

**SUSTAINABILITY BY DESIGN: MOTIVATING PRO-ENVIRONMENTAL ACTION  
AND IMPROVING WASTE DIVERSION**

by

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A DISSERTATION SUBMITTED IN PARTIAL FULFILLMENT OF  
THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF PHILOSOPHY

in

THE FACULTY OF GRADUATE AND POSTDOCTORAL STUDIES

(Resources, Environment and Sustainability)

THE UNIVERSITY OF BRITISH COLUMBIA

(Vancouver)

October 2018

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### **SUSTAINABILITY BY DESIGN: MOTIVATING PRO-ENVIRONMENTAL ACTION AND IMPROVING WASTE DIVERSION**

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the degree of Doctor of Philosophy

in Resources, Environment and Sustainability (RES)

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## **Abstract**

Engaging the public in sustainable actions is essential for reaching local and global sustainability goals. The first two research questions of this dissertation focus on strategies to reduce contamination of waste in private and public areas through active and passive prompts, and immediate feedback on errors. The third research question expands the behavioural analysis to examine willingness to act in several pro-environmental domains: waste, water, food and biodiversity. Together, this thesis aims to contribute to best practices in the field of waste diversion, community engagement and long-term pro-environmental behaviour change.

The first study of this dissertation shows that providing active guidance during a public festival helped people sort waste significantly better than stand-alone prompt interventions of 2D signage and real-life 3D items. The effects were consistent across all waste streams and show the importance of guidance and feedback at the time of sorting to help reduce contamination and achieve zero waste goals. The second study demonstrated that immediate feedback on sorting errors through a computer game also improved sorting accuracy in the lab, and benefits persisted even when feedback was removed in the second trial. The game was additionally tested in a field study in student residence buildings, resulting in the weight of compost materials increasing while bin contamination decreased. The third key finding of this dissertation demonstrates that botanical gardens can help engage local visitors in sustainability topics through team-building activities while immersed in nature. After their visit, participants were more knowledgeable about environmental issues, more connected to nature, and showed greater willingness to engage in sustainability actions.

These findings in aggregate suggest that active guidance, timely feedback, and engaging nature tours can be effective tools to raise awareness and educate the public in recycling and composting adherence. However, knowledge alone is insufficient to lead to pro-environmental behaviour if the overarching systems of provision are not designed to leveraging people's desire for convenience and behavioural shortcuts. In addition to environmental education and awareness, special attention needs to be paid to convenience, socio-normative cues and material infrastructure.

## **Lay Summary**

This dissertation explores theory and practice behind strategies that engage individuals and communities in sustainable actions involving waste, water, food and biodiversity. Using quantitative experiments, I test strategies that help reduce recycling and composting contamination of consumer waste and assess the impact of nature-based education tours on participants' willingness to act sustainably. Use of a computer game to teach better sorting and providing active guidance upon waste disposal significantly reduced contamination of waste streams. Botanical gardens and nature-based educational organizations can contribute to sustainability engagement with tours and programs that raise participants' environmental knowledge, attitudes and willingness to act. These studies confirm that various forms of feedback can improve people's knowledge and willingness to act. However, knowledge alone is insufficient to lead to pro-environmental behaviour if external factors (infrastructure, convenience, or incentives), are not designed and aligned to support people's long-term action.

## Preface

My dissertation consists of six chapters. I am the sole author of Chapters 1, 2 and 6, first author of Chapters 3 and 5, and a co-author with equal contribution of Chapter 4. The experiments in Chapter 3 and 5 have been published, and the experiments in Chapters 4 are currently under review in a peer-reviewed academic journal. My contributions in research Chapters 3, 4, and 5 include identifying research questions, designing the experimental protocol, collecting data, performing data analysis, interpreting the results, and writing the manuscripts for publication.

Study I (Chapter 3): *Toward zero waste events: Reducing contamination in waste streams with volunteer assistance*

I am the first author of this study. I devised the research questions with help of Dr. Jiaying Zhao and planned the experiment parameters to compare the effectiveness of various prompts and volunteers on waste sorting accuracy. I conducted the data collection and data analysis, and with feedback from Dr. Zhao interpreted results and wrote the manuscript. Revision of the manuscript was assisted with comments from Dr. Zhao and Dr. Tara Moreau (UBC Botanical Garden), along with three anonymous reviewers who provided constructive comments on the scope of the work. The manuscript has been published in *Waste Management* and can be accessed at:

<https://www.sciencedirect.com/science/article/pii/S0956053X18301727>.

The methods and research protocol were approved by UBC Behavioural Research Ethics Board, Number: H15-02949.

Study II (Chapter 4): *Beyond posters: Using a digital sorting game feedback to improve recycling and composting accuracy*

I am the second author with equal contribution with Yu Luo (a master's student from Psychology). For this study, I contributed in design of the online sorting game, the feedback script, and the research questions. I conducted the field study (Experiment 3), organized the game playing sessions in the lobby, managed the RAs, collected the data and did the data analysis. Yu Luo was the lead on design of the sorting game, conducted the lab studies (Experiments 1 and 2), did the data analysis, made figures and wrote up the analysis. Dr. Zhao provided feedback throughout the study and in interpretation of the results, and I co-authored the manuscript with Yu Luo. Dr. Zhao provided comments on the manuscript which has been submitted for publication and is currently under review. The methods and research protocol was approved by UBC Behavioural Research Ethics Board, Number: H15-02949.

Study III (Chapter 5): *Sustainability education in a botanical garden promotes environmental knowledge, attitudes, and willingness to act*

I am the first author of this study and was responsible for devising the research questions and the survey instrument, conducting the surveys, analyzing the data, and writing the manuscript. Along with Dr. Zhao, Dr. Tara Moreau (UBC Botanical Garden) and Oliver Lane (Society Promoting Environmental Conservation), I helped finalize the Field School tour protocol, script, and activities. Dr. Zhao helped with data interpretation, and I wrote the manuscript. Dr. Moreau, Oliver Lane, Dr. Zhao and three anonymous reviewers provided comments on the manuscript which has been published in [\*Environmental Education Research\*](#). The methods and research protocol were approved by UBC Behavioural Research Ethics Board, Number: H17-01766.

## Table of Contents

<b>Abstract.....</b>	<b>iii</b>
<b>Lay Summary .....</b>	<b>v</b>
<b>Preface.....</b>	<b>vi</b>
<b>Table of Contents .....</b>	<b>viii</b>
<b>List of Tables .....</b>	<b>xiii</b>
<b>List of Figures.....</b>	<b>xiv</b>
<b>Acknowledgements .....</b>	<b>xv</b>
<b>Dedication .....</b>	<b>xvii</b>
<b>Chapter 1: Introduction .....</b>	<b>1</b>
1.1    Research Context .....	4
1.1.1    Sustainability, Human Action and Waste Management .....	4
1.1.2    Motivating Pro-Environmental Behaviour Change .....	6
1.1.3    Cities and Communities as Agents of Change.....	9
1.1.4    Waste Sorting Challenge: Participation and Contamination .....	10
1.1.5    Education in Nature: Botanical Gardens and Sustainability Engagement.....	13
1.2    Research Questions .....	14
1.3    Description of Chapters .....	16
<b>Chapter 2: Theoretical Background .....</b>	<b>19</b>
2.1    Early Models of Behaviour Change: Emphasis on Rationality and Knowledge .....	20
2.2    Limitations of Cognition: Shortcuts, Biases and Convenience .....	22
2.3    But Wait - Knowledge and Feedback Matter! .....	27

2.5	Contextual and Infrastructural Influence .....	32
2.6	Socio-Cultural Approaches to Behaviour .....	35
2.7	Synthesis and Research Direction.....	38
2.7.1	Design with Visual Prompts and Volunteer Assistance .....	39
2.7.2	Designing with Immediate Feedback.....	41
2.7.3	Design with Education in Nature .....	44
<b>Chapter 3: Toward Zero Waste Events: Reducing Contamination in Waste Streams with</b>		
<b>Volunteer Assistance.....</b>		<b>47</b>
3.1	Introduction.....	47
3.2	Motivating Waste Sorting .....	48
3.3	Current Study .....	50
3.4	Methodology .....	51
3.4.1	Participants.....	51
3.4.2	Materials .....	52
3.4.3	Procedure .....	55
3.5	Results.....	56
3.6	General Discussion .....	60
3.7	Recommendations for Waste Management at Events and Festivals .....	65
<b>Chapter 4: Beyond Posters: Using a Digital Sorting Game Feedback to Improve Recycling</b>		
<b>and Composting Accuracy .....</b>		<b>68</b>
4.1	Introduction.....	68
4.2	Current Study .....	71
4.3	Pilot Study.....	72

4.3.1	Participants.....	73
4.3.2	Apparatus .....	73
4.3.3	Stimuli.....	73
4.3.4	Procedure .....	74
4.3.5	Results.....	74
4.4	Experiment 1 .....	75
4.4.1	Participants and Stimuli .....	75
4.4.2	Procedure .....	75
4.4.3	Results and Discussion .....	78
4.5	Experiment 2.....	80
4.5.1	Participants.....	80
4.5.2	Apparatus .....	81
4.5.3	Stimuli and Procedure.....	81
4.5.4	Results and Discussion .....	83
4.6	Experiment 3.....	86
4.6.1	Participants.....	87
4.6.2	Stimuli.....	88
4.6.3	Procedure .....	88
4.6.4	Results and Discussion .....	90
4.7	Conclusion and General Discussion .....	95
4.8	Sorting Errors and Feedback.....	98
4.9	Limitations and Future Directions .....	100

## **Chapter 5: Sustainability Education in a Botanical Garden Promotes Environmental**

### **Knowledge, Attitudes, and Willingness to Act .....103**

5.1	Introduction.....	103
5.2	Education in Nature: Botanical Gardens as a Venue for Sustainability Education ....	104
5.3	Factors Facilitating Behaviour Change.....	105
5.4	Roles of Knowledge and Education.....	106
5.5	Role of Environmental Attitudes .....	107
5.6	Role of Nature.....	107
5.7	Current Study .....	109
5.8	Methods.....	111
5.8.1	Participants.....	111
5.9	Survey Design.....	111
5.10	Procedure .....	115
5.11	Results.....	120
5.11.1	Environmental Knowledge .....	120
5.11.2	Environmental Attitudes and Intentions to Act .....	122
5.11.3	Willingness to Engage in Pro-Environmental Behaviours .....	124
5.11.4	Regression Analyses .....	127
5.12	Conclusion and General Discussion .....	130
5.13	Limitations and Directions for Future Research.....	134

### **Chapter 6: Conclusion and General Discussion.....137**

6.1	Summary of Chapters .....	137
6.1.1	Chapters 3 and 4: The Waste Sorting Challenge .....	138

6.1.2	Chapter 5: Education in Nature.....	142
6.3	Theoretical and Practical Implications.....	147
6.5	Advancing Behavioural Sustainability .....	157
<b>Bibliography .....</b>		<b>165</b>
<b>Appendices.....</b>		<b>182</b>
Appendix A Supporting Materials for Chapter 4.....		182
A.1	80 Items Used in the Pilot Study with Mean Sorting Accuracy .....	182
A.2	Signage for the UBC Waste Stream Bins .....	183
A.3	Image Set 1 in One Block: .....	184
A.4	Image Set 2 in Another Block:.....	184
A.5	Bin Layout in the Game Buildings .....	185
A.6	Sorting Game Posters and Lobby Set-up. ....	185
Appendix B Supporting Materials for Chapter 5.....		186
B.1	Pre-visit and Post-visit Surveys .....	186
B.2	Instructor Scripts and Photos of the Field School Tour.....	188
B.3	Within-Subjects Analysis of the FS Participants .....	203

## List of Tables

Table 1. Number of bins in each condition in each waste stream.....	54
Table 2. ANOVA and Tukey's HSD tests on sorting accuracy in each bin .....	78
Table 3. ANOVA and Tukey's HSD test on sorting response times.....	79
Table 4. ANOVA and Tukey's HSD test results on sorting accuracy .....	83
Table 5. ANOVA and Tukey's HSD test results on motion deviation.....	85
Table 6. ANOVA and Tukey's HSD test results on sorting response times .....	86
Table 7. Building conditions, residents and game statistics .....	88
Table 8. List of scales and statements used in the pre-visit and the post-visit surveys .....	113
Table 9. List of actions in four sustainability domains in both pre-visit and post-visit surveys.	114
Table 10. A description of the stops during a typical Field School tour .....	118
Table 11. Regression analysis.....	128

## List of Figures

Figure 1. Map of the Apple Festival grounds with four experimental conditions.....	52
Figure 2. An image of the experimental conditions.....	54
Figure 3. Average number of contaminants per bin per waste stream.....	57
Figure 4. Average kilogram of material per bin per waste stream.....	59
Figure 5. Average number of contaminants per kilogram per bin per waste stream .....	60
Figure 6. Chapter 3, Experiment 1 sorting accuracy with and without feedback .....	77
Figure 7. Chapter 3, Experiment 2 sorting accuracy results .....	82
Figure 8. Chapter 3, Experiment 3 field study results. ....	91
Figure 9. Map of the garden with stops during a typical Field School tour .....	117
Figure 10. Knowledge response of FS participants compared to GV.....	121
Figure 11. Average rating of attitude scales FS participants compared to GV.....	122
Figure 12. Percentage of participants willing to do water conservation actions .....	124
Figure 13. Percentage of participants willing to do waste reduction actions.....	125
Figure 14. Percentage of participants willing to do sustainable food choices .....	126
Figure 15. Percentage of participants willing to do biodiversity conservation actions. ....	127

## Acknowledgements

I would like to first acknowledge that my time at UBC took place on the ancestral and unceded territory of the Musqueam, Squamish, and Tsleil-Waututh Nations.

I offer my enduring gratitude to my advisory committee: Dr. Jiaying Zhao, Dr. John Robinson and Dr. Alan Kingstone: I am thankful to have been privileged to study with you and benefit from your insights on the theory and practice of sustainability and behaviour. You have impacted me more than I can express. I have also learned tremendously from the IRES faculty and fellow students (Sylvia, Anne-Mareike, Lisa, Julia, Stefan, and many others) who have all inspired me to continue my work in interdisciplinary sustainability.

I am very grateful for the financial support from the Social Sciences and Humanities Research Council of Canada (SSHRC) 4-year grant 752-2012-1554, and the UBC 4-year Fellowship grant. Thank you, Dr. Tara Moreau for funding my Botanical Garden studies, and for many encouraging words such as: “Trust the Process!”. I am also thankful to Dr. Jiaying Zhao for tuition support, and the AMS Sustainability Projects Fund which financed the materials for my experiments in Chapters 3 and 4.

I would like to also acknowledge and thank the research assistants who helped with data collection throughout the pilots and studies: Michele Lee, Leanne Zeng, Hannah Barath, Keiko Nariya, Matthew Burke, Erin Morgan, Florence Blessing, Patricia Herrera and Yimiao Gong. Immense thanks to Yu Luo for the collaborative work on the sorting game study, and to Ru, Brandon and Nishtha for statistical advice. Big thanks to Bud Fraser from UBC Sustainability

and Engineering who provided Bin Toppers used in Chapter 3, and for many useful discussions on waste management.

And finally, THANK YOU to my constant rock of support - my partner Jessica, also my near and dear Zelenika-Zovko family, mom Anka and sister Katarina, and my cherished friends for the encouragement throughout my graduate journey. I could not have done it without your love and support.

## **Dedication**

*For the women that raised me: mama Anka and baka Fila.*

*In hope for a sustainable future: to co-exist, thrive and flourish.*

## Chapter 1: Introduction

Creating change to mobilize a transition toward a more sustainable future is one of the most significant challenges of our time. Scientists have urged for a substantial change in values and behaviour in every nation of the world, with a systemic and integrated collaborative work across sectors and nations to help societies move toward a more sustainable future (Lubchenco, 1998; Moore & Rees, 2013; Raskin et al., 2002). Despite the growing awareness of environmental problems and the collective need to act, change is difficult, and humanity has not yet set the course toward this significant transformation. Since people's actions are at the center of the sustainability challenge, behavioural research is essential to help motivate mobilization toward achieving local and global sustainability goals. With an interdisciplinary perspective centered in environmental psychology, this thesis investigates feedback and education strategies that lead to motivation and adoption of pro-environmental behaviour<sup>1</sup>. One of the central focuses of this work is to examine approaches to reduce contamination of recycling and composting streams in household and public realms. In addition to waste, I also examine other environmental domains such as water conservation, sustainable food choices, and biodiversity conservation. All of the experiments are conducted within the context of the University of British Columbia (UBC) campus: in the lab, student residence buildings and the UBC Botanical Garden. As such, this dissertation also observes UBC's role as an agent of change, and its institutional influence on behaviour, education and culture of sustainability.

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<sup>1</sup> I adopt Steg et al. (2014) definition of pro-environmental behaviour as any action that enhances the quality of the environment, regardless of the intent. Pro-environmental behaviour is synonymous with sustainable behaviour or sustainable actions.

Waste production and how we manage it is in many ways a telltale sign about our culture and our relationship to the environment. Are we a part of the nature or do we see ourselves as separate? Do we take resources, consume and dispose of wastes by burning or landfilling, or can we learn how to connect the systems of production with disposal to minimize negative consequences, and conserve energy and resources? Participation in actions like recycling and composting can also be a proxy for other pro-environmental behaviours (Holland, 2000), so the insights and strategies can have relevance to other sustainability domains. Urban waste management is a growing issue for cities and communities alike due to the environmental and financial costs associated with the collection, sorting, resource quality, and transport of waste (Statistics Canada, 2013). The focus on the waste sorting problem has also been inspired by my work with the UBC Campus & Community Planning department as a Zero Waste Coordinator. During my appointment over one million dollars worth of infrastructure was rolled out to boost recycling and composting rates to meet UBC's Climate Action goals (UBC, 2015). Employed in this learn-work position for two years, I helped draft waste sorting education and outreach campaigns, trained food service staff in recycling procedures, and organized infrastructure upgrades in student residence and academic buildings. This involvement gave me first-hand experience about the need for strategies to educate and inform proper sorting practices, and the importance of infrastructure (i.e. bins, signage, convenience, consistency) as well as personal and social elements (i.e. people's attitudes, perceptions, interests and norms) necessary for the success of waste diversion programs.

Because recycling and composting has been around for a long time, I assumed that most of the consumer waste produced in big cities was diverted from landfill. I quickly learned that even

when people participate in the recycling and composting programs, the contamination<sup>2</sup> inside the bins can be so severe to result in all the bins' contents going to the landfill. As more municipalities and communities throughout Canada expand their services to include separate food scraps/ organics collection and implement stringent regulations (such as no food allowed in garbage), participation in recycling and composting programs is increasing. However, an increase in participation does not solve problems of contamination of recycling bins and may in fact exacerbate it. Like motivating participation, contamination of waste streams can be caused by numerous factors, such as lack of knowledge on local sorting guidelines, missing or inconvenient infrastructure, or lack of personal or social norms. The growing complexity and variety of materials in the marketplace is another factor as it often confuses people when it goes against their intuition. For example, most single use coffee cups and containers are recyclable, but there are types which are compostable, biodegradable or disposable (non-recyclable), with different local guidelines signaling which bin they should go into, even if they look identical to the user. If a local composting facility cannot 'digest' rigid compostable cutlery and cups, even if it says compostable on the item, they must go into the garbage stream. Many items may look and feel recyclable but are not allowed in local recycling streams – such as soft plastics, bags, styrofoam, propane tanks, tinfoil, or greasy containers. In fact, most household items, like toothbrushes, coat-hangers, ceramics, clothes, batteries and electronic waste are not accepted in standard recycling collection. Encountering these issues throughout my appointment made me change my perspective to become more sympathetic to people's struggles to live and act

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<sup>2</sup> Contamination is a technical term for a non-recyclable material that should not be in that bin or waste stream. It can range from left-over food in a take-out container, a non-recyclable plastic packaging (like styrofoam, unmarked plastics or soft plastics), to other garbage items like coat-hangers, clothing or propane tanks.

sustainably. I recognized that asking people to participate in an environmental action, such as waste sorting or water conservation, is one thing, but having them be capable to do so is another problem entirely, if the available materials, local policy and economics are acting against their agency. I became curious about ways to motivate people's participation in sustainable actions by enhancing their knowledge and willingness to act, examining the roles of attitudes, convenience and contextual factors.

