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FROM AWARENESS TO ACTION: ENGAGING STUDENTS IN ZERO WASTE INITIATIVES

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ABSTRACT

Within the circular economy, zero waste is an aspirational concept and practical approach aimed at keeping materials at their highest value for as long as possible through rethinking, reducing, reusing, and only subsequently recycling and composting. Rather than focusing solely on waste management, zero waste also seeks to strengthen local economies, protect the environment, sustain livelihoods, and promote community empowerment. Cooperation with social actors such as youth—often excluded from policy processes—can help address gaps in waste reduction and resource diversion. With youth representing a significant and growing share of the global population, and in the context of escalating environmental challenges, engaging young people in sustainability and climate action has become increasingly important. Meaningful engagement depends on creating spaces for learning and capacity building that enable youth to act as innovators and local champions. Initiated in 2024, this research takes place in Victoria, Canada, and in São Bento do Sapucaí and Gonçalves in southeastern Brazil. The project engages youth in participatory research on waste management and promotes sustainable practices in schools and communities. Through interviews, workshops, and student mentoring, middle school students explored waste, recycling, and sustainability, developing practical solutions such as improved sorting stations, reduced plastic use, and awareness campaigns. Students also extended their efforts beyond schools by mapping neighborhood waste hotspots and proposing initiatives including tree planting, community gardens, curriculum integration, and student-led ambassador programs. The project demonstrates the potential of youth-driven, grassroots initiatives to foster environmental responsibility and contribute to more sustainable and resilient communities.

1. INTRODUCTION

Waste management has emerged as one of the most urgent environmental challenges of present times, driven by rapid urbanization, population growth, and unsustainable production and consumption patterns. Addressing this issue requires not only long-term systemic changes but also the implementation of practical, immediate strategies to reduce waste generation at the source. Emphasizing achievable actions can foster more sustainable habits and build momentum for broader environmental transformation (Marín-Beltrán, et al., 2022).

Zero Waste is a working method to keep materials in their highest value for as long as possible (Hannon & Zaman, 2018). It is an aspirational goal and an approach that encourages communities, organizations, and individuals to fundamentally rethink how resources are used and discarded, emphasizing the importance of minimizing waste at both the source and the end of a product's life cycle (Favoino & Kriipsalu, 2018). This involves not only reducing the amount of waste produced, recycling or composting, but also reusing materials whenever possible. Zero Waste strategies seek to keep materials within the economy for as long as possible, preserving their highest value and thus reducing the environmental impact not only associated with disposal, but also with extraction and manufacturing. By promoting circularity, Zero Waste initiatives inspire innovative solutions such as designing more durable products,

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establishing community composting programs, or implementing extended producer responsibility policies (Zaman, 2022).

Educational campaigns, programs, and participatory research can play a critical role in reinforcing this shift by empowering citizens - particularly youth - to become active agents of sustainability within their schools and communities (Cox et al., 2019). The Zero Waste framework is also closely linked to broader processes of sustainable urban development, seeking more equitable, resilient, and resource-efficient cities.

Youth participatory action research is a strategy that creates opportunities for young people to exercise voice and agency by engaging them as active contributors to research and action processes. Including children and adolescents in discussions about their territory and empowering them with critical thinking are strategic for enhancing children's and adolescents' resilience, adaptability to climate change, and citizenship (Dias et al., 2023). Recent studies exploring geographical knowledge within urban environments have engaged children and youth, whose perspectives offer valuable insights into tackling complex challenges such as climate change, disaster risk reduction, and resource security, while also proposing more effective and tailored solutions (Marchezini & Trajber, 2016). The knowledge and perspectives of young people are often disregarded despite their disproportionate vulnerability to socio-environmental impacts. Youth represent a significant portion of the global population: 1.2 billion young people aged 15 to 24 years, accounting for 16% of the worldwide population, of whom the majority live in the global South (UN, 2020). Moreover, they have a high capacity to change community behaviour due to their strong communication and engagement skills (Trajber et al., 2019; Aerts et al., 2018). Their experiences and innovative ideas can offer valuable insights into waste management while contributing to responses to climate change and urban sustainability. Furthermore, as the generation most likely to face the long-term consequences of today's environmental decisions, they are vital to shaping effective policies and solutions. By excluding youth voices, we miss opportunities to harness their creativity, resilience, and willingness to drive meaningful and transformative change (Percy-Smith, et al. (Eds.), 2023).

