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# Transforming food waste into natural pigments: Raising community school awareness of food waste recycling opportunities through co-design methods

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**Abstract:** In a world grappling with ongoing food scarcity, the issue of food waste in US school cafeterias remains a pressing concern, often without sufficient attention given to recycling. School communities play a pivotal role in shaping behaviors, as individuals are significantly influenced by their peers' actions and opinions, making them more open to positive reinforcement. This research explores design opportunity to raise awareness and encourage food waste recycling behaviors through a co-design approach. Students are invited to participate in the interactive exhibitions, where they learn and provide feedback about the pigment-making process from food waste using a toolkit for art painting. Through sharing their experiences, students help spread awareness and foster a commitment to recycling behaviors among their peers. Engaging students as active participants in these activities shows promise as a strategy to increase awareness of food waste recycling opportunities and empower school communities to support circular food systems.

**Keywords:** Food waste; Co-design; School community; Design for sustainable behavior

## 1. Introduction

The United States Department of Agriculture (USDA) in 2017 noted that while the National School Lunch Program (NSLP) is instrumental in providing daily meals to about 30 million children, a significant challenge remains: an extensive amount of edible food, approximately valued at \$5 million, goes unconsumed in school cafeterias each day. Annually, this equates to a staggering 90 billion pounds of untouched food nationwide, resulting in an average cost of \$372 per individual (WWF, 2019). Although the prevention of food waste is essential and promises significant long-term benefits, various obstacles such as regulatory and operational constraints in schools, difficulties in managing the meal portions and individual choices of



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students, and the unpredictable nature of food procurement and preparation, make food waste reduction a more viable and effective strategy for many educational institutions (USDA, 2016; Terry et al., 2015). Consequently, schools are identified as a critical sector for food waste intervention, underscoring the need to reevaluate waste management strategies. This issue not only has substantial financial ramifications but also exerts a significant toll on the non-renewable resources utilized in food production, with fruits and vegetables alone contributing to 19% of this waste. In the US, students waste vegetables and fruits the most, accounting for over 50% of their plate waste (USDA, 2017).

In a Circular Economy (CE) for food, natural systems of regeneration are mirrored so that waste does not exist, but is instead feedstock for another cycle (Ellen MacArthur Foundation, 2019). This approach follows principles of designing out waste and pollution, keeping products and materials in use, and renewing natural systems. One of the most environmentally conscious actions within this context is transforming food by-products and edible food waste into a wide array of valuable products. Achieving this requires ensuring by-products and waste are collected at their highest value, redistributing surplus edible food, turning the remaining inedible by-products and human waste into new products, from organic fertilizers to biomaterials (Carrillo et al., 2022; Mapelli et al. 2002), thereby driving new revenue streams in a thriving bioeconomy. There will be a significant reduction in resource consumption, such as water, energy, and land, which would have otherwise been associated with new production and waste management. As the transition towards a comprehensive CE progresses, the opportunity to transform food waste into value-added products, such as natural pigments have potential, particularly in environments like school cafeterias. Today's paints often depend on vibrant, durable pigments derived from toxic petrochemicals, which harm the environment during both production and disposal (Challener, 2017). Moreover, pigment waste not only leaks into the surrounding landscape, poisoning water and soil for humans and animals but also, synthetic pigments release petrochemicals into the air long after they have dried, causing respiratory problems and damaging the ozone layer (EPA, 2005). Accordingly, transforming waste into value added product requires the promotion of sustainable recycling behaviors within the school community.

Design for sustainable behavior (Dfsb) is a research area that focuses on understanding how individuals interact with products. It explores the potential impacts of design interventions on these interactions, drawing insights from multiple disciplines to influence more environmentally friendly and socially beneficial usage of products and services. (Scurati et al., 2021; De Medeiros et al., 2018; Niedderer et al., 2014). The tools and frameworks of were developed for application as part of a user-centered design (UCD) process, that to design products and services that cater to user needs. In UCD, designers, seen as experts, navigate the balance between product properties and user capability, needs, and goals. (Rizzo, 2010). Yet, measuring the effectiveness of these tools across all user types, particularly children can be challenging as the designed products or services need to be tested in a real-world setting. Furthermore, understanding user motivations for behavior change and the required design strategies to be applied is limited. Whilst Co-design is a collaborative process in which non-

designers, actively participate in generating ideas and creating designs (Örnekoğlu-Selçuk et al., 2023; White & Kennedy, 2021; Shore et al., 2018; Slattery et al., 2020). This process goes beyond mere collaboration, representing a shared reflection that transcends mere knowledge generation and connection (Selloni, 2017). Co-design integrates the creativity of both professional designers and those without formal design training, fostering an environment where participants take an active, empowered role (Sanders & Stappers, 2008). By involving the community in the design process tailors designs to user values and preferences, amplifies their voice, and enhances their societal knowledge, ultimately influencing their behavior (Maye & Claisse, 2023; Sanders & Stappers, 2008; Druin, 2002).