Next sections of this Introduction further outline the research context within the environmental and sustainability goals, including effective waste management, followed by a brief theoretical background behind the studies, and dissertation research questions and goals.

## **1.1 Research Context**

### **1.1.1 Sustainability, Human Action and Waste Management**

The collective impact of human activities has caused adverse effects on Earth's ecosystems and created a myriad of environmental problems (Sathaye et al., 2007), at such unprecedented levels that we have ushered a new geologic period called the Anthropocene (Zalasiewicz et al., 2010). More than 80 percent of Earth's surface has been altered by human activity, two-thirds of major marine fisheries are overexploited or depleted, and a global biodiversity loss underway looms as the worst mass extinction since the dinosaurs (FAO, 2013; Folke et al., 2004). The unsustainable management of natural resources along with the changing climate is contributing to rising mean temperatures, destabilizing glacial ice-sheets, and threatening to weaken the North-Atlantic gulf stream, considered as the engine of the Ocean (Connor, 2015; Secretariat of the Convention on Biological Diversity, 2014). This increasing environmental degradation and modification of our

planet's biological and physical systems is having serious and profound implications for all life on Earth, including the ability of our species to thrive, with expected and unexpected threats to current and future populations (Estes et al., 2011; Lubchenco, 1998). It is becoming apparent that the current trajectory of the ecological devastation cannot be halted or reversed without action to radically transform systems of provision and human consumption, and bring it in line with what natural systems can regenerate and support (Amel et al., 2017).

Among the many environmental problems facing humankind, generation of consumer waste has reached unprecedented levels and requires direct attention (Geyer et al., 2017; UNEP, 2015).

Consumer and household waste has numerous deleterious effects on human health and ecosystems (Schlossberg, 2017): from landfill emissions contributing to global warming, water, soil and air pollution from incineration or leaching, to the growing environmental threats of plastics bioaccumulation (Humes, 2012; Tammemagi, 1999). Negative effects of plastic pollution are particularly problematic since plastic polymers do not biodegrade and essentially turn into smaller pieces that bioaccumulate in the environment and build up throughout the food chain (Jambeck et al., 2015). It is estimated that of 8.3 billion metric tons of plastic produced to date, only 9% has been recycled, 12% incinerated, leaving 79% accumulating in landfills and oceans (Geyer et al., 2017). Recycling rates in high income countries have been increasing over the decades (UNEP, 2015), with multi-stream bins becoming a common sight in cities and municipalities around Canada. However, the amount of residential waste has also been increasing. Residential waste in Canada has increased by 30% in the last decade, as each person throws out about 750 kilograms of waste on average every year (Statistics Canada, 2014). The overall recycling rate of household waste in Canada (e.g. mixed paper, plastics, glass, metal, and

organic matter) is currently estimated around 35% with some municipalities doing better than others (Dewis & Wesenbeeck, 2016; Statistics Canada, 2014). Canada's overall waste diversion is below the European average of 45% led by Germany, Austria, Wales and Switzerland at around 55 %<sup>3</sup> (Paben, 2017). The reasons for Germany's success in waste management are a mix of strong government policies regarding producer responsibility which mandates a closed cycle system of provision, collection, and treatment of waste, as well as citizens embracing recycling (Nelles et al., 2016). Currently many communities in the world and in Canada rely on front-end sorting of waste (i.e. by households and consumers), but the contamination of compost, paper and containers streams poses a drawback to the program's effectiveness and profitability (Thomas & Sharp, 2013; Varotto & Spagnolli, 2017). While the majority of household consumer waste (~70-90%) could be recycled or composted, most of it still ends up in landfills (Geyer et al., 2017; Hottle et al., 2015). Global Waste Management Outlook estimates that current global waste generation is around 3.3 million tons per day (UNEP, 2015), with this amount estimated to increase 70% by 2025, tripling by 2100 (Hoornweg et al., 2013).

### **1.1.2 Motivating Pro-Environmental Behaviour Change**

This thesis is methodologically rooted in environmental psychology to investigate how individuals and communities experience and respond to environmental conditions, and how to motivate them toward sustainable actions. Since people's actions are at the center of sustainability problems, it is crucial to study and understand the mechanisms that enable or constrain behavioural sustainability as people live their day to day lives. Tremendous progress

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<sup>3</sup> This recycling rate does not include waste to energy incineration.

has been made in the last few decades to better understand patterns of human behaviour and apply that knowledge toward motivating pro-environmental behaviour (Abrahamse & Steg, 2013; Amel et al., 2017; Gifford, 2011). Research in this arena has shown that human actions are determined by a large range of internal and external factors such as cognitive and affective factors, personal attitudes, social norms, habits, culture, materials and infrastructure, just to name a few (Gifford et al., 2011; Kahneman, 2011; Steg & Vlek, 2009; Weber & Johnson, 2012). This research has enlightened our understanding of human behaviour and given rise to new domains of research that applies behavioural principles from economics and psychology to motivate sustainable consumer behaviour and pro-environmental actions. Since human behavioural aspects are profoundly social and multidimensional, there are no quick fix interventions that can work for all types of sustainability problems due to the variability of factors (Jackson, 2005; Nolan et al., 2008; Shove, 2010). As we try to motivate individuals and communities into action we must remember that personal agency is often restricted by technical, economic or cultural factors, beyond one's control. As human behaviour and sustainability are extremely complex multi-layered phenomenon that cut across all disciplines and realms of life, it is practical to apply an interdisciplinary lens to study and try to solve such wicked<sup>4</sup> problems as each discipline brings unique insights (Rittel & Webber, 1973). Furthermore, pro-environmental behaviour needs to be studied within the context in which it is generated, which for this dissertation is Metro Vancouver and UBC campus.

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<sup>4</sup> Environmental problems are an example of 'wicked' problems which are difficult or impossible to solve for many reasons: incomplete or contradictory knowledge and opinions, large economic burden, and the interconnected nature of these problems with other problems. That said, wicked problems are very much worth working on!

While this thesis is primarily centered in literature from psychology, I also draw extensively from the socio-cultural and systems thinking literatures in my examination of pro-environmental behaviour. Experiments featured in this dissertation are grounded in practical context solving specific problems (such as inaccurate sorting or waste), but at the same time I examine how these behaviours come about and function as a sub-system of other systems. In other words, while individual and collective behaviour is at the center of my examination, it exists in larger system of multi-directional influences, that effect and reinforce behaviour over time, often in emergent and unpredictable ways with a force of their own (Meadows, 2002; Shove et al., 2012).

I set out with the main premise that most people do not set out to be unsustainable consumers, but are implicated in ecologically disruptive practices set up by powers out of their control, where their intentions to be sustainable clash with other lifestyle desires and goals (Steg & Vlek, 2009; Whitmarsh et al., 2013). Similarly, we often place expectations of people to “Do the right thing!”, think logically and exercise agency, when disciplines like behavioural economics have shown that this is simply not realistic for all people and all behaviours (Kahneman, 2011; Weber & Johnson, 2012). For example, most people likely do not want to emit tons of greenhouse gasses and melt away glacial ice sheets, but if their work requires frequent driving or flying, or they want to visit family and friends during holidays, they have little choice (other than abstaining from the action) to augment that aspect of their life which depends on the available technology and the energy that powers it. Likewise, people attend concerts and street festivals to have fun and enjoy entertainment, but when they buy foods and drinks at these venues they contribute to waste generation and contaminate recycling bins due to lack of knowledge, time, clarity of signage or other factors. As Herbert Simon pointed out: the complexity (and thus

unsustainability) of human behaviour is largely a reflection of the complexity (and unsustainability) of the environment in which humans live and act (Simon, 1996). Therefore, as we try to inform and engage individuals in pro-environmental actions, it seems pertinent to also examine the big picture of local contexts and social elements giving rise to and shaping human behaviour in powerful ways. At the heart of the matter is the idea that there are opportunities to intervene and design systems of provisions that support human desires for goods and services, while fulfilling long-term sustainability goals.

### **1.1.3 Cities and Communities as Agents of Change**

Half of the world's population lives in cities consuming 80% of all energy and releasing 70% of all global greenhouse gas emissions (Seto et al., 2012). The urban metabolism and the ecological footprint of cities extends many times beyond the area which they physically occupy (Rees, 2002). Cities will continue to have tremendous implications for global sustainability as 70% of global population is expected to live in cities by 2050 (United Nations Development Programme, 2018). Cities and communities, like school campuses, have an opportunity to lead the change toward more sustainable practices. With the goal of urban sustainability and managing the growth of solid waste output, many municipalities in Canada have begun to set up comprehensive recycling and composting policies to increase waste diversion away from landfills (Environment and Climate Change Canada, 2014). To this end, Vancouver's Greenest City 2020 Action Plan has established a waste diversion target of 80% by 2021, with a 50% reduction of solid waste going to incineration or landfill from 2008 levels (City of Vancouver, 2012).

Located in Vancouver, Canada, the University of British Columbia (UBC) is matching the municipal waste diversion goal of 80% by 2020, and investing heavily in zero-waste<sup>5</sup> infrastructure, research and communication on campus (UBC Communications & Marketing, 2017). These are some steps UBC and Metro Vancouver are undertaking to institutionalize sustainability through operations, infrastructure, education, and research with tangible targets and bylaws (i.e. no food allowed in garbage). In this way, cities, communities and campuses can build capacity to act as agents of change in sustainability through policies, bylaws, and infrastructural improvements to motivate action and the culture of sustainability over time.

#### **1.1.4 Waste Sorting Challenge: Participation and Contamination**

As mentioned, in many parts of the world effective waste diversion relies on public participation to correctly sort waste at home and in public using designated bins for paper, recyclable containers (metal, glass, and plastics), food scraps (organics) and garbage (Chung, 2018; Thomas & Sharp, 2013). Public engagement and knowledge of the sorting system is crucial to the recycling efforts, because they can dictate the frequency of participation, how difficult or important people perceive the behaviour to be, and their willingness to act (Best & Kneip, 2014; Schultz et al., 1995b). People may lack the know-how (knowledge and skills), past experience, materials (bins and signage), or have low personal values and attitudes, which affect both participation and bin contamination (Varotto & Spagnoli, 2017). While many approaches have been successful in increasing participation rates in recycling and composting (Best & Kneip,

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<sup>5</sup> Zero waste is defined as a process that emulates sustainable natural cycles so that all materials are designed to become a resource for others to use. Zero waste goals are nestled in the “cradle to cradle” design and manufacturing process, as described and popularized by McDonough and Braungart (McDonough & Braungart, 2002).

2014; DiGiacomo et al., 2017; Miller et al., 2016), more research is needed on effective strategies to help reduce contamination of waste streams in family households, multi-unit residential buildings, and outdoor venues like festivals and events. As mentioned, contextual factors like the availability of bins, convenience, and social norms may all motivate people to participate in recycling or composting, but they do not guarantee the accuracy of sorting actions (Wu et al., 2016). By focusing on strategies that reduce contamination in waste streams, this thesis aims to fill in a crucial research gap, given that accuracy of sorting is directly related to achieving zero waste targets.

Contamination in waste streams is a serious problem due to tremendous strain on local resources regarding costs, time and labour required to correctly re-sort items at a centralized sorting facility (Morawski, 2009). Often heavily contaminated collections require additional trucking to the landfill from sorting facilities, increasing GHG emissions and transportation costs of materials that could have instead been sold into manufacturing supply chains (Chung, 2018; Hershkowitz, 1998). In Canada, many cities are striving to lower their contamination rates, especially communities that collect their recyclable containers, glass and paper comingled together (Statistics Canada, 2014). Contamination damages other materials as it moves through the waste management system, turning tons of otherwise good recyclable materials into garbage to be processed and shipped to the landfill. Cities that collect their materials comingled, like Toronto and Edmonton, often have the biggest contamination rates (between 25-27%) which reduces the amount of valuable materials that can be sold, increasing the costs of running the program (Chung, 2018). It is estimated that each percentage point decrease in a city's contamination could lower recycling costs by \$600,000 to \$1 million a year (Chung, 2018). Metro Vancouver's

overall contamination rate is around 5% with specific streams for compost, paper, recyclable containers, and glass. At UBC<sup>6</sup> when bins are contaminated past the agreed threshold (~5-10% depending on the material stream), the entirety of the bin's contents can be sent to the landfill. As a result, incorrect sorting can cancel out the positive intent of participation, and yet public participation is crucial for the success of the program. Therefore, in addition to promoting public participation in waste diversion, we must also encourage and promote accuracy of the actions, lessening contamination. An intake of thousands of new students every year creates a spike in contamination throughout the UBC campus (Bud Fraser, UBC Senior Planning and Sustainability Engineer, personal communication, 2016). Considering the ecological and economic implications of contamination, correct waste sorting can have direct contribution to sustainability targets and financial benefits that extend back to communities.

The problem of participation and accuracy in recycling programs is often due to lack of knowledge and infrastructural conveniences, further exacerbated by the varied and numerous amount of packaging materials available in the marketplace. Audits have shown that people do not have trouble sorting pop cans or newspapers, finding these materials are accurately sorted around 88-96% of the time (UBC Communications and Marketing, 2014). Instead, people are struggling with mixed material items that have become more complex which has led to counter intuitive recycling assumptions. Contributing factors to contamination are the bin and signage discrepancies between Metro Vancouver regions. For example, paper bins on UBC campus are blue and container bins are grey, while Metro Vancouver's colour scheme is yellow for paper

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<sup>6</sup> UBC is technically not a part of Metro Vancouver as it is located on the University Endowment Lands.

and blue for container bins. In city parks, there are often no recycling or compost bins due to wildlife concerns, and it is common to come across garbage bins in a variety of colours: grey, black, green and blue. Considering these differences and the complexity of waste management, it is unsurprising that people make sorting errors. Furthermore, this complexity also makes behavioural research interventions in this topic difficult because they must parse through the noise, inform, and simplify sorting behaviour without further overloading people's mental capacities. Waste sorting is a two-part problem, both requiring participation in the program, as well as the ability to correctly sort and not contaminate waste streams. This is one of the main questions of this dissertation: how best to reduce contamination of the recycling and compost bins while working with peoples' limited interests, knowledge, and time to motivate and inform better sorting practices.

### **1.1.5 Education in Nature: Botanical Gardens and Sustainability Engagement**

While the first two research chapters (3 and 4) focus on the problems of waste sorting accuracy and contamination, Chapter 5 expands the analysis to examine willingness to act in other pro-environmental actions, including waste, water, food and biodiversity. Working with the UBC Botanical Garden and Society Promoting Environmental Conservation, I study and evaluate the effects of an adult program advertised as a team-building retreat, aiming to engage employees of local businesses and organizations in topics of sustainability. Promoting public engagement is central to reaching local and global sustainable development goals, however this remains a challenge for governments, organizations, and institutions alike (Gifford, 2011; Weber & Johnson, 2012; Whitmarsh et al., 2012). In a culture where environmental problems are at least partially caused by a growing disconnection from the natural world (Suzuki & McConnell,

2007), botanical gardens and nature-based groups are uniquely situated to provide a contribution to sustainability education while fulfilling their other goals. Most botanical gardens around the world already promote research, plant conservation, and public education through courses, tours, and events (Dodd & Jones, 2010). With the growing awareness of environmental threats, there has been a rise in interest toward education for sustainable development, with gardens around the world working to broaden audiences and diversify programs (Williams et al., 2015). With over 3300 botanical institutions and public gardens around the world receiving over 240 million visitors per year (Botanic Gardens Conservation International, 2018), there is a tremendous opportunity for these nature-based groups to re-connect communities with the natural world, illustrate the web of connections of ecosystem services, and motivate actions toward a more sustainable future. With this goal in mind, Chapter 5 evaluates strategies of collaborative community engagement and sustainability education, and its impact on participants' knowledge, environmental attitudes and willingness to act in 20 pro-environmental behaviours.

## **1.2 Research Questions**

Broadly stated, the purpose of this dissertation is to explore the theory and practice behind feedback and education strategies to engage individuals and communities in pro-environmental behaviours. Two research chapters are specifically focused on strategies that reduce contamination in consumer and household waste streams, while the third examines willingness to act in several sustainability domains, of which waste is one. Past studies on recycling and composting have often focused exclusively on participation and studied a single intervention, such as signs or behaviour modeling. My first study makes a contribution to literature by examining participation and contamination while testing multiple interventions which differ in

level of information and convenience provided, with theoretical and practical implications for effective design of future interventions. The second study builds on the premise that to correctly participate in waste diversion people need to know what goes where, but without feedback on errors people are likely to continue to contaminate bins and make errors. Since signs and posters are often insufficient, and volunteers and social modeling is not always available or practical, the second research question employs a digital sorting game to test the effectiveness of immediate feedback on sorting errors in the lab and under real-world conditions. Finally, the third research study expands the scope of pro-environmental action to examine the impact sustainability education tours can have on motivating general public's willingness to act. While each of the research chapters is focused on a specific research question, cumulatively they form a broader narrative about motivating pro-environmental behaviour.

1. How do visual prompts compare with active volunteer guidance regarding waste sorting participation (weight of materials) and accuracy (contamination) across different waste streams?
2. Can an interactive online sorting game, with immediate feedback on errors, improve sorting accuracy over time compared to standard recycling signage?
3. What is the impact of a sustainability education program held in a botanical garden on people's environmental knowledge, attitudes, and willingness to act?

The overarching inquiry that connect the research chapters is concerned with catalyzing human agency and capacity toward sustainability (i.e. motivating pro-environmental behaviour), by leveraging and presenting information and feedback in new and useful ways. At the same time, I

observe behaviour as a system intertwined within larger systems (such as infrastructure and policy) which can limit or enable individual agency, looking for opportunities to design sustainability pathways that make pro-environmental behaviour take place by default whenever possible. Insights from this dissertation will provide valuable practical and theoretical knowledge for future of sustainability engagement and research.

### **1.3 Description of Chapters**

Chapter 1 gives context on two key research areas of this thesis: issues regarding consumer waste management, and strategies to engage local communities through a nature-based sustainability education program and concludes with my research questions. Chapter 2 unpacks the theoretical underpinnings and literature which have informed studies in this dissertation. I focus primarily on the role and influence of information, education, social elements, and contextual factors in motivating pro-environmental behaviour.

Chapter 3 is the first study and examines effectiveness of passive visual prompts and active volunteer guidance on reduction of contamination in recycling and compost streams during a popular public event: UBC's Apple Festival. The problems of designing effective passive prompts and visual cues are brought to light, stemming from a mix of human, technical and economic factors. Complexity of take-out materials, the infrastructural ability to recycle and compost items, and environmental attitudes impact people's ability to make optimal sorting decisions. The study highlights the effectiveness of trained volunteers giving guidance to help festival-goers sort their waste more accurately, which helps significantly reduce contamination of bins.

Chapter 4 builds on the findings that people need help to sort more accurately, examining novel strategies to facilitate learning of recycling guidelines to reduce contamination of bins.

With a goal to move beyond flyers and posters, I help design a waste sorting game that provides immediate feedback on errors and test the effectiveness of the game in lab and real-world environments. The lab studies use motion tracking and compare sorting accuracy across the four waste streams (food scraps/ organics, containers, paper and garbage) with and without feedback of sorting errors. With positive learning effects in the lab, I deploy the game in one of the largest UBC student residences, and compare contamination levels to a building where residents did not play the game and instead relied only on signage posters in the recycling room. In addition to teaching UBC students better sorting habits, studies in this chapter also uncover and examine the most incorrectly sorted waste items on campus.

