Abstract

Youth can impact environmental attitudes and behaviors among adults. Indeed, research on intergenerational learning has demonstrated the influence of young people on adults in their lives for myriad environmental topics. Intergenerational learning (IGL) refers to the bidirectional transfer of knowledge, attitudes, or behaviors from children to their parents or other adults and vice versa. We suggest an educational framework wherein K-12 marine debris education designed to maximize IGL may be a strategy to accelerate interdisciplinary, community-level solutions to marine debris. Although technical strategies continue to be developed to address the marine debris crisis, even the most strictly technical of these benefit from social support. Here, we present 10 Best Practices grounded in educational, IGL, and youth civic engagement literature to promote marine debris solutions. We describe how integrating IGL and civic engagement into K-12-based marine debris curricula may start a virtuous circle benefiting teachers, students, families, communities, and the ocean.

Introduction

Plastic marine debris damages marine, freshwater, and coastal ecosystems (Elias, 2018) threatening food security, food safety, and human health (Barboza et al., 2018; Rhodes, 2018). Although the "Age of Plastics" (Avio et al., 2017) has provided modern conveniences including disposable packaging, sterile medical products, and transportation components that reduce fuel usage, over a third of the global plastic produced is made into single-use items and used in packaging products (Thompson et al., 2009). Without comprehensive and aggressive intervention, the flow of plastic into the aquatic environment will reach up to an annual 20 – 53 million metric tons by 2030 and a cumulative 710 million metric tons by 2040 (Borrelle et al., 2020; Lau et al., 2020), presenting a growing threat to marine ecosystems and people depending on them (Gall & Thompson, 2015; Lau et al., 2020; Rochman et al., 2015; Wilcox et al., 2015; Worm et al., 2017).

Diverse technical strategies exist for reducing existing marine debris and preventing additional waste generation (Lau et al., 2020), and the most promising of these involve a public engagement component. Scientific advances designed for reduction and prevention include developing plastic alternatives (Löhr et al., 2017); toothpastes and face soaps free of microplastics; and filters for washing machines to capture microfibers (McIlwraith et al., 2019). These technological advances are critical to reducing plastic pollution, and their development and implementation may benefit from public and social support (Hartley, et al., 2018; Pahl et al., 2017; Vince & Stoett, 2018). Encouragingly, several technical strategies are specifically designed to engage the public. Notable examples include the popular Baltimore "Mr. Trash Wheel," a hydro- and solar-powered trash interceptor with almost 30,000 followers on Twitter (Lindquist, 2016). Similarly, Ocean Conservancy's "Skip the Straw" campaign has engaged companies (e.g., Starbucks), local communities, and schools in collaborative efforts to reduce or eliminate single-use plastics (Mahdawi, 2018). This ongoing campaign has resulted in over 19,500 pledges to choose straw alternatives (Ocean Conservancy, n.d.), in addition to sparking a national conversation on why and how to reduce marine plastic (Mahdawi, 2018). Technical solutions to environmental challenges work best when paired with socially supported institutions (Ostrom, 1990). Public engagement on marine debris has promoted corporate social responsibility (Lyon & Maxwell, 2008) and encouraged support for a future circular economy (ten Brink et al., 2008), both of which hold hope for impacts that reduce waste generation at its source. While this coupling of technical solutions with public involvement is encouraging, the plastic pollution problem continues to grow, highlighting a need to engage wider audiences.

Youth have played an increasingly important role in civic engagement throughout history, and social movement scholars agree that they continue to be "critical to the rise of many social movements" (Earl et al., 2017, p.2; Shiller, 2013). Recently, youth leadership has shaped social movements including March for Our Lives, the DREAMers, and Black Lives Matter, among others (Earl et al., 2017). This leadership includes action in environmental contexts, such as the Flint, Michigan water crisis, the fight at Standing Rock to stop the North American Dakota Access Pipeline (Hogan, 2019), and the Fridays for Future school-strike movement (Alter et al., 2019; Corner et al., 2015). In this paper, we propose that simultaneous outreach to local officials and voters via youth is a promising strategy to build community support for addressing marine debris. We offer a framework of best educational practices and examples of actionable strategies that build ocean literacy among students, contributes to marine debris research through citizen science, and empowers students to engage their parents and broader communities (see *A Suggested Framework* section below).

Building students' ocean literacy—an understanding of how the ocean and humans are interconnected—is critical to address marine debris as it ensures a future citizenry has the knowledge, skills, and motivations to support healthy marine ecosystems (Hartley et al., 2015). Furthermore, K-12 schools serve as community centers, with that role being strongest in underserved communities (Bingler et al., 2003). Within these school settings, curricula rooted in citizen science (wherein youth contribute to the collection of scientific information [Bhattacharjee, 2005]) are positioned to extend youth-led engagement from family units to the communities, as citizen science is an inherently public process (Turrini et al., 2018). Children are well-positioned to inspire awareness and action on marine debris among their parents, as has been shown to work in environmental contexts like flood resilience and climate change (Lawson et al., 2019; Williams et al., 2017). This process of transferring knowledge, attitudes, or behavior from children to adults and vice versa is known as intergenerational learning (IGL) (Bottery, 2016), and emerging research suggests that IGL from the child-adult direction might extend beyond the immediate family from children to local officials and voters. We suggest that designing education for youth-led marine debris solutions may contribute to mitigation of the marine debris global crisis by accelerating community-level awareness.

