RESEARCH + EDUCATION FORUM 2022

Design for the Unimagined

Proceedings Document

WDO WORLD DESIGN ORGANIZATION

The following document is the published collection of technical papers accepted to the 2022 WDO Research and Education Forum that took place online, hosted by Economic Promotion Bureau of Shunde People's Government of Foshun (China) on 22 February 2022.

Special thanks

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About this publication

Held online on 22 February 2022, under the banner of Design for the Unimagined, the 2022 WDO Research and Education Forum hosted by the Economic Promotion Bureau of Shunde People's Government of Foshun (China) aimed to share perspectives and explore trends to better prepare young design professionals for new challenges and opportunities.

Bringing together academics, students and industry leaders online due to the ongoing COVID-19 pandemic, the event explored three sub themes relating to the new dawn facing designers in the aftermath of the largest pandemic in a century: response in extreme times, human centred technologies and the emergence of new learning. Through a series of online activities, the forum fostered engagement around the challenges universities and design schools had to overcome in remote environments, the ways we lean on technology at an increased pace and the possibilities available to us when we explore the unimagined.

The following proceedings are the collection of papers selected for publication.

To view the keynote presentations, panel discussions, as well as the poster presentations, please visit WDO.org/world-design-assembly

Theme 1 Response in extreme times

Our world is facing many complex challenges – from the ongoing COVID-19 pandemic to climate change, overpopulation and global migrations. These extreme circumstances have not only forced us to rethink how we live our lives, shifting daily habits and patterns, but have also brought us together in new ways that showcase how humans can adapt in times of crisis.

Theme 2 Human-centred technologies for social and environmental benefit

Big Data. Artificial Intelligence. The Internet of Things. These technologies are influencing our world, but questions loom about what value they can really bring to our everyday lives. The key, it would seem, to unlocking this potential is evaluating the balance between human-centred and performance-based technologies. As we look to address some of our most pressing social and environmental challenges, designing with people in mind allows us to better understand where we came from and how we can move forward together.

Theme 3 Emergence of new learning

Changes in society, student expectations, and technology continue to shift the ways in which we learn. A distinctive rise in online learning has caused both design educators and students alike to explore new tools to keep up with the demands of 21st century learning. As new forces reshape the academic landscape and conversations around educational accessibility pervade public debate, how can existing methodologies of design research and curricula evolve to enhance the student experience and equip them with the skills needed for future professional practice?

Title:

Envisioning Safe and Sustainable Labs with Human-centered System Design: An Experimental Study on Disposable Material Flow

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Abstract

The purpose of the study is to explore disposable laboratory material flow on campus using Human-centred System Design (HCSD). We used Massachusetts Institute of Technology (MIT) campus as a testbed to conduct the experimental study for sustainable innovation. We selected four types of labs: biological, chemical, material, and mechanical engineering, and two makerspaces to interview principal investigators (PI) and shop managers about building safe, sustainable labs. Besides field research and interviews, we launched a survey of lab pipette tip boxes as a case study to have more in-depth material flow information from procurement to disposal. The aim of the study is to refine lab material purchasing, inventory management, recycling and disposal to identify pain points and opportunities to make lab material flow more sustainable and safer on campus.

Keywords: Sustainability, Safe, Lab, Material Flow, Human-centred System Design

1. Introduction

Massachusetts Institute of Technology (MIT) has announced a goal of reducing greenhouse gases to achieve a 32% reduction of overall emissions by 2030. Labs at MIT collectively used over 65% of campus energy, even though labs only occupy 25% of the physical footprint [1, 2]. In the study, we researched disposable lab material flow as a starting point to envision how to build a safe, sustainable laboratory on campus and provided a case study of pipette tip box usage in laboratories. Understanding laboratory material flow is an integral part of this study.

At MIT, they use the latest technologies and research to promote the campus not only as a testbed for sustainable innovation but also as a living lab to enable the creation of a safe and sustainable blueprint in the most efficient and socially impactful ways. MIT Green Lab Program [3], founded in 2016, is a great example demonstrating how they collaborate with schools across MIT to enable laboratories to establish guiding principles, communication channels, collaborative platforms, shared visions, tools, knowledge, and training programmes to operate in a sustainable manner.

In this study, we conducted two types of research to collect the first-hand material. First, we completed field research. We visited four different types of labs: biological, chemical, material, and mechanical engineering and two campus makerspaces: The Deep and Metropolis. Second, the pipette tip box survey: we used pipette tip boxes as a case study to demonstrate the material flow, from procurement, to disposal, and recycling in laboratories.[4] Since this is a one-year experimental study, we defined this initiative as an entry point for us to understand users' pain points, the challenges of the institute, and how complicated it is to build a safe and sustainable laboratory on campus.

2. Literature review

The study used MIT campus as a case study. We emphasized journals, papers, and laboratory reports of disposable laboratory material flows. We also conducted interviews with MIT Office of Sustainability (MITOS), MIT Department of Facilities, MIT Environment, Health & Safety Office (MIT EHS), MIT Office of the Vice President for Finance (MIT VPF), and two makerspaces: The Deep and Metropolis to help define the scope and problems regarding disposable laboratory material flows (Figure 1.).