Chapter 5 expands the behavioural focus to examine the effectiveness of Field School (FS), a community-based education program, to engage employees of local businesses and organizations in topics of sustainability. More specifically I evaluate a corporate team-building program delivered out of UBC Botanical garden which delivers activities and curriculum focused on waste, food, water and biodiversity. I examine the impact of engaging sustainability education on participants' knowledge, attitudes, and willingness to act before and after their garden visit, comparing results to those of regular garden visitors who did not receive the FS program.

Chapter 6 concludes the dissertation by summarizing the key findings from each chapter, their significance, research limitations and future directions. Reflecting back to the research questions and the theoretical frameworks discussed, I provide an overall synthesis of the research results,

their implication for pro-environmental behaviour and effective public waste management, and explain theoretical and practical significance of my research.

## **Chapter 2: Theoretical Background**

Since people's actions are at the center of sustainability problems, it is crucial to study and understand the mechanisms that enable or constrain pro-environmental behaviour as people strive to achieve their daily needs. In recent years there has been a rise in interest in behaviour change approaches from community groups and policy makers, to help guide citizens into sustainable actions at home and in the public in order to address growing environmental problems (Dietz et al., 2009; Ehrenfeld, 2008; Weber, 2008). Research across various domains of behaviour change has demonstrated that there is no such thing as a simple solution to change given the varying environments, contexts and scales of the problem (Crompton & Thøgersen, 2009; Hjorth & Bagheri, 2006; Jackson, 2005). Instead, it is apparent that human action is determined by a large range of internal and external factors, such as cognition, emotion, environmental attitudes, social norms, past experiences and habits, cultural influences, economics and infrastructure, just to name a few (Kahneman, 2011; Steg & Vlek, 2009; Weber & Johnson, 2012). Most pro-environmental behaviours are dependent on additional factors like convenience and habit, and mediated by multiple values (i.e. social status, personal goals), and so people's environmental motivations and actions will vary across populations and geographic contexts (Jackson, 2005; Stern, 2000). Wide-ranging investigations on behaviour and change have spawned a seemingly endless number of models and frameworks stemming from all branches of knowledge, with disciplinary boundaries that define the problem, level and the unit of the analysis (Jackson, 2005). Due to the epistemologically incompatible differences across disciplines in problem definitions and context scope, it appears that a unifying synthesis is simply an impossible endeavor (Darnton, 2008). Some traditions, like psychology and sociology, can have quite contradictory approaches to behaviour and human action which lead to very

different research activities and proposals for interventions. At the same time, exploring approaches from different disciplines for common themes and points of connection can lead to a better understanding of the problems and lead to a design of strategies with powerful and lasting effects. With the focus on effective communication and education to communicate sorting errors and motivate communities towards a pro-environmental action, this thesis draws primarily from the environmental and social psychology literature. At the same time, since the individual needs, attitudes and decisions are in large part constructed by the complex external systems of policy, technologies, infrastructures and institutions, I have explored an array of literatures and benefited tremendously from the insights of social sciences and complex systems thinking. The next sections unpack and discuss common behaviour change frameworks and elements which have been applied in this dissertation's research, namely importance and influence of: i) knowledge and feedback, ii) social norms and attitudes, and iii) the contextual (i.e. material, infrastructural and environmental) factors.

## **2.1 Early Models of Behaviour Change: Emphasis on Rationality and Knowledge**

Among the many models of decision-making and behaviour change, the focus on knowledge, powers of reason and personal agency have been among the most dominant (Darnton, 2008). The early behaviour change theories were heavily influenced by the popularity and the reach of the classical economic theory based on instrumental rationality and expected utility theory (Armitage & Conner, 2001; McFadden, 1999). Following the individual agency and rational approach model, the early behaviour change models reasoned that human beings are logical, driven by utility maximization, and making use of information through objective deliberation (Ajzen & Fishbein, 1980; Becker, 1976; Friedman & Savage, 1948). Placing a strong emphasis

on individual agency, personal norms, and the power of information as instrumental drivers of behaviour, these approaches often dealt with behaviours like gambling, investing, and health, and were centered on the utility maximization (Armitage & Conner, 2001). Information and attitudes are common factors in many psychological models on behaviour. For example, theory of reasoned action (Fishbein & Ajzen, 1975) and theory of planned behaviour (Ajzen & Fishbein, 1980) are based on a deliberate calculation on the benefits and drawbacks on the consequence of actions, mediated by the available information, the subjective norms and the person's intent to act. Theory of planned behaviour also contains 'a perceived behavioural control' to account for additional constraints that may influence behaviour, such as does the person have the power to act. Theory of planned behaviour has become one of the most widely cited and applied models with an empirical formula and the ability to predict 20-30% of the variance in some behavioural outcomes via intention (Ajzen & Fishbein, 1980; Armitage & Conner, 2001). Success of the rational choice theories inspired linear models of behaviour change, which assume a straightforward progression from environmental knowledge to environmental awareness and action, and gave rise to "information-deficit models" of change, where the missing component for action is more information (Blake, 1999; Kollmuss & Agyeman, 2002; Owens, 2000).

The underlying assumption of information based strategies is that people can be knowledge-hungry and capable to act in line with their values and goals, but they might not know about a specific environmental problem, or what they can do about it, and so providing knowledge can increase awareness and concerns, encouraging individuals to change their behaviour (Schultz, 2002). The information-centered approaches can work in instances when information is indeed the only piece missing, however, the criticism is that such assumptions over-emphasize the

power of individual agency and rationality, especially when it comes to a myriad of pro-environmental actions, which are not all equal in difficulty or cost (Kollmuss & Agyeman, 2002). This in turn can over-simplify the behaviour change problem and paint a rather optimistic version of human agency, where the solution to the behavioural conundrum is to keep providing more information with the emphasis on individuals to “do their part” and help the environment (Blake, 1999; Kollmuss & Agyeman, 2002; Whitmarsh et al., 2010). This approach is problematic because knowledge is often not the only barrier to inaction, and while information is often necessary it is not easy to communicate and provide to desired audience when needed, and therefore simply providing information is not sufficient to change most people’s unsustainable behaviours (Owens, 2000). Due to popularity of the early rational choice models, and the relative low cost of implementation, the information provision strategies have become deeply entrenched in the institutions and structures of modern Western society, and this model of thinking dominates much of the intervention widely deployed today (Jackson, 2005).

## **2.2 Limitations of Cognition: Shortcuts, Biases and Convenience**

*“Human beings, viewed as behaving systems, are quite simple. The apparent complexity of our behaviour over time is largely a reflection of the complexity of the environment in which we find ourselves.” - Herbert A. Simon*

In contrast to the assumptions of the rational choice theory, behavioural economists have shown that people of all backgrounds and levels of education can make systematic errors of judgement, miss clear information or visual cues, and neglect to weigh the pros and cons of all possible outcomes before making decisions (Kahneman, 2011). In short, people have limited time and interests, and their mental capacities are susceptible to fatigue and lapses of judgement (Ariely, 2008). Over the years, the behavioural research has demonstrated that people’s attention and

cognitive capacities are a precious resource, and we cannot expect people to be the heroic decision makers and agents of change on all matters, including sustainability. Instead the behavioural research has shown that much of our behaviour is instinctive, habitual and follows a path of convenience, simplicity and social cues (Kahneman & Tversky, 2001; Weber & Johnson, 2012). This is just one of the reasons why installing more recycling flyers or posters will have a very limited effect on recycling participation or contamination, since people may not even see the poster, have the time or interest to read or memorize it, and they might have already pre-sorted their waste in the apartment and do not want to exert more energy to sort. This lack of attention may also help explain why many of my early pilots to reduce contamination in compost bins through stickers and similar visual prompts were not very effective.

Human decision-making (and thus behaviour) relies on the thinking and non-thinking elements. Importantly, it appears that the non-thinking elements operate most of the time, and are driven by habits, shortcuts, biases and emotions. They operate sub-consciously and help people navigate through the complex world (John et al., 2011; Kahneman & Tversky, 2001). Herbert Simon, coined the term ‘bounded rationality’ to explain that human beings have finite computational abilities and that the mind simply cannot absorb nor process all of the information in its environment (Simon, 1982). Dual process theory by Kahneman and colleagues added to the idea of bounded rationality showing that human minds operate through two distinct systems: System 1 being rapid, automatic and associative; and System 2 as analytic, reasonable, and slow (Kahneman, 2011; Sloman, 1996). It is difficult to discern the way in which the two systems interact, but the key insight comes through acknowledgement that System 1 is on most of the time operating on an intuitive level, looking for patterns and shortcuts to decisions. Since System

1 is primarily driven by intuition, relying on rapid, automatic, and associative thought patterns, this system of thinking is prone to biases, which might be flawed, and errors of judgement (Kahneman, 2011). Some of the shortcuts to the automatic behaviour can be driven by heuristics such as framing, priming, anchoring, loss aversion, cognitive dissonance, and status quo preference; these heuristics, while important in helping people navigate the complexity of their world, contribute to errors in judgement as they operate sub-consciously (John et al., 2011; Kahneman & Tversky, 2001). These biases and cognitive errors often have self-reinforcing feedback loops which make it more difficult to change existing behaviour (Darnton, 2008). For example, confirmation bias can cause someone who isn't in favor of recycling to search for and interpret information pertaining to recycling in a negative way so it confirms his or hers pre-existing beliefs and/or behaviour and lack of action. That said, the balancing or reinforcing feedback loop can also be useful if the message is geared toward the benefits of pro-environmental action for those who are already participating. Since intuitive automatic behaviour is borne out of past experiences it is possible to change it, but the behaviour needs to be targeted, not information which may fall on deaf ears.

In comparison to the more automatic response of the intuitive System 1, System 2 involves more effort, concentration, and energy, all of which are scarce and limited resources in today's busy and complex world. As a result, System 2 is not always "on" or capable of processing all the necessary information instantly or sufficiently. In a further demonstration of human cognitive limitations, insights from neuro-science show that the growth in information volume and complexity requires more adaptation and attention than ever before, yet, our modern brains are still very similar to our ancestors who lived thousands of years ago – wired to rely on emotions,

storytelling, shortcuts, and a primary concern for our most immediate needs and closest surroundings (Marshall, 2014). This kind of wiring makes complex environmental problems with long-term horizons and often invisible cumulative effects, difficult to bring into people's conscious awareness, let alone use it as a motivational cry for action. The problem of waste management falls into this category since it is something most people would rather not think about, and since it is taken away in such efficient manner, we never get to see the cumulative impact of our individual, let alone collective, daily waste generation and impacts.

Currently, the recycling and composting infrastructure is set up to rely on citizens' abilities to self-educate and sort correctly to facilitate better material recovery downstream at the recycling plant. However, most people are not sorting experts and generally want to dispose of their waste quickly; if they make some errors along the way it is generally considered 'good enough'. However, each of those individual errors adds up into thousands of contaminants at the facility, resulting in loss of time, revenue, and resources. The amount and diversity of take-out materials with ever-changing guidelines, and mixed messaging from multiple sources, makes citizen self-education extremely difficult, resulting in intuitive error-prone sorting. For example: coffee cups, milk and juice containers should go into the recyclable container bins because they have a plastic lining inside, but people focus on the exterior paper coating look and feel of these items and incorrectly put the recyclable cups into the paper or compost bins. Similarly, dirty paper plates, paper towels, and napkins should all go into the compost bin since they are not clean sheet paper and cannot be made into another newspaper or a magazine, but people often place them into the paper bins since they are clearly made of paper.

The lessons from the behavioural economics on limitations of individual thinking and rationality in decision-making paints a limited role of individual agency, and demonstrates the need to simplify and streamline thinking and behavioural processes if we wish for people's successful participation in sorting their recyclables. It also tells us it is possible to harness the intuitive habitual behaviour if we can kick-start people into action through convenience or other incentives. Looking across the disciplinary divides, these lessons fit well with social and environmental psychology, which also claims that most human actions are not consciously driven, but follow a path conditioned by the contextual environment and social norms (Cialdini, 1993; Nolan et al., 2008; Sussman & Gifford, 2011). In other words, when people see other like minded individuals or groups participate in pro-environmental actions, they are more likely to reciprocate.

In light of these insights, in order to work with people's limited interests, cognition, and preference for defaults and status quo, there has been a shift in policy to help 'nudge' individuals and communities towards making better choices (John et al., 2011; Thaler & Sunstein, 2008). Nudge or "Architecture of Choice" argues that people can be offered choices in such a way to help steer them toward desirable patterns of behaviour (John et al., 2009; Loewenstein et al., 2014). This is done not by eliminating choices but by shifting defaults and layout of choices, but utilizing different forms of framing and contextual augmentation to change the default outcome of people's decisions. This strategy has been found to be very effective in many social policy issues such as dealing with healthy eating, voting, organ donation, financial savings, as well as recycling (John et al., 2011; Thaler & Sunstein, 2008). Nudges work very well when there are simple places to intervene involving a default position. For example, in a school cafeteria

without changing the menu but simply shifting around the way the food was displayed (e.g. healthy food placed so it appears first), nudge influenced a healthier eating choice by up to 25% (John et al., 2009). Similar changes can be done with many environmental choices where defaults are wasteful or not necessary, such as changing the factory settings of household appliances (i.e, default setting for clothes washing in cold water), and providing convenient recycling bins with more consistency in layout, design, and associated messaging (Duffy & Verges, 2008). A recent study investigating convenience in high-density residential buildings showed that by moving recycling and compost bins closer to people's apartments (1.5m from the suite door) boosted participation rates by 141 per cent (DiGiacomo et al., 2017). Therefore convenience and design of contexts can greatly motivate action, and requires thinking ahead of time to design systems that will enable people's individual agency.

### **2.3 But Wait - Knowledge and Feedback Matter!**

Currently, much of the waste diversion procedures in Canada and abroad rely on public participation to correctly sort waste at home and in public. Therefore, knowledge is a crucial component of the recycling and composting behaviour as it affects contamination and the effectiveness of the collection program. Along with infrastructure, lack of information and knowledge is recognized as one of the main barriers to participation in the recycling schemes (UBC Communications and Marketing, 2014; Varotto & Spagnolli, 2017). Many studies have demonstrated that education and increase in knowledge can help influence actions, and that increases in knowledge correlate with some pro-environmental behaviours (Bamberg & Möser, 2007; Schwartz, 1992; Stern et al., 1999). For example, knowledge about recycling programs and sorting guidelines has been associated with increased recycling (De Young, 1989; Schultz et al.,

1995), and knowledge in the form of feedback, with social norm comparisons, has also been effective in reducing consumption (Allcott & Rogers, 2012; Nolan et al., 2008; Owens, 2000). Providing information can be especially effective if people are already motivated to participate and the lack of knowledge on how to do it correctly is the key barrier (Mckenzie-Mohr, 2000). The role of information as feedback has been especially useful in many behavioural studies on water, energy and waste, whether by providing individual comparison of performance over time (De Young, 1989; Schultz et al., 1995), or showing comparisons with their neighbours (Abrahamse & Steg, 2013; Cialdini, 2003). When feedback on individual performance is personalized, frequent and gives social comparison with others, the more effective the behavioural intervention (Thomas & Sharp, 2013; Varotto & Spagnolli, 2017).

Feedback strategies can also be combined with personal commitments or pledges, especially when aimed at specific goals or targets to achieve within a specific period of time (Lutzenhiser et al., 2009). Others have also pointed out how the power of information and feedback can be enhanced based on how the information is presented (i.e. clarity, visual appeal), who delivers the message (i.e. do they have trust-worthiness, expertise or high social standing) and what medium is used for delivery of message (i.e. a poster on a bus versus a viral meme / video). How information is delivered to its potential audience matters a great deal. Solely providing facts or general knowledge through posters and flyers is not likely to lead to behaviour change, especially when the contextual factors contribute to inhibition of action or a change in behaviour. As such, there are instances when it is necessary to communicate information and educate people using visually appealing and engaging methods, but there are also opportunities when nudging

and choice architecture are more suitable to change defaults so the sustainable actions can take place automatically.

## **2.4 Attitudes and Normative Influence of Other People**

Research in psychology and sociology has shown that attitudes and values<sup>7</sup> can influence behaviour in specific circumstances, and that many people who engage in pro-environmental behaviour typically have behaviour-supporting attitudes (Bamberg & Möser, 2007; Stern et al., 1999). Similarly, people who engage in pro-environmental actions have stronger altruistic (or self-transcendent) values (Stern et al., 1995). The influence of norms and peer pressure has been shown as a powerful motivator for pro-environmental behaviour, as people look for social proof when constructing personal norms (Allcott & Rogers, 2012; Lutzenhiser, 1993; Schultz et al., 2007). Social norms have a direct influence in personal attitudes and norms about environment and their role and responsibility to act, which can influence behaviour. Having more positive environmental attitudes, individually and collectively, can make members of the public more receptive to policy and innovation in sustainability (Tibbs, 2011).

The interplay between the social and individual norms and level of agency has been conceptualized differently by different theorists. For example, in moral norm-activation theory Schwartz presents personal norms as originating from social interactions but arising from an individual's innate values, and therefore 'anchored' in the self (Schwartz, 1992). Building on this approach, value belief norm theory, devised by Stern et al. (1999), postulates that pro-

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<sup>7</sup> Attitudes are often defined as positive or negative feeling about some person, object, or an issue. Values are the regard that something is held to deserve the importance, worth, or usefulness of something. Beliefs are closely related to attitudes and refer to the information/ knowledge a person has about a person, object, or issue.

environmental behaviour can be influenced by personal values (biospheric, altruistic or egoistic), beliefs (ecological worldview and understanding of adverse consequences), perceived ability to act, and personal norms with sense of obligation to act. Findings revealed evidence that each variable in the chain can affect variables down the line, with personal norms connected to the individual values and the moral norms (Stern, 2000). The triggers to behaviour or personal norms can be initiated by social influences, and an awareness of consequences and responsibilities. When drawn attention to the norm it is internalized by the individuals as of their own and appropriated within their internal values, beliefs or attitudes. Using the theory of planned behaviour, environmental attitudes can be a predictor of pro-environmental behaviour, if the constraints of the behaviour have been addressed, such as the difficulty and individual behavioural control (Kaiser et al., 1999).

Similar to the role of information, positive environmental attitudes alone are not enough to motivate specific actions, especially when the behaviour is difficult or costly (Darnton et al., 2011; Gifford, 2011; Kollmuss & Agyeman, 2002; Stern, 2000). Values and attitudes toward pro-environmental behaviour also have a weak correlation when the psychological constructs are more general in nature (Gifford et al., 2011; Jackson, 2005a). For example, people may support a recycling policy, but they may not (always) participate, or do so correctly, depending on difficulty of the task and the required effort. There is also evidence that positive environmental attitudes and values tend to be linked with low-impact behaviours, whereas high-impact behaviours are primarily explained by contextual factors and typically more difficult to change (Gifford, 2011; Stern et al., 1999). Similarly, environmental values may not be relevant in contexts where individuals lack perceived self-efficacy due to feelings of helplessness

(Whitmarsh, 2009; Whitmarsh & O'Neill, 2010), or if an action conflicts with other life goals or requires self-sacrifice (Steg & Vlek, 2009). Incidentally this is often the case for actions with the biggest environmental impact, such as flying or eating meat, which is why Stern et al. suggests that the more important a behaviour is in terms of its environmental impact, the less it depends on the attitudinal variables (Stern, 2000). The same sentiment can apply to information centered campaigns.

It is also important to note the plurality of values, meanings and motivations behind any particular behaviour: people may engage in pro-environmental behaviour (e.g. cycling to work or taking public transit), for reasons such as personal health or financial costs. While some actions might not be triggered by pro-environmental reasons, the environmental factors may come into play later, and act as an additional motivation that serves to reinforce the behaviour already being performed by the subject (Gatersleben et al., 2002; Sussman, 2015). Ajzen elaborated that in order to find a high correlation between attitudes and behaviour one has to measure the attitude toward a particular behaviour, and then add other predictors to the model since many behaviours contain automatic and habitual aspects not accounted for in earlier models (Ajzen, 2001). Other theories have also suggested that by engaging in the action and through positive experiences, behaviour supporting attitudes and knowledge form to further motivate the behaviour in a positive feedback loop (Bem, 1967; Sussman, 2015). This is another argument that pro-environmental campaigns would be wise to focus on generating the behaviour, while boosting people's knowledge and attitudes.