Both Brazil and Canada face significant challenges and opportunities in waste management, particularly in engaging young people and fostering sustainable practices. In the research project conducted between 2024 and 2025, participatory action approaches were implemented in Victoria, Canada, and in the Brazilian cities of São Bento do Sapucaí and Gonçalves. These case studies with youth highlight both the differences and similarities in the waste management landscapes of the two countries, as well as the potential for youth-driven initiatives to address local waste issues.

2. THEORETICAL FRAMEWORK

Urban Political Ecology (UPE) is a robust framework for studying cities and their waste flows and gaps, taking into consideration structural challenges, diverse actors and their power dynamics, involved in managing, diverting and reducing waste. In addition, UPE draws attention to questions of social justice, inequality and the connection between political economy and everyday material lives. The theory incorporates understandings of circularity as a pre-requisite for achieving greater sustainability (Stahel, & MacArthur, 2019; Suárez-Eiroa, et al., 2019).

Supported by theories on human-environment interactions (Turner & Kaplan, 2019; Swyngedow, 2009; Gregson & Crang, 2010; Hacking, 2019) and Assemblage (Anderson & McFarlane, 2011; Spies & Alff, 2020), this study sheds light on the composite and heterogeneous elements involved in waste reduction, with particular attention to the agency of youth as grassroots actors, and thus provides a more relational and dynamic understanding of UPE.

A lens situated in the local and regional context recognizes the specific geographic, historical, political, socio-economic and environmental urban circumstances (Lawhon, et al., 2014; Lawhon, Le Roux, Makina & Truelove, 2020). Within UPE, the Urban Metabolism analogy (Fernandez, 2014) and Assemblage theory help understand waste flows and reveal the actors, ideas, materials and technologies involved in these flows, e.g., identifying who benefits and who is excluded; disentangling social and power relations that underpin the predominant forms of generating and managing waste under the current waste regime (Gille, 2013). This theoretical framework incorporates understandings of circularity (Circular Economy) as a prerequisite for advancing sustainability outcomes (Kirchherr, Reike & Hekkert, 2017; Stahel, & MacArthur, 2019; Suárez-Eiroa, et al., 2019). Waste regimes describe the multifaceted aspects of governance and waste management, helping to understand the relationships between waste and society. We seek to expand these approaches by situating concepts within local contexts to capture the particularities and textures of place, thereby contributing to the overcoming of Eurocentric views on urban development (Frey, 2012; Frey, Gutberlet & Jacobi, 2019; Mabin, 2014).

Moreover, engaging youth in understanding waste management across different contexts through the UPE lens supports the development of contextualized alternatives and solutions, helping to fill critical gaps in urban planning (Adelina, et al, 2024; Hendra et al, 2025). It is crucial to consider the potential of young people´s arguments to drive changes in urban public policy sectors, such as waste management (Walker, 2019).

In the context of circular urban flows, the concept of Zero Waste is important, as a driver for designing and managing products and processes to systematically avoid and eliminate the volume and toxicity of waste and materials, particularly plastics (Zaman, 2022). It is a visionary concept that encompasses people changing their lifestyles and practices so that waste is avoided and that all discarded materials are designed to become resources for future uses (Tamminen & Lobin, 2022). Zero Waste challenges the assumption of waste as valueless and unavoidable consequence of consumption (Gutberlet, 2018).