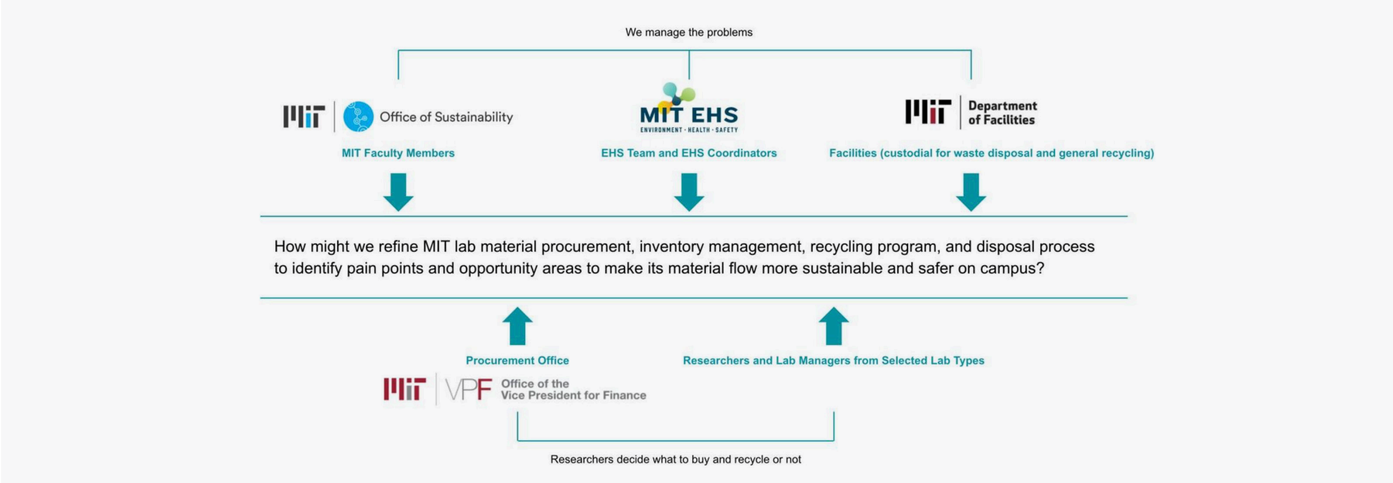

Figure 1: Key stakeholder map

2.1 Disposable laboratory material flow

We categorized a typical disposable laboratory material flow into four phases: procurement, inventory management, recycling and disposal [1]. According to the literature and interviews, we summarized the top five common disposable laboratory items at MIT: nitrile gloves, pipette tips, pipette boxes, centrifuge tubes, and conical test tubes. We used field research and a survey to analyze the disposable material flow of these items from procurement, inventory management, and recycling, to disposal [5]. In the study, we used pipette tip boxes as an experimental case study to demonstrate people's consideration and behavior in relationship with material flow in laboratories. The concept of a circular makerspace [6], a space with a shared sustainable vision by applying circular design methodologies and human-centered design to achieve carbon neutrality in the environment and system, can also tie to the disposable material flow in laboratories. The ultimate goal is to reduce the carbon footprint both in laboratories and makerspaces on campus.

2.2 Human-centred system design (HCSD)

HCSD is a modified research process curated with IDEO's version of design thinking [7] and system engineering [5, 6, 8, 9] to analyze its model. We visualize the journey of disposable laboratory material paired with people's behaviour with these materials to discuss the pros and cons among sustainable laboratory material, procurement cost, recycling process, and decision making [10, 11] (Figure 2.). We used HCSD to analyze the disposable laboratory material flow, which is an innovative approach to the study and helped us identify pain points across the design journey [12]. HCSD not only provides us a holistic view of the challenges, but also allows us to change the fidelity and zoom into the target [13, 14].

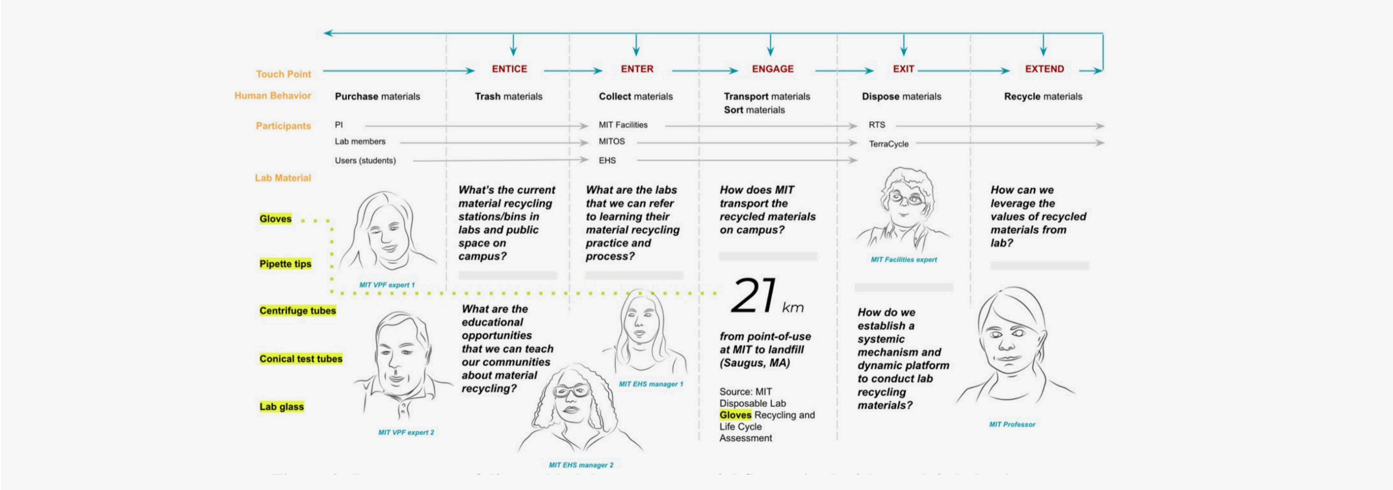

Figure 2: Journey map of disposable laboratory material flow paired with people's behaviour and interviewee's questions.

2.3 Reduce plastic waste of pipette tip boxes

In laboratories, we found that pipette tips and boxes make up approximately 80% of laboratory plastic waste from MIT waste audit [15]. Pipette tip boxes are definitely one of the largest sources of laboratory plastic waste (Figure 3). Therefore, we wanted to investigate potential area of opportunity for recycling pipette tip boxes in laboratories. Research indicated that to reduce this waste, we had three strategies to consider: 1) plastic reduction strategies 2) choosing recyclable plastics and 3) selecting components that use less disposable material [16].