## **2.5 Contextual and Infrastructural Influence**

As has been suggested throughout, socio-technical and contextual factors are also powerful determinants of individual behaviour and must be considered when formulating long-term meaningful pro-environmental change (Gifford, 2011; Hargreaves, 2010; Jackson, 2005; Rabinovich et al., 2012). Research has shown that external conditions influence behaviour both directly by defining available choices and their relative attractiveness, as well as indirectly through attitude formation (Jackson, 2005; Kollmuss & Agyeman, 2002; Stern, 2000). By making it possible for people to engage in behaviour because it is easy, convenient, socially acceptable and personally rewarding can make preferences more attenuated and increase the likelihood of behaviour change taking place (Crompton, 2010; Lucas et al., 2008; Steg & Vlek, 2009). Any successful behaviour change intervention needs to consider the conditioning effects of contextual (social and physical) environments, and examine how its components shape and influence people's actions (Jackson, 2005; Whitmarsh et al., 2010).

The contextual components in any given situation will vary. They can be more immediate (e.g. the design/availability of recycling infrastructure in the building, or social norms present in the neighbourhood); but, they can also extend broadly throughout multiple geographic, political and economic settings. Design and functionality of recycling and composting infrastructure (e.g. bins inside the unit or in the recycling room), their availability, convenience, and appeal all matter because they help define contexts and enable habits that lead to sustained behaviour. For example, convenience of infrastructure cannot be overstated if the goal is to motivate behaviour. A recycling study showed that when garbage chutes are present in a building about 90% of the building's waste is sent to the landfill; however, when the recycling bins were provided in every

hallway, the diversion rate was increased to 68% (DiGiacomo et al., 2017). Similarly, placing recycling and composting bins closer to the suite doors increased the recycling and composting rates by 141% (DiGiacomo et al., 2017). Consistency in the order of sorting bins, signage, and even the lid openings have been proven to make a difference in amount of waste diverted (Duffy & Verges, 2008). Simply being situated in a more sustainable LEED designed building can influence people to participate more in waste diversion compared to a building that was not designed with sustainability in mind (Wu et al., 2016). In other words, building on the insights from cognitive studies, people can learn subconsciously and can quickly adapt to different contextual cues, if they are made salient.

A large component of the waste contamination problem (and the knowledge gap) is due to the complexity of the whole waste management system: the diverse number of takeout and household materials available in the marketplace, the infrastructural discrepancies, policy differences between communities, and the market factors that all shape the affordability and recyclability of various materials. There are collection, signage and infrastructure discrepancies regarding materials even within close communities, let alone across Canada coast to coast. For example, UBC does not allow pizza boxes or rigid compostable utensils in the compost bins as they don't break apart in their composting machine<sup>8</sup>, but Metro Vancouver does allow them since the materials are sent to an industrial composting facility. Paper bins on campus are blue and container bins are grey, while Metro's colour scheme is yellow for paper and blue for container bins. Similarly, cutlery and take-out containers that don't have a recycling number (or

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<sup>8</sup> UBC invested in their own composting machine in 2000. The in-vessel composting facility is located at UBC's South Campus and is capable of processing 5 tons of organic waste daily. The Building Operations are responsible for pick up, drop off and cleaning of all green organic bins on campus.

made of mixed plastics) appear recyclable but are not actually accepted in the local collection systems.

Given the lack of consistency and overall complexity required in what's expected of them, people resort to decision-making shortcuts when asked to sort their waste. Inevitably, people can make errors, resulting in the contamination of recycling and waste streams in all the bins. The overwhelming amount of information that people are inundated with, combined with the complexity of materials and infrastructure they face on a daily basis, creates a cognitive overload which causes a trade-off between the effort (doing things quickly) and judgmental accuracy (doing things right). As Simon (1996) rightly pointed out, this leads to people choosing “a satisfactory option”, instead of an option that is “the most optimal” (Simon, 1996). This evidence stands in stark contrast to the economic assumptions of a rational agent where humans are portrayed as rational utility-maximizing heroic decision-makers. When systems are complex and unclear, humans search for a ‘satisficing’ or ‘good enough’ solution, instead of an optimal one (Simon, 1996). Expanding on this notion further, some have proposed that instead of the *Homo-Economicus* of rational choice theories, people are more like *Homo Efficiens* or cognitively efficient managers of massive complexity (Levine et al., 2015). This effect can be observed during festivals or outdoor events when people attempt to sort their waste: they approach the bins, scan for a moment and then place all of their contents into one bin that mostly fits the description. While this may be considered completely normal and even ‘rational’ behaviour (because it saves time), it creates contamination in the waste streams and leads to cumulatively (expensive) problems. In other words, successful participation in the recycling programs depends on many elements coming together: from individuals and their cumulative actions, to municipal

and regional policies, available materials and technologies, and even to general economic factors that make certain processes and materials preferred and prevalent, and the whole enterprise feasible.

## **2.6 Socio-Cultural Approaches to Behaviour**

While this dissertation did not specifically incorporate socio-cultural theory in any experimental intervention, its philosophical spirit was present throughout the work in order to examine pro-environmental behaviour change from the socio-cultural and technical lens. As mentioned earlier in this chapter, there are significant epistemological differences between psychological and sociological approaches to behaviour and change. For example, the psychological approaches mainly focus on the individual behaviour, knowledge, attitudes, preferences, motivations and incentives. The cultural theories instead point toward the overarching culture, history and structures that enable the reproduction of the practice and their location of the social (Reckwitz, 2002; Shove et al., 2012). Instead of behaviour, their focus is on ‘practice’ which is best defined as a routinized type of behaviour which consists of several interconnected elements, that often include: i) bodily activities, ii) mental activities, iii) things and their use, iv) background knowledge and know-how, as well as v) motivation and emotion (Reckwitz, 2002). Founded on the works of Giddens and Bourdieu, the social practice theory has evolved as a response to the structure- agency dualism debate, incorporating both elements in the manifested practices (Gram-Hanssen, 2011). Giddens’ structuration theory points to the interconnectedness of daily routines with the larger structures of institutions that organize and generate behaviour, meanings, symbols and relationships (Reckwitz, 2002). Where the psychological lens places the unit of analysis on individuals doing the action, the social theorists suggest studying the practice-as-a-

whole (i.e. recycling, showering, car driving), with its material and cultural elements (i.e. objects, meanings and skills) and how they come together to form lives of their own (Shove, 2003a). While social psychology incorporates the interaction of psychological, social and contextual factors, socio-cultural approach focus on connections between and across different elements and practices, including the systems of technologies, routines, markets and social expectations that take hold over what is considered normal life (Shove, 2003a).

Despite the many theoretical and methodological differences between psychology and sociology, I believe there are points of connection that can be useful signposts for change strategies. The most obvious are the agreements on limitations of rationality and individual agency, and a recognition of unconscious layers of social organization (Reckwitz, 2002; Shove et al., 2012). Behavioural researchers have argued that people's lifestyles and life goals ultimately drive unsustainable behaviour and consumption (Jackson, 2005; Steg & Vlek, 2009). Similarly, social theorists like Shove claim that people's desire for services such as comfort, cleanliness and convenience are the primary reasons for the unsustainable practices (Shove & Pantzar, 2005). However, psychology and sociology disagree on research direction and activities. Psychologists may advocate for education, social interaction and choice architecture to help nudge individuals boost their agency and action. In contrast social practice advocates may use a range of methods such as historical data, interviews, and case studies to examine practices at different scales, how they nestle within and around each other, coming together or evolving. Both social practice theories and social-environmental psychology acknowledge the complexity of relationships, elements and inter-mingling of micro and macro levels, which strengthen or weaken action over time as more people are recruited into the practice. Going a step further however, akin to the

complex systems thinking, social practice theory embraces unpredictability, complexity, and emergent properties that cannot always be anticipated or controlled (Meadows, 2002; Shove & Pantzar, 2005). This approach is also consistent with living systems principles that highlight different scales of interaction, inter-dependent relationships, non-linearity of behaviour, feedback loops and emergent properties, just to name a few (Capra, 1996; Levin, 2005, 2014).

Socio-cultural analysis of behaviour is very critical of the extent to which individuals can be autonomous agents and exert change onto the system, especially given that our individual actions are often mediated by a powerful socio-technical interface (Jackson, 2005). For social practice theorists, the choices and attitudes of individuals are more often secondary to the socio-cultural factors, because human behaviour is fundamentally social and embodied within a context-dependent and co-creative environment, where individuals are seen as ‘carriers’ and reproducers of the practice (Reckwitz, 2002; Shove et al., 2012). With a long-term timescale, the focus is often on the history and evolution of ‘the behaviour’ over time, with observed practices, historically grounded and integrated systems of related institutions, and infrastructures (Hargreaves, 2011).

An interesting method of social practice theory is the use of three key elements (materials, meanings and competence) that can also be found in most pro-environmental behaviours, like recycling. These elements can also be represented as: i) infrastructure and materials (recycling bins, their availability and physical features, household materials and their properties), ii) knowledge and skills (knowledge of what goes into which bin and the embodied ‘performance’ of effective sorting based on previous experience), and iii) meanings (social norms, personal

attitudes, motivation to recycle). While the social practice examines these elements as interconnected and how they evolve over time (giving rise to the practices), in this dissertation I am using them as contextual markers that can help us think through the problem of waste sorting, by determining the available choices, social influences and infrastructure, which normalize behaviour over time and create routines. Through this interdisciplinary inclination I am not proposing a simplified integration of different behavioural and sociological approaches. Instead I look for synergies across disciplines pointing out of possibilities for mutually-beneficial collaborations in the future. The combined insights seem to point to the importance of thinking and non-thinking components to human behaviour (with unconscious part playing a large role), social influences (importance of others around us and what they are doing), technology and materials we do things with, environmental policies, and the meanings and motivations behind actions (consuming goods and services with or without environmental predispositions).

## **2.7 Synthesis and Research Direction**

Given the evidence showing that individual needs, attitudes and decisions are in large part constructed and determined by the complex external system of social norms, technologies, infrastructures and institutions (Cialdini, 2003; Jackson, 2005; Nolan et al., 2008), this thesis adopts the premise that people ought to be engaged in the sustainability endeavor as consumers and citizens, but they need help. Furthermore, since behaviour involves thinking and non-thinking elements we should study the micro elements (individual's cognitive and affective processes) as well as the macro elements (social, technical and contextual) which all influence the individual. While economic models of behaviour change emphasize the importance of individual agency, logic and rational utility maximization, work in behavioural economics and

other fields has demonstrated that many aspects of human behaviour are inconsistent with these rational actor assumptions (Kahneman, 2011; Kahneman & Tversky, 2001; McFadden, 1999).

This finding is consistent with the research in social psychology, which has shown powerful influence social norms (i.e. thoughts and actions of other people) and the contextual environment on shaping individual behaviour (Stern, 1999). Similarly, socio-cultural theories point to the overarching socio-technical regimes, history, and culture which provide the context for the unit of analysis. Therefore, while people are at the center of the behavioural challenge, so are the built and natural environments that make it easier or harder for sustainable behaviour to take place, or become a common and acceptable thing to do over time.

The next sections of this chapter unpack how these literatures have informed the behaviour change queries in this dissertation's research, and introduce the research chapters to come. The three research chapters investigate the following: i) impact of passive and active feedback on contamination during an outdoor festival, ii) teaching better sorting through a game with immediate feedback on errors, and iii) public sustainability education and engagement with activities in nature.

### **2.7.1 Design with Visual Prompts and Volunteer Assistance**

An under-served area of waste research involves strategies that help reduce contamination of recycling and compost streams in public domains. For example, public events and festivals can create a large amount of consumer waste, especially when food and drinks are sold (Hottle et al., 2015; Martinho et al., 2017). Contamination of bins and improper waste sorting during events is influenced by infrastructural components, such as availability and the layout of the bins, as well

as the behavioural factors, such as limited attention, knowledge and time to sort (Duffy & Verges, 2008; Schultz et al., 1995). The ever-changing diversity of take-out materials that range from disposable, recyclable, biodegradable and compostable, adds to the confusion and sorting errors, especially when people have limited interest and time to sort. It is also not uncommon that different vendors at the same event will provide an item, like coffee cups, where some are compostable and others recyclable. With these factors combined, contamination of recycling and compost bins at events can be so severe that all of the bin contents are sent to the landfill.

Previous research in the recycling domain has shown the importance of infrastructure augmentation and convenience (DiGiacomo et al., 2017; Duffy & Verges, 2008; Sussman et al., 2013; Wu et al., 2016), and the effectiveness of prompts and visual cues via signage or personal modelling of desired behaviour (Miller et al., 2014; Schultz et al., 1995; Sussman et al., 2013). Salience of signage, bin colours and the layout are especially important in drawing people's attention while reducing cognitive strain. While past studies have focused exclusively on increasing participation in waste sorting (i.e. putting stuff into recycling bins), there is a research need for strategies that helps to reduce contamination errors at the time of waste sorting. Similarly, past studies on contamination examined single interventions, such as signage, prompts or staff guidance, but knowledge on how the interventions compare to each other, and which one yields lowest contamination would be especially useful for event organizers.

With this goal in mind, the first research question in this thesis (Chapter 3) examines and compares the effectiveness of active instruction via trained volunteers with passive visual cues and prompts in 2D and 3D forms. Use of volunteers or trained staff has been successfully tested at Arizona State University sporting events (Hottle et al., 2015), and UBC's annual Welcome

Back BBQ (Preiss, 2015). However, comparing the active guidance with the stand-alone prompts has not yet been done. Working with UBC's Campus Sustainability office and Building Operations, I test newly designed bin tops (plastic inserts) made exclusively for waste management at events. They are placed inside the bins, and have standard signage stenciled which remains always visible, and removes the need to open and close lids, which can be an inconvenience when trying to sort across multiple bins. A bin top 3D intervention used the real-life items like cups and containers on top of the bin tops to give users more clarity about which items go into which bin. I hypothesized that volunteer staffed bins would perform the best and contain the least amount of contamination, since the problems of thinking and sorting would be minimized with volunteers giving clear direction to the users. I also hypothesized that the bin top 3D display would perform second best, followed by bin top alone, and control (standard bin carts only), because of the visual salience of real-life materials providing quick cues for common items like coffee cups and compostable containers. Campus pilot projects have shown some usefulness of 3D displays compared to 2D signage in reducing bin contamination in a food-court setting (Foster, 2016), but more empirical examination is lacking .

### **2.7.2 Designing with Immediate Feedback**

Lack of knowledge about sorting is often cited as a key barrier in people's sorting ability and accuracy (UBC Communications and Marketing, 2014; Varotto & Spagnolli, 2017). However, providing relevant feedback and useful guidance when need it, such as at the time of sorting, is one of the key challenges. People may not have the knowledge or the access to the sorting guidelines when disposing their waste, and their behaviours will vary depending on their environmental/ recycling attitudes, past experiences, and contextual environments (Gifford,

2011; Jackson, 2005; Schultz et al., 1995; Sussman et al., 2013). All of this makes a formulation of a single education strategy for all people and contexts difficult to implement. The most common approach is to provide information on sorting rules through signage, posters, and flyers. This approach is limited in several ways. First, even when the information is present it may be incomplete or difficult to comprehend. Second, waste disposal signage is rarely standardized even within the same jurisdiction (Andrews et al., 2013), which can lead to confusion and decrease user compliance (Ben-Bassat & Shinar, 2006). Third, with posters and signage the onus is always on the individuals to take the time, read and make sense of the guidelines, when, as discussed, people have limited interest and cognitive capacities to study and memorize the information. Additionally, trying to engage and educate people through signage in the recycling room just before they dispose of the waste may be too late, especially if people have pre-sorted or bagged the items in advance and now want to quickly drop them off and go. People in multi-unit buildings are rarely given any feedback about the accuracy of their sorting behaviour, and even if feedback is given, it is often delayed, and might only deal with one specific item, or give general historic or social comparisons (Duprè & Meineri, 2016; Schultz et al., 1995). Lack of timely feedback when people are keen to learn leads to persistent errors in recycling behaviour and beliefs about sorting. It becomes impossible to rectify if people don't even realize they are recycling and sorting incorrectly, or when we tackle contamination on item by item basis, instead of adopting a more systematic approach, such as by waste stream type.

The second research question of this thesis (addressed in Chapter 4), is focused on examining benefits of immediate feedback by providing correct answers to sorting errors through an online game, so that participants can learn and improve sorting accuracy compared to the control

condition that doesn't get feedback and only relies on standard signage. Teaching better sorting practices through a game can be an effective way to build knowledge, fill in the gaps in people's understanding of sorting rules, and correct recycling errors and biases. Decades of research in cognitive psychology show that feedback facilitates learning and improves task performance by correcting errors (e.g., Anderson et al., 1971; Butler et al., 2007; Kulhavy, 1977, Mory, 2004; Shute, 2008). Past studies have demonstrated that weekly (DeLeon & Fuqua, 1995), biweekly (De Young et al., 1995), or monthly feedback on the quantity of recyclable materials increases recycling rates and the quantity of recyclable materials (Goldenhar & Connell, 1991; Duprè & Meineri, 2016). However, these studies provided delayed feedback, where feedback was only given at least one week later. Immediate feedback at the time of sorting may be beneficial since it has been shown to enhance the retention of course materials (Dihoff et al., 2003), facilitate learning (Pashler et al., 2005), and promote efficient learning (Corbett & Anderson, 2001). In a collaborative effort to harness the power of ICTs and 'gamify' the sorting experience via a computer interface, a Master's student Yu Luo and I design an online sorting game with feedback on common recyclable and compostable materials. Given the effectiveness of immediate feedback on learning, an unexplored question is whether immediate feedback facilitates the acquisition of recycling and composting knowledge, and improves sorting accuracy by correcting recycling errors immediately. We test the game in the lab and in one of the largest student residences on campus, with a hypothesis that immediate feedback would correct sorting errors, and result in a reduction of contamination in the game building, compared to the building that only had standard recycling signage as a feedback instrument.

### **2.7.3 Design with Education in Nature**

The natural and built environment plays a large role in shaping behaviour. Many studies have demonstrated that exposure to nature has benefits on cognition, well-being, and sustainable behaviour (Barton & Pretty, 2010; Chawla, 2015; Nisbett & Ross, 2011; Pretty, 2004; Wells & Evans, 2003; Zelenski et al., 2015). Research has also shown that having a connection with nature is associated with environmental attitudes, concerns, and behaviours (Dunlap et al., 2000; Nisbet et al., 2009; Schultz et al., 2004), which are identified as one of several key factors in pro-environmental behaviour change (Geng et al., 2015; Stern et al., 1995). Previous research has also shown that personal values, attitudes, and beliefs can determine the motivation to express concerns about the environment and the adoption of behaviours that are in line with those values and attitudes (Crompton, 2010; Schultz et al., 1995). People who engage in pro-environmental behaviour typically have pro-environmental attitudes (Bamberg & Möser, 2007), and people with strong pro-social values or biospheric values (orientations in which people assess their own and others' actions considering costs or benefits to ecosystems or the biosphere) are more likely to engage in pro-environmental behaviour (Schultz et al., 2007; Stern et al., 1999). Exposure to nature also provides a range of other benefits, such as reducing fatigue and stress (Berg & Berg, 2007; Gidlöf-Gunnarsson & Öhrström, 2007), and enhancing memory and attention (Barton & Pretty, 2010; Berman et al., 2008; Kaplan, 1995; Kaplan & Kaplan, 2011; Mackay et al., 2014; Pretty, 2004; Wells, 2000; Wilson et al., 2009). Education research has shown that education in nature can have positive impacts on knowledge, environmental attitudes, and behaviour (Chawla, 2015; Morgan et al., 2009; Sellmann & Bogner, 2013). Psychologists, anthropologists, and ecologists have long maintained that human connection with nature (or lack thereof) is a large determinant of people's ecological worldview and behaviour (Bateson, 1979; Rees, 2002;

Walker et al., 2004). In a culture where environmental problems have been brought on by a growing disconnection from the natural world (Suzuki & McConnell, 2007), there is a growing understanding that we need more nature in everyday life. For these reasons, access to nature has been established as a critical component of a healthy, liveable, and thriving city (City of Vancouver, 2016; de Vries et al., 2003).