3. METHODS

The study site in Canada is the City of Victoria (population of 91,867), located on Southern Vancouver Island, British Columbia, covering an area of 19.47km^2. Victoria is widely recognized as a leader in sustainability and climate action and, in March 2019, declared a climate emergency, uniting with cities across the country to address the crisis, accelerate the transition toward net-zero carbon emissions, and advance a Zero Waste strategy. The two Brazilian study sites (population of 17,000), while characterized by a more rural profile, share a nature- and culture-based tourism economy, like that of the Canadian case. This economic profile places increasing pressure on local governments to pursue socio-environmental innovations, particularly in response to the growing urgency of waste reduction. Yet the region hosts relatively few community-based initiatives working with recycling, composting, and repair. The project was conducted in partnership with three middle schools (Monterey Middle School in Victoria, Escola Estadual João Ribeiro da Silva in Gonçalves, and Escola Estadual Professor José Maria Priante in São Bento), identifying four grade 6 classrooms (60 students in each city) in Brazil and one grade 7 classroom (24 students) in Canada.

We applied a participatory community-based methodology (Amauchi et al., 2021; Clifford, French & Valentine, 2010), developing a set of five workshops with discussion groups, participatory mapping, Virtual Reality (this activity was only conducted in Victoria), and the use of creative tools to elicit students' reflections and ideas (Figure 1).

Participatory mapping uses several tools to capture citizens' perceptions and knowledge, resulting in maps that represent community understandings in multiple ways (Etmanski, et al., 2014). City planners can then spatialize this information and analyze it alongside other information using geoprocessing software, thereby supporting planning and decision-making processes, including those related to waste management (McCall, 2003). Participatory mapping and related approaches constitute powerful instruments for social change, and engaging youth offers additional benefits, such as stimulating social protagonism and strengthening a sense of community responsibility. Moreover, young people can contribute meaningfully to changing their urban environments and express their desire to be active participants in their communities (Kallio et al., 2013; Kraftl, 2013).

The main objective of these activities was to identify problems, bottlenecks, and possible solutions related to waste within the school environment, while promoting student's active engagement in the process, and the co-production of impactful products capable of influencing waste management practices within the school, in other schools, and in their wider communities. Student volunteers were selected to serve as Zero Waste Ambassadors through a democratic voting process: five students in each of the two Brazilian cities and four ambassadors in Victoria. These ambassadors took on a leadership role within the project, serving as student representatives and a key link between their classmates and the research team. Their responsibilities included co-developing project outputs, supporting awareness-raising activities, and helping to sustain the initiative within their school communities. Through their engagement, the ambassadors played a critical role in maintaining momentum, fostering peer-to-peer learning, and ensuring that the project remained grounded in the students' perspectives and everyday experiences.

The participatory approach adopted in this project provided valuable insights into students' perceptions of waste management and the broader environmental challenges associated with urbanization, tourism growth, and climate change. Through interactive activities and discussions, the project enabled the identification of key waste-related issues and potential areas for improvement, both within school environments and in the surrounding neighborhoods. This engagement also facilitated the co-creation of educational and policy-support materials that have the potential to strengthen Zero Waste strategies and reinforce integrated urban development policies in the study areas.

4. RESULTS AND DISCUSSION

4.1 Key informant semi-structured interviews

Interviews with school principals and teachers in Victoria (Canada), Gonçalves, and São Bento do Sapucaí (Brazil) reveal several shared and divergent challenges regarding Zero Waste education and practices. Across both countries, educators are familiar with the Zero Waste concept; however, they perceive that students generally lack understanding and practical engagement. In Canada, students may have heard about Zero Waste but rarely practice it. In contrast, in Brazil, the concept is predominantly associated