Tiffany Fierros wrote in her research article that the first point, plastic reduction strategies, could mean using stackable racks since their modular design makes them more flexible for laboratories based on people's needs in terms of volume. Also, one stackable tower of racks needs only one plastic cover. People needed to leverage the rack refill systems to refill pipette tips without accumulating tips boxes in laboratories and purchase bagged tips to reduce the accumulation of plastic containers.

Figure 3: Conducted field research at MIT Building 66 (Landau Building) to observe the large volume of wasted pipette tip boxes from laboratories.

Regarding the second point, choosing recyclable plastic, Fierros suggested we need to be mindful of the type of plastic being purchased. For plastic recycling in the United States, only a few are acceptable: polyethylene (PET, plastic #1), polyethylene terephthalate (PETE, plastic #1), or high- density polyethylene (HDPE, plastic #2).

The last point, selecting components that are made of less disposable material, might mean finding laboratory supply companies that design pipette tip boxes packaging or construction with thinner walls of plastic containers, not only reducing plastic waste, but also saving significant costs in the manufacturing process.

In summary, these three strategies can effectively reduce the plastic used manufactured for pipette tip boxes, so that laboratories can have more space to use for other valuable experiments.

We also found that other campus initiatives repurposed their pipette tip boxes as a plant pots giving them a second life with educational reason and emotional attachment [17]. Due to the scope of this research and the limitation of the cost and time, we won't discuss the detailed design the product of the pipette tip box. Instead, we emphasized on service models of the pipette tip box recycling programme in laboratories provided by MIT EHS.

3. Experimental research approaches and results

3.1 Field research—Visit laboratories and makerspaces on campus

To get the first-hand information on campus, we selected three laboratories and two makerspaces out of MIT research units/ departments to help us capture survey data, listen to people's stories, and document their pain points. The field research of laboratories and makerspaces was conducted in three-week period during summer vacation in 2021, following the MIT pandemic protocol.

When we visited four types of laboratories (biological, chemical, material, and mechanical engineering), it was critical to observe some common problems between the four types of laboratories and two makerspaces. For example, over-purchasing disposable materials, the lack of an organized laboratory procurement and material tracking system, the incentives of using sustainable products versus the ratio of cost and value, and the communication between laboratories and institutions needs to be more transparent considering the efficiency of decentralized institute's system. We summarized these common problems to make a hypothetical assumption: these common problems might originate from people's behaviour (e.g., laboratory culture and life ritual), the institute's environment (e.g., physical and policy), and the tradeoff of using sustainable products (e.g., product cost and time cost).

One professor from the department of civil engineering shared how her laboratory re- designed the flow of a pipette tip box recycling to optimize the life cycle of the disposable product in general (Figure 4). What impressed us was how her laboratory built a flexible-yet-rigorous recycling system based on their previous experimental experience and knowledge to make scientists or graduate students who just join the laboratory understand clear principles to follow and double check the system if anything goes wrong.

At another two laboratories, we visited the professors who focused on the material-and- mechanical-engineering-related research. They also set up their own 'laboratory ritual' such as using different colors of tapes as a name tag for each lab member to make a clear responsibility for who owns which equipment. They've also created an internal 'student on duty' system, which allocated laboratory members to each have a set time to maintain laboratories facilities and manage any emergency situations.