Building on this important work (Jackson, 2005; Schultz et al., 1995; Stern, 2000), Chapter 5 of this dissertation examines if sustainability education in nature with hands-on activities can influence people's knowledge, environmental attitudes, and willingness to engage in pro-environmental behaviour. As discussed in earlier sections, increases in knowledge are associated with pro-environmental actions (Hines et al., 1986; Schwartz, 1992; Stern et al., 1999), and trust in the source of information and poignant storytelling using relatable examples, along with engaging hands-on activities, can help engagement, comprehension, and retention of information (Mckenzie-Mohr, 2008). With over 3300 botanical institutions and public gardens around the world receiving over 300 million visitors per year (Dodd & Jones, 2010), there is an exciting opportunity for gardens to re-connect communities with the natural world and motivate individual action toward a more sustainable future. To this goal, Chapter 5 evaluates the impact of a nature-based education program on participants' sustainability knowledge, attitudes, and willingness to engage in 20 pro-environmental behaviours, including waste reduction. Working with the UBC Botanical Garden and the Society Promoting Environmental Conservation, I design and employ a survey instrument to compare the participants' pre-and-post visit responses, and compare them to regular garden visitors who did not receive the education tour. The hypothesis is that participants who attended the education tour would show better environmental

knowledge, higher environmental attitudes (i.e. connection with nature), and more willingness to engage in 20 sustainable actions compared to the control group which did not receive the education tour and activities.

## **Chapter 3: Toward Zero Waste Events: Reducing Contamination in Waste Streams with Volunteer Assistance**

### **3.1 Introduction**

The increasing volume of solid waste in landfills contributes to unprecedented levels of environmental problems, such as water and soil contamination via leaching of heavy metals, and air pollution via emission of greenhouse gases (Humes, 2012; Statistics Canada, 2013; Tammemagi, 1999). Given that the amount of global waste has increased ten-fold over the past century and is expected to double by 2025, it is urgent and imperative to divert waste from landfill in the form of recycling and composting which can help mitigate the negative impacts of waste and recover useful materials from landfills (Hershkowitz, 1998; Hoornweg et al., 2013). While recycling and composting bins are becoming more prevalent in cities and municipalities, most of the waste created in North America is still sent to landfill. For example in Canada, the overall diversion rate of household waste (e.g., mixed paper, plastics, glass, metal, and organic matter) is estimated to be around 33% (Dewis & Wesenbeeck, 2016; Statistics Canada, 2014), while the rate for the U.S. household is around 35% (Environmental Protection Agency, 2013). This rate is well below the European average, and the potential 75-90% diversion rate of household waste which could be recovered and recycled (Geyer et al., 2017).

Public festivals and events generate a tremendous amount of waste every year, especially when the events involve food and drink (Gibson and Wong, 2011; Laing and Frost, 2010). One study found that the largest amount of waste generated at a festival was residual waste, followed by food and kitchen waste and packaging waste (Martinho et al., 2018). While waste management is one of the priorities for an increasing number of event organizers, it is currently not well

understood how best to reduce waste at events (Laing and Frost, 2010). Waste reduction at events depends on a number of factors, including the host organization, the participating vendors, the materials used, and the participants of the events (Getz, 2009). Previous research has suggested that waste reduction at events depends strongly on the environmental values and beliefs of the managers and the host organizations of the events, who can act both as a champion and a steward of waste reduction (Mair and Laing, 2012). However, the reality often involves a disconnection between the intentions and the operations of the event managers (Henderson, 2007; Laing & Frost, 2010). This disconnection is largely driven by barriers such as the financial costs involved in recycling and composting, a lack of time, and a lack of control over venues or suppliers (Mair and Laing, 2012). One study suggests that the outsourcing of compostable biopolymer is often driven by organizational sustainability goals, while the ability to compost depends on local waste management legislation and available infrastructure (Meeks et al., 2015).

### **3.2 Motivating Waste Sorting**

Like many sustainability problems, the waste diversion challenge is located at the intersection of behavioural and infrastructural domains. Low waste diversion rates can be caused by a mix of common barriers such as: i) lack of infrastructure, including availability and design of sorting bins; ii) lack of environmental attitudes or social norms regarding recycling; iii) policy support such as composting bylaws and refunding deposits for cans and bottles; iv) lack of knowledge how to properly sort waste (Schultz et al., 1995; Thomas & Sharp, 2013). Recent studies have demonstrated that distance to bins, convenience and infrastructure design are crucial in motivating recycling participation (DiGiacomo et al., 2017; Duffy & Verges, 2008; Wu et al., 2016). However, contamination of bins is a critical component of waste diversion. When

materials are not properly sorted and the recycling bins get too contaminated (around 10% depending on the stream), all the contents are sent to the landfill, cancelling out the positive intent of participation. This is especially problematic for food waste as organic items carry extra emissions when sent to landfill where they release methane under anaerobic conditions (Statistics Canada, 2013). Therefore, as we motivate people to participate in waste diversion, we must also help enable proper sorting of materials, otherwise bins will get contaminated and sent to the landfill. Lack of knowledge or feedback about what goes into which bin is one of the key issues of the sorting challenge. This problem has most often been addressed by providing the missing information in written form through use of posters and signage (Duprè & Meineri, 2016; McKenzie-Mohr, 2000).

More recently, studies have attempted to reduce waste contamination and motivate waste diversion with additional visual prompts such as 3D displays (Foster, 2016) and modeling of the desired behaviour (Sussman et al., 2013). Another successful case study of waste management at events involved the use of volunteer staff who guarded the recycling and composting bins at sporting events at Arizona State University (Hottle et al., 2015). In this study, the authors examined the impact of volunteer staffed bins on contamination rates at University baseball games. The first game served as a baseline, the second game used staffed bins, and the third game had non-staffed bins. The authors found that contamination rates in both recycling and compost bins were reduced from 34% in the first game without the staff bins, to 11% on the second game with the staffed bins, and to 23% at the third game without the staff bins (Hottle et al., 2015). This study presented quantitative evidence that volunteer staff helped reduce waste contamination at public events.

### **3.3 Current Study**

An under-served area of research involves waste generation and contamination of bins at events and festivals, which can create a significant amount of trash. Contamination in the waste streams can be a serious issue because when organic or recycling bins are contaminated, all the materials in the entire bin will be dumped into the garbage bin (i.e., landfills) by custodial staff, unless they have a way to re-sort the waste after the fact. While previous studies have separately examined the impact of volunteer assistance (Hottle et al., 2015), signage, modelling and prompts (Duffy and Verges, 2008; Sussman et al., 2013), it is currently known which method is the most effective at reducing contamination, since each study examined one factor in a unique context. The goal of the current study was to examine and directly compare the impact of three different interventions on contamination in the same context, in order to identify the best practice for waste management at public events. Doing so can provide practical and theoretical evidence in support of identifying and implementing best practices of recycling and composting at festivals and events. Specifically, a randomized control trial was conducted to examine impact of volunteer staff assistance, bin tops displays, and sample 3D items with bin tops on the level of contamination at a public event regarding all four waste streams: organics, recyclable containers, paper, and garbage. The event was the annual Apple Festival hosted at the Botanical Garden of the University of British Columbia (UBC), which is attended by thousands of visitors every year. Like typical festivals, the Apple Festival features a large variety and quantity of different food and drinks for purchase, and as a result creates a large amount of organic, paper, and plastic waste. Working with the Campus Sustainability Office and UBC Building Operations, the goal was to test newly designed bin-tops that sit on top of the bin carts with and without real-life 3D items on top of the inserts, and comparing the effectiveness with the trained volunteer staff and a

control condition consisting of regular bin carts (see Figure 2). The interventions differ in the level of convenience they afford, and the effort required by participants to correctly sort, which has theoretical implications for pro-environmental research regarding convenience and effort people are able or willing to exert. The hypothesis was that the Volunteer Staffed bins would have the least contamination, since the problems of thinking and sorting would be minimized with volunteers giving direction what to do. I also hypothesized that the Bin Top 3D display would be a second-best condition, followed by Bin Top alone and the control. The reason I anticipated the Bin Top 3D display to do better than Bin Top alone is due to earlier research on campus indicating usefulness of 3D displays (Foster, 2016) as salient visual cues to help with information processing, rather than interpreting information from 2D signage alone.

### **3.4 Methodology**

#### **3.4.1 Participants**

Hosted at the UBC Botanical Garden, the annual Apple Festival is a popular family event that draws around 10,000 visitors over a weekend. The Apple Festival, in its 25th year features apple trees and apples for sale, apple tasting, with food trucks, live entertainment, and activities throughout the garden. With over 35,000 pounds of apples for sale featuring 60 local and heritage varieties, and other food and drink products for purchase, the event generates a large amount of waste, such as food, cardboard, coffee cups, and take-out containers. According to UBC sorting guidelines, food scraps, napkins, and compostable take-out containers should go to the organics bin; drinking containers (plastic, paper, or glass) and any cutlery should go to the recyclable containers bin; clean sheet paper should go to the paper bin; and styrofoam, unmarked and soft plastics should go to the garbage bin (i.e., landfills). As such, most of waste at UBC can

be diverted from landfills, going into compost and recyclable streams. The event took place from 11am to 5pm on a Saturday and from 11am to 4pm on a Sunday (October 17 to 18, 2015). While the festival takes place throughout the whole Botanical Garden (Figure 1), the intervention was focused at two main locations where food and beverages were sold: entrance to the garden (location A) and main festival lawn (location B).



Figure 1. Map of the Botanical Garden Apple Festival grounds, where Locations A (entrance to the garden) and B (festival lawn) tested the four experimental conditions.

### 3.4.2 Materials

There were four conditions in the experiment (Figure 2): i) Volunteer Staffed station, ii) Bin Top with 3D display (BT3D), iii) Bin Top (BT) alone, and iv) Control (just the carts). In the *Volunteer Staffed* condition, bins are set up like in the control condition but have trained volunteers beside them to help people their waste at the time of disposal. The volunteers verbally instructed people which item should go to which bin, sometimes holding the bins open, but

people had to sort the waste themselves. A total of 39 volunteers were recruited to serve in this experiment via Eventbrite. Each volunteer guarded one waste station during one shift which was between one to three hours long, and each volunteer received a training and orientation session one day before or on the day of the festival. The second intervention *Bin Top 3D Display (BT3D)*, used plastic inserts (bin tops) that go inside the bins, and include real physical examples of items that should go into each bin. The third condition was *Bin Top (BT)* display alone. Bin tops are plastic bin additions designed by UBC Campus Sustainability and Building Operations that slide into the carts so the bins remain always open and users don't have to handle the lids. Bin tops also have standard 2D signage imprinted on them which remains visible facing the users. The fourth and final condition was the *Control*, which is the standard bin set up of recycling carts as they usually appear for events. Waste services bring the recycling and composting Schaefer bins and they are placed next to a garbage bins. The main problem with stand-alone bin carts is the inconvenience of opening and closing the lids while sorting waste, which also affects visibility of the signage which is located on top of the lids. Once the lid is open users can no longer see the signage instructions and errors can take place. In busy or transient environments like events, people are often in a hurry to dispose of waste, and are more likely to take shortcuts to decision-making. It is not uncommon for people to simply follow the lead of sorters in front of them (for better or worse), and place all the waste into one bin that best fits the description of items they have in the hand. Therefore, the stand-alone bins can get contaminated quickly and continue to generate severe contamination of materials as users cope with incomplete information around them while trying to sort waste. In each condition, there were four bins representing four waste streams: organics (food scraps), recyclable containers, paper, and garbage. The organics, recyclable containers, and paper bins were Schaefer bins

(22×24×40 inches), and the garbage bin was a smaller round bin covered with a black garbage bag. The garbage bin did not have a lid, whereas other bins had lids. This was true in every condition in the experiment, so any difference between conditions could not be attributed to this factor.

Table 1. Number of bins in each condition in across each waste stream

	Organics	Recyclable Containers	Paper	Garbage
Volunteer staffed	10	5	4	5
BT3D	9	5	4	6
BT	3	3	3	3
Control	5	5	6	6
<b>Total</b>	27	18	17	20



Volunteer Staffed



Bin Tops + 3D Items



Bin Tops



Control (bins only)

Figure 2. An example of the experimental conditions used in location B of the festival. The location A was set up in the same way.

### 3.4.3 Procedure

The four conditions at location A (garden entrance) were set up the same way as four conditions at location B (main festival lawn). The four bins in each condition were placed next to each other, and the bins in each condition were at least 30 feet away from the bins in a different condition. The bins in the experiment were labeled by a masking tape on the side of the bin indicating which condition and location they were in. When the bin was full, a research assistant replaced it with an empty bin, and took the full bin to a holding area at the garden. At the end of each day, I gathered the research assistants at the holding area to weigh and inspect each bin. Each bin was first weighed by a digital DYMO® S250 shipping scale, and we recorded the net weight of the contents inside the bin in kilograms (kg), by subtracting the weight of an empty bin (12kg) from the total weight. After weighing each bin, we used gloves to dump all the items out of the bin, inspected all items, and counted the number of items that did not belong to the waste stream. When the contaminants were food or organic materials, we counted the number of contaminants as the number of compostable containers or individual food pieces, because most of the food contaminants were food scraps in compostable boxes or plates, such as a compostable chilli bowl with or without chilli leftovers in the box which would be counted as one contaminant. When there was an individual food item (such as an apple core, or pizza crust), we counted each item as one contaminant. Thus, for every bin we recorded contamination as the number of incorrect items in the bin, and the weight of the total materials inside the bin. Table 1 shows the total number of bins we measured in the experiment in each condition within each waste stream. The number of bins per waste stream per condition was unequal because of the different generation rates in the four waste streams. During the contamination count, the RAs and

myself put the contaminants into the appropriate bins, thereby un-contaminating the recycling and compost bins post hoc, and helping the festival achieve zero waste goals.

### **3.5 Results**

Since there were four conditions (volunteer staffed, BT3D, BT, and control) and four waste streams (organics, recyclable containers, paper, and garbage), a two-way between-subjects analysis of variance (ANOVA) was used to examine the effects of interventions on contamination and weight of the bins. Doing so allowed to examine whether there was a significant difference among the four conditions, the waste streams, and whether there was a significant interaction between conditions and waste streams. The average number of contaminants per bin is presented in Figure 3. The ANOVA analysis of the bin contamination showed there was a main effect of bin condition [ $F(3,66)=14.21, p<.001, \eta_p^2=.39$ ] but not of the waste stream type [ $F(3,66)=0.78, p=.50, \eta_p^2=.03$ ], and no significant interaction between bin type and waste stream [ $F(9,66)=1.38, p=.21, \eta_p^2=.15$ ]. This means that bin intervention set up had a significant effect on the amount of contamination, but the type of waste stream (organics, paper or container) did not. Lack of interaction between bin set up and waste stream shows that bin set up does not depend on waste stream type when predicting effect on contamination, and we can trust the main effect of bin set-up alone on the contamination. To examine which conditions were different, I conducted post-hoc Tukey's HSD tests, which showed a significant difference between volunteer staffed and BT conditions ( $p<.001$ ), volunteer staffed and BT3D conditions ( $p<.001$ ), and volunteer staffed and control conditions ( $p<.001$ ). These results demonstrate that the volunteer staffed condition had the lowest level of contamination among all conditions. Specifically, volunteer staff helped reduce contamination by 96.1% compared to other conditions

on average in the organics bin, 96.9% in the recyclable containers bin, 97.0% in the paper bin, and 84.9% in the garbage bin. Most of the contaminants were items that should have gone to other recycling or composting streams. For example, the key contaminants in the paper bin were used napkins and compostable containers (with and without food scraps) which should have gone to the organics bin. The key contaminants in the organics bin were coffee cups which should have gone to the recyclable containers bin. Biggest contaminants in the recyclable containers bin were compostable containers (with and without food) which should have gone to the organics bin. The key contaminants in the garbage bin were food scraps, compostable containers, and used napkins.

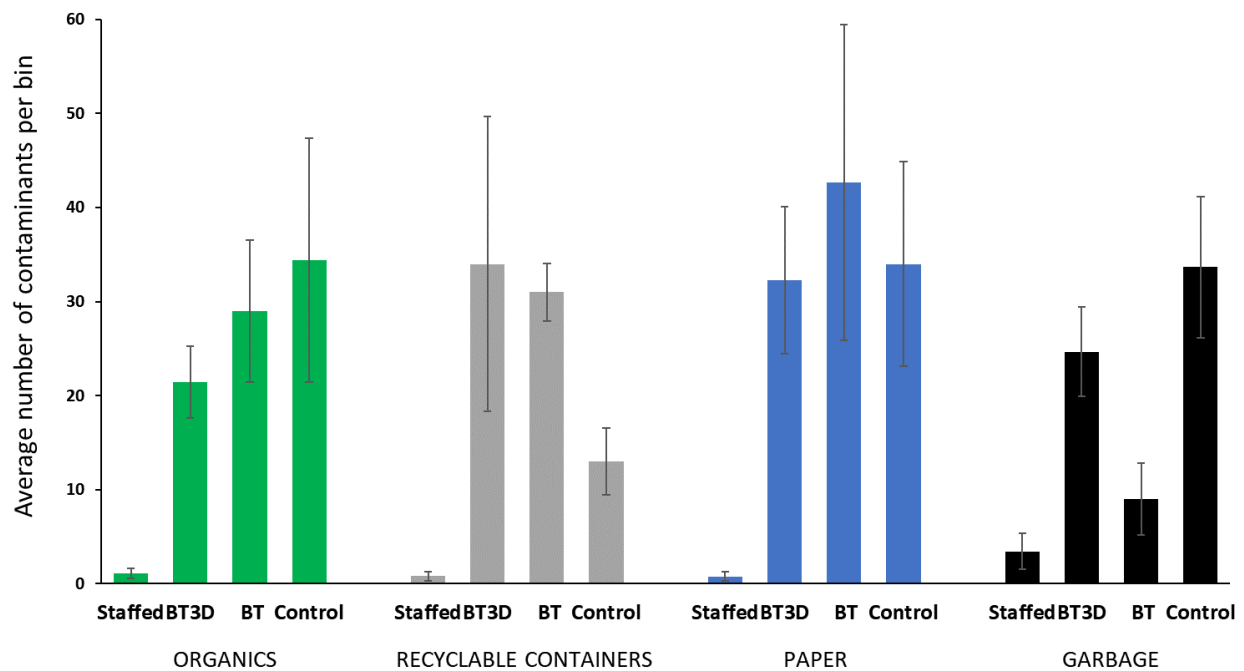


Figure 3. Average number of contaminants per bin per waste stream (organics, recyclable containers, paper and garbage) across interventions: Volunteer Staffed, Bin Top 3D Display, Bin Top, and Control. Error bars reflect  $\pm 1$  SEM

To examine the impact of the interventions on the volume of the materials, I also measured the total net weight (kg) of materials in each bin including contaminants (Figure 4). The ANOVA showed that there was no main effect of conditions [ $F(3,66)=0.42, p=.73, \eta_p^2=.01$ ], a main effect of waste streams [ $F(3,66)=5.84, p=.001, \eta_p^2=.20$ ], but no significant interaction between conditions and waste streams [ $F(9,66)=0.37, p=.94, \eta_p^2=.04$ ]. This shows that there was no significant difference in the weight of the materials in the bins between different conditions, suggesting that the interventions had no impact on the weight of materials. The total weight of waste generated at the Festival was 108kg of organics, 37kg of recyclable containers, 35kg of paper, and 51kg of garbage. Additional Tukey's HSD post-hoc test of bin weight (in kg) showed a significant difference between the organics and recycling containers ( $p=.004$ ), organics and paper ( $p=.008$ ), and organics and garbage ( $p=.04$ ). The results indicate that the compost bins were the most highly used waste stream at the festival. This is not too surprising as this was a food related event and compostable materials (such as food scraps and apple leftovers) weigh more than empty drink containers or paper products.