Raising awareness and education are a promising intervention in Dfsb (Bhamra et al., 2011). Indeed, engaging students in the design process and offering them opportunities to develop inspiring designs could enhance their awareness of sustainable food practices. Allowing the school community to contribute ideas and participate in the process of turning waste into valuable resources can heighten their awareness of extending the lifespan of food waste. This can also foster healthier student habits regarding the consumption and disposal of food waste in school cafeterias as school students are often swayed by the opinions and actions of their peers, particularly those they admire or wish to associate with (LaRue, et al., 2015). Moreover, their involvement will reveal the tools, skills, and knowledge the school community needs to take proactive steps towards recycling behavior. Numerous studies have explored insight into co-design with children (Ganna et al., 2023; Gaudion et al., 2015; Melonio & Gennari; 2013; Iversen & Smith, 2012). However, existing co-design literature predominantly focuses on healthcare interventions (Thabrew et al., 2018; Vaajakallio et al., 2009) and digital technology for sustainable behavior (Bonino et al., 2016; Walsh & Foss, 2015). Yet, very few studies focus on understanding motivations for children's food recycling behavior to create awareness and design opportunities with their involvement in design development.

Increasing awareness can be achieved through making information more visible, whether through organizing exhibitions, facilitating talks, or providing education (Fuad-Luke, 2013). This research discusses 'Food Magic – Turning Food Waste into Colors', a live co-design research project accompanied by a pop-up interactive exhibition at Moss Art Center. By focusing on three themes: infographics, tools, and painting, this research aim is to examine how a co-design approach can enhance students' understanding of the food life cycle and offer practical insights into motivating the school community to reconsider food consumption and positively affect their recycling practices. This paper will discuss the conceptualization of this project and share insights from the participatory exhibition. It will then use the project evaluation to analyze the findings and highlight design opportunities for future research.

## **2. Barriers**

The potential barriers that prevent school communities from recycling food waste into valuable products are discussed under three categories below, drawing on insights from the

"Food Waste Warrior" report by WWF (2019) and related literature. Firstly, school community lack information about their environmental impact through wasting food and the value of recycling for turning inedible food and by-products into new products and its methods. Furthermore, there are no efficient and user-friendly tools for ensuring food waste is collected at the highest value and converting them into new products within localized waste management systems, aside from food waste composters. These composters, while addressing some issues, encounter problems like clogs and unpleasant odors, especially when dealing with oil-based food residues. Another significant barrier is the negative perceptions surrounding food waste. Influenced by prevailing social norms, these negative attitudes deter individuals from utilizing food by-products and edible food waste, even if they could serve other purposes (Aleshaiwi & Harries, 2021; Andrews et al., 2018; Cecere et al., 2014; Cappelini, 2009). Thirdly, there are not enough student engaging activities aimed at raising awareness about adding value to food waste. Opportunities for student experiential learning are limited, though it is an essential method to foster understanding of sustainable practices. Lastly, the logistics of collecting, storing, and converting waste into new products are not just time-consuming but also labor-intensive, which often leads to a lack of engagement from students during disposal, necessitating supervision from teachers. As a whole, these issues have been largely overlooked by designers, contributing to inefficiencies that could otherwise divert waste away from landfills and reduce waste management costs.

### 3. Methods and procedure

This study adopts an interdisciplinary approach by exploring through diverse disciplinary lenses, recognizing and synthesizing contributions from various fields to achieve a comprehensive understanding (Repko & Szostak, 2020; Steph et al., 2016), as depicted in Figure 1.

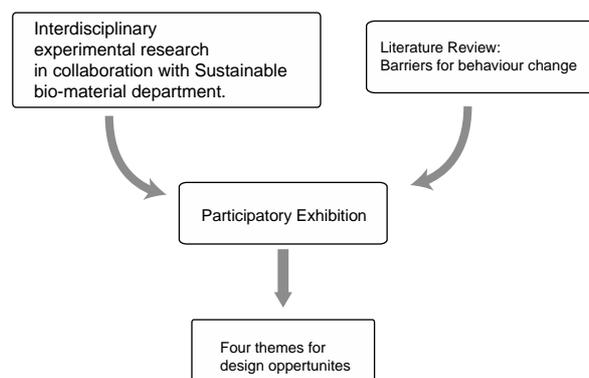


Figure 1 A diagram of research methods and procedures.