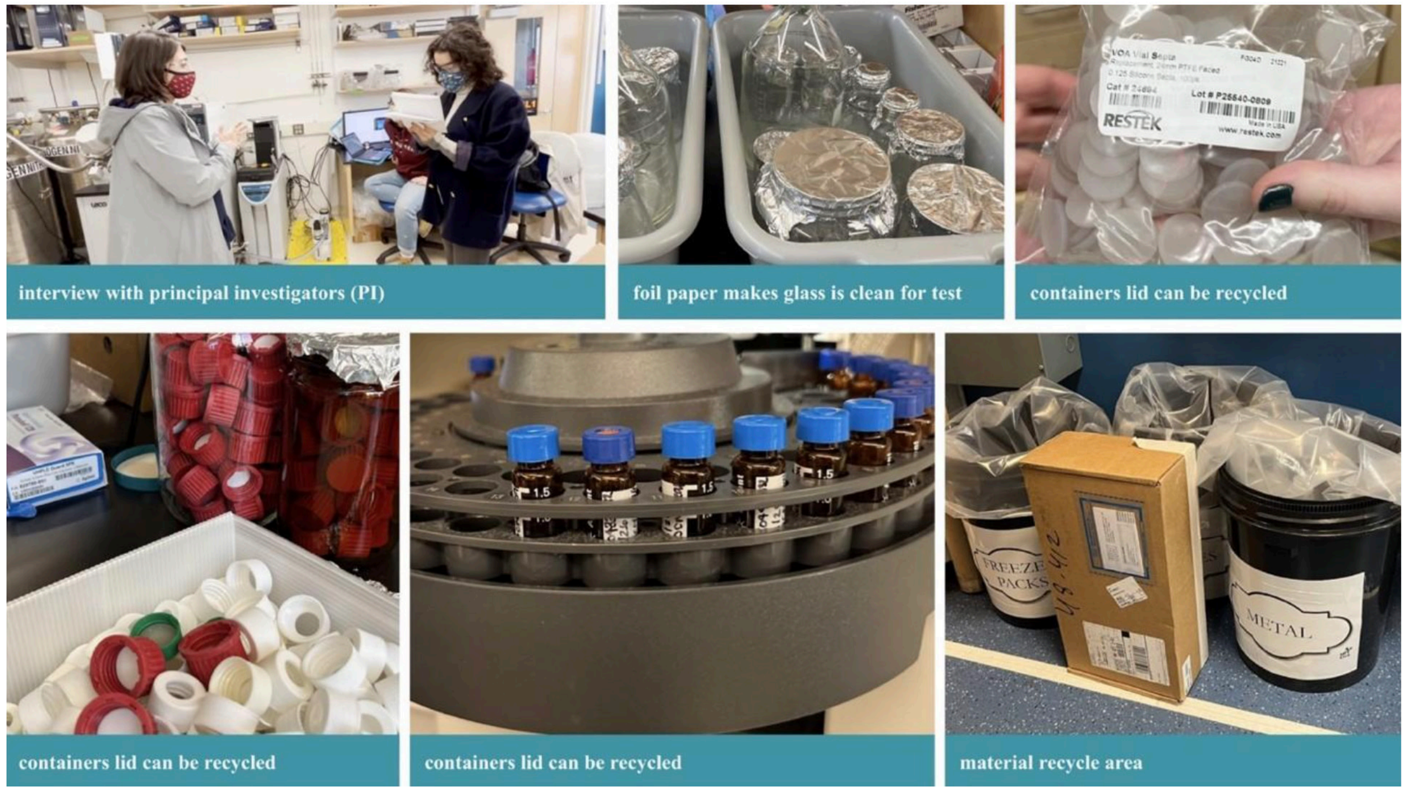

Figure 4: Field research at MIT civil and environmental engineering laboratory during interview of principal investigators.

Besides the laboratories, we also collaborated with the leadership team from MIT Project Manus, MIT's effort and investment to upgrade makerspaces and cultivate stronger maker communities on campus [18]. The Deep makerspace offers milling, turning, SLA 3D printing, mold making, and small screen printing, whereas Metropolis makerspace contains welding, laser cutting, FDM 3D printing, basic electronics, sewing, and waterjet (Figure 5).

The makerspace manager gave us a three-hour tour and explained how they organized their waste material paired with the recycling programme following the regulation from the institute. Both makerspaces are designed with great way-finding systems, allowing for great navigation of the space, but also creating signage for each piece of equipment/machine, so that makerspace members or first-time users can easily know how to use or even master the machines quickly.

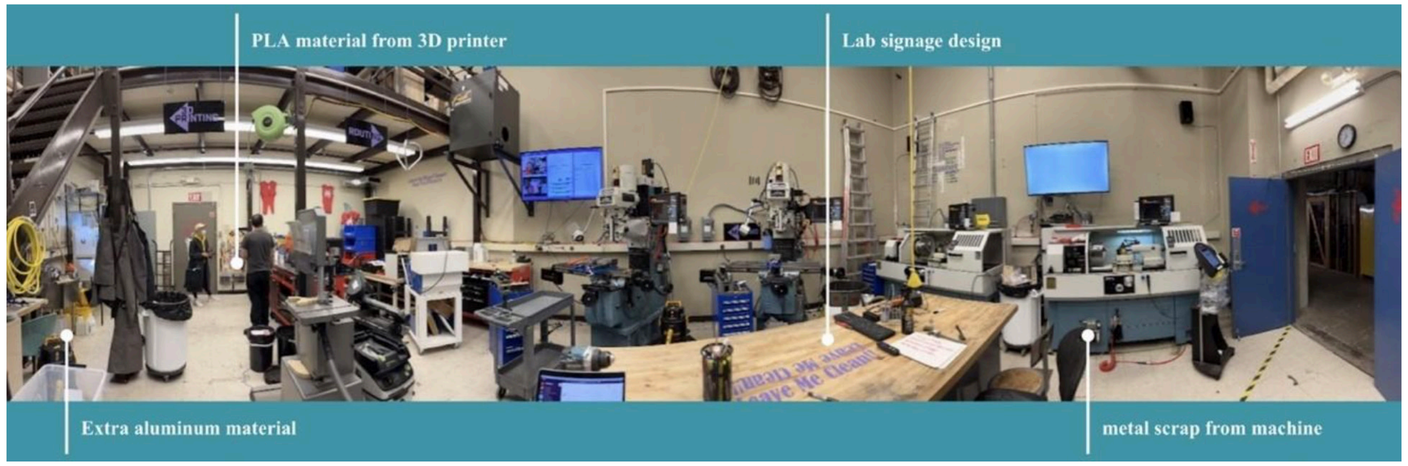

Figure 5: Field research at MIT The Deep makerspace

During the tour, we specifically focused on questions around the disposable material flow. The makerspace managers showed us where they stored metal scrap (e.g., aluminum), built an area for material recycling (e.g., acrylic, cardboard, wood), and designated a place for trash (Figure 6). They also mentioned that 3D printing is a very popular prototyping method among students, but the waste of PLA filament generated by 3D printers is difficult to recycle or is non-recyclable. Some 3D printing companies provide filament recycling services, but most don't have the awareness or service/business model to support the concept of sustainable printing.

During our visit, one shop manager said, "I want to know how the institute or MIT EHS team recycles the disposable material such as cardboard, acrylic, and wood, because I am curious to know where the material goes? If I know the recycling process or at least the next step, I can have a better sense of how I can improve the recycle protocol of [the] makerspace [making it] more efficient." It informed us of the importance of transparency of the material flow on campus both in laboratories and makerspaces. Thus, it has become one of our focuses within our scope of research.