Why is intergenerational learning so promising for addressing marine debris?

Integrating IGL into K-12-based marine debris curricula may help address marine debris by starting a "virtuous circle" (Norris, 2000) benefiting teachers, students, families, communities, and the ocean. We propose that a purposefully-designed curriculum can support a virtuous circle benefiting stakeholders and the ocean (Figure 2.1). In a purposefully-designed curriculum with the links of this circle in mind, teachers engage students in learning about marine debris causes and solutions through classroom-, field-, and citizen science-based activities. Students then share what they learn with their parents and community members, creating multiple links in a circle to unite communities in response to marine debris. In such a virtuous circle, as benefits to each link (teachers, students, parents, and communities) become apparent, community support for K-12 marine debris curricula progressively grows, feeding back into the beginning of the process and encouraging future adoption. Perpetuation of this cycle can create benefits at each step and help reduce marine debris while also improving K-12 education. Links in the circle could be strengthened by young people who hold a unique power to influence their peers, parents, and potentially adult community members (Ballantyne et al., 1998). We propose that such a curriculum can support a virtuous circle, benefitting youth, teachers, parents, and community members while also providing broad benefits to the ocean.

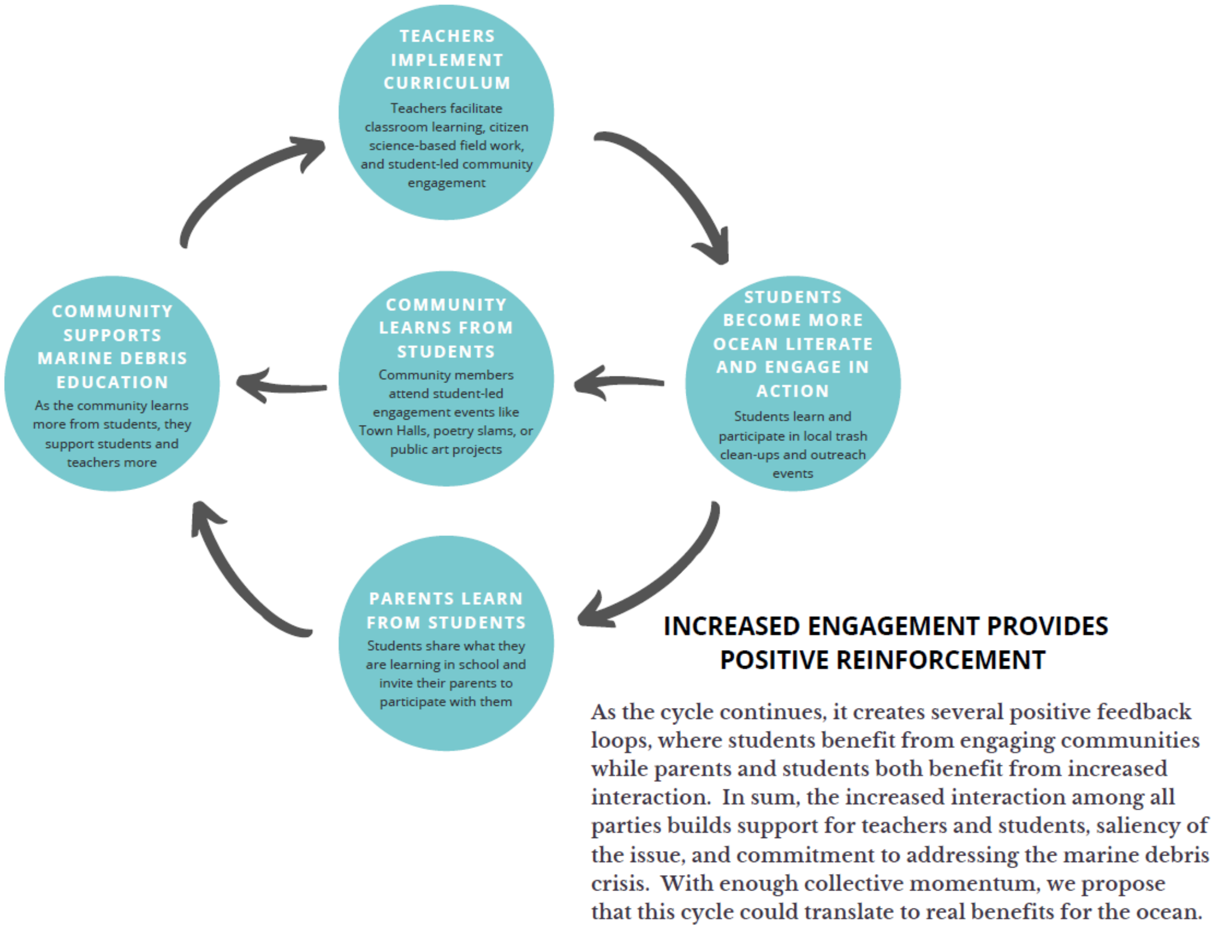

Figure 2.1. Proposed virtuous circle connecting K-12 education, students, parents, and community members**.**