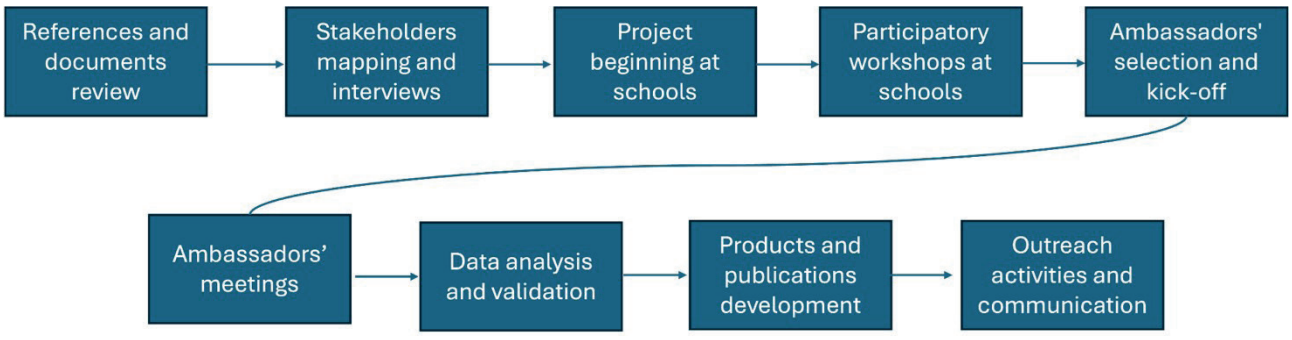

FIGURE 1: The research process.

with inorganic recycling, with limited recognition of organic waste and broader sustainability issues.

Interviewees in both contexts reflected on the social inequalities that shape students' environmental behavior:

- In Brazil, teachers expressed concern that students from lower-income households may have fewer options to reduce waste and should not be burdened with environmental guilt.
- In both countries, conversely, more affluent students may be detached from the impacts of consumption, viewing sustainability as an abstract or optional concern.

Despite general awareness, all interviewees highlighted significant gaps between knowledge and practice:

- In Victoria, recycling systems were suspended during the COVID-19 pandemic and have not been fully reinstated. Only office paper is currently recycled, while general student waste is disposed of as garbage.
- In Gonçalves, waste separation is neither systematically practiced nor meaningfully addressed within the curriculum. A prior school project aimed at reducing classroom waste failed mainly due to a lack of student engagement.
- In SBS, some awareness-raising initiatives exist, and collaboration with a local waste picker cooperative has brought speakers into classrooms. Yet, there are still no structured Zero Waste guidelines or consistent waste management practices in place.

A notable difference between the two countries is the presence in Brazil of local waste-picker cooperatives that could engage with schools to offer community-based learning opportunities, which is not evident in the Canadian setting. Nonetheless, both contexts reveal behavioral barriers, including students' difficulty in adopting correct waste habits, and a disconnect between environmental knowledge and daily practices. Social inequality further complicates these dynamics; educators highlight disparities in students' consumption patterns and levels of environmental responsibility, which are closely associated with students' socioeconomic conditions.

Several pedagogical limitations were noted:

- Waste is not yet systematically integrated into curricula. In Brazil, coverage is often indirect or limited to occasional events (e.g., science fairs).
- Teachers face time constraints and lack coordinated opportunities for interdisciplinary planning of environmental content.
- There is a shortage of teaching materials focused on Zero Waste, particularly in Portuguese.
- In Canada, environmental clubs and periodic litter collection activities exist, but are not fully leveraged to sustain waste education.

Overall, interviews suggest that effective Zero Waste education requires systemic support, including adequate infrastructure, curricular integration, community partnerships, and targeted awareness campaigns. Parting from an urban political ecology perspective and highlighting waste in the urban metabolism provides a visually attractive form of communication with teachers and students to be explored in the classroom. The metabolism analogy (Heynen, et al. (Eds.), 2006) visualizes the pathways of waste in the city and surrounding areas, and it highlights the environmental, social and economic impacts and possible alternatives. In both regional contexts, coordinated efforts between schools and municipal authorities to foster consistent practices and empower students as active agents of sustainability would be beneficial.

4.2 Classroom activities

In 2024, five participatory workshops were conducted in each of the schools involved in the project. The workshop outcomes revealed a strong capacity among students for critical reflection, place-based environmental awareness, and creative problem-solving regarding waste management, as reiterating by Marchezini and Trajber (2016). Despite contextual differences, several shared themes emerged (Table 1). Students in both countries understood waste as a byproduct of human consumption, linking it not only to local issues, such as littering or inadequate disposal infrastructure, but also to broader environmental concerns, including pollution, climate change, and the unsustainability of prevailing consumption modes. Canadian students critically questioned the very concept of "zero waste" as an unattainable ideal, demonstrating a nuanced understanding of systemic challenges.

