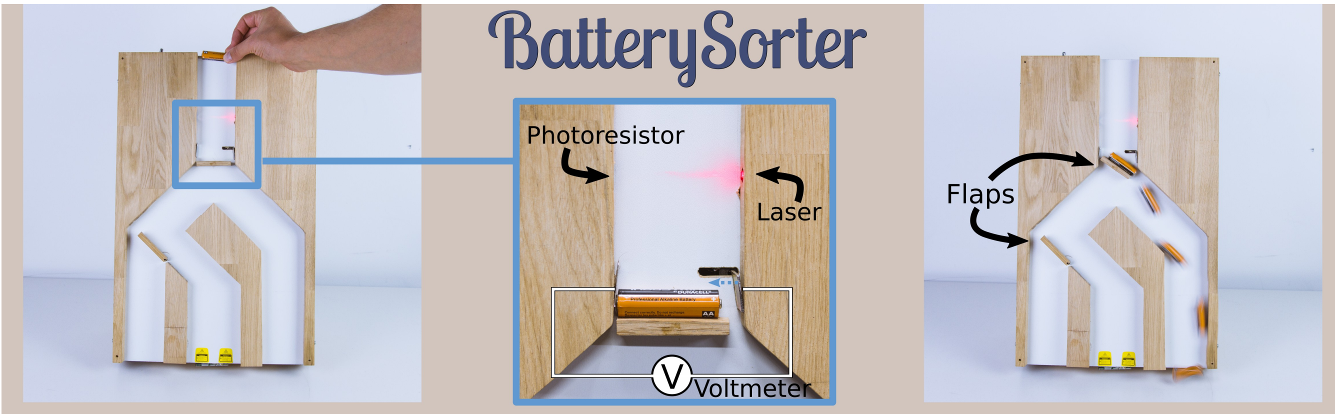
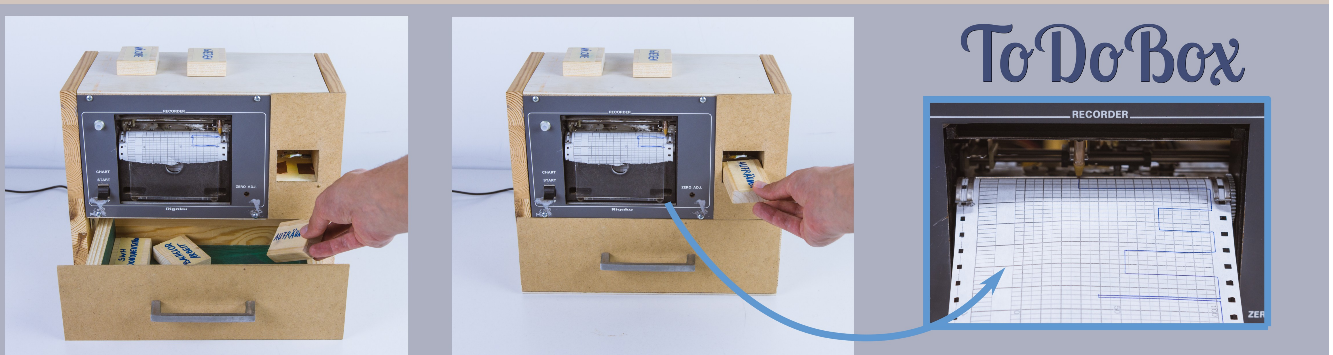


Figure 4: Two prototypes built by course attendees as their final projects: MarbleMusicMaker and JunkJam.



BatterySorter is a device that sorts batteries according to their remaining charge. Users can drop batteries into the opening at the top. While falling down, the battery blocks a light barrier and the device starts its operation. Metal probes are moved towards the battery's contacts and voltage is measured.

As a battery's voltage drops when it is discharged, it can be sorted into one of the categories full, half full, and empty. After the category has been determined, flaps inside the device are arranged to form a path for the battery to fall through. By placing a container underneath each bottom opening, batteries can be sorted easily.



ToDoBox serves as a tangible ToDo list. The drawer at the bottom of the device contains several wooden blocks. Users can write tasks onto these blocks, for example for watering plants, doing the laundry, or working on a thesis. In the morning, tasks for the day can be selected from the drawer and placed on the top of the device.