Considering the first link in the virtuous circle, education for youth-led marine debris solutions has the potential to benefit teachers and students by promoting academic achievement. However, for teachers and students to benefit, the academic achievement must be linked to educational standards that often control instructional time (Johnson, 2006). Fortunately, marine debris aligns well with national science standards in many developed nations such as the Next Generation Science Standards in the United States (e.g., NGSS Lead States, 2013; Table S1), regional standards (e.g., Table S2), and localized standards such as the University of Toronto's Trash Team in Ontario, Canada (Rochman Lab, 2020; Table S3). Marine debris curricula also lend themselves to best practices grounded in learning theory. Situated learning theory suggests that direct connections between concepts covered in the classroom and daily life renders learning more effective (Brown et al., 1989; National Academies of Sciences, Engineering, and Medicine, 2018). These connections are easily made for marine debris because the debris and its sources are highly visible (Tudor & Williams, 2003) where most K-12 students live. Though the widespread nature of the problem makes it urgent, it also means students can directly address the problem with visible and tangible results (Hartley et al., 2015), such as citizen science-based waterway clean-ups or class competitions to reduce plastic use (DeMattia et al., 2020).

In addition to opportunities for standards-based, situated learning approaches, marine debris management offers opportunities for social, emotional, and cultural engagement, which improve learning outcomes for students (Brossard et al., 2005; Myers et al., 2004; National Academies of Sciences, Engineering, and Medicine, 2018; Spence, 2003; Tuss, 1996; Young et al., 2018). For instance, marine debris negatively impacts charismatic megafauna including sea turtles and whales (Ellis, 2003), triggering social and emotional connections between young people and the subject. Indeed, physical and online responses to whales and sea turtles struggling with marine debris have become paradigmatic of wildlife conservation in general. For example, a 2015 video of a young scientist pulling a straw out of a sea turtle's nose had over 41 million views at the time of writing (Figgener, 2015) and sparked international conversations surrounding single-use plastic use (Rosenbaum, 2018). Such empathetic connection to wildlife can inspire awe and wonder which supports strong cognitive connections with the animal world and sparks empathy for wildlife (Young et al., 2018).

Marine debris education in K-12 contexts can engage broad and diverse groups of parents and community members, the next links in the virtuous circle. Children have been shown to boost adult knowledge, attitudes, and behaviors related to environmental topics including air pollution, water pollution, and litter (Ballantyne et al., 2001), including increased support for watershed management (Sutherland & Ham, 1992), building flood resilience (Williams et al., 2017), and addressing climate change (Lawson et al., 2019). Notably, child-to-parent IGL has historically been effective in domains similar to marine debris (i.e., littering and recycling) (Istead & Shapiro, 2014). Child-driven IGL can be fostered through simple conversations between children and parents (Lawson et al., 2019). Child-to-parent IGL based on K-12 marine debris curricula have the potential to reach far more adults than any other marine debris program to date because 20% to 90% of all households globally include children, varying upon the country (United Nations, 2017). Additionally, child-driven public engagement events (e.g., creating public art displays from marine debris, hosting slam poetry nights, speaking at Town Hall meetings, etc.) have the potential to extend IGL beyond classrooms and dinner tables into the broader community.

In addition to building ocean literacy among individuals, efforts to link students, parents, and community members may strengthen community ties that can complete and reinforce the virtuous circle, translating to real benefits for the ocean. Supporting child-led initiatives requires adult engagement, which benefits students, parents, teachers, and communities (Henderson & Mapp, 2002). For instance, parent engagement in schoolwork leads to increased engagement and academic achievement (Román et al., 2008), improved social skills and behavior, and higher self-esteem among students (Cotton & Wikelund, 1989). Parents benefit from increased involvement by developing more sensitivity to their children’s needs, increased confidence in parenting abilities, and more positive relationships with children, teachers, and schools (Henderson & Berla, 1994). Community-engaged school initiatives may lead to greater support for schools, as well as greater community cohesion, as school-based events can bring together community members who would normally not interact (Epstein et al., 2018). These mechanisms and partnerships can create positive feedback loops which add to the sustainability of these initiatives, ensuring benefits continue (Epstein et al., 2018). When linked to marine debris, this intergenerational and community-wide learning has the potential to transform how communities may approach marine debris, which is arguably needed to address the global crisis. Seeking marine debris solutions tends to be less partisan than other environmental issues such as climate change (Eilperin & Dennis, 2019), and a recent study detected that environmental advocacy videos on the topic of marine debris were able to reduce attitude and behavioral gaps between partisan groups (Jennings et al., 2020). The potential for bipartisan plastic prevention and/or reduction may help ease the way for children to develop broad community coalitions.