Students identified a range of practical issues in their immediate environments. In Canada, students highlighted improper waste separation, unclear bin labeling, gum and plastic waste (e.g., sushi containers used during school lunches organized by the Parents Advisory Council-PAC), and limited student engagement in recycling. In Brazil, the key points mentioned by the students were a lack of separation at home, litter in schoolyards, and insufficient infrastructure for proper waste disposal.

These observations were grounded in students' everyday experiences and demonstrated, at least among some of them, a strong awareness concerning the tangible impacts of waste in their communities. From these perspectives, some solutions and creative ideas emerged during our workshops and conversations.

Students proposed a variety of actionable solutions, including:

- Increasing the number of waste and recycling bins on school premises and in the community and clearly labeling what should go into each bin.
- Encouraging recycling and reuse practices, such as using biodegradable or reusable containers during school lunches and school-related activities.
- Creating awareness campaigns in the school through posters, blogs, and peer-led presentations.
- Incorporating sustainability into school routines (e.g., clean-up field trips, bike-to-school initiatives).
- Installing green infrastructure, such as solar panels or rain gardens.

Brazilian students also highlighted the importance of tree planting and environmental preservation near rivers.

TABLE 1: Comparative Analysis of Participatory Workshop Results – Canada and Brazil.

Thematic Area	Canada (Monterey Middle School)	Brazil (São Bento do Sapucaí & Gonçalves)
Student Engagement	High engagement with open discussion; students showed critical thinking and proposed concrete actions.	Strong enthusiasm from the beginning; students volunteered and were elected as ambassadors.
Understanding of Waste	Defined as materials like plastic, food packaging, and gum, linked to broader issues like climate change.	Understood as leftovers from consumption, associated with pollution, dirt, and environmental harm.
Observed Problems at School/Home	Lack of proper waste separation; unclear bin labeling; plastic waste (e.g., sushi containers); gum littering.	No separation at home; littering at school, especially wrappers and gum on the floor.
Proposed Solutions	More bins with clear labeling; student awareness campaigns; school-wide presentations; use of reusable materials; solar panels; rain gardens.	Selective collection; proper disposal infrastructure; tree planting; recycling education.
Participatory Mapping Outcomes	Identified local waste hotspots; proposed community gardens, solar panels, bike lanes, and improved signage.	Mapped key landmarks and environmental problems; highlighted the river as a key asset; proposed photo-documentation walk.
Creative/Arts-Based Activities	Used Virtual Reality to explore Brazilian waste picker cooperatives; created maps and awareness materials.	Created a recycling mosaic using painted cardboard squares; the artwork was displayed in school.
Final Student-Led Initiatives	Developed student ambassador-led presentations; proposed lunchtime waste monitoring; advocated for a shift to the circular economy.	Built a "Dream Tree" expressing personal and collective visions for a sustainable future.
Focus on Social Dimensions of Waste	Emphasis on the role of school practices and institutional limitations (e.g., staff constraints, contract limitations).	Highlighted the role of waste pickers in the recycling chain; strong awareness of social aspects of waste.
Educational Tools Used	Workshops, focus groups, participatory mapping, VR, ambassador program, peer presentations.	Workshops, focus groups, participatory mapping, arts-based methods, and an ambassador program.
Key Takeaways	Youth can act as change agents with the right tools and institutional support; the importance of linking local action with global awareness.	CBR and arts-driven approaches promote local ownership, a strong link between identity, place, and environmental stewardship.

In contrast, Canadian students emphasized system-wide change, linking waste to climate policy and the transition from a linear to a circular economy.

Students in all three cities showed a growing sense of environmental responsibility and agency. They recognized the role of individual behavior (e.g., "people are lazy," "we need to do better") but also critiqued institutional barriers, such as a lack of school policies and staff limitations. Brazilian students expressed respect for waste pickers and a desire to support them, while Canadian students called for teachers and staff to lead by example.