Such approach was integrated at the stage to develop a natural pigment from food waste, involving collaboration with material scientists from the Sustainable Biomaterial discipline. Empirical data were collected by exploring pigment extraction methods. Concurrently, tools like infographics and waste sorters were developed to facilitate conversations about the

value of food waste. This approach was further employed by involving artists and art educators to define pigment quality standards and to design a toolkit. This toolkit is intended for further refinement with children during an interactive exhibition. Insights from this exhibition were analyzed to identify future design opportunities, highlighting the value of involving children in the design process. This collaboration aims to increase awareness and influence behavior towards recycling food waste in school cafeterias, fostering a collective search for needs and solution development (Sander, 2002).

Selection criteria for participating school community in this project included: 1) The organization must be a public school enrolled in the NSLP, and 2) the target group had to be fifth graders. Research indicates this age is pivotal for developing critical thinking, creativity, and foundational knowledge in science and math, essential for adopting new recycling behaviors, making them ideal participants for the toolkit (Hungerford, 2010). The Center for Educational Networks and Impacts (CENI) at Virginia Tech offered these students an opportunity to engage in a "Hokie for a Day" event where it features a pop-up interactive exhibition. Seventy fifth-grade students from public elementary schools were invited to this hands-on exhibition. Participation, facilitated by CENI, was entirely voluntary, with the option to withdraw at any point without repercussions. Demonstrations of the toolkit and pigment production process were provided to minimize risks. Participants shared their intervention development ideas and engaged in activities to explore the application of these interventions and enact change.

### *3.1 Interdisciplinary research*

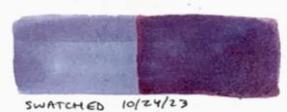
Interdisciplinary research involves integrating knowledge and methods from different disciplines, using a real synthesis of approaches (Jensenius, 2012; Stember 1991). Bringing together researchers who may not typically interact, can foster a sense of shared purpose and promote innovative thinking (Dahm et al., 2021). The collaboration bridges knowledge gaps and stimulates new ideas (Jensenius, 2012), bringing unique insights and skill sets to intricate issues. Developing a pigment extraction process requires understanding of the advanced scientific knowledge that has been discovered. In collaboration with scientists from the sustainable biomaterials discipline, a method was explored to produce natural pigments, aiming to provide a non-toxic alternative. The method was based on a process that breaks down intermolecular bonds among food waste components using high pressure and temperature. This results in significant pigment extraction from fruit and vegetable waste, depending on the composition of the material. Table 1 presents the selected processes for common waste sourced from school cafeterias, as identified through interviews with a local school in Virginia. Through investigating twenty distinct methods, adjusting the fractionation of individual components using a combination of liquification and vaporization processes, a deeper understanding of pigment extraction was achieved. Table 2 shows the swatches evaluated during selected experimental trials.

Table 1 T selected process for common food by-products and waste sourced from school cafeterias.

	<b>Name</b>	<b>Process description</b>	<b>Additive</b>	<b>Outcome</b>	<b>Code</b>
Trial 1	Carrots	Oven Dried + Isopropyl Alcohol Extraction	None	Yellow pigmented alcohol	Pigment of high purity
Trial 2	Carrots	Water Boiling + Boil Reduction	None	Pale orange pigmented water	Pigment of high purity
Trial 3	Carrots	Isopropyl Alcohol Extraction + Boil Reduction	None	Thick, sticky, orange pigment	Pigment of high purity
Trial 4	Blueberries	Isopropyl Alcohol Extraction + Boil Reduction	Gum Arabic	Purple watercolor	Pigment of high purity
Trial 5	Blueberries	Isopropyl Alcohol Extraction + Evaporation Reduction	Gum Arabic	Purple watercolor	Pigment of high purity
Trial 6	Spinach	Isopropyl Alcohol Extraction	Gum Arabic	Green watercolor	Pigment of high purity
Trial 7	Carrots	Boiled Isopropyl Alcohol Extraction	Gum Arabic	Light orange watercolor	Pigment of high purity
Trial 8	Raspberries	Oven Dried	Gum Arabic	Brown watercolor	Mixed substance
Trial 9	Red Onion Skins	Microwave Dried + Isopropyl Alcohol Extraction + Evaporation Reduction	Gum Arabic	Green/brown watercolor	Pigment of high purity
Trial 10	Carrot	Juicing + Fermenting & Separation + Freeze Drying	Gum Arabic	Saturated Orange Watercolor	Mixed substance
Trial 11	Corn husk	Isopropyl Alcohol Extraction	Gum Arabic	Olive green watercolor	Pigment of high purity
Trial 12	Celery	Juicing + Rotavapor Condensing	Gum Arabic	Pale green watercolor	Mixed substance
Trial 13	Celery	Juicing + Freeze Drying	Gum Arabic	Light green watercolor	Mixed substance
Trial 14	Banana peel	Water Boiling + Freeze Drying	Gum Arabic	Brown watercolor	Pigment of high purity



Table 2 Swatches evaluated during selected experimental trials.