Although this community-level IGL has not yet been examined for the topic of marine debris, qualitative research suggests children have led communities to act more sustainably in Australia (Stuhmcke, 2012), to participate in forest renewal through planting trees in Thailand (Gallagher et al., 2000), and to participate in a beach clean-up and natural area rehabilitation efforts in Mexico (Schneller, 2008). These qualitative studies are encouraging, but empirical research is needed to test and understand the magnitude of children's influence on community-level knowledge and behavior across contexts that include marine debris. If children can inspire adults both within and outside of their families to learn about and address marine debris challenges, then K-12 marine debris curricula in the youth-led marine debris solutions model may be a catalyst for the community-level change needed to address the global crisis. The benefits to communities could be multiplicative, resulting in stronger partnerships, cleaner watersheds, waterways, and oceans. The successful creation and implementation of such an ambitious curriculum (which is not the norm in classrooms) requires the development of guiding principles supported by theory and literature**.**

Intergenerational learning: A suggested framework for helping children lead marine debris solutions

We offer ten practices for developing education for youth-led marine debris solutions that support IGL by: *1) helping students learn* (Table 1; practices 1–4), *2) helping students engage their parents* (Table 1; practices 5 and 6), *3) empowering students to engage their communities* (Table 1; practices 7 and 8), and *4) providing structural and logistical support for students who are engaging with their communities* (Table 1; practices 9 and 10). The framework proposed here is modeled after existing IGL literature reviews and frameworks (Duvall & Zint, 2007; Lawson et al., 2018) and the practices are drawn from environmental education literature (Schusler et al., 2009; Schusler & Krasny, 2010; Volk & Cheak, 2003), IGL literature (Ballantyne et al., 2001; Duvall & Zint, 2007; Lawson et al., 2018; Lawson et al., 2019), and civic engagement and youth development literature (Christens & Dolan, 2011; Derr et al., 2018; Jensen & Schnack, 2006; Kirshner, 2015; Zeldin et al., 2013) respectively.

Child-driven intergenerational learning research related to environmental behavior is a nascent field, and no one to our knowledge has investigated the potential for children to affect change in communities at the scale which we are proposing. There has been research on how children can influence their immediate families (Lawson et al., 2019), and there has been research on how best to engage children in civic action (Kirshner, 2015). Our framework (Table 1) combines these two lines of research to propose a K-12 based intergenerational learning approach for promoting civic action to address marine debris. Best practices in the framework (Table 1) are representative of the ideas we present and we offer them as illustrative examples of the points we are trying to make, but do not provide a compendium of the literature. The table

(Table 1) is structured in chronological order of actions practitioners would take, and associated references reflect paradigmatic examples for each principle. We define practitioners broadly, noting that specific actors may vary across context. We invite others to test, refine, and build upon our proposed framework.

Helping Students Learn

First, we recognize that committed and interested teachers have better success generating student enthusiasm. We suspect that this will be especially true on the topic of marine debris as teachers can visibly model marine debris prevention activities including avoiding plastic straws and not using single-use water bottles in the classroom. Teacher-related factors predict student achievement in many domains (Hattie, 2009; Mahler et al., 2018), and we expect no different in marine debris contexts. Accordingly, we suggest that *offering professional development opportunities aimed at nurturing teacher motivation* (Mahler et al., 2018) (Table 1, practice 1) and engaging motivated teachers in education for youth-led marine debris solutions may simultaneously offer benefits to teachers (e.g., increased job satisfaction: Klusmann et al., 2008; Moè et al., 2010) and to their students in the form of improved learning outcomes, ultimately supporting an ocean literate citizenry.

Second, we recommend *long-term and in-depth lessons about marine debris* (Table 1, practice 2). Ideally, these long-term lessons would incorporate the science of marine debris, its impacts, and its solutions over an entire school year or an entire unit of study. The interdisciplinary nature of marine debris instruction can facilitate a longer and more in-depth course of study because lessons can be distributed among teachers of different subjects and encompass numerous standards (e.g., Tables S1-S3). A long-term approach can also facilitate durable learning (Bransford et al., 2000; Zelezny, 1999), as well as facilitating hope by helping students see pathways to solutions before they become disillusioned (Gifford, 2014; Ojala, 2012). Hope is a prerequisite for generating conservation solutions (Hobbs, 2013), and acting on them (Ojala, 2012; Stevenson & Peterson, 2015). Accordingly, long-term approaches may ensure children grow into ocean literate adults committed to action.

