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Communication

Learning from Tomorrow's Recyclers: Extension of Hands-on Recycled Waste Activity

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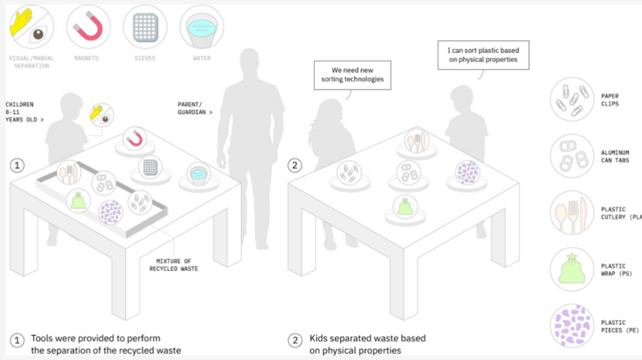
ABSTRACT: We previously developed a plastic sorting activity for high school students. In that activity, several tools were provided to separate plastic waste materials based on their physical properties while considering the time and cost for each separation step. Here, we aimed to understand the impact of this activity on the awareness of and learning about plastic sorting in a younger age group (8 to 11 years old) and explored how parental involvement influenced students' interest in the topic. The activity was part of the STEM Zone Saturday program at the University of Houston. Pre- and post-evaluations were used to assess students' understanding of plastic sorting and overall experiences. While some insights into plastic sorting were derived from previous experiences, the activity improved awareness among students, particularly regarding sorting based on physical properties. The involvement of parents encouraged exploration, discovery, and enjoyment. These findings underscore the importance of early education and community engagement in fostering sustainable practices and advancing toward a circular economy.



KEYWORDS: *polymers, identity, plastic sorting, K-12 activity*

Sorting waste is a crucial step to improve recycling, as a mixture of different types of plastic will impact the quality and properties of the recycled material compared to its predecessor.[1−3] As part of the National Recycling Goal presented by the EPA in 2020, there is a need to introduce more collective efforts, such as awareness of the complexities of the whole recycling process to individuals and how to alleviate the increased contamination in recycled material streams.[4] Introducing activities specially crafted for younger age groups is integral to pushing sustainable solutions, creating awareness, and moving toward a circular economy.

In our previous work, we introduced a hands-on activity presenting the sorting process of recycled waste to high school students aged 15 to 17.5 years old.[5] In previous work, we emphasized the importance of plastics and their connections to chemistry and materials that contain carbons and hydrogens. We provided several tools to separate the waste based on often studied physical and chemical properties (such as size, magnetism, density, and transparency) while keeping in mind the time and cost of each step. The activity effectively enhanced students' understanding of the sorting process of recycled waste. Here, we aimed to extend this activity by understanding how it impacts awareness of plastic sorting among younger learners. At the same time, as parents were present in the activity, the aim was to understand how the involvement of parents encouraged students' interest in the demonstration.

The activity was provided to students participating in STEM Zone Saturday. This is a hybrid monthly program that offers students the opportunity to learn about science and engineering.[6] Students (boys and girls) aged 8 to 11 years old volunteered to participate and were received at the University of Houston accompanied by their parents and/or guardians. A modified activity was developed to accommodate the time constraint from this event (see Activity Logistics in Supporting Information). Students followed the instructor systematically to separate the recycled waste into piles.

Pre- and post-evaluations approved by the Institutional Review Board (IRB) using Likert-scale rated responses (5 − Strongly Agree, 4 − Agree, 3 − Neutral, 2 − Disagree, and 1 − Strongly Disagree) were provided to all participants during the program time (See Supporting Information Pre- and Post-evaluations). Questions 1−6 were included in both evaluations

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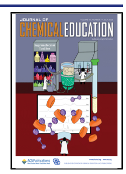

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Table 1. Pre- and Post-evaluation Responses from Students Participating in the Activity