	Food waste	Swatch
Trial 1	Carrots	 GROUND ROASTED CARROTS FROM B/S NOT MULLED ISOPROPYL EXTRACTION 7% 5% CARROTS 20g IPA 8/25 - 9/1/23 FILTERED THROUGH
Trial 2	Carrots	 8/27/23 CARROTS BOILED IN WATER REDUCED BY BOILING
Trial 3	Carrots	 
Trial 4	Blueberries	 BLUEBERRIES ISOPROPYL ALCOHOL EXTRACTION BALL REDUCTION MULLED W/OUM ARABIC SWATCHED 10/24/23
Trial 5	Blueberries	 BLUEBERRIES ISOPROPYL ALCOHOL EXTRACTION EVAPORATION REDUCTION MULLED W/OUM ARABIC SWATCHED 10/24/23
Trial 6	Spinach	 SPINACH ISOPROPYL EXTRACTION MULLED W/ GUM ARABIC SWATCHED 10/24/23
Trial 7	Carrots	 CARROTS BOILED FOR 10 MIN IN ALL RUN THROUGH CHEESE CLOTH
Trial 8	Raspberries	 SWATCHED 10/24/23 RASPBERRIES DRYN DRIED + GRIND MULLED W/ GUM ARABIC
Trial 9	Red Onion Skins	 RED ONION ISOPROPYL EXTRACTION EVAPORATION REDUCTION MULLED W/ GUM ARABIC SWATCHED 10/24/23
Trial 10	Carrot	 SWATCHED 10/16/23 JUICED CARROTS - PULSED DRIED AFTER JUICE FERMENTED + SEPARATED SOLIDS SOLIDS GROUND + MULLED WITH GUM ARABIC
Trial 11	Corn husk	 CORN HUSKS 70% ISOPROPYL ALC. EXTRACTION REDUCED W/ EVAPORATION @ ROOM TEMP + FAN MULLED WITH GUM ARABIC SWATCHED 10/16/23
Trial 12	Celery	 CELERY JUICED + CONDENSED (S. 810) MULLED W/ GUM ARABIC SWATCHED 10/24/23



During the early stages, three school art teachers and two painters with experience in natural pigment painting were interviewed to determine the criteria for evaluating pigment quality. The following five factors were considered important for pigment success:

**Stability:** How well the pigment withstands external elements like sunlight, moisture, or added substances, and if it keeps its initial properties under such conditions.

**Longevity:** Whether the color keeps its intensity for at least a month.

**Purity & Consistency:** Whether the pigment color is consistent without noticeable contaminants.

**Solubility:** Does the pigment mixes with solvents or mediums, such as water.

**Safety:** Ensuring the pigment is safe for children to handle.

The necessary steps involved grinding, boiling (either in water or Isopropyl Alcohol), and mixing with gum arabic. To enhance the product's longevity, a vaporization process like freeze drying of pigments was essential to eliminate the liquid components from the boiled, water-rich fruit and vegetable peels. Figure 2 shows the tendency of effective methods for extracting pigment from different fruits and vegetable waste.

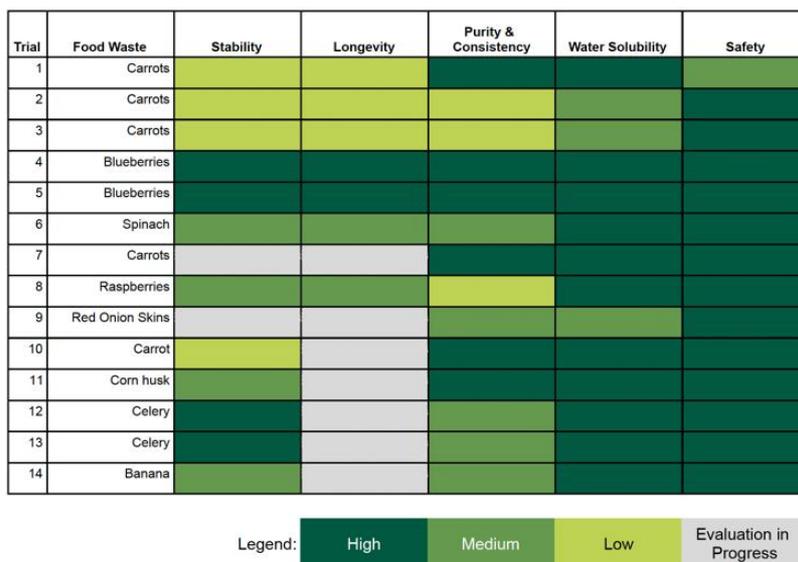


Figure 2 The swatches evaluated during selected experimental trials using the heat map method.