Third, we suggest that interventions *focus on local marine debris issues* (Table 1, practice 3), and *use experiential learning approaches* to connect place-based learning with the larger global context (Table 1, practice 4). Focusing on local inputs to waterways, whether marine or freshwater, can facilitate a concrete understanding of sources and impacts of marine debris (Tudor & Williams, 2003), as well as leverage benefits of place-based learning, such as strengthening community bonds and building appreciation for the natural world (Sobel, 2004). The local marine debris focus can be linked to the global context through experiential learning, which incorporates action, reflection, conceptualization, and application (Kolb, 1984). Students can participate in local waterway clean-ups (action), which can promote a concrete understanding of the marine debris problem. Reflection after this experience can help students make connections between their local waterways and the global crisis (Brossard et al., 2005). Similarly, students can make local-to-global links (conceptualization) as they generate solutions to a local marine debris or freshwater debris challenge, with teachers guiding students to link their actions to the global marine debris crisis (application) (Brossard et al., 2005; Tuss, 1996). A particularly effective strategy for engaging in experiential education is through citizen science (Thiel et al., 2018). Citizen science is an emerging practice for enhancing classroom teaching (Bonney et al., 2009), developing students' scientific efficacy (Hiller & Kitsantas, 2014), strengthening students' sense of place and critical thinking skills (Jenkins, 2011) and building scientific literacy (Vieira & Tenreiro-Vieira, 2016). Two examples of marine debris-targeted citizen science projects include the *International Coastal Cleanup* (from Ocean Conservancy) and the *Marine Debris Tracker* (sponsored by the NOAA Marine Debris Program), which have connected millions of users from around the world to address marine debris (Thiel et al., 2018). Citizen science with K-12 students has addressed marine debris science on Chilean beaches (Hidalgo-Ruz et al., 2018) and rivers in both Chile (Rech et al., 2015) and Germany (Kiessling et al., 2019). Eastman et al. (2014) suggested that citizen science with students simultaneously supports school curricula, an increased understanding of the scientific process, and environmental management policies, and we agree with this potential.

Helping Students Engage their Parents

Our suggestions for helping students engage their parents or other caregivers build on the central theme of facilitating communication between students and their parents. We recommend utilizing school assignments to *provide and promote space for at-home conversations around marine debris* (Table 1, practice 5) and *encouraging parental involvement in marine debris activities* (Table 1, practice 6). Potential assignments include parental interviews or interactive family activities and also inviting parents to participate in student-led activities including service-learning projects, litter clean-ups or field trips (Duvall & Zint, 2007; Schneller, 2008). Previous IGL research suggests the substance of these activities matter less than the frequency, and that increased family interaction around environmental topics can lead to more pro-environmental attitudes and behaviors among both children and parents (Lawson et al., 2019; Stevenson et al., 2019; Valdez et al., 2018).

Empowering Students to Engage their Communities

Extending the impact of IGL marine debris curricula from classrooms to communities requires targeted efforts to empower young people. Drawing on calls to integrate more activism into environmental education (Chawla & Cushing, 2007; Stevenson, 2007), we first suggest *providing civic engagement training opportunities* for students to maximize community engagement success (Table 1, practice 7). Students can adopt diverse approaches to engaging their communities, including making public service announcement videos (PSAs), giving presentations to local Town Halls and School Boards, writing letters to their local mayors or community leaders, writing editorials for their local papers, and hosting marine debris poetry events. In the classroom, civic engagement training opportunities include real-time political discussions (Shiller, 2013), rehearsing town hall speeches (Kirshner, 2015) and encouraging youth-led efforts involving activism, media, and research as driven by their own interests (Zeldin et al., 2013). Because some adult settings like town hall meetings can be intimidating for young people, we recommend educators support students in several ways. Educators can help students prepare and rehearse presentations; give coaching and feedback without imposing adult views (Kirshner, 2015); help students envision and review what will happen upon their arrival at the venue; encourage young people to bring written and rehearsed notes; and prepare the adult audience for the youth presentation (Derr et al., 2018). Allowing students to choose if and when to engage local officials also encourages positive experiences and empowerment for youth.

A second strategy to empower students is to orient *instruction toward promoting youth decision making-authority and action competence* (Table 1, practice 8). This means letting students think critically about an issue, reflect on how to take action themselves (not as prescribed beforehand), and choose actions supporting their chosen solutions (Breiting & Mogensen, 1999). These steps require a learning environment that is inclusive, prioritizes open dialogue, has group-developed norms centered on respect, and mirrors a broader shift towards full inclusion in the group dynamic (Maine Environmental Changemakers Network, n.d.). Allowing youth to drive decision-making around civic engagement facilitates content mastery (Zeldin et al., 2013), develops agency, belonging, competence (Mitra, 2004; Zeldin, 2004), civic identity (Youniss et al., 1997), enhances community connections (Zeldin, 2004), strengthens emotional wellbeing (Zeldin et al., 2013), and can increase students' confidence (Dworkin et al., 2003).