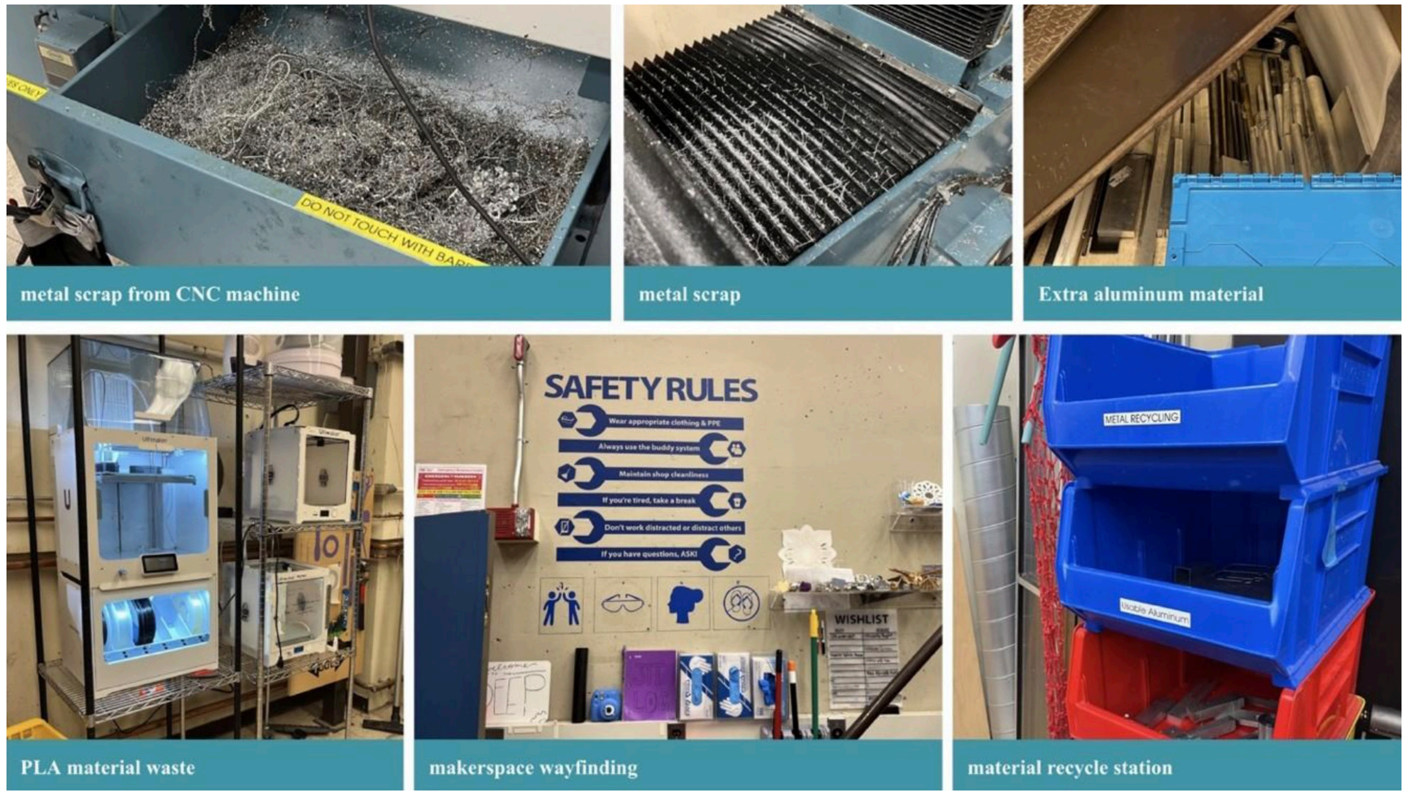

Figure 6: Field research at MIT The Deep makerspace

3.2 Survey design—Using pipette tip boxes in laboratories as a case study

The goal of this case study is to 1) improve the current MIT EHS pipette tip box recycling programme and user experience, 2) consider how to scale the initial solutions, starting with specific laboratories to the entire campus at multiple types of laboratories, and 3) learn how the MIT initiative to build a safe and sustainable laboratory project can impact our collaborative venders and business strategies.

In our survey, besides covering the sustainable design of pipette tip boxes, including using recycled content, consuming less plastic content, using less packaging, and consuming renewable energy during manufacturing, we specifically focused the questions on two sections: 1) purchasing and 2) recycling, with yes/no questions, multiple choices, and open-ended questions so that we can capture the responses both qualitatively and quantitively. The intention of this survey was to help us understand comprehensively the key touch points across the disposable material flow on campus.

For the first section, purchasing, we were curious about the input of the disposable material flow system. Before discussing the disposal and recycling stage, we need to consider the procurement stage of the system. In the study, MIT VPF played an important role in procurement. They've started to plan criteria of 'sustainable' purchasing from the institution's perspective: examining how to build the criteria and who is responsibile at the levels of individual, laboratories, and institutions collectively.

Based on the material from MIT VPF and our research, we listed the questions emphasizing not only people's purchasing behaviours, sustainable product design (e.g., reusable, refillable, and recyclable), but also brands/vendors with sustainability awareness.

For example, do participants know the brand of the pipette tip box or plastic conical tube racks that their laboratory uses? Does the brand provide any pipette tip box or plastic conical tube rack recycling service? How frequently does the laboratory order pipette tip boxes or plastic conical tube racks? Do they or their laboratory choose to buy racked tips or bagged tips? Why do they choose to buy racked tips? Could they use bagged tips instead? Are they aware of sustainable options for pipette tip products? Are they willing to pay more for sustainable pipette tip products? And, if so, how much more (1%, 5%, 10%)?

For the second section, recycling, we want to use the participants' feedback to improve the current MIT EHS pipette tip box recycling programme. 88% of the survey participants/laboratories have collaborated with MIT EHS box recycling programme. Major pain points when people/laboratories engage in pipette tip box or plastic conical tube rack recycling, include it's time-consuming, lack of clear instructions, cost of recycling, no incentives/motivation to recycle, and no one to manage the recycling in laboratories.

Some questions we added to the survey incude, does your laboratory recycle pipette tip boxes or plastic conical tube racks by participating in the EHS managed recycling programme or by a direct return to the supplier? If the brand of the pipette tip box or plastic conical tube racks provides recycling services, can you share with us the cost of this service? How many boxes (waste) are being generated per month? We were also curious to know whether laboratory participants were interested in expanding their recycling efforts to additional forms of non-contaminated laboratory plastic such as buffer bottles.

In summary, we expected that the survey results hypothetically can help MIT to improve pipette tip box or plastic conical tube rack recycling through setting up a complete recycling programme, partnering with sustainable vendors/agencies, enhancing people's recycling awareness through education, redesigning the recycling flow across the campus, and making the rental service of pipette tip box or plastic conical tube rack instead of purchasing a one-off experience.

3.3 Survey result and discussion

We've distilled selected interesting insights after the pipette tip box survey analysis covering two sections: purchasing and recycling. In two-weeks, we launched the pipette tip box survey and documented the result from 31 participants ranging from graduate students (18%), MIT EHS representatives (18%), lab managers (36%), and scientists (27%). Since we considered people's attention span within a short amount of time, the survey was made so participants could fill it out within 10 to 15 minutes (Table 1).