	Question	Category[a]	Pre-evaluation[b]	Post-evaluation[b]
Q1	Sorting plastic is important	SC	4.3 ± 0.9	4.7 ± 0.5
Q2	All trash in the recycling bin will be recycled	SC	3.6 ± 1.4	3.4 ± 1.5
Q3	Sorting plastic is cheap	SC	3.1 ± 1.2	2.5 ± 1.3
Q4	Sorting plastic takes too much time	SC	3.0 ± 1.2	3.2 ± 1.2
Q5	I can sort plastic based on what it looks like	SC	3.3 ± 1.4	3.7 ± 1.3
Q6	I can use new technologies to sort plastic	SC	4.0 ± 1.3	4.1 ± 1.0
Q7	I enjoyed the activity	E		4.3 ± 0.9
Q8	I want my friends to do this activity	E		4.0 ± 1.1
Q9	I now understand how to sort plastic by its physical properties	E		4.5 ± 0.8
Q10	Now I know the challenges of sorting plastics	E		4.0 ± 1.1
Q11	This activity improved my understanding in plastic sorting	E		4.2 ± 1.2
Q12	It was cool having my parent/guardian join in the activity	P		3.8 ± 1.1
Q13	I felt more confident trying new things with my parent/guardian around	P		3.6 ± 1.1
Q14	Having my parent/guardian participate helped me understand the activity better	P		3.4 ± 1.3
Q15	I would like my parent/guardian to do activities like this with me again in the future	P		3.4 ± 1.3

[a]Question categories: Sorting concepts (SC) [total responses: 49], Students experience (E) [total responses: 49], Parent involvement (P) [total responses: 45]. [b]Likert-scale rated responses: 5 − Strongly Agree, 4 − Agree, 3 − Neutral, 2 − Disagree, and 1 − Strongly Disagree.