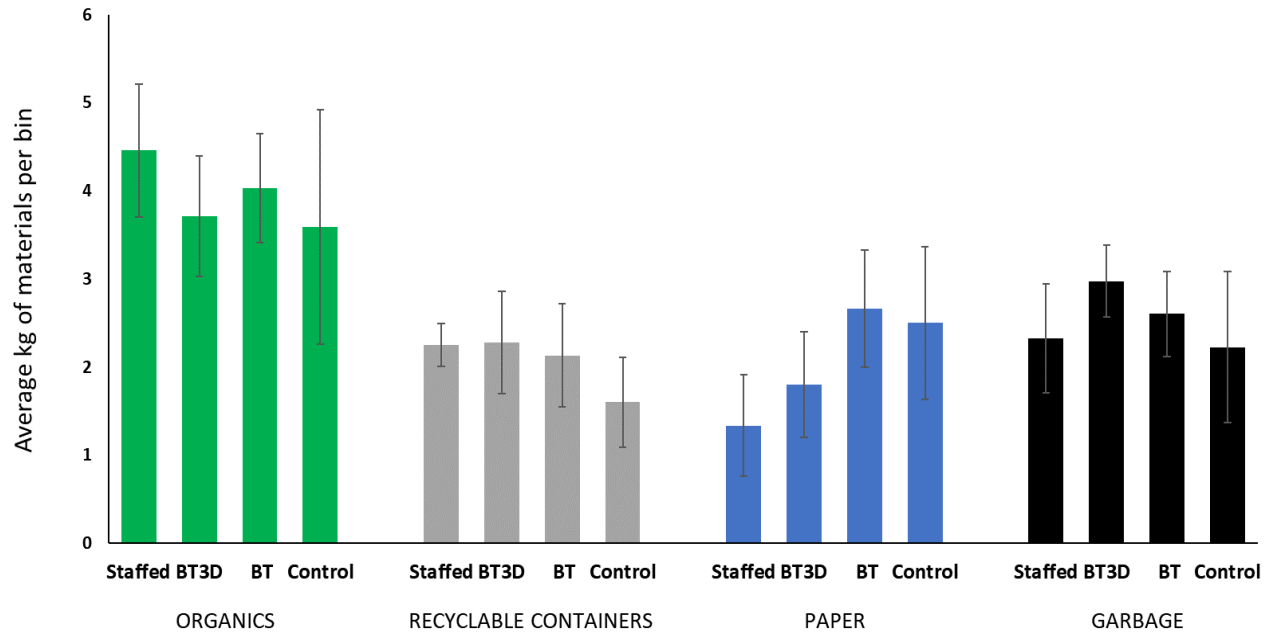


Figure 4. Average Kilogram of material per bin per waste stream (organics, recyclable containers, paper and garbage) across interventions: Volunteer Staffed, Bin Top 3D Display, Bin Top, and Control. Error bars reflect  $\pm 1$  SEM.

Since I had the weight of materials and the contamination count per bin, another analysis was conducted to calculate the number of contaminants per kilogram (Figure 5). The ANOVA showed a main effect of conditions [ $F(3,66)=9.47$ ,  $p<.001$ ,  $\eta_p^2=.30$ ], a main effect of waste streams [ $F(3,66)=3.63$ ,  $p=.01$ ,  $\eta_p^2=.35$ ], but no significant interaction between conditions and waste streams [ $F(9,66)=.94$ ,  $p=.49$ ,  $\eta_p^2=.12$ ]. Post-hoc Tukey's HSD tests showed a significant difference between volunteer staffed and BT3D conditions ( $p<.008$ ), and between volunteer staffed and control conditions ( $p<.001$ ), and close to marginal difference between volunteer staffed and BT conditions ( $p=.11$ ). These results confirm that the volunteer staffed condition had the lowest level of contamination among all conditions. Examining differences between streams, Tukey's HSD test showed a significant difference between paper and organics bins ( $p=.01$ ), and a marginal difference between recyclable containers and paper bins ( $p=.09$ ).

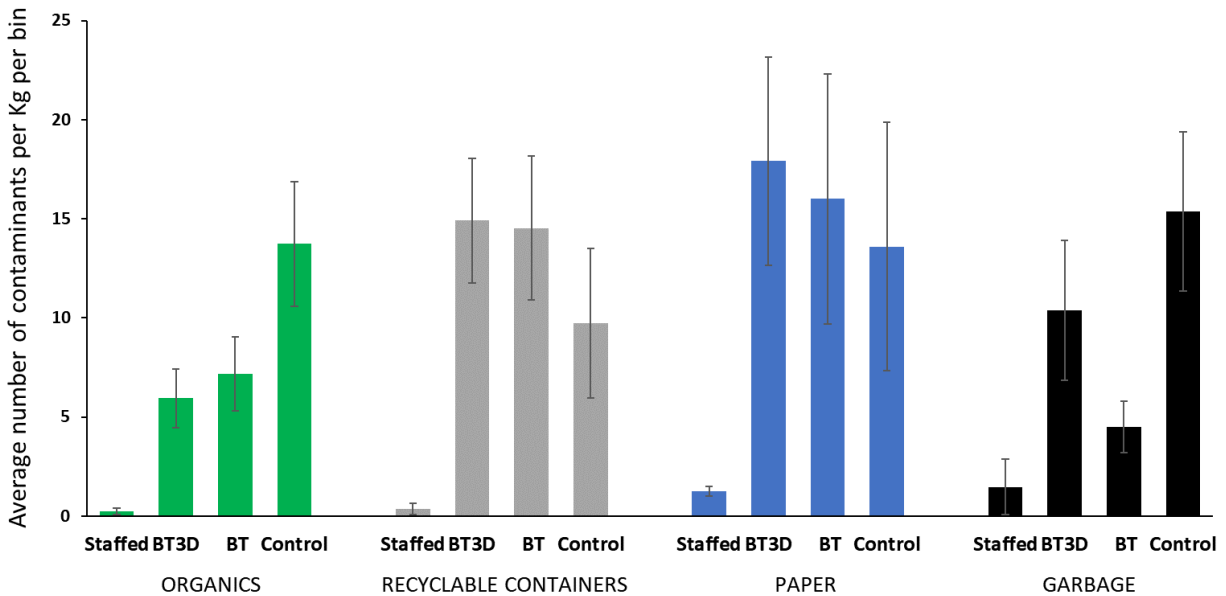


Figure 5. Average number of contaminants per kilogram per bin per waste stream (organics, recyclable containers, paper, and garbage) across the four conditions: volunteer staffed, bin tops with 3D displays (BT3D), bin tops only (BT), and control. Error bars reflect  $\pm 1$  SEM.

### 3.6 General Discussion

The goal of this first waste study was to examine the impact of three different interventions on contamination in waste streams at a public event, in order to identify the best practices for waste management at events. Specifically, a randomized control trial was conducted at the Apple Festival at UBC examining the impact of four conditions: volunteer staff assistance, bin tops, sample 3D items with bin tops, and a control (standard bin carts and signage on them). Myself and research assistants measured weight of bins and counted contamination in four waste streams: organics/ food scraps, recyclable containers, paper, and garbage bins. The results showed that volunteer staff significantly reduced contamination in all waste streams, compared to the other interventions. Since most waste management systems require front-end sorting which relies on individuals to sort waste at the bins, using volunteers offers a teaching

opportunity to give feedback to people on how to sort. According to the waste management practice on UBC campus, if an organic or recycling bin has more than 10 pieces of contaminants, all the materials in the entire bin will be dumped into garbage by custodial staff. By reducing contamination in the bin, volunteer staff can prevent the bin from going to the garbage stream, thus diverting waste from landfill and helping events reach zero waste goals.

Unlike the volunteer-staffed condition, there was no significant effect of the bin tops or the use of bin tops with 3D items on contamination. There are five explanations. First, the icons presented on the bin tops may not be sufficiently salient or clear to instruct people how to sort. Second, the icons presented on the bin tops were identical to the icons on the lids of the bins in the control condition, so there was no additional information presented in the bin top condition. The only difference was that with the top condition the bin lid remained always open, whereas people had to lift the lid to dispose waste in the control condition. The null effect implies that whether people had to lift the lid or not had no impact on sorting accuracy. Third, at the end of each day we found that people misused the bin tops with 3D displays, and put extra waste items on the bin tops, which suggests that they might have mistaken the 3D items on the bin tops as waste from other people. Fourth, the waste items at the Apple Festival were diverse and complex, and the visual signage on the bins was not comprehensive enough to guide sorting. Finally, there were inconsistencies in the sorting rules between UBC and Metro Vancouver, and since the attendees of the festival were people from Metro Vancouver, they may not know what UBC's sorting guideline is, and therefore still followed Metro Vancouver's guidelines. For example, pizza boxes and compostable rigid cutlery are accepted in the compost bins of Metro Vancouver, but these items need to go in the garbage bin at UBC campus because UBC

composts their own organic materials and the facility cannot process these items. This calls for a need to standardize the sorting guidelines and infrastructural capabilities across municipalities.

Examination of the contamination shows that paper bins were one of the most contaminated streams, with many guests incorrectly throwing “paper-like” products into the paper bins, when they should go into the compost or container streams. For example, napkins and coffee cups are technically made of paper so people instinctively put them into paper or compost bins. However, the signage on the bins (Appendix A.2) is clearly showing napkins go to compost, coffee cups to container bins, and only clean sheet paper allowed into paper bins. However, a mix of factors like general confusion, lack of interest or knowledge causes people to rely on their intuition and shortcuts to make decisions that are not optimal (Kahneman & Tversky, 2001; Simon, 1996). In addition to active guidance and better signage, another possible way to help minimize bin contamination is to remove a waste stream that is under-utilized, or has severe contamination. In the case of food-related events this may often be the paper stream bin. Unless an event will generate a significant amount of clean paper waste, paper bins may not be needed as they get easily contaminated with food-soiled paper products such as napkins, pizza plates and boxes, sandwich wrappers, compostable containers and coffee cups, which ideally go into other streams (compost, containers or garbage). This of course does not guarantee that contamination will be eliminated since a person who would have thrown a coffee cup into the paper bin may now incorrectly throw it into the compost bin (instead of containers), but removing one less category for people to ‘think’ with could nudge them closer to the correct stream. This hypothesis should be further tested empirically. Furthermore, since provision of recycling and compost bins can be

costly for event organizers, not including a waste stream that is not needed (such as paper bins at food and drink related events) could help reduce costs of waste management.

While the finding that volunteer staffed bins had the lowest amount of contamination is unsurprising, this study provides further empirical evidence that to effectively reduce contamination of recycling bins and ensure diversion of useful materials away from the landfill, the event organizers would be wise to have trained staff direct and help people participate correctly in the pro-environmental behaviour we want them to do. If it is not possible to arrange sorting assistance at front end (as people use bins), back-end sorting after the bins are full can be a viable alternative. That said, back end sorting may be messier and some items (like paper) might get too contaminated to recover. In addition, by opting out of front-end sorting guidance organizers also miss out on an engagement opportunity to interact with people, teach right sorting practices and signal social norms. A surprise finding from the data is how poorly the bin top 3D display performed compared to just signage. I had hypothesized that using real colourful items obtained from the festival vendors as examples on top of bins should have performed better than the 2D inanimate signs, since real items would draw attention as visual cues signalling exactly in which bin to put which item. However, there was no significant difference between the 2D and 3D interventions, and there was even a waste stream (containers) where the control performed better than 3D and 2D display in reduction of contamination. This shows limitations of passive communicative material to educate and guide more accurate sorting (and similar pro-environmental behaviour), which match the behavioural economics and other literature critical of information provision campaigns covered in Chapter 2.

Among many other obstacles, high costs of recycling bins can be an institutional barrier to running zero-waste events. Based on our conversation with the event organizer, there were significant costs in the provision of the organics and recycling bins. Specifically, each organics bin costs \$30 to order, a recyclable containers and paper bin is \$5 each, but each garbage bins are completely free. From Table 1, I calculated that the organics bins cost \$810, the recyclable containers bins cost \$90, the paper bins \$85, and the garbage bins cost \$0. The greater costs of the organics and recycling bins present a financial barrier for the event organizer aspiring to do the right thing and recycle and compost their waste. Thus, to increase waste diversion and zero waste endeavors, the cost structure of the bins should be reversed, such that the garbage bins should be the most expensive. At the same time, at UBC the maintenance and provision of organics bins includes transport to the on-site facility and their cleaning, which can help explain the high cost.

The current study had several limitations. First, while we placed the bins in the most populous locations at the garden, we could not control the foot traffic near each bin. There was variability in how often people used the bins throughout the day, and how convenient the bins were to access. This variability may have contributed to the large error bars. Second, I don't know the longevity of the effect because we did not track participants after they left the festival. Third, the null effects of bin tops or bin tops with 3D displays do not necessarily mean that signage does not work. This only highlights the need to develop more effective signage to guide sorting at events, or alternatively reduce the amount of materials available in the system so that the former task may be made easier. Finally, the current study did not find direct evidence that volunteer

staff increased waste diversion from landfill since the weight of the bins did not change. This raises limits of volunteer guidance on zero-waste goals.

### **3.7 Recommendations for Waste Management at Events and Festivals**

Results of this study showed that passive methods of education like 2D signage and 3D prompts were not as effective in reduction of contamination as having volunteer staffed stations give feedback on what goes where. Therefore, waste contamination during festivals or public events can be severe if not properly addressed and actively managed with help of volunteers. This study also demonstrates difficulty of devising clear and effective visual cues and prompts, and inefficiency of passive methods of education and feedback, given the diversity of take-out materials available in the marketplace and people's inability to parse through all the information quickly and effectively. People's attention and cognitive abilities are limited to make perfect decisions when environmental conditions are unclear or complex, which is often the case with waste sorting at events and festivals. Volunteers are already a key component of many events and festivals. Training them to provide active guidance can ensure useful recycling and composting materials are diverted away from the landfill, and while providing opportunities for education, interaction and social modelling of desired behaviour.

In addition to the behavioural components which depend on people's cognitive and affective ability and interests, another crucial component of the zero-waste endeavor are infrastructure and materials. While this study did not explicitly test material and infrastructural components, its influence was observed throughout the project. Infrastructure refers to type of bins available (recycling, composting and garbage) as well as their placement, such as being close to where

people need them (next to food trucks or seating areas), easily visible with clear signage and consistency in layout. After ensuring a proper recycling infrastructure is in place, food and drink materials should be examined to ensure all materials provided or sold to the public can be recycled or composted. Event organizers ought to work with vendors ahead of time to simplify and standardize take-out materials given out, and ensure they are acceptable in the local recycling or composting system. One way this process can be simplified is to communicate ahead of time what local systems can and cannot recycle and compost, and have all vendors follow the same guidelines as much as possible. One suggestion provided by the UBC Senior Planning and Sustainability Engineer, Bud Fraser, is that anything that touches foods should be compostable, and anything you drink from to be recyclable (Bud Fraser, personal communication, 2015).

- Recruit volunteers at events to help people sort and reduce contamination.
- Work with vendors ahead of time to ensure materials provided are standardized, consistent, and can be recycled or composted in local systems.
- Ensure sufficient numbers of composting and recycling bins at the event.
- Reduce financial barriers of composting and recycling by reducing the costs of bins.
- Communicate and promote the benefits of composting and recycling and/or the negative impacts of landfilling.

With foresight and inclusion of zero waste principles at the start of the event planning, the organizers can better control what type of waste is generated on site and ensure that most of it is diverted from landfills. Policymakers, food and beverage manufacturers, and recycling

companies need to continue to work together to implement a closed-loop waste management system where all take-out materials are recyclable and more intuitive for consumers, while making the infrastructure more affordable for organizers.

## **Chapter 4: Beyond Posters: Using a Digital Sorting Game Feedback to Improve Recycling and Composting Accuracy**

### **4.1 Introduction**

Among the many environmental problems facing humanity (Secretariat of the Convention on Biological Diversity, 2014), the volume of solid waste has reached alarming levels: the amount of waste has increased ten-fold over the past century around the globe, with the current amount expected to double by 2025 (Hoornweg et al., 2013). In Canada, residential waste has increased by 27% from 2002 to 2012, and on average each Canadian currently throws out about 700kg of waste every year (Statistics Canada, 2014). In the U.S., solid waste generation per capita has increased by 64% from 1960 to 2013, and on average each American currently throws out about 800kg of waste each year (Environmental Protection Agency, 2013). The dramatic increase of global solid waste is especially worrisome since dumping and burning of garbage contribute directly to water, air, and soil pollution (UNEP, 2015). Global plastics production has increased by four-fold over the past 50 years, and is expected to double again in the next 20 years (World Economic Forum, 2016), causing significant issues for marine and terrestrial ecosystems (Geyer et al., 2017). The accumulation of waste in landfills not only has deleterious effects on human health and ecosystems (Hossain et al., 2011; Schlossberg, 2017), but also contributes to global warming (Humes, 2013; Tammemagi, 1999). Specifically, organic waste accounts for 33% of landfill materials and releases methane during anaerobic decomposition, a gas that is 25 times more potent than carbon dioxide in terms of trapping the sun's heat and thus warming the atmosphere (Intergovernmental Panel on Climate Change, 2007; Statistics Canada, 2013).

Given the urgency of waste problems, many municipalities in the world have set up recycling and composting policies to increase waste diversion from landfills. For example, Vancouver's Greenest City Action Plan has set the waste diversion target to 80% by 2020, with a 50% reduction of solid waste going to incineration or landfill from 2008 levels (City of Vancouver, 2016). Even with stringent regulations in place and the prevalence of recycling and composting facilities in public and private spaces, the overall recycling in North America is about 35% which is quite low compared to European nations (Environmental Protection Agency, 2013; Statistics Canada, 2014). It is estimated that of the 8.3 billion metric tons of virgin plastic produced to date, only 9% has been recycled, 12% incinerated, and 79% accumulating in landfills and oceans (Geyer et al., 2017; Jambeck et al., 2015).

There are many reasons for the low recycling rate, including a lack of infrastructure (e.g., placing recycling and composting bins), policy backing (e.g., setting up bylaws discouraging food waste in garbage bins), poor environmental attitudes and social norms, or a lack of knowledge about what goes into which bin (Schultz et al., 1995; Thomas & Sharp, 2013). Recent studies in behavioural science have examined strategies to motivate recycling behaviour, demonstrating the effectiveness of infrastructure, design, and convenience (DiGiacomo et al., 2017; Duffy & Verges, 2008; Wu et al., 2016), personal environmental values and social norms (Cialdini 2003; Cialdini et al., 1990; Crociata et al., 2015; Schultz et al., 1995), as well as the role of information and feedback (De Young, 1989; Duprè & Meineri, 2016) in improving recycling and composting rates. While the past approaches have increased participation rates in recycling and composting, it is currently unclear what strategy is most effective at reducing contamination in the recycling streams. In other words, convenience or social norms may motivate people to throw items into

the recycling or composting bins, but these factors do not necessarily guarantee the *accuracy* of sorting actions (Wu et al., 2016). Contamination in waste streams is costly in terms of the time and labour required to correctly re-sort items at a centralized sorting facility or at the pick-up truck (Bohm et al., 2010). To inform people about how to sort, the traditional and the most common approach is to use signage, posters, and flyers to educate the users about the sorting rules. This approach is limited in several ways: First, waste disposal signage is often not standardized even within the same jurisdiction or institution (Andrews et al., 2013), which can lead to confusion and decrease user compliance (Ben-Bassat & Shinar, 2006); and second there is rarely feedback given to the users as they throw items into the bins, and even when feedback is given it is often delayed and vague, such that people may not remember what items were sorted incorrectly. These problems can result in persistent errors in recycling behaviour and beliefs about how to sort.