Background	Gender
• Graduate Student (18%) • MIT EHS Representative (18%) • Lab Manager (36%) • Lab Scientist (27%)	Male (31%) • Female (62%) • Prefer not to say (8%)

Table 1. The demography of survey participants (n=31)

3.3.1 The information of pipette tip box

67% of participants knew the brand of the pipette tip box or plastic conical tube racks, whereas 24% did not know. About 10% were not sure about their pipette tip box brands. The brands that participants did remember were: VWR, Genesee, USA Scientific, Sorenson, Neptune, Integra, Rainin, and ART. The majority of the brands (80%) did not provide any pipette tip box or plastic conical tube racks recycling service according to participants' experience. Only 20% of the companies were associated with the product recycling service.

Regarding the frequency of ordering of pipette tip boxes or plastic conical tube racks, 30% of the participants said that they purchased once per month. Only 4% ordered once per week. Some mentioned that the laboratory normally purchased multiple times per month or every other month or even once a quarter. Others said that they had a huge demand for pipette tip boxes, and therefore they order in bulk which is less correlated with the frequency of purchasing.

3.3.2 The cost of time and usability from sustainable pipette tip product

Interestingly, 82% of participants and laboratories choose to buy racked tips and none of them wanted to purchase bagged tips. The remaining 18% didn't know how to decide. Even though bagged tips were relatively sustainable compared with the racked ones, participants said ease of use, convenience, safety, cleanliness, speed were more critical to them.

One participant said, "Sometimes I buy bagged tips and then put them into racks. However, most people prefer racked tips because they get less easily contaminated.

If we buy bagged tips, we would put them into racks ourselves to keep them clean, which can be time-consuming. Also, it is harder to find bagged tips from our suppliers." This was echoed in another response: "Bagged tips are too time-consuming to place in racks one by one. I do buy reloads that are already in the wafer saving waste." For most participants, the bagged tip design was not ideal, since they did not have time to stack the tips into racks themselves, and the cost of their time was not worth the money they might have saved.

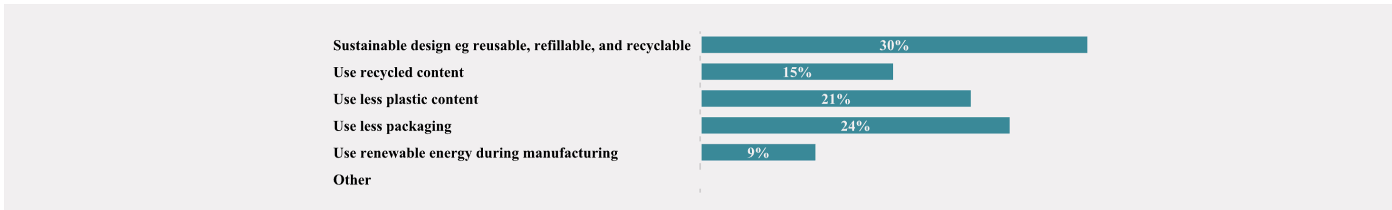

Figure 7: The survey result shows how participants are aware of sustainable options for pipette tip products.

Meanwhile, we were also curious to know if they were aware of sustainable options of pipette tip products exclusive brands and types of tips that we discussed (Figure 7) and how willing they were to put them on their shopping list (Figure 8); 50% of the participants said yes, because it can diminish resources used and improve environmental stewardship, reduce waste to save energy, and it is a 'green' action for them.

One participant identified the potential problem that "I do think that it can be a small effort for a good cause. However, it would be helpful to have a guide of sustainable pipette tips suppliers and catalogue numbers for example. Usually, the issue is the seal or release from the pipettor."

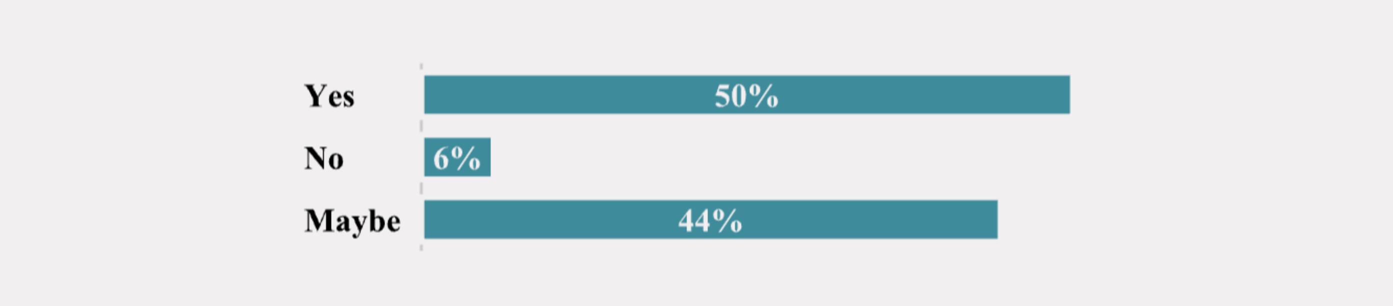

Figure 8: The survey result show how willing participants are to use sustainable pipette tip products.

Since 44% of the participants replied “maybe,” which was close to half of the percentage, we wanted to discuss their intention to better understand. These quotes captured their reasons:

- *“Sustainable pipette tip product needs to be sustainable within reason. However, convenience and ease of use is far more important.”*
- *“We would need to ensure that functionally sustainable pipette tip product works as well as what we use.”*
- *“The sustainable pipette tip option has to be compatible with our automation equipment. We are happy to aim to be sustainable as long as it’s amenable to our needs.”*

In short, people considered sustainable options based on the quality and usability of the product. At the very least, it needs to have the same function and fit the laboratory’s current pipette system with appropriate pricing.

3.3.3 The relationship between value and volume

We also discussed the percentage range of pricing that participants or laboratories were willing to pay for sustainable pipette tip products.