One workshop was dedicated to a participatory mapping activity, in which students identified waste-related problems and proposed solutions by annotating maps of the school premises and the wider neighbourhood. Figure 2 shows the consolidated map summarizing the issues the students identified in the neighbourhood.

In another workshop, we constructed a "Dream Tree" (Figure 3) to allow students to express their hopes for the future. These included dreams of a more conscious society, better public infrastructure, and stronger environmental education programs in their schools. Students emphasized the importance of being heard and recognised their own capacity to initiate meaningful change within their schools and communities. The word cloud was constructed with the keywords collected from the students' responses.

The workshop results underscore that, when provided with adequate space, tools, and support, students are not only capable of critically analyzing environmental problems but also of generating innovative, place-based solutions rooted in lived experience and collective action. Their insights contribute valuable perspectives to local sustainability planning and broader discussions on environmental justice and youth participation. Moreover, the activities allowed the research team to observe differences in the students' perspectives, connected to the urban context they live in and to the structure of the education system. For example, in Canada, the research team faced time constraints put on by the school in developing additional project activities, whereas in Brazil, more flexibility was given to the researchers.

Students reported a deeper understanding of waste origins, its environmental impacts, and the broader zero-waste concept, including the roles of waste pickers in both the Global South and the Global North. They recognized specific local issues, such as plastic packaging, and valued learning about social inequities associated with waste management. The Virtual Reality experience applied in Victoria was convenient in enabling Canadian students to engage with and understand the realities of waste pickers in Brazil. Students expressed enthusiasm for expanding the project, suggesting the inclusion of more grades, a broader geographic reach, and the development of teaching materials or courses. They saw ambassadors as vital leaders in awareness-raising and community engagement. Overall, students appreciated the project's interactive and participatory approach, noting its importance for fostering environmental responsibility and empowerment.

4.3 Student ambassadors for zero waste

The ambassadors were elected by their peers, fostering a sense of belonging and responsibility. In Victoria,

FIGURE 2: Waste-related issues mapped by students in Oak Bay, Victoria.

the ambassadors delivered a presentation of the project to teachers and staff. They also planned a presentation in other classrooms, but this activity could not be completed due to time constraints. As a final output, the ambassadors produced an educational publication on fast fashion and

FIGURE 3: Students' dreams for a zero-waste future.

the impacts on waste management and policies to be distributed among students and schools.

In Brazil, the Zero Waste ambassadors also presented their proposals to their teachers and to peers in other classrooms (Figure 4). In Gonçalves, they proposed school activities such as environmental assessment walks and demonstrated interest in leading awareness campaigns both inside and outside the school. They also requested a meeting with the local mayor and the Environmental Officer to discuss waste-related challenges in their communities, and they wanted to plant trees.

In São Bento do Sapucaí, the ambassadors stood out for their ability to connect with school staff and their appreciation for local partnerships, such as with the waste pickers' cooperative. In these schools, students were motivated to continue the project, develop educational initiatives, and maintain dialogue with other young participants, including through online networks. The role of ambassadors has established itself as an effective strategy for encouraging student leadership, strengthening ties with the community, and promoting a zero-waste culture in their schools.

The ambassador program was concluded by the end of 2025. The next phase will be focused on the dissemination of the research findings and the materials produced to other classes in the same schools and to contribute to broader citizen education on Zero Waste. In Brazil we want to explicitly target rural areas adjacent to the towns under study, which have been identified as critical challenges for waste management. Students are committed to organizing a community clean-up day and to presenting a poster on zero waste to increase awareness during the forthcoming "Environment Day" event.

FIGURE 4: Students presenting the zero-waste proposal.

As part of the project, each ambassador was invited to record a short video introducing themselves and sharing their motivation for engaging in zero-waste activism. These video clips were then shared among all ambassadors, enabling students to recognize themselves as part of a broader network of youth actors committed to sustainability. The videos were translated into Portuguese for the Brazilian students, and many appreciated also the opportunity to engage with the original English versions, viewing it as a meaningful and enjoyable challenge.