Once a task is finished, the corresponding block can be inserted into the hole on the right hand side. The device recognizes the block and drops it back into the drawer by opening a trap door mechanism. At the end of the day, users can flip the switch on the left hand side.

Then, the device documents the day's productivity by drawing a bar on a roll of paper with a writing unit we could salvage from discarded lab equipment. The height of the drawn bar represents the number and difficulty of tasks finished this day. This way, the ToDoBox generates a physical representation of a user's productivity over a period of time.

SustainaBalls is an interactive device to motivate people towards more social, healthy, and sustainable behavior. It resembles a shelf and is built robustly for use in public settings. Once the button on the top is pressed, a short melody is played and a clear ball is ejected. The ball contains a strip of paper with a motivational phrase from one of the following categories:

- Health (e.g. "Take a walk in the park today!")
- Social (e.g. "Call your parents today!")
- Sustainability (e.g. "Only vegan food today!")

SustainaBalls

Figure 5: The remaining three prototypes built for students' final projects: BatterySorter, ToDoBox, Sustainaballs.

4 FINDINGS

We found that our students were very motivated to rely as much as possible on materials and components salvaged from the trash. Some components that were available in our lab, such as small servo motors, were used in addition. Furthermore, scrap wood was used to build boxes to house some of the prototypes – for example, a painted piece of wood from an older, disassembled prototype was used as the base of the *ToDoBox*'s drawer. The dark chipboard used for the encasings of *SustainaBalls* and *MarbleMusicMaker* was sourced from a shelf a student unsolicitedly got from the city's waste disposal site. Additionally, students seemed to be particularly aware of modularity and repairability when building their prototypes. In total, the course produced significantly less additional waste than usually. As a drawback, because only a fraction of salvaged components made it into final projects, we had two large boxes of disassembled devices in our lab after the course.

Salvaging prototyping material from our university's trash gave us access to components we would not have had otherwise. This includes engineered metal parts such as the disk used for *MarbleMusicMaker*, specialized units like the analog chart recorder used for *ToDoBox*, as well as mechanical components such as linear rails, sturdy stepper motors, and gears. Students had to look up data sheets or reverse-engineer the interface of some components to control them with their Arduinos. This is a valuable skill that would not be conveyed when components are ordered from online shops. Furthermore, working with a limited set of components forced our students to think with the available material in mind. For example, the idea for *MarbleMusicMaker* emerged primarily from affordances the disk provided: rotation, holes that could hold round objects, and the similarity to a vinyl record. When building *JunkJam*, students explored the percussive sounds of different materials and experimented with different ways to hit them to achieve the intended sound. For *SustainaBalls*, students decided to keep the æsthetics of the original shelf and for *BatterySorter*, they had to work out how to design the device around the physical properties of a battery.

Even though trash has turned out to be an interesting resource for prototyping interactive artifacts for us, our approach still has some drawbacks. First of all, not everyone has access to multiple containers of electronic waste and even discarded laboratory equipment. The staff of our university's trash site has been very supportive by allowing us to access the waste, providing us with enough time and space to thoroughly inspect components. Presumably, we would not have found such interesting material at a public waste disposal site – granted we would have even got access to their trash. Additionally, one does not know beforehand which and how many useful components can be found in the trash. Even though this can make the whole process more engaging and foster creativity, this is a severe limitation if one has a specific goal in mind. One way to counteract this random factor would be to regularly check the trash and collect interesting material. However, this approach is time-consuming and requires suitable space for long-term storage. Finally, one should be cautious when disassembling discarded devices. Besides the obvious risk of getting cut at sharp edges, some devices might contain dangerous substances. For example, we discovered leaden plates in the X-ray machine we disassembled and an employee of the garbage collection site warned us about asbestos used as insulation for old ovens. Accordingly, we do not recommend following our exact approach with groups of children or young adolescents.

In conclusion, upcycling has been a valuable resource for prototyping tangible artifacts. It has opened up new design spaces by challenging established mindsets with the unusual set of available components and material. Even though relying only on salvaged material can be a limiting factor for some projects, upcycling can be a useful method that complements other approaches.

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