In Figure 9, we can tell that 5% more significantly stood out among other options.

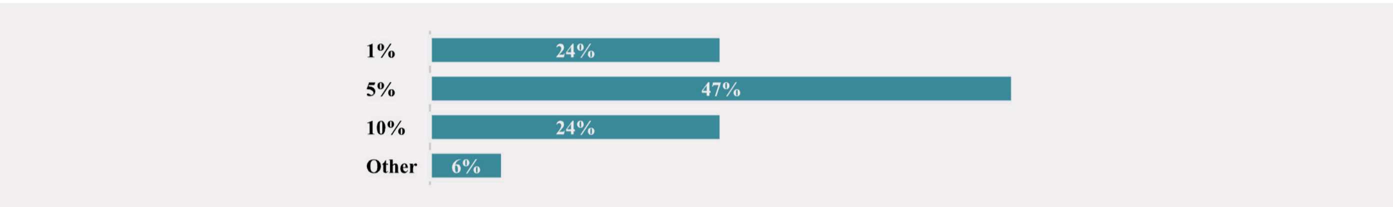

Figure 9: The survey result shows the percentage increase participants are willing to pay for sustainable pipette tip products.

A total of 70% of the participants thought the brand of the pipette tip box or plastic conical tube racks recycling services should be free, whereas the rest (30%) were unsure how much they should charge for these recycling services, which has a correlation with the volume of the wasted boxes generated from laboratory per month.

60% of laboratories generated less than 25 units per month, while 20% of laboratories between 76 units to 100 units per month. But this also depends on the types of laboratories and experiments (Figure 10).

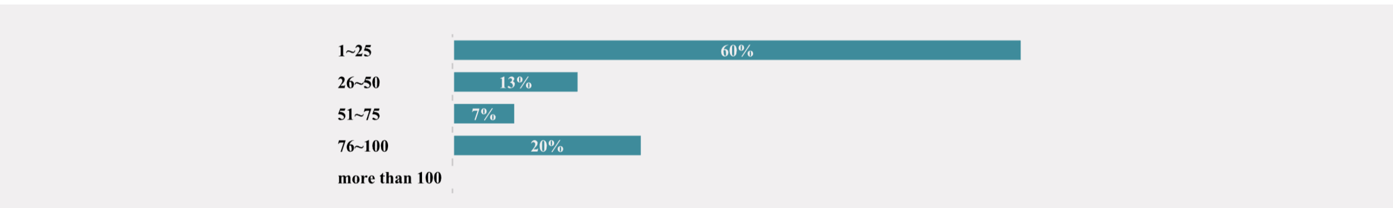

Figure 10: The survey result show how many boxes (waste) are generated from laboratories per month.

3.3.4 The challenges for individual and institution

A total of 60% of the participants felt good when they/laboratory did pipette tip box or plastic conical tube rack recycling; 10% felt they were lacking clear instructions, or no one actually completed the recycling in laboratories; 5% considered the cost of recycling and there was no incentives/motivation to do so (Figure 11).

But, if we viewed the pain points through the lens of the institute, how would the participants/laboratories help MIT to improve pipette tip box or plastic conical tube rack recycling or how could MIT help the participants/laboratories to do this? (Figure 12).

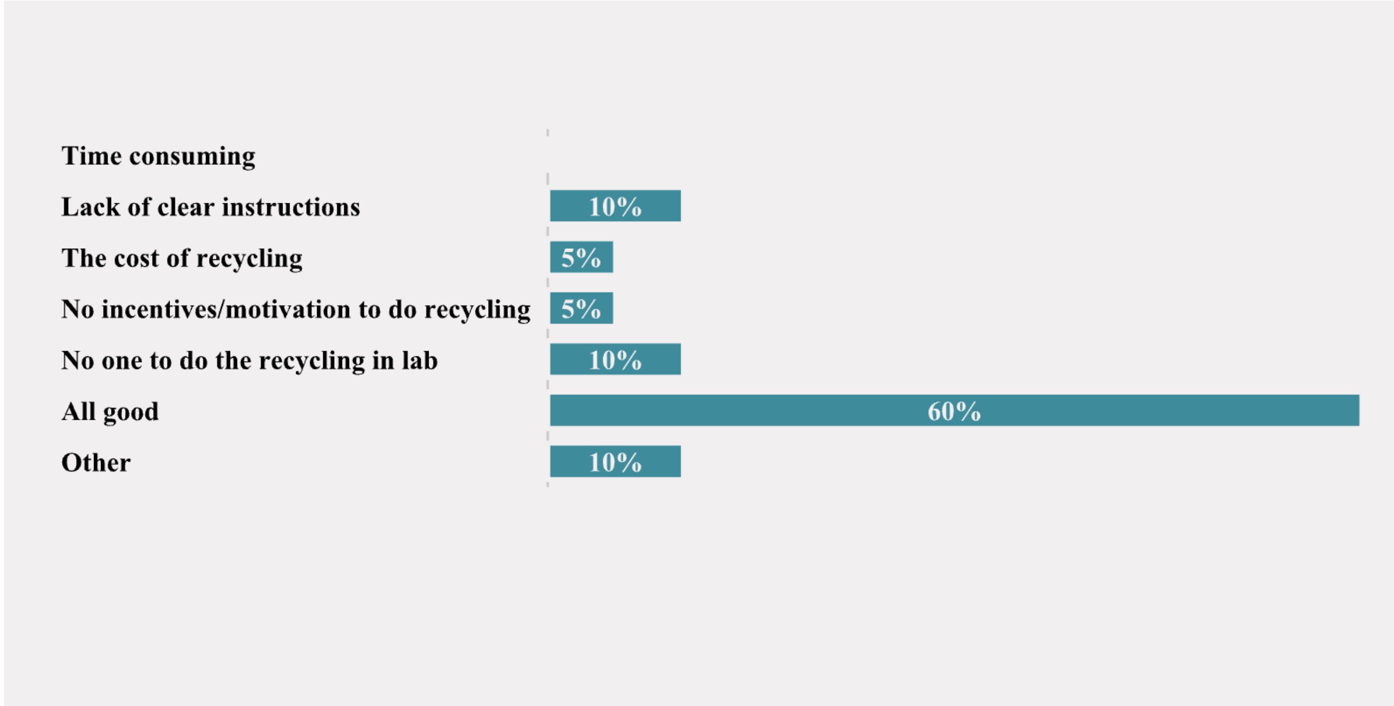

Figure 11: The survey result shows the current pain points when participants/laboratories did pipette tip box or plastic conical tube rack recycling.