### 3.2 Interactive exhibition

Exhibitions, considered as vehicles for knowledge creation, have significant potential as communication mediums for research (Treimo, 2019; Rust & Robertson, 2003). An interactive exhibition was organized, involving seventy children aged ten and three teachers. The goal was to co-develop the essential tools and provide engaging experiences for converting waste into pigments, and raised awareness about the food lifecycle, collectively redefine the concept of 'waste'. Children were encouraged to engage in discussions, use the tools, and employ the high-quality pigments produced from the experimental trials for painting. Upon completing their paintings, the children filled out feedback cards to understand whether the experience could have an impact on everyday school life while fostering co-responsibility. Appendices 1 and 2 show the detailed process of analyzing the feedback cards. Additionally, insights were gathered from participants' comments. An affinity diagram approach was used to analyze the data, helping identify common themes from the vast amount of information and guiding design directions (Martin & Hanington, 2012; Moggridge & Atkinson, 2007). These themes were clustered into meaningful categories, forming the basis for future design opportunities to promote recycling behavior.

## 4. Design Opportunity

The interactive exhibition was organized around three main themes – Infographics, tools, painting with natural pigments. It aimed to raise awareness and engage children in a design process for better practices in food waste recycling.

### 4.1 Infographic

Increasing consumer awareness of the product lifecycle and its impacts has been described as one of the best hopes for a transition to CE (Ghisellini et al., 2016). To raise awareness about school cafeteria food waste and the value of repurposing this waste, infographic posters were created (Figure 3).



Figure 3 The infographic illustrates by analogy, the extent of food waste generated in school cafeterias each year. It also provides information about the valuable substances in fruit and vege-

table waste that have the potential to produce natural pigments (Left). It illustrates the significant amount of chemical-based paints wasted every year, emphasizing their negative environmental impact (Right).

These posters introduced the 'Food Magic' project and quickly emerged as an effective means to foster discussions about recycling behaviors, especially regarding the consistent waste of fruits and vegetables. This infographic functioned as a tool for students to question and stimulate personal reflection on their own food consumption and disposal behavior and to inform them about the necessary actions to be taken. Furthermore, it provided an opportunity to consider converting food waste into new products. During the facilitated discussions, children shared that they were unaware that the individual components of fruits and vegetables play key roles in producing new products, such as natural pigments. If students were educated about the significant amount of waste accumulating in landfills and the inherent value of the components within fruits and vegetables, they might be better positioned to make informed choices regarding their food disposal behavior.

#### 4.2 Tool

Within the framework of the CE, it's vital to illustrate how fruit and vegetable waste can add value, with the waste from one enterprise serving as a resource for another (Ellen MacArthur Foundation, 2019). However, recycling all food waste remains a challenge, especially when different types of waste are mixed together in a single bin. Sorting is essential to maximize the utility of food waste, ensuring that the recyclable food waste is free from contaminants, streamlining the process and yielding a high-quality end product (Ellen MacArthur Foundation, 2019). By providing an option to segregate food waste and introducing tools to transform this waste into new resources, there lies a potential opportunity to enhance community-based waste management systems. To this end, a downsized sorting bin was developed and exhibited to gather feedback from students and explore further ideas for co-developing the design (Figure 4).



Figure 4. Three examples of color based scaled down sorting bin design exhibited at the stand (Left). Participating student exploring the design (Right).

This bin was conceptualized to motivate students to categorize their food waste based on the type and color of the fruit or vegetable. Informative labels on the bin lid detail the composition of various fruits and vegetables, enlightening students about the potential uses and value of the waste they are discarding. Through the facilitated conversation, children shared their ideas for a tool that allow waste to be easily sorted. One student mentioned color scheme-based bins would make the sorting activity fun for kids, although it will be a challenging task at the beginning. If the school support the education of students, then this will become part of their habits. Another student mentioned that they favored the idea of having a window on the top of the bin so they can see which food goes where. Rewards systems will encourage students to be part of the sorting activity, once the bin is full. Yet, the design of the bins in general received mixed responses, citing the extra work required to sort after each meal. Furthermore, missorted waste might create an impact on the color production process. The prototyped tool functioned as a conversational tool in actively involving the school community to explore and develop ideas for adapting their own school cafeteria experience related to disposal behavior. While it was identified that sorting food waste was a complex task as not many people know how to sort, nor is it easy to know which waste has more value, there is currently no available design to facilitate sorting on site. Empowering students with relevant knowledge is another key motivation for making the most of food waste.