Providing structural and logistical support for students who are engaging with their communities

Teachers and adults can help students engage their communities *by providing help in overcoming structural barriers to action* throughout the process (Table 1, practice 9). Providing this type of logistical support is critical because youth often face structural barriers linked to lack of transportation and lack of formal standing in public venues (Derr et al., 2018). Teachers can request a dedicated special youth session or time explicitly for youth voice in formal venues such as town halls (Derr et al., 2013; Derr et al., 2018). With the right preparation and support, formal adult settings can be places of high impact for youth (Derr et al., 2013; Derr et al., 2018).

Encouraging youth-adult partnerships (Table 1, practice 10) provides teachers an avenue for sharing efforts to empower youth. Youth-adult partnerships (Y-APs) exist when adults recognize youth as full partners in efforts to address issues youth face (Zeldin et al., 2013). The teachers guiding students as described in this essay represents a necessary but insufficient Y-AP. When teachers pair students with community leaders at the beginning of class projects, those leaders can develop and contribute to Y-APs. Youth-led action supported by diverse community Y-APs promote community change, stimulate critical discourse, and galvanize collective action (Zeldin et al., 2013). Higher levels of mutuality, equity, and respect between the youth and adults typically yield better outcomes for Y-APs (Zeldin et al., 2013). Effective Y-APs can propagate healthy communities by motivating existing community leaders and creating future community leaders, as youth who experience voice and power in intergenerational networks learn to see themselves as powerful civic actors (Flanagan & Christens, 2011) and have a stronger overall sense of community going forward (Evans & Prilleltensky, 2007).

Conclusion and Call to Action

Youth are already taking the lead in many social and environmental movements and are enthusiastically seeking solutions to combat marine debris (Prisco, 2017). For instance, 4^{th} & 5^{th} grade students led a campaign encouraging a styrofoam ban at Dunkin' Donuts (*Dunkin' Donuts: Stop Using Styrofoam Cups*, 2015) and there are many examples of recently-formed youth-led NGOs to protect the ocean (e.g., Jr. Ocean Guardians, Lilly's Plastic Pickup, Ocean Heroes Bootcamp, One More Generation, Heirs to Our Oceans). Accordingly, education for youth-led marine debris solutions has the potential to harness the energy already present among young people and mobilize change, however marine debris curricular experiences must first and foremost be added into school curricula and then should also be purposefully designed to support IGL. Multiple marine debris educational materials are already available for teachers and include the NOAA "Marine Debris Monitoring Toolkit for Educators" (Nally et al., 2018), the University of Toronto "Trash Team" Waste Literacy activities (Rochman Lab, 2020), the Washed Ashore Integrated Arts Marine Debris Curriculum (*Integrated Arts Marine Debris Curriculum*, 2020), and the Duke University Marine Lab's Marine Debris Curriculum for 4^{th} & 5^{th} grade students (DeMattia et al., 2020).

Although our proposed youth-led marine debris solutions educational framework may hold great promise, future research is needed to establish and understand the causal mechanisms for impacts on students, families, and communities. Experimental studies with treatment and control groups of teachers, students, parents, and local civic leaders are needed to test whether youth-led marine debris solutions curricula create the effects hypothesized in this essay. Innovative research designs drawing psychology, sociology, and social contagion approaches (de Lange et al., 2019), could help reveal the mechanisms through which information and motivation move through communities and how kids may drive that information mobilization. Understanding the potential and limitations of the education for youth-led marine debris solutions model can improve youth and community education about marine debris. Only then will we start to uncover, document, and improve the potential for education to move from something “nice to have” to a critical tool for addressing the marine debris crisis and potentially propelling community engagement on other environmental issues.

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Table 1.1. Suggested framework of environmental education (EE) curricula for youth-led marine debris solutions, adapted from intergenerational learning (IGL) content in Lawson et al. (2018) and Duvall and Zint (2007).

Best Practices		**Suggested Action Items for youth-led marine debris solutions** (based on existing EE, youth civic engagement, and IGL literature)	**Recommended Practitioners**	**Reference(s) & Examples**
Helping Students Learn	**1**	**Offer professional development opportunities aimed at nurturing teacher motivation** on ocean conservation, marine life, environmental education, youth civic engagement, or other related topics	School systems, educational leadership agencies, environmental education centers offering teacher programming, etc.	(Istead & Shapiro, 2014; Lawson et al., 2018; Mahler et al., 2018)
	2	**Use long-term and in-depth marine debris lessons or unit plans** • Preferably with repeated contact at least as long as an educational unit (recommended 12 weeks)	Curriculum developers, teachers, professional learning networks of teachers, teaching communities of practice, etc.	(Duvall & Zint, 2007; Lawson et al., 2018)
	3	**Focus on local marine debris issues**	Teachers, environmental educators,	(Ballantyne et al., 2001; Jambeck &