Figure 12 reveals that besides the current MIT EHS recycling programme, 42% of the participants pointed out that MIT should set up a complete recycling programme from procurement to disposal and consider people’s behavioural change, policy from the government, technology implication, and culture cultivation.

Besides the pipette tip box recycling programme, 92% of the participants showed their laboratories were interested in expanding their recycling efforts to additional forms of non-contaminated lab plastic such as buffer bottles.

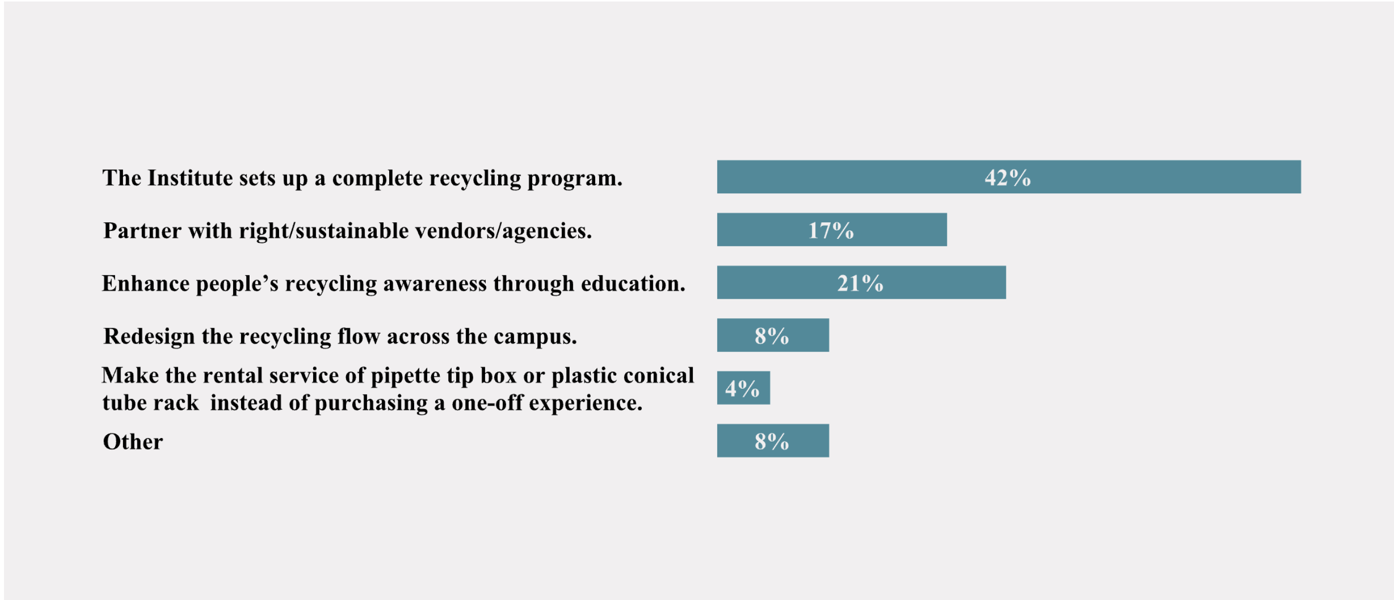

Figure 12: The survey result show how participants/laboratories would help MIT to improve pipette tip box or plastic conical tube rack recycling.

4. Summary and further study

4.1 Inventory management

"Reuse material, know your inventory, and mindful purchasing are easy concepts, but hard to do," said an expert from MIT VPF. Over-purchasing is a common behavior caused by a lack of material tracking [19]. In our pipette tip box case study, even though 60% of laboratories generated boxes (waste) under 25 units per month, which the waste was relatively little and easy to track, they were still unsure of the number of exact orders being made (Figure 10).

According to the field research, interviews and survey results, most people naturally have a mindset towards purchasing more rather than facing less material during their experiment. In conclusion, we observed that improving the laboratory inventory system is a critical step to enable PIs to make smarter material purchases, which also helps laboratory members sort in an ordered way before sending them for recycling or disposal.[20]

4.2 Human behaviour

In our interviews, people said selecting sustainable products is important, but when they make decisions about laboratory material procurement, people naturally consider an item's value per cost first before they think of sustainable impact. Take pipette tip box as an example, 44% of the survey participants replied "maybe" they are willing to use sustainable pipette tip products (Figure 8). It clearly indicated that close to half of the survey participants considered sustainable options in terms of the quality and usability of the product, and the functionality and the compatibility to fit their laboratory current pipettes system with appropriate pricing.

In response to the problem at the institute level, MIT VPF has created a Green Purchasing contract by coining specific terms to make sure vendors not only provide sustainable products with competitive prices but also minimize the carbon footprint of laboratory materials. However, we should carefully take human behavior into consideration when planning sustainable initiatives.

4.3 Safe and sustainable laboratory model

Researching disposable laboratory material flow is the tip of the iceberg of building safe, sustainable laboratories. We need to examine this complex and systemic problem in a comprehensive way to build an ideal model of safe, sustainable laboratories on campus for the future. How do we scale learning from the study? When we consider four phases of material flow analysis, how do we evaluate each phase on the institutional level and individual level?

For further study, we aim to research areas of sustainability practice in laboratories and makerspaces from the perspective of individuals and institutes, identify key touchpoints of disposable material waste with the product and service model, and consider the connection between sustainability actions and people's behavior.

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