#### *4.3 Natural pigment painting*

Students often have a negative perception of waste from fruit and vegetables, not recognizing its potential value. This perception is, in part, influenced by the financial cost associated with the price of these items and the recycling of these food waste (Aloysius et al., 2023). When deciding on whether to recycle food waste or not, people tend to weigh the costs and benefits. For instance, one student expressed uncertainty about the benefits their sorting actions would yield, while another was unsure about the positive environmental impact of their sorting efforts. Some responses highlighted that since fruits and vegetables are affordable and readily available, there isn't much value seen in the leftovers.

During an exhibition, students were encouraged to paint using pigments derived from food waste collected from the local community (Figure 5). Additionally, educational sessions were offered, teaching the art of painting with natural pigments, bound with water and gum arabic. Unlike their petroleum-based counterparts, natural pigments may require repeated application to sustain their color intensity over time. These novel painting techniques stir the children's interest and enthusiasm, encouraging them to explore deeper into the sustainable process. Involving students in the creative art process proved to be an effective method to engage children and shift negative perception linked to food waste (WWF, 2019). Their artistic creations, employing these natural pigments, were exhibited, allowing the students to take pride in their work and gain confidence in their ability to use natural materials (Figure 6). Some students were eager to share their paintings at home, and others proudly pre-

sented their work to teachers. This sharing and acknowledgment of their efforts typically results in praise, which is highly valued and rewarding for them. Additionally, the curiosity of one student, who inquired about producing pigments from various kinds of food waste encountered at home and the tools required for this process, highlights the initiative's capacity to broaden knowledge. This, in turn, empowers children to become more confident in recycling efforts and in creating natural pigments.



*Figure 5 Fifth grade students painting with natural pigment produced from food waste.*



*Figure 6 Selection of fifth grade students' paintings produced during the exhibition.*

The recipe cards were handed out to students with simple suggestions for how to play an active role and engage them in systematic transformation towards CE. They include a basic guide on producing pigments from food waste, designed for home experimentation. They also proposed activities to minimize waste at the initial phase of food consumption and suggest ways for students to share their experiences.

## 5. Analysis of participant feedback

The project's residency in Blacksburg, Virginia provided a live research setting to support participatory activities, allowing the school communities to respond and share their feedback. The project was evaluated using feedback cards (Figure 7), and informal conversations. Participants shared their learnings from the exhibition and made recommendations for the project's future expansion.



Figure 7 Feedback card.

### 5.1 Evaluation cards

The data set from forty feedback cards was organized using an Excel spreadsheet and then automatically analyzed to present interim insight. Out of 40 responses, more than 92% of participating students agreed that they learned something new that day and more than 90% of them said they learned that food waste has value to be converted into natural paint. 61% of students wanted to share what they learned that day at home. However, sorting remains a challenge for children; 63.3% of the students were not inclined to separate food waste into different bins. This indicates that the task might require more than just facilitating tools. 45.5% of the participants mentioned they would use the natural pigments if given the opportunity. Thus, informing school community and providing an accessible and cost-effective tool that provides an engaging activity presents a promising opportunity to motivate recycling behavior.

### 5.2 Future recommendations from participants

The insights were categorized into clusters, revealing four emerging themes through the co-design process. These themes, which can be explored as further design opportunities, serve as a foundation for influential factors motivating recycling behavior: Reducing the Knowledge Gap, Engaging Tools, Art-Oriented Education, and Diverse Applications. Table 3 displays the emerging themes that will be explored in the subsequent phase of research, along with grouped comments from participants.

Table 3 Emerging themes for future design opportunities.

Code	Theme 1 Reducing the knowledge gap	Theme 2 Engaging tool	Theme 3 Art oriented education	Theme 4 Diverse application
Comments from participant	I want to learn how not to waste food in the first place.	I want to learn how they made the paint from waste.	Painting with natural pigment was a fun and engaging activity.	I want to use the pigment to dye my clothing.
	I was amazed by how waste from fruits and vegetables can be turned into pigment.	Having fun and receiving rewards are very important for kids.	Hands-on experiential learning was valuable.	Can this pigment be mixed with other mediums, such as oil?
	I'm surprised by the painting quality.	I'm concerned about asking students to sort all the fruits and vegetables into a separate bin.	I want to draw a sea turtle using green paint made from celery waste.	Can by-products, like leftover extracted banana fiber, be used to make paper or textiles?
	Compared to commercial pigments, this quality is distinctive and authentic, and I appreciate that.	I tend to purchase commercial paint because natural paint is more expensive.	I want to learn how to paint animals with multi-colored paint derived from waste.	Is it feasible to use any kind of fruit and vegetable waste to produce natural pigment?
	It also has a natural scent.		My painting wasn't perfect, but I'm proud of my work.	
	Can leftover strawberry extract be used as pigment?		I'd like to sketch my dog.	
	I want to know which food waste will produce which color.			