		• Consider that (it is widely cited that) 80% of marine debris originates from land; therefore, any cleanup will make positive contributions, no matter how far from the coast • Focus on your local waterbodies (e.g., streams, creeks, rivers, lakes, etc.) – even local school grounds will work	informal educators, etc.	Johnsen, 2015; Lawson et al., 2018; Sutherland & Ham, 1992)
	4	**Incorporate experiential learning elements in the marine debris curriculum** • Action, reflection, conceptualization, and application model (Kolb, 1984) • Citizen science marine debris activities fit well in this cycle	Teachers, environmental educators, informal educators, etc.	(Ballantyne et al., 2001; Kolb, 1984; Moline, 2019; Thiel et al., 2018; Turrini et al., 2018)
Helping Students Engage their Parents	**5**	**Provide and promote space for at-home conversations around marine debris** • Encourage guided conversations at home with parents and caregivers • Teachers can do this directly by including parents in at-home assignments and activities (e.g., TIPS [Teachers Involve Parents in Schoolwork] worksheets in the Duke University Marine Lab Marine Debris curriculum).	Teachers, environmental educators, informal educators, etc.	(DeMattia et al., 2020; Lawson et al., 2018; Lawson et al., 2019)

	6	**Encourage parental involvement in marine debris activities** • Design activities for family engagement (e.g., at-home waste audits, reflection of family consumption patterns of single-use plastic) • Encourage family attendance at field trips and school events (e.g., Science Nights, Talent Shows, Trash Fashion Shows, etc.)	Teachers, environmental educators, informal educators, etc.	(Ballantyne et al., 2001; Duvall & Zint, 2007; Lawson et al., 2018; Sutherland & Ham, 1992)
Empowering Students to Engage their Communities	**7**	**Provide civic engagement training opportunities for students** • Include specific civic trainings (i.e., what is civic voice, understanding public forums, public speaking basics, etc.) • Practice and rehearse different public speaking scenarios so that students can develop confidence and skills	Local civic action partners (non-profit organizations, etc.), curriculum developers, teachers, professional learning networks of teachers, teaching communities of practice, etc.	(Derr et al., 2018; Kirshner, 2015)
	8	**Promote youth decision-making authority and action competence *(if the students choose to engage in solutions)*** • Build trust among students and their communities • Give students ownership. Let the students decide on the type of community engagement event that they would like to conduct (e.g., giving a formal presentation at their Town Hall vs. making PSA videos vs. hosting a Trash Fashion show, etc.) • Provide areas for student and youth leadership in various activities (e.g., service-	Teachers, environmental educators, informal educators, etc.	(Derr et al., 2018; Christens & Dolan, 2011; Jensen & Schnack, 2006; Maine Environmental Changemakers Network, n.d.; Schusler et al., 2009; Schusler & Krasny, 2010; Volk & Cheak; 2003)

		project coordinator, PSA video director, project manager, etc.)		
Providing structural and logistical support for students who are engaging with their communities	**9**	**Provide help in overcoming structural barriers to action** • Help schedule the event or coordinate a community event organization team • Ensure that all students can get to the event (e.g., organize rides, etc.) • Engage local media outlets at the events to amplify youth voice on a larger-scale	Educational leadership (e.g., Principals, Administrators, School Directors, etc.), teachers, environmental educators, informal educators, etc.	(Derr et al., 2018; Kirshner, 2015)
	10	**Encourage ongoing youth-adult partnerships (Y-APs) in learning/addressing marine debris** • Engage local-level adult experts (if possible) to problem-solve alongside the students (e.g., local businesses that are interested in adopting more sustainable practices, local Stormwater manager for the town, Sustainability coordinator for the town – if there is one, etc.) • Use Y-APs to provide training for kids as well as avenues to amplify their voice • Focus adult roles on teaching kids what it is like to be a scientist/leader; focus student roles on exposing adult leaders to new solutions generated by kids	Local civic action partners (non-profit organizations, etc.), curriculum developers, teachers, professional learning networks of teachers, teaching communities of practice, etc.	(Benson et al., 2006; Evans & Prilleltensky, 2007; Flanagan & Christens, 2011; Hamilton & Hamilton, 2005; Shiller, 2013; Zeldin et al., 2013)

Supplementary Material: Appendices

Table S1. US Next Generation Science Standards that may align with marine debris content (NGSS, 2013).

NGSS Science & Engineering Practice (SEP)	Examples at matched grade level (3-5)
Asking Questions & Defining Problems	· Ask questions about what would happen if a variable is changed. · Identify scientific (testable) and non-scientific (nontestable) questions. · Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships. · Use prior knowledge to describe problems that can be solved. · Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.
Developing and Using Models	· Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution. · Develop and/or use models to describe and/or predict phenomena. · Develop a diagram or simple physical prototype to convey a proposed object, tool, or process. · Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.
Planning and Carrying Out Investigations	· Evaluate appropriate methods and/or tools for collecting data. · Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.
Analyzing & Interpreting Data	· Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings. · Analyze data to refine a problem statement or the design of a proposed object, tool, or process. · Use data to evaluate and refine design solutions.
Using Mathematics and Computational Thinking	· Organize simple data sets to reveal patterns that suggest relationships. · Describe, measure, estimate, and/or graph quantities (e.g., area, volume, weight, time) to address scientific and engineering questions and problems.
Constructing Explanations and Designing Solutions	· Construct an explanation of observed relationships (e.g., the distribution of plants in the back yard).

	· Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem. · Identify the evidence that supports particular points in an explanation. · Apply scientific ideas to solve design problems. · Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.
Engaging in Argument from Evidence	· Compare and refine arguments based on an evaluation of the evidence presented. · Distinguish among facts, reasoned judgment based on research findings, and speculation in an explanation. · Respectfully provide and receive critiques from peers about a proposed procedure, explanation, or model by citing relevant evidence and posing specific questions. · Construct and/or support an argument with evidence, data, and/or a model. · Use data to evaluate claims about cause and effect. · Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.
Obtaining, Evaluating, and Communicating Information	· Read and comprehend grade-appropriate complex texts and/or other reliable media to summarize and obtain scientific and technical ideas and describe how they are supported by evidence. · Compare and/or combine across complex texts and/or other reliable media to support the engagement in other scientific and/or engineering practices. · Combine information in written text with that contained in corresponding tables, diagrams, and/or charts to support the engagement in other scientific and/or engineering practices. · Obtain and combine information from books and/or other reliable media to explain phenomena or solutions to a design problem. · Communicate scientific and/or technical information orally and/or in written formats, including various forms of media as well as tables, diagrams, and charts.

Table S2. Text of selected North Carolina state standards (NCSCOS – North Carolina Standard Course of Study) that may be easily tied to marine debris education (Instructional Services, North Carolina Department of Public Instruction, 2010).

Subject	NCSCOS Standard	Text

Science	4.L.1.1, 4.L.1.3	*Give examples of changes in an organism's environment that are beneficial to it and some that are harmful;* and *Explain how humans can adapt their behavior to live in changing habitats.*
English Language Arts	4.R.7	*Integrate and evaluate content presented in diverse media and formats, including visually and quantitatively, as well as in words.*
Math	4.NBT.5	*Multiply a whole number of up to four digits by a one-digit whole number, and multiply two two-digit numbers.*
Social Studies	4.G.1.3	*Exemplify the interactions of various peoples, places and cultures in terms of adaptation and modification of the environment*.
Technology	4.TT.1	*Use technology tools and skills to reinforce classroom concepts and activities.*
Art	4.V.3.3	*Create art using the processes of drawing, painting, weaving, printing, stitchery, collage, mixed media, sculpture, ceramics, and current technology.*

Table S3. Image of University of Toronto Trash Team's Curriculum Connections demonstrating how their lessons are tied to marine debris educational standards in Ontario, Canada **(**Rochman Lab, 2020**).**

U of T

Trash Team

Grade 5 Curriculum Connections
U of T Trash Team Lesson Plans created in 2019/2020

Adapted from The Ontario Curriculum Grades 1 - 8:

- Science & Technology http://www.edu.gov.on.ca/eng/curriculum/elementary/scientec18currb.pdf
- Social Studies http://www.edu.gov.on.ca/eng/curriculum/elementary/social-studies-history-geography-2018.pdf

Lesson 1 - Plastics Cycle

Grade 5 - Science and Technology	
Forces Acting on Structures and Mechanisms	1.1, 1.2, 3.4
Properties of and Changes in Matter	1.1, 3.2, 3.3, 3.4, 3.5
Conservation of Energy and Resources	1.1, 2.2, 2.4, 2.5, 3.2
Grade 5 - Social Studies	
The Role of Government and Responsible Citizenship	B1.1, B2.5, B2.6, B3.2, B3.4, B3.7, B3.9

Lesson 2 – Watersheds and their Relationship to Litter

Grade 5 - Science and Technology	
Forces Acting on Structures and Mechanisms	1.2, 2.2, 2.5, 3.2, 3.4
Properties of and Changes in Matter	1.1, 1.2, 2.3, 3.2
Conservation of Energy and Resources	1.1, 2.2, 2.5
Grade 5 - Social Studies	
The Role of Government and Responsible Citizenship	B2.3

Lesson 3 – Impacts of Plastic on Ecosystems

Grade 5 - Science and Technology	
Forces Acting on Structures and Mechanisms	1.2
Properties of and Changes in Matter	2.2, 2.3, 2.5, 2.6
Conservation of Energy and Resources	1.1, 2.2, 2.5

Lesson 4 – Solutions to Plastic Pollution

Grade 5 - Science and Technology	
Properties of and Changes in Matter	1.2
Conservation of Energy and Resources	1.1, 2.2, 2.5
Grade 5 - Social Studies	
The Role of Government and Responsible Citizenship	B1.1, B1.2, B2.1, B2.2, B2.4, B2.5, B2.6, B3.1, B3.2, B3.4, B3.5, B3.7, B3.9