At Monterey Middle School, in Victoria, Canada, the educational program with the ambassadors was conducted from November 2024 to June 2025. During the meetings, the concepts of zero waste and the impacts of waste generation were discussed, along with related topics such as climate change. A first presentation was delivered by the ambassadors to the staff meeting. The second product was a booklet about Fast Fashion, which is currently under development, with the main aim of online distribution.

4.4 Research limitations

While the Zero Waste project demonstrated strong potential to foster youth engagement in sustainability and participatory environmental education, its implementation revealed several structural and logistical limitations that merit careful reflection. These challenges, common in school-based research and intervention projects, underscore the need for more supportive institutional frameworks and adaptive project design to ensure broader, more equitable participation.

One of the most significant limitations was the restricted availability of time within the formal school schedule. Teachers consistently reported difficulty in allocating time for project activities, including the workshops, due to the demands of meeting prescribed curricular goals. As schools are under pressure to deliver standard content within fixed timelines, integrating extracurricular or cross-disciplinary projects, such as Zero Waste, often competes with other educational priorities. This constraint not only limited the depth of engagement possible within each workshop but also hindered follow-up activities that could have reinforced learning outcomes.

Closely related to this, there was minimal time available to work with the student ambassadors during school hours. Although the ambassador model proved highly effective in fostering leadership and peer-led awareness, the scheduling of regular, dedicated sessions with ambassadors was challenging. Specifically in Victoria, these meetings had to be condensed or postponed due to competing school activities or a lack of availability in the timetable. As a result, the full potential of the ambassador-led initiatives was not fully realized.

Ethical guidelines and institutional policies around student privacy posed another notable challenge. Communication with students outside designated project hours was impossible due to limitations on accessing student emails or digital communication platforms. These restrictions, while necessary for safeguarding student welfare, also made it difficult to maintain continuity between sessions, respond to student queries, or provide ongoing mentorship to ambassadors. The absence of a flexible communication strategy reduced opportunities for sustained engagement and deeper collaboration beyond workshop settings.

The project's cross-national and multi-regional nature, spanning Canada and Brazil, also introduced logistical and financial barriers. Due to resource constraints, it was not feasible to organize interactions between ambassadors from Brazil and Canada, which could have enriched the project's intercultural and comparative dimensions. Although virtual tools were considered, limitations in infrastructure, internet access, time zone differences, and language mediation made such exchanges difficult to implement meaningfully within the available timeframe.

The project successfully empowered several highly motivated and engaged students, and it gave particular attention to fostering inclusive participation. Activities were de-

signed to encourage contributions from quieter students, including small-group discussions and targeted efforts to involve those who were less outspoken or less confident. Despite these efforts, it remained a challenge to fully overcome the pre-existing dynamics of classroom participation. Students who were already perceived as natural leaders tended to take on more visible roles, including selection as ambassadors. This highlights a continued limitation in terms of equitable representation, as students with learning difficulties, lower academic engagement, or social reticence may have participated less actively. Future iterations of the project should further explore strategies to democratize access to environmental education and leadership, ensuring that diverse voices and experiences are meaningfully included. Addressing these limitations requires a multi-faceted approach, including stronger institutional support for integrating sustainability projects into curricula, clearer communication protocols that allow for safe yet flexible engagement, and targeted strategies to include a broader spectrum of students. Despite these constraints, the Zero Waste project has laid the necessary groundwork for future school-based initiatives and has highlighted key areas for structural improvement in participatory environmental education.

5. CONCLUSIONS

The Zero Waste project, implemented across educational institutions in Victoria, Canada, and in the municipalities of Gonçalves and São Bento do Sapucaí in Brazil, provides a valuable lens for analyzing the intersections of environmental education, youth participation, and structural inequalities in urban sustainability. Framed through the theoretical perspectives Urban Political Ecology (UPE) and Urban Metabolism, the project's findings contribute to ongoing discussions about the socio-material processes shaping waste governance in urban and peri-urban contexts.