To overcome these problems, providing immediate feedback during sorting can be an effective way to build knowledge and fill in the gaps in people's understanding about sorting rules. Decades of research in cognitive psychology show that feedback facilitates learning and improves task performance by correcting errors (e.g., Anderson et al., 1971; Butler et al., 2007; Kulhavy, 1977, Mory, 2004; Shute, 2008). Past studies have demonstrated that weekly (DeLeon & Fuqua, 1995; Schulz, 2010), biweekly (De Young et al., 1995), or monthly feedback on the quantity of recyclable materials increases recycling rates and the quantity of recyclable materials (Goldenhar & Connell, 1991; Duprè & Meineri, 2016). However, these studies provided delayed feedback, where feedback was only given at least one week later. Immediate feedback may be more beneficial since it has been shown to enhance the retention of course materials (Dihoff et

al., 2003), facilitate word learning (Pashler et al., 2005), and promote efficient learning (Corbett & Anderson, 2001). Given the effectiveness of immediate feedback on learning, an unexplored question addressed in this study is whether immediate feedback facilitates the acquisition of recycling and composting knowledge, and improves sorting accuracy by correcting recycling errors immediately.

To incorporate immediate feedback in sorting behaviour, one approach is to ‘gamify’ the sorting experience via a computer interface. The proliferation of Information and Communication Technologies (ICTs) have a wide-ranging array of applications in the field of sustainable development, such as engaging communities in climate change scenarios (Robinson et al., 2011) or bridging the collaborative divide with a technological solutions library (Zelenika & Pearce, 2012). Similarly, the fun and engaging elements of games, have led to a rise in ‘gamification’ in sustainability development by adding game-like elements (e.g., scoring, rules, and competition) to various activities. For example, studies have shown that digital tools and gamification can be an effective way to engage people and stimulate learning, since games increase the player’s motivation and attention (Connolly et al., 2012; de Freitas, 2006; Mitchell & Savill-Smith, 2004). Game technology has been successfully used to positively impact students’ learning of mathematics (Shin et al., 2012), geography (Tüzün et al., 2009), sustainable consumption (Huber & Hilty, 2015), and energy related attitudes and behaviours (Knol & DeVries, 2011).

## **4.2 Current Study**

With a goal to develop an effective teaching tool to improve sorting accuracy and reduce contamination in recycling streams, the current study aims to examine the impact of a sorting

game with immediate feedback on recycling and composting decisions. Given the effectiveness of immediate feedback on learning, an unexplored question is whether immediate feedback facilitates the acquisition of recycling and composting knowledge and improves sorting accuracy by correcting recycling errors immediately. As such this study addresses the second research question of this dissertation with practical and theoretical implications. Working with the University of British Columbia (UBC) Campus Sustainability office, and a psychology Master's student (Yu Luo), I developed and tested a digital sorting game based on the UBC sorting guidelines. We first identified the most problematic items that cause confusion and contamination across the four waste streams (pilot study). Targeting these items in particular, we designed the sorting game where participants manually sorted items into four bins (food scraps, recyclable containers, paper, and garbage) via computer interface, and receive immediate feedback on their performance. Participants sorted the items in two ways: pressing a key on the keyboard to indicate to which bin the item belongs (Experiment 1), or manually dragging the item to the bin so their motion is tracked (Experiment 2). Feedback was given after each trial in one condition, but not in the control condition. After the lab tests I rolled out the game in student residences on campus in a field study, and examined whether the game influenced actual sorting behaviour under real world conditions (Experiment 3).

### **4.3 Pilot Study**

The goal of the game was to build knowledge and fill in the gaps in people's understanding about sorting rules. To understand the gaps, I first needed to know what are the problematic items and which sorting mistakes occurred most often. In this pilot, we tested people's existing knowledge about sorting without giving them feedback. Undergraduate students from UBC

campus were recruited to sort 80 common take-out and household items into four bins (food scraps, recyclable containers, paper, and garbage), and help us identify items with the lowest accuracy based on UBC sorting guidelines.

#### **4.3.1 Participants**

Fifty undergraduate students (30 female; mean age=20.1 years, SD=1.8) from UBC participated for a course credit. Participants in all experiments reported normal or corrected-to-normal vision and provided informed consent. All experiments reported were approved by the UBC Behavioural Research Ethics Board.

#### **4.3.2 Apparatus**

Participants in this pilot study and Experiment 1 were seated 50cm from a computer monitor (refresh rate=60Hz). Stimuli were presented using MATLAB (Mathworks) and Psychophysics Toolbox (<http://psychtoolbox.org>).

#### **4.3.3 Stimuli**

The stimuli consisted of 80 images of items, 20 in each of the four bins: food scraps (e.g., an apple core), recyclable container (e.g., a pop can), paper (e.g., A4 paper) and garbage (e.g., a plastic bag). The item images are listed in Appendix A.1. Each image (subtending 10.3° of visual angle) was presented at the lower center of the screen against a white background. Four bin signage posters (each subtending 10.7°) designed by the UBC Campus and Community Planning, represented the four waste streams found on the UBC campus (see Appendix A.2). The signage consisted of organics/ food scraps (R/G/B values: green=32/138/56), recyclable container (grey=101/101/101), paper (blue=32/86/147), and garbage (black=19/19/19). They

were presented from left to right on the top of the computer screen (see Fig. 6a). The order of the four bins followed the standardized bin positions at each waste station on UBC campus.

#### **4.3.4 Procedure**

The pilot study consisted of 80 trials. In each trial, one item appeared on the screen, and participants were instructed to sort the item into one of the four bins, as if they were to throw away the item at a waste station on campus. Participants sorted the item by pressing the “3”, “5”, “7”, or “9” key on the keyboard for food scraps, recyclable container, paper, or garbage bin, respectively. If they did not respond, the item remained on the screen until response. The inter-trial interval was 500ms. The order of the trials was randomized. There was no feedback given during the sorting task, and their total accuracy score was presented at the end of study. Each participant first received eight trials for practice before starting the sorting task, and received feedback for each practice trial. The items from the practice trials were excluded from the subsequent experiments or analyses. A debriefing session was conducted after the study to clarify the purpose of the study and to answer any questions the participants had about the study.

#### **4.3.5 Results**

Accuracy of each item was analyzed based on UBC composting and recycling guidelines. The full list of mean accuracy for each item in each bin is presented in Appendix A.1. Overall, the garbage bin had the lowest accuracy (53.7%), followed by the food scraps bin (72.1%), the recyclable containers bin (79.9%), and the paper bin (86.0%). The 10 items with the lowest accuracy in each bin were considered as the most problematic items. For example, in food scraps the most problematic items were napkins, paper towels and pizza boxes, for containers

aluminium trays, pringles tubes and aerosol cans, and in paper stream egg cartons, paper bags and rolls. In the garbage bin, participants criticized four items: styrofoam bowl, black plastic tray, muffin wraps and styrofoam tray as ambiguous and hard to recognize, so we chose to use the next four items with a low accuracy: straw, hanger, zip lock bag, and bubble wrap. The 40 items were selected as stimuli in the sorting game in subsequent experiments. These items were also verified by the UBC Campus Sustainability Office as common contaminants in the waste streams on campus.

#### **4.4 Experiment 1**

After the feedback on the most common contaminants, Experiment 1 aimed to examine how the immediate feedback on sorting accuracy after trial each influenced the sorting performance in the lab.

##### **4.4.1 Participants and Stimuli**

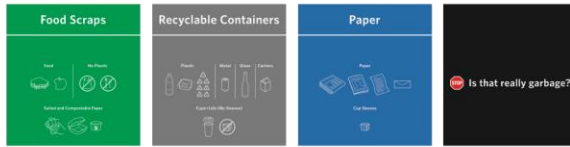
A new group of 100 undergraduate students (89 female, mean age=20.5 years, SD=2.9) from UBC participated in the experiment for course credit. From the pilot study, the 40 items with the lowest accuracy were used as stimuli, with ten item images in each bin. To test the effect of learning, we also created a second set of images of the same 40 items, but each item was represented by a different image. The two sets of images are listed in Appendix A.3 and A.4.

##### **4.4.2 Procedure**

There were two conditions in the experiment: a learning condition and a control condition with 50 participants in each. In the learning condition, participants completed two blocks of trials with 40 trials in each. In the first block, they sorted each item into one of the four bins, just as in pilot

study (Fig.6a), except now they received immediate feedback after each trial, which informed them whether they sorted the item into the correct bin (Fig.6b). The feedback appeared below the item after participants pressed a key to sort. For correct trials, the feedback was simply “Correct!” but for incorrect trials, the feedback informed the participant into which bin the item should be sorted (e.g., “Wrong! This should go to Food Scraps”). The feedback remained on the screen for 1 second before the next trial started. In the second block, participant performed the same sorting task, with a different set of images, but no feedback was provided this time in order to test whether participants had learned to sort better after the first block with feedback (Fig.6b). In the control condition, participants performed the same sorting task in the two blocks, except that they did not receive any feedback in the first or the second block (Fig.6c). Thus, the only difference between the two conditions was the presence or the absence of feedback in the first block. The inter-trial interval was 1 second, and there was a 2-minute break between the two blocks of trials. The order of two sets of images was counterbalanced over the two blocks across participants. The order of trials in each block was randomized. Participants received eight practice trials before starting the experiment, and a debriefing session was conducted after the experiment to answer any questions the participants had about the study.

### a) Sorting task



Task: press a key that corresponds to each bin to sort the item



### b) Learning condition

1<sup>st</sup> block (with feedback)



2<sup>nd</sup> block (without feedback)



### c) Control condition

1<sup>st</sup> block (without feedback)

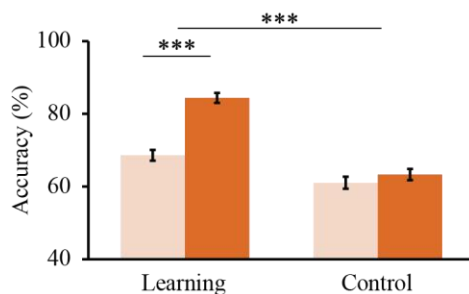


2<sup>nd</sup> block (without feedback)



### d) Overall sorting accuracy

lighter bar=1<sup>st</sup> block  
darker bar=2<sup>nd</sup> block



### e) Sensitivity analysis by bin

lighter bar=1<sup>st</sup> block  
darker bar=2<sup>nd</sup> block

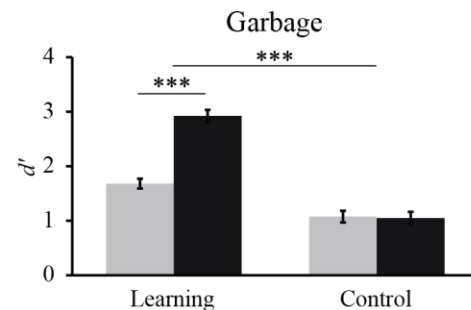
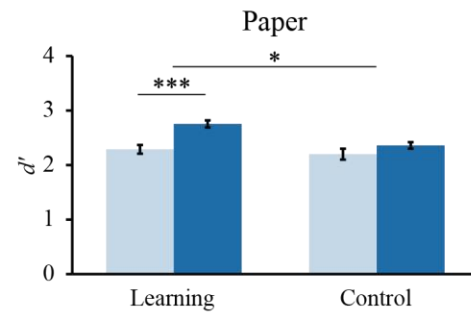
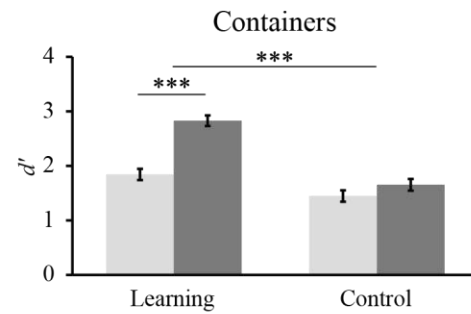
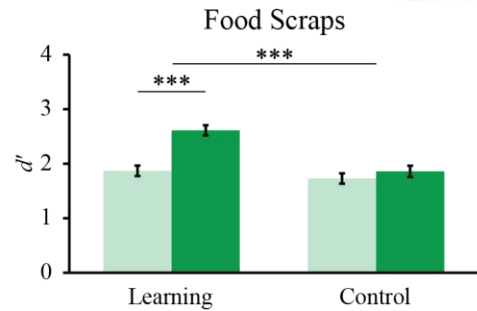


Figure 6. Experiment 1. (a) In each trial, participants sorted an item into one of four bins (food scraps, recyclable container, paper, or garbage) by pressing a key on the keyboard. (b) In the learning condition, participants received feedback after each trial in the first block, but not in the second block. (c) In the control condition, participants did not receive any feedback in either block. (d) The overall sorting accuracy. (e) The mean  $d'$  of each bin was analyzed using 2 (condition: learning vs. control; between-subjects)  $\times$  2 (block: first vs. second; within-subjects) mixed-effects ANOVA. (Error bars reflect  $\pm 1$  SEM; \* $p < .05$ ; \*\*\* $p < .001$ )

#### 4.4.3 Results and Discussion

The sorting accuracy was analyzed using a 2 (condition: learning vs. control; between-subjects)  $\times$  2 (block: first vs. second; within-subjects) mixed-effects ANOVA in each of the four bins (food scraps, recyclable containers, paper, and garbage). The sorting accuracy is presented in Figure 5d, and the ANOVA and Tukey's HSD post-hoc test results are shown in Table 2.

Table 2. ANOVA and Tukey's HSD tests on sorting accuracy in each bin. In the Tukey's HSD results, the number in the parenthesis is the mean accuracy in the block and in the condition (L=learning condition; C=control condition).

Bin	Effect	ANOVA results	Tukey's HSD post-hoc test results	<i>p</i>
Food Scraps	Condition	$F(1,98)=2.77, p=.099, \eta_p^2=.03$	1 <sup>st</sup> block L (78.2) vs. 1 <sup>st</sup> block C (77.3)	.98
	Block	$F(1,98)=18.46, p<.001, \eta_p^2=.16$	2 <sup>nd</sup> block L (89.4) vs. 2 <sup>nd</sup> block C (80.3)	<.001
	Interaction	$F(1,98)=6.34, p=.01, \eta_p^2=.06$	1 <sup>st</sup> block L (78.2) vs. 2 <sup>nd</sup> block L (89.4)	<.001
			1 <sup>st</sup> block C (77.3) vs. 2 <sup>nd</sup> block C (80.3)	.59
Recyclable Containers	Condition	$F(1,98)=62.84, p<.001, \eta_p^2=.39$	1 <sup>st</sup> block L (64.6) vs. 1 <sup>st</sup> block C (51.9)	<.001
	Block	$F(1,98)=80.90, p<.001, \eta_p^2=.45$	2 <sup>nd</sup> block L (85.6) vs. 2 <sup>nd</sup> block C (54.7)	<.001
	Interaction	$F(1,98)=47.52, p<.001, \eta_p^2=.33$	1 <sup>st</sup> block L (64.6) vs. 2 <sup>nd</sup> block L (85.6)	<.001
			1 <sup>st</sup> block C (51.9) vs. 2 <sup>nd</sup> block C (54.7)	.45
Paper	Condition	$F(1,98)=4.59, p=.03, \eta_p^2=.04$	1 <sup>st</sup> block L (74.1) vs. 1 <sup>st</sup> block C (72.2)	.73
	Block	$F(1,98)=20.54, p<.001, \eta_p^2=.17$	2 <sup>nd</sup> block L (83.0) vs. 2 <sup>nd</sup> block C (75.2)	<.001
	Interaction	$F(1,98)=4.98, p=.03, \eta_p^2=.05$	1 <sup>st</sup> block L (74.1) vs. 2 <sup>nd</sup> block L (83.0)	<.001
			1 <sup>st</sup> block C (72.2) vs. 2 <sup>nd</sup> block C (75.2)	.37
Garbage	Condition	$F(1,98)=29.3, p<.001, \eta_p^2=.23$	1 <sup>st</sup> block L (67.3) vs. 1 <sup>st</sup> block C (57.2)	.008
	Block	$F(1,98)=14.19, p<.001, \eta_p^2=.13$	2 <sup>nd</sup> block L (86.5) vs. 2 <sup>nd</sup> block C (54.5)	<.001
	Interaction	$F(1,98)=24.77, p<.001, \eta_p^2=.20$	1 <sup>st</sup> block L (67.3) vs. 2 <sup>nd</sup> block L (86.5)	<.001
			1 <sup>st</sup> block C (57.2) vs. 2 <sup>nd</sup> block C (54.5)	.83

As Table 2 shows, there was a significant main effect of condition, block, and a significant interaction between condition and block for all four bins, except that there was a marginal main effect of condition for the food scraps bin. This means that sorting accuracy was higher in the learning condition than in the control condition, higher in the second block than in the first block, and the difference between the learning and control conditions in the second block was greater than that in the first block (Fig.6d). Based the Tukey's HSD post-hoc tests, the sorting accuracy increased significantly from the first to the second block in learning condition for all bins

( $p$ 's<.001), but there was no difference in accuracy between the two blocks in the control condition for any bin ( $p$ 's>.36). Moreover, in the second block the accuracy was significantly higher in the learning condition than in the control condition for all bins ( $p$ 's<.001). Even in the first block, the accuracy was higher in the learning condition than in the control condition for the recyclable container bin and the garbage bin ( $p$ 's<.01), suggesting the feedback already improved sorting accuracy in the first block, since control condition never got any feedback. These results demonstrate that immediate feedback in the first block increased sorting accuracy even when feedback was no longer provided. This suggests that participants have learned to sort more accurately after receiving feedback in the first block. The reaction times (RTs) of only correct trials (the time between the presentation of the stimulus and the key press) were analyzed with a 2 (condition: learning vs. control; between-subjects)  $\times$  2 (block: first vs. second; within-subjects) mixed-effects ANOVA, with test results shown in Table 3.

Table 3. ANOVA and Tukey's HSD post-hoc test results on sorting response times in each bin. In the Tukey's HSD results, the number in the parenthesis is the mean response times (seconds) in the block and in the condition (L=learning condition; C=control condition).