Theme 1 addresses the importance of informing and educating, which can serve as motivational factors. Theme 2 is related to the provision of accessible and cost-effective tools and that process of involving in the development of tool represents a promising design opportunity. Theme 3 is related to the role of art-oriented education in motivating recycling behavior. An inspiring painting process using natural pigments and exhibiting their art works in public space, can influence students' behavior toward recycling. Lastly, Theme 4 suggests that experimenting with various applications, like using pigments for fabric dyeing, and demonstrating their use in multiple contexts can serve as motivation for recycling.

## 4. Discussion

This project explored how the school community could recognize their unique role and be engaged in a systematic transformation towards a CE, fostering a more sustainable and lasting relationship with food waste that still has value. The school community was invited to an exhibition to share developed tools and infographics, further exploring ideas through a co-design process. They were also encouraged to create their own paintings using natural pigments produced in collaboration with the sustainable biomaterial team, adopting an interdisciplinary approach. These activities prompt them to question, create, and reflect their understanding of the impact of their behavior. This initiative also mediated conversations with a school audience, awakening that no food items are purely waste and highlighting methods to optimize their value, challenging prevailing negative perceptions about food waste.

UCD approach has been widely applied in the Dfsb (Lilley & Lofthouse, 2006; Lockton et al., 2010; Daae & Boks, 2011). Meanwhile, the co-design approach enhances our understanding of people's experiences, taking into account their past, present, and future lives, by introducing playful activities to participants. As a live research project, 'Food Magic' project served as a platform for experimenting with ideas, offering hands-on experience, and conducting activities in an exhibition setting with an engaged audience. This not only stimulates creativity but also promotes reflection (Thabrew et al., 2018), enabling designers to identify design opportunities and make modification for next iterations. However, capturing every student's preference and design insights was a challenge, as more assertive students might overshadow others' input. Some students act differently in public environments; they may commit to actions but not follow through. Furthermore, ideas originating from students don't always prove successful in application (Thabrew et al., 2018).

In the food industry, it is acknowledged that more research is needed to determine how we can reduce excessive food consumption and adjust our consumption behavior, instead of primarily focusing on converting food waste into new materials (Ellen MacArthur Foundation, 2019; Goodwin, 2023; EPA 2024). However, implementing prevention strategies within schools involves navigating through tight regulatory and operational constraints. It requires accurate forecasting and adjustments in food procurement and preparation to align with actual consumption, along with fostering longer-term behavioral and operational changes, the impacts of which may only become visible over time (Terry et al., 2015; USDA, 2016; Berkenkamp, 2018). Nonetheless, waste reduction can have immediate effects and serves as

an effective strategy for many schools. In the context of a CE, circular systems efficiently utilize biologically derived materials, promoting multiple economic applications before reintegrating nutrients into natural systems (Ellen MacArthur Foundation, 2019). To initiate a change in food waste reduction within the school community, we need systems that actively incorporate users, acknowledging their pivotal role in the food lifecycle.

This study delved into design opportunities that foster awareness and seek to understand the motivation behind recycling behaviors associated with food waste, with a specific focus on involving the school community in the process of turning food waste into new products. Through a co-design approach, four future themes were identified, offering promising design opportunities aimed at diminishing barriers. By combining engaging and rewarding experiences with the tools and services provided to students, the school community can be integrated into the circular system, altering their negative perceptions of food waste. An accessible tool that allows for the repurposing of food waste into usable products, such as pigments, empowers schools to produce their own materials for educational purpose. This approach not only reduces waste but also offers a safer, non-toxic alternative for art supplies. Additionally, art-oriented education presents a substantial opportunity to educate students about the lifecycle of food and to engage them in the process of making and using pigments made from waste materials, thereby encouraging shared responsibility. Introducing such initiatives into the school curriculum can heighten the school community's awareness of environmental and societal challenges, empowering them to become 'active users' who effectively manage, recycle, and repurpose their food byproducts and waste (Tietze & Hansen, 2013). Furthermore, acknowledging the value of food waste for various applications across different sectors—by transforming it into valuable products like fiber, fertilizer, and energy—plays a crucial role in promoting recycling behaviors. This approach also demonstrated the potential for replication in communities beyond schools, such as farmers and artist, who could benefit from these insights as well.