Urban political ecology foregrounds the uneven power relations that structure urban environments and the socio-natural processes that define access to, and control over, urban resources and infrastructures (Heynen, Kaika & Swyngedouw, 2006). Waste, within this framework, is not merely a technical or managerial problem but a socio-political artifact, shaped by the spatial, institutional, and class dynamics that govern urban life. The Zero Waste project made these dynamics visible by exposing how waste is differently experienced across geographical contexts and within urban social groups, particularly through students' reflections on the roles of waste pickers, the visibility of litter in schools, and the unequal burdens of environmental degradation.

Students' recognition of waste pickers as "environmental heroes," especially in the Brazilian context, aligns with UPE's emphasis on marginalized labor and informal infrastructures that sustain the formal operations of urban metabolism. These actors, often excluded from mainstream sustainability narratives, were repositioned by students as central to the city's ecological functioning. Their acknowledgment marks a critical pedagogical and political intervention, challenging dominant narratives that render such labor invisible and re-signifying it as an essential component of circular and just urban futures (Tamminen & Lobin, 2022).

Moreover, the project sheds light on the scalar dynamics of urban environmental governance. Students identified both micro-scale interventions (e.g., improving school recycling systems, reducing lunch packaging) and macro-scale concerns (e.g., links between waste and climate change, zero waste policies at the city level) (Nelson, Ira & Merenlender, 2022). This scalar awareness reflects an emergent understanding of urban metabolism, understood as the circulation of energy, materials, and labor through urban systems (Kennedy et al., 2007). By engaging students in mapping and localized diagnostics, the project invited them to conceptualize their schools and neighborhoods as metabolic nodes, sites where socio-environmental flows can be visualized, contested, and potentially transformed.

In future iterations of the project, this participatory mapping approach could be expanded to include continuous monitoring and evaluation of progress in collaboration with students. Teachers could work with students to track changes in waste generation, both reductions and increases, across specific locations, thereby fostering greater student engagement and a stronger sense of responsibility. The resulting data could then be analyzed to refine strategies and inform targeted interventions, while also serving as a valuable tool for communicating outcomes and impact to the broader public.

The project also revealed limitations in how schools operate as spaces of socio-ecological transformation. In both countries, students and educators highlighted structural barriers to effective waste management, including inconsistent recycling infrastructure, limited environmental education in curricula, and a disconnect between knowledge and practice. These findings echo UPE critiques of technocratic and depoliticized approaches to sustainability, which often fail to engage with the lived realities of urban residents or to confront the deeper political-economic logics that produce waste in the first place (Swyngedouw, 2009).

Furthermore, the fragmentation of responsibility—between schools, municipalities, and households—revealed by the interviews underscores a metabolic disjuncture, whereby the social and material flows that constitute urban waste remain poorly coordinated and unevenly governed. Students' efforts to visualize and intervene in these flows, for instance, through mapping hotspots or proposing changes to packaging norms, represent an attempt to re-politicize waste by linking individual actions to systemic patterns of consumption and disposal.

Notably, the project's methodological design, centered on participatory research and youth agency, serves as a prefigurative political practice within the UPE tradition, pointing toward more democratic, place-based forms of environmental governance. The student ambassadors' proposals for greater inclusion, curricular integration, and community outreach reflect an emergent ecological citizenship, one that resists passive environmental messaging in favor of co-produced, justice-oriented sustainability.

Through the lenses of urban political ecology and urban metabolism, the Zero Waste project illustrates the pedagogical and political potential of engaging youth in critical environmental praxis, echoing the findings of other scholars (Cox et al., 2019, Han & Ahn, 2020, Ritchie, 2021). The findings reinforce the idea that waste is not only a material byproduct but a reflection of broader urban power relations, metabolic configurations, and cultural narratives (Hird, 2022). As students began to recognize and challenge these dynamics, through reflection, mapping, and proposal-making, they also began to enact alternative imaginaries of the urban, rooted in equity, responsibility, and collective action. Future interventions should build on these insights to further embed political-ecological literacy in schools and to strengthen youth roles as co-producers of more just and sustainable urban futures.

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