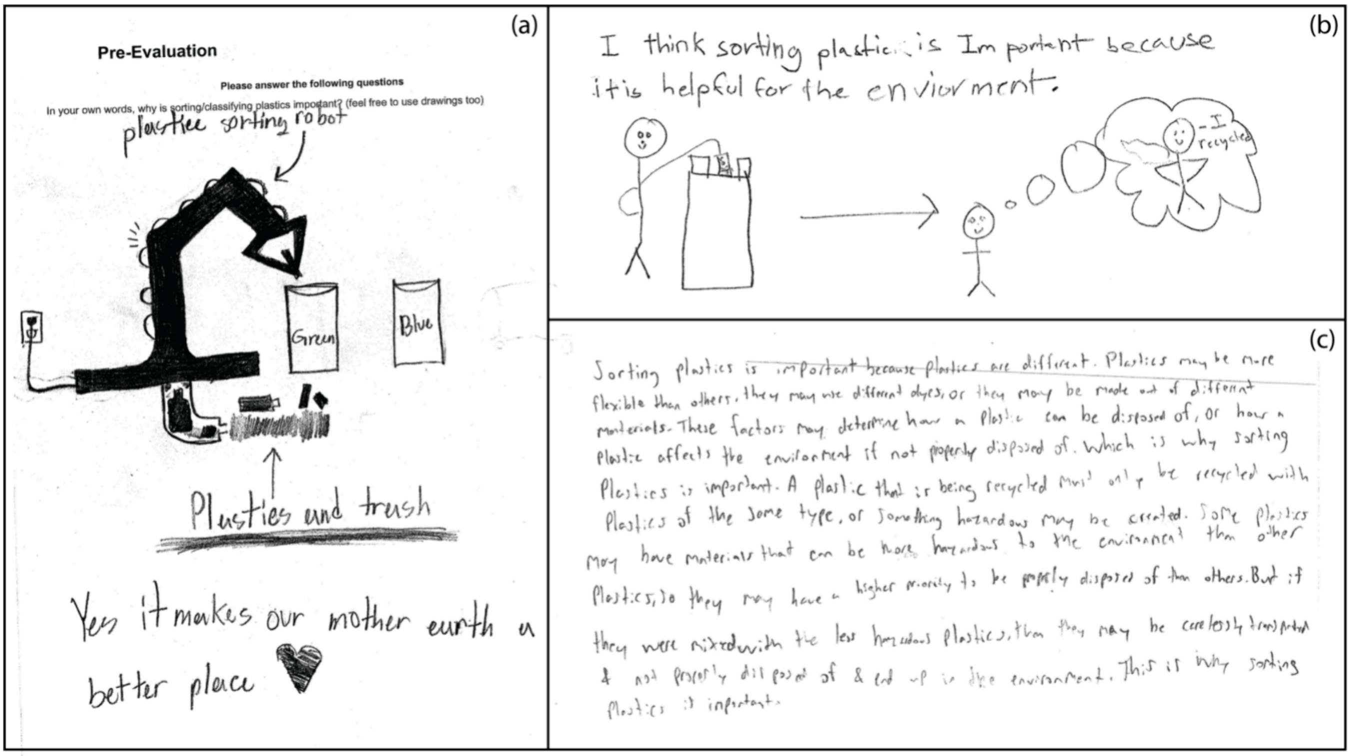

Figure 1. Representative sketches obtained from the pre-evaluation survey.

to understand how this activity impacted the students' learning about plastic sorting. In the post-evaluation, nine additional questions were added related to the students' experience with the activity (questions 7−11) and their experience with having parents/guardians around (questions 12−15). A total of 49 surveys were collected, and the mean and standard deviation were determined for each question. An open-ended question was also added to help contextualize Likert-scale responses on both the pre- and post-survey.

Table 1 shows a summary of the pre- and post-evaluation responses. Students showed no improvement in questions 1, 4, and 6, highlighting that certain insights about plastic sorting have been derived from previous experiences. Statements such as "I think sorting plastics is important because it's good for recycling" and "It is important because you can recycle them [plastic] differently" from the pre-evaluation support the results from these questions. Figure 1a also shows the drawing of a child who talked about the use of technology to sort plastics, specifically, the use of robotic arms. Figure 1b is the drawing of another child who mentioned that plastic sorting is important as it is helpful for the environment. In several open-ended responses from the pre-evaluation, students noted that this process is essential to prevent plastics from going to the oceans, prevent global warming, increase the efficiency of recycling, and prevent hurricanes and wildfires, among others. Moreover, a student wrote an extensive response to why this

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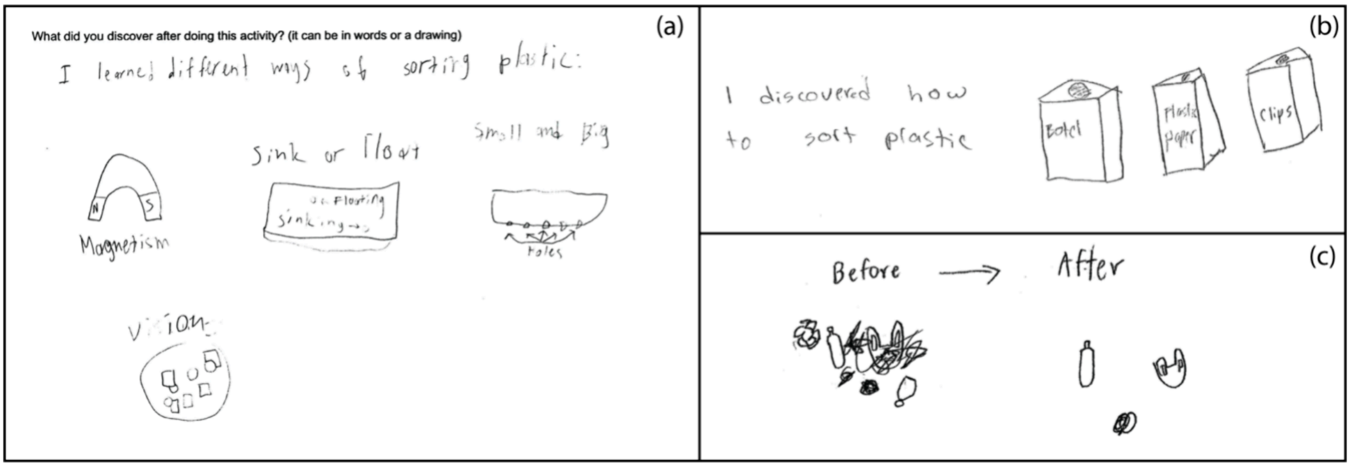