## 5. Conclusion

This research highlights the critical importance of interdisciplinary collaboration and community engagement in the design process to tackle the complex issue of food waste recycling. By adopted an interdisciplinary approach, it integrates insights from various fields to achieve a holistic understanding of the problem, synthesizing diverse approaches, and proposing promising solutions. Center to this approach was developing knowledge through the integration of co-design approach into the Dfsb. Through this approach, this study addresses underlying motivational factors for recycling food waste and provides designers with broader opportunities to increase awareness, educate, and inspire students' behavior. It offers communities the opportunity to adopt proactive steps toward a sustainable future and develop essential skills for radically rethinking food waste management. The value of this research for the broader design field lies in identifying methods for creating pigments from food waste in collaboration with the sustainable biomaterials discipline, and the discovery four design opportunities that act as motivational drivers for repurposing food waste into new products

within the school environment. Exploring various methods to raise awareness within the school community through practice-based research will be beneficial for design researchers. Future research directions include collaborating with the school community to develop a framework centered on motivation and challenges in optimizing food usage within school cafeterias.

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## Appendices

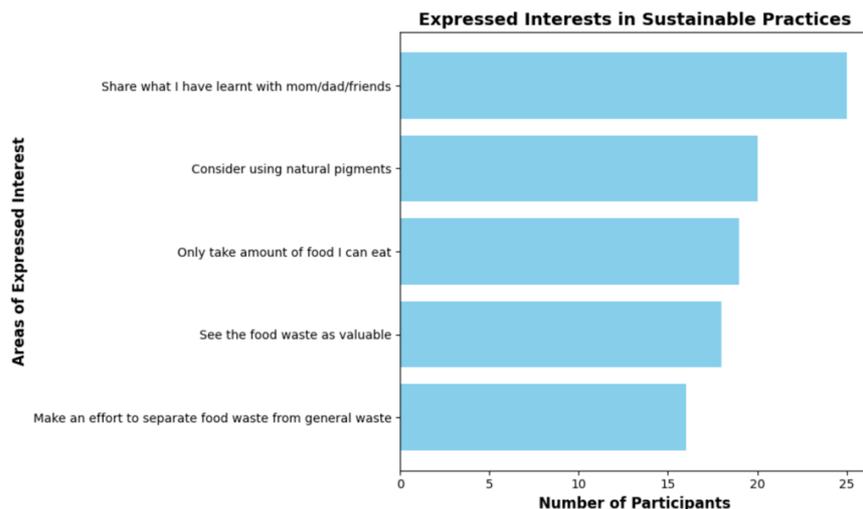
Appendix 1. The table below displays responses to the short-answer questions from the feedback cards received.

Learned Something New?	What did you learn?	What to draw?	future learnings
Y	how to make paint with food	draw hats with pink color from strawberry	
Y	make water colors with food and vegetables	draw strawberry with purple color from grape	how to dry fruits
Y	make paint with veggies	draw apple	
Y	to make paint		
Y	paint better and draw carrot	Draw a dog and house	
Y	that plant's make paint with the CO2 that we breathe		how to make paint at home
Y	using food for paints	draw apple from red color from carrots	
Y	to make paint	draw flower with bean juice from beans	
Y	different stuff about food and paint	draw mat with blue color from banana	
Y	make paint out of food waste		How to dry
Y	using food for paint	draw carrot from orange from carrot	How to paint with corn, banana

Y	i can go to my fridge and start painting		
Y	that food can be turned to paint	draw pumpkin with orange/ green from spinach	Food to paint
Y	how to paint good	Draw a dog	drawing, painting, coloring
Y	food can be paint		
Y		Draw beans/ watercolor and brown	beans, cheese, popcorn
Y		Draw banana with yellow color from corn	
Y	N/A		
Y	Food is paint	draw stuff with colors from food	art, food art, painting art
Y	Food can be paint	draw onion with purple from onion	how not to waste food
Y	how good, amazing this exhibition is	Draw orange from orange	
N	N/A	draw hamburger with brown color from orange	
N	That I am good at art		
Y	fun to draw and colors from food waste are amazing	Banana, yellow, grape	paint
Y	carrots and banana	banana, yellow, yellow	cars, nature, foods
Y	that food from	draw dog with rainbow color from all food color	
Y	paint was made from vegetables		

Y	the paint is made of trash	draw sea turtle with green paint from celery	how not to waste food
Y	Some paint is made from waste	draw bat-eared fox with tan color from potato	
Y		shirt with yellow color from banana	
Y	lots of stuff	draw a sunset with different colors from a variety of food waste	
Y		draw blueberry with purple color from grape	
Y	make paint with food		
Y	you can paint with food waste	draw animals with multiple colors from different type of food waste	how not to waste food
Y	make paint from waste	draw flower with purple color	painting
Y	paint was made from vegetables waste		how to make paint
N	N/A		
Y	make paint with veggies	draw berries	painting
Y	make paint from waste	draw a house	
Y	make paint with veggies	draw berries	making paint

Appendix 2. The figure below shows responses to the multiple-choice questions from the feedback cards received.



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