Figure 2. Representative sketches obtained from the post-evaluation survey.

process is crucial (Figure 1c). Here, the student touched on different aspects discussed in the activity (i.e., sorting based on their properties). A one-point improvement for questions 2, 3, and 5 was observed, pointing out that the activity provided insight into students on the economics and science behind plastic sorting.

Overall, from the post-evaluation questions, students enjoyed the activity, as shown in Table 1, questions 7 to 11. A common theme in the post-evaluation was learning through discovery about sorting recycled waste based on its physical properties. Some emphasized the concepts of density "I discovered if it floats its high density and drowns if it's low" and "I discovered most plastic that we use can float", the magnetic properties "magnets are important when sorting trash", and a combination of all of them "I could sort plastics by physical properties like magnets, sink or float, size, and see-through". This supports work that suggests that out-of-school learning offers greater instructional flexibility[7] and gives students more agency to discover and explore questions that appeal to them in a lower-stakes setting than a traditional classroom.[8,9] Figure 2a−c shows some of the drawings obtained from the post-evaluation responses representing the understanding of separating based on physical properties. Another recurring theme was the recognition of the bottlenecks of sorting and how to improve this process. "I discovered that there are fun ways to sort plastics instead of picking plastics out by hand", "I discovered manual labor to sort plastic takes time. I also discovered that machines will make sorting plastic much easier and faster", and "It might be $ [expensive], but it's good for our planet".

Parent involvement in the activity (Table 1, questions 12−15) suggests that, as parents positioned themselves as STEM learners in the space, students were encouraged to explore/discover. This is consistent with research that points to the importance of parents and families for students' academic outcomes[10−12] and success in STEM in particular.[7,13−17] Further, Sjaastad et al. found that, when parents engage in STEM, they become models who help students "define" themselves as STEM learners. Importantly, they revealed that parents can be role models without necessarily having a career in STEM.[18] Our findings suggest that offering such activities in hybrid spaces may help expand, understand, and demystify STEM and processes, such as plastic sorting, among the general public.

The endeavor to enhance awareness and understanding of recycled waste sorting among younger learners is crucial for fostering a sustainable future and improving recycling. This activity, adapted for students aged 8 to 11, demonstrated a positive impact on their perception and comprehension of the sorting process. Through hands-on exploration, students not only enjoyed the activity but also gained insight into the challenges and potential solutions in sorting waste. Furthermore, the involvement of parents proved instrumental, as their participation was encouraged.

Moving forward, several initiatives emerge from this study. First, investigating parents' experiences with the activity from their perspective could provide insights into the dynamic of family engagement in STEM education. We also propose observing the extent to which parents participated in the activity. The development of a "Plastic Recycling STEM Kit" that is readily available for teachers and out-of-school STEM practitioners can broaden the reach of educational initiatives focused on sorting recycled waste and recycling. By providing accessible resources and materials, educators can integrate hands-on learning experiences into the curriculum, empowering students to explore sustainable and environmental stewardship concepts. Finally, we will collaborate with university partners to implement the activity in communities with significant numbers of K−12 students who are traditionally underrepresented in engineering. This holds promise for promoting inclusivity and diversity in these domains.

■ ASSOCIATED CONTENT

Supporting Information

The Supporting Information is available at https://pubs.acs.org/doi/10.1021/acs.jchemed.4c00387.

Activity logistics (PDF; DOCX)

Figure transcripts (PDF; DOCX)

Post-evaluation (PDF; DOCX)

Pre-evaluation (PDF; DOCX)

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Notes

The authors declare no competing financial interest.

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