Bin	Effect	ANOVA results	Tukey's HSD post-hoc test results	$p$
Food Scraps	Condition	$F(1,98)=2.00, p=.16, \eta_p^2=.20$	1 <sup>st</sup> block L (2.8) vs. 1 <sup>st</sup> block C (3.2)	.36
	Block	$F(1,98)=63.42, p<.001, \eta_p^2=.39$	2 <sup>nd</sup> block L (1.6) vs. 2 <sup>nd</sup> block C (1.8)	.67
	Interaction	$F(1,98)=0.13, p=.72, \eta_p^2=.001$	1 <sup>st</sup> block L (2.8) vs. 2 <sup>nd</sup> block L (1.6)	<.001
			1 <sup>st</sup> block C (3.2) vs. 2 <sup>nd</sup> block C (1.8)	<.001
Recyclable Containers	Condition	$F(1,97)=6.39, p=.08, \eta_p^2=.03$	1 <sup>st</sup> block L (2.9) vs. 1 <sup>st</sup> block C (3.3)	.18
	Block	$F(1,97)=61.56, p<.001, \eta_p^2=.39$	2 <sup>nd</sup> block L (1.9) vs. 2 <sup>nd</sup> block C (2.3)	.33
	Interaction	$F(1,97)=0.05, p=.82, \eta_p^2=.0006$	1 <sup>st</sup> block L (2.9) vs. 2 <sup>nd</sup> block L (1.9)	<.001
			1 <sup>st</sup> block C (3.3) vs. 2 <sup>nd</sup> block C (2.3)	<.001
Paper	Condition	$F(1,98)=0.25, p=.62, \eta_p^2=.003$	1 <sup>st</sup> block L (2.5) vs. 1 <sup>st</sup> block C (2.4)	.73
	Block	$F(1,98)=44.12, p<.001, \eta_p^2=.31$	2 <sup>nd</sup> block L (1.8) vs. 2 <sup>nd</sup> block C (1.8)	.99
	Interaction	$F(1,98)=0.26, p=.61, \eta_p^2=.003$	1 <sup>st</sup> block L (2.5) vs. 2 <sup>nd</sup> block L (1.8)	<.001
			1 <sup>st</sup> block C (2.4) vs. 2 <sup>nd</sup> block C (1.8)	<.001
Garbage	Condition	$F(1,91)=16.51, p<.001, \eta_p^2=.03$	1 <sup>st</sup> block L (2.5) vs. 1 <sup>st</sup> block C (3.9)	<.001
	Block	$F(1,91)=22.70, p<.001, \eta_p^2=.39$	2 <sup>nd</sup> block L (1.5) vs. 2 <sup>nd</sup> block C (2.7)	<.001
	Interaction	$F(1,91)=0.005, p=.94, \eta_p^2=.0006$	1 <sup>st</sup> block L (2.5) vs. 2 <sup>nd</sup> block L (1.5)	.004
			1 <sup>st</sup> block C (3.9) vs. 2 <sup>nd</sup> block C (2.7)	.008

From Table 3, there was a main effect of block (1<sup>st</sup> vs 2<sup>nd</sup>) in that sorting was faster in the second block than in the first block for all bins, possibly due to familiarity with the game after the first block. However, there was no main effect of condition (learning vs control), or interaction between condition and block for all bins. The only main effect of condition was found in the garbage bin, where sorting was faster in the learning condition than in the control condition. Tukey's HSD post-hoc tests showed that for all bins, sorting was faster in the second block than in the first block for both conditions ( $p$ 's<.01). There was no difference in RT between the learning and the control conditions for all bins, except for the garbage bin where sorting was faster in the learning condition than in the control condition ( $p$ 's<.001). These results suggest that feedback had minimal impact on the sorting speed, except for the garbage bin. Overall, the results suggest that feedback increased sorting accuracy even when feedback was no longer provided, but not sorting speed.

## **4.5 Experiment 2**

This experiment aimed to replicate Experiment 1 using a different sorting method. Specifically, we examined how the game influenced sorting performance using motion tracking technology. Under normal daily conditions, sorting items into bins is a manual task involving hand motions, we used motion tracking to better capture the daily sorting actions.

### **4.5.1 Participants**

A new group of 100 undergraduate students (74 female, mean age=20.5 years, SD=2.4) from UBC participated in the experiment for course credit.

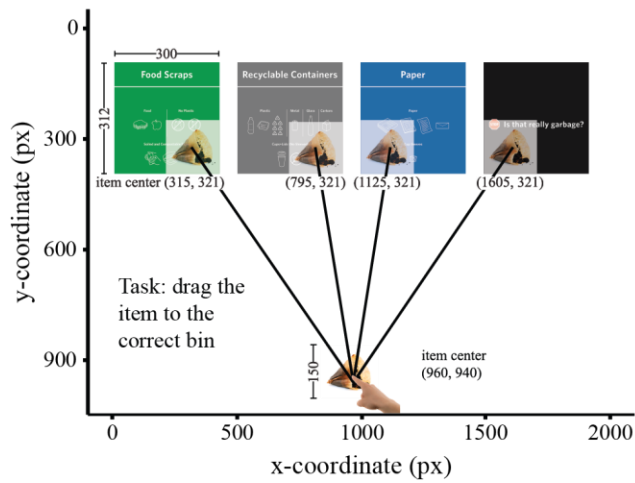
### **4.5.2 Apparatus**

Participants in this experiment were seated 50cm from a 21.5-inch touch screen monitor (refresh rate=60Hz, resolution: 1080×1920 pixels) in the lab. Stimuli were presented using MATLAB (Mathworks) and Psychophysics Toolbox (<http://psychtoolbox.org>).

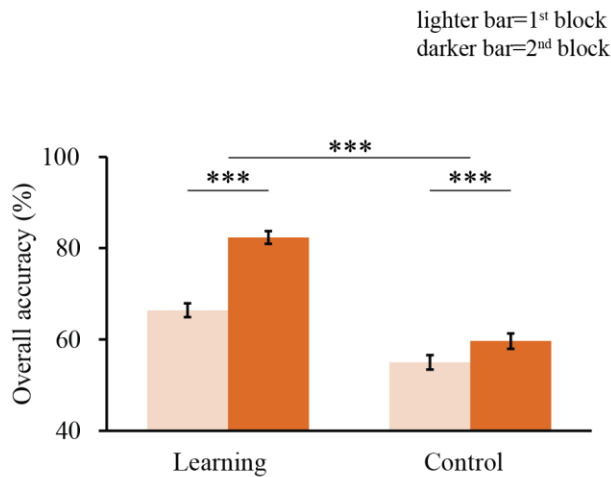
### **4.5.3 Stimuli and Procedure**

The stimuli and the procedure were identical to those in Experiment 1 (Figure 6a), except that participants sorted each item in each trial by dragging the item with their finger to one of the four bins on the touch screen monitor, rather than pressing a key on the keyboard. In each trial, the item remained on the screen for five seconds. If participants did not respond within the five seconds, the trial ended and the next trial started after an inter-trial interval of 500ms. In each trial, the item image appeared at the lower center of the screen, with the center of the image located at 960 on the x-coordinate and 940 on the y-coordinate on the screen. The size of each item image was 150×150px and the size of the bin signage was 300×312px. Participants were instructed to sort the item into one of the four bins by dragging the image with their finger on the screen (they could use the finger or hand of their preference). Participants were also told that the entire item image had to be within the bin image to complete the trial. The shortest trajectory was the straight line between the initial position of the item image and the corner of the bin image that fit the size of the item image (Fig.7a). For example, the shortest path to sort a food item was between the initial position of the center of the item (960, 940) to the bottom right corner of the food scraps bin image that could contain the item image, where the center of the corner was (315, 321). The location of the item image on the screen was tracked every 100ms during each trial so that the x and y coordinates were recorded to indicate the motion trajectory.

### a) Sorting task



### b) Overall sorting accuracy



### c) Sensitivity analysis by bin

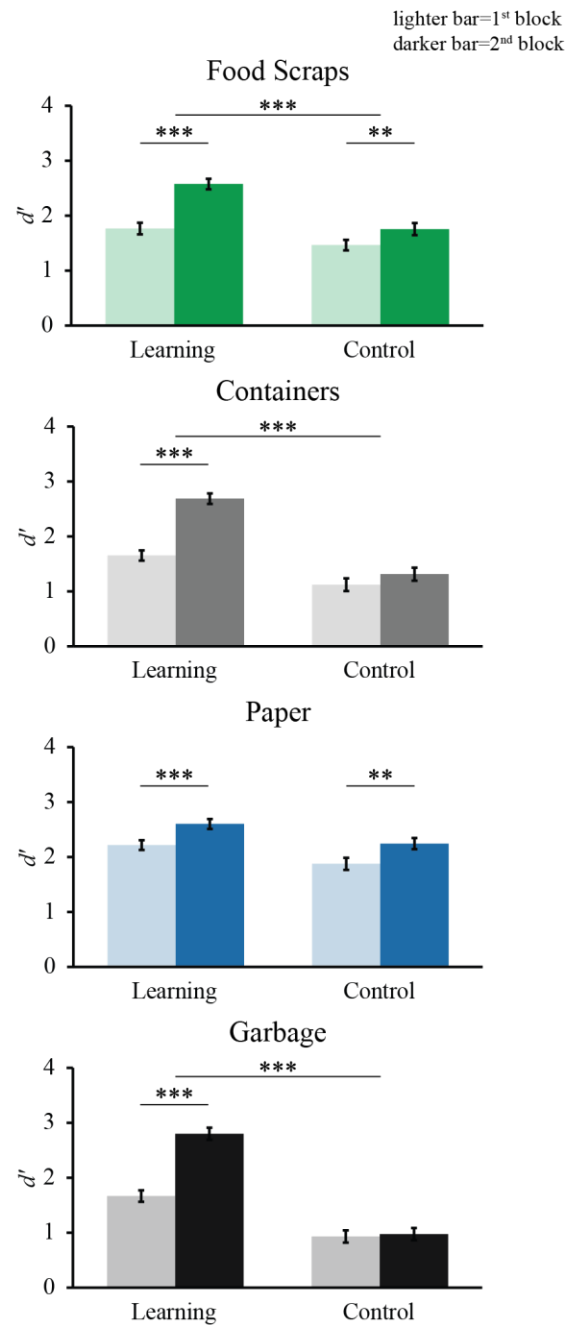


Figure 7. Experiment 2. (a) The game interface on the screen with x and y coordinates. In each trial, four bin signage (food scraps, recyclable containers, paper, and garbage) appeared on the top of the screen from left to right, and the item image appeared on the lower center on the screen. Participants were instructed to sort the item into one of the four bins by dragging the item to the bin on the screen using their finger. For a trial to complete, the item had to be fully contained within the bin. The black lines represent the shortest trajectory from the initial position of the item to each bin. (b) The overall sorting accuracy. (c) The sensitivity  $d'$  of each bin was analyzed using 2 (condition: learning vs. control; between-subjects)  $\times$  2 (block: first vs. second; within-subjects) mixed-effects ANOVA (Error bars reflect  $\pm 1$  SEM; \*\* $p < .01$ ; \*\*\* $p < .001$ ).

#### 4.5.4 Results and Discussion

As in Experiment 1, we first analyzed the sorting accuracy using a 2 (condition: learning vs. control; between-subjects)  $\times$  2 (block: first vs. second; within-subjects) mixed-effects ANOVA in each of the four bins (food scraps, recyclable containers, paper, and garbage). The sorting accuracy is presented in Figure 7, and the ANOVA and Tukey's HSD post-hoc test results are shown in Table 4.

Table 4. ANOVA and Tukey's HSD post-hoc test results on sorting accuracy in each bin. In the Tukey's HSD results, the number in the parenthesis is the mean accuracy in the block and in the condition (L=learning condition; C=control condition).

Bin	Effect	ANOVA results	Tukey's HSD post-hoc test results	<i>p</i>
Food Scraps	Condition	$F(1,98)=1.56, p=.21, \eta_p^2=.02$	1 <sup>st</sup> block L (73.9) vs. 1 <sup>st</sup> block C (74.3)	.99
	Block	$F(1,98)=17.46, p<.001, \eta_p^2=.15$	2 <sup>nd</sup> block L (89.2) vs. 2 <sup>nd</sup> block C (80.0)	.05
	Interaction	$F(1,98)=3.61, p=.06, \eta_p^2=.04$	1 <sup>st</sup> block L (73.9) vs. 2 <sup>nd</sup> block L (89.2)	<.001
			1 <sup>st</sup> block C (74.3) vs. 2 <sup>nd</sup> block C (80.0)	.38
Recyclable Containers	Condition	$F(1,98)=55.33, p<.001, \eta_p^2=.36$	1 <sup>st</sup> block L (59.9) vs. 1 <sup>st</sup> block C (46.6)	<.001
	Block	$F(1,98)=63.04, p<.001, \eta_p^2=.39$	2 <sup>nd</sup> block L (79.6) vs. 2 <sup>nd</sup> block C (50.1)	<.001
	Interaction	$F(1,98)=30.96, p<.001, \eta_p^2=.24$	1 <sup>st</sup> block L (59.9) vs. 2 <sup>nd</sup> block L (79.6)	<.001
			1 <sup>st</sup> block C (46.6) vs. 2 <sup>nd</sup> block C (50.1)	.34
Paper	Condition	$F(1,98)=5.40, p=.02, \eta_p^2=.05$	1 <sup>st</sup> block L (72.0) vs. 1 <sup>st</sup> block C (66.4)	.05
	Block	$F(1,98)=37.30, p<.001, \eta_p^2=.28$	2 <sup>nd</sup> block L (81.4) vs. 2 <sup>nd</sup> block C (75.9)	.07
	Interaction	$F(1,98)=0.003, p=.96, \eta_p^2=.00$	1 <sup>st</sup> block L (72.0) vs. 2 <sup>nd</sup> block L (81.4)	<.001
			1 <sup>st</sup> block C (66.4) vs. 2 <sup>nd</sup> block C (75.9)	<.001
Garbage	Condition	$F(1,98)=50.37, p<.001, \eta_p^2=.34$	1 <sup>st</sup> block L (68.6) vs. 1 <sup>st</sup> block C (47.9)	<.001
	Block	$F(1,98)=43.84, p<.001, \eta_p^2=.31$	2 <sup>nd</sup> block L (87.6) vs. 2 <sup>nd</sup> block C (51.7)	<.001
	Interaction	$F(1,98)=19.59, p<.001, \eta_p^2=.17$	1 <sup>st</sup> block L (68.6) vs. 2 <sup>nd</sup> block L (87.6)	<.001
			1 <sup>st</sup> block C (47.9) vs. 2 <sup>nd</sup> block C (51.7)	.41

As Table 4 shows, there was a main effect of condition for all bins except for food scraps ( $p's < .05$ ), a main effect of block for all bins ( $p's < .001$ ), an interaction for the recyclable containers and garbage bins ( $p's < .001$ ), and a marginal interaction for the food scraps bin ( $p=.06$ ), but not for the paper bin ( $p=.96$ ). Tukey's HSD post-hoc tests showed that for the food scraps bin, sorting accuracy was marginally higher in the learning condition than in the control condition in the second block ( $p=.05$ ), and accuracy was significantly higher in the second block

than in the first in the learning condition ( $p < .001$ ), but there was no difference in the control condition ( $p = .38$ ). For the recyclable containers and garbage bins, all pair-wise comparisons were significant, except for the difference between the two blocks in the control condition ( $p$ 's  $> .33$ ). For the paper bin, sorting accuracy was marginally higher in the learning than the control condition for block 1 ( $p = .05$ ) and block 2 ( $p = .07$ ), and significantly higher in the second block than in the first block for both conditions ( $p$ 's  $< .001$ ). These results largely replicated those in Experiment 1, suggesting that feedback in the learning condition improved sorting accuracy for all four bins, except that the effect was weaker for the paper bin. The motion trajectory of all correct trials and incorrect trials in all bins are plotted in Figure 7b. Each dot on the graph is a data point (sampled every 100ms) during participants' sorting movement. The green dots indicate correct trials and the red dots indicate incorrect trials. Visually, there are more green dots and fewer red dots in the second block than in the first block in the learning condition, or in any block in the control condition, suggesting an improvement in sorting after receiving the feedback in the first block in the learning condition.

To measure the change in motion, trajectory data were analyzed for each participant in each trial based on the deviation (in pixels) of their movement from the shortest path which was the distance between the initial position of the item and the closest corner of the bin that could fit the entire item image. For each bin, the absolute quadratic coefficient of the correct trials was computed to represent the absolute deviation from the shortest path, since quadratic curvature metric has been shown to be an effective way to represent the deviation of curved trajectories.

The absolute deviation of movement for each bin was then analyzed with a 2 (condition: learning vs. control; between-subjects)  $\times$  2 (block: first vs. second; within-subjects) mixed-effects ANOVA. The results are shown in Table 5. There was no main effect of condition, block, or interaction for any bin, suggesting that providing instant feedback in the first block does not optimize sorting motion, but only improves sorting accuracy.

Table 5. ANOVA and Tukey's HSD post-hoc test results on absolute motion deviation in each bin. In the Tukey's HSD results, the number in the parenthesis is the mean deviation (pixels) in the block and in the condition (L=learning condition; C=control condition).

Bin	Effect	ANOVA results	Tukey's HSD post-hoc test results	<i>p</i>
Food Scraps	Condition	$F(1,94)=0.005, p=.94, \eta_p^2<.001$	1 <sup>st</sup> block L (48.3) vs. 1 <sup>st</sup> block C (47.2)	.99
	Block	$F(1,94)=3.73, p=.06, \eta_p^2=.04$	2 <sup>nd</sup> block L (37.6) vs. 2 <sup>nd</sup> block C (37.8)	.99
	Interaction	$F(1,94)=0.01, p=.91, \eta_p^2<.001$	1 <sup>st</sup> block L (48.3) vs. 2 <sup>nd</sup> block L (37.6)	.48
			1 <sup>st</sup> block C (47.2) vs. 2 <sup>nd</sup> block C (37.8)	.57
Recyclable Containers	Condition	$F(1,97)=0.24, p=.63, \eta_p^2=.002$	1 <sup>st</sup> block L (37.0) vs. 1 <sup>st</sup> block C (42.3)	.98
	Block	$F(1,97)=0.03, p=.87, \eta_p^2<.001$	2 <sup>nd</sup> block L (38.5) vs. 2 <sup>nd</sup> block C (43.9)	.98
	Interaction	$F(1,97)=0.00, p=1, \eta_p^2=.00$	1 <sup>st</sup> block L (37.0) vs. 2 <sup>nd</sup> block L (38.5)	.99
			1 <sup>st</sup> block C (42.3) vs. 2 <sup>nd</sup> block C (43.9)	.99
Paper	Condition	$F(1,98)=0.08, p=.78, \eta_p^2<.001$	1 <sup>st</sup> block L (28.4) vs. 1 <sup>st</sup> block C (32.8)	.90
	Block	$F(1,98)=1.16, p=.28, \eta_p^2=.01$	2 <sup>nd</sup> block L (26.6) vs. 2 <sup>nd</sup> block C (25.1)	.99
	Interaction	$F(1,98)=0.45, p=.50, \eta_p^2=.005$	1 <sup>st</sup> block L (28.4) vs. 2 <sup>nd</sup> block L (26.6)	.99
			1 <sup>st</sup> block C (32.8) vs. 2 <sup>nd</sup> block C (25.1)	.61
Garbage	Condition	$F(1,93)=0.64, p=.43, \eta_p^2=.007$	1 <sup>st</sup> block L (43.2) vs. 1 <sup>st</sup> block C (65.5)	.76
	Block	$F(1,93)<0.01, p=.97, \eta_p^2<.001$	2 <sup>nd</sup> block L (51.4) vs. 2 <sup>nd</sup> block C (54.9)	.99
	Interaction	$F(1,93)=0.35, p=.56, \eta_p^2=.004$	1 <sup>st</sup> block L (43.2) vs. 2 <sup>nd</sup> block L (51.4)	.98
			1 <sup>st</sup> block C (65.5) vs. 2 <sup>nd</sup> block C (54.9)	.97

Finally, we examined the response times of correct trials using the same 2-way mixed-effects ANOVA. As Table 6 shows, there was a main effect of block in that sorting was faster in the second block than in the first block for all bins, possibly due to familiarity with the game itself. There was no main effect of condition, or interaction between condition and block for all bins, except that there was a main effect of condition for the garbage bin, where sorting was faster in the learning condition than in the control condition. Additionally, Tukey's HSD post-hoc tests showed that for all bins, sorting was faster in the second block compared to the first block for

both conditions ( $p$ 's<.001). There was no difference in RT between the learning and the control conditions for all bins, except for the garbage bin where sorting was faster in the learning condition than in the control condition ( $p$ 's<.05). These results are highly consistent with those in Experiment 1, suggesting that the immediate feedback had minimal impact on the sorting speed, except for the garbage bin.

Table 6. ANOVA and Tukey's HSD post-hoc test results on sorting response times in each bin. In the Tukey's HSD results, the number in the parenthesis is the mean response times (seconds) in the block and in the condition (L=learning condition; C=control condition).

Bin	Effect	ANOVA results	Tukey's HSD post-hoc test results	$p$
Food Scraps	Condition	$F(1,94)=0.48, p=.49, \eta_p^2=.005$	1 <sup>st</sup> block L (2.3) vs. 1 <sup>st</sup> block C (2.3)	.72
	Block	$F(1,94)=106.49, p<.001, \eta_p^2=.53$	2 <sup>nd</sup> block L (1.8) vs. 2 <sup>nd</sup> block C (1.8)	.90
	Interaction	$F(1,94)=0.07, p=.80, \eta_p^2=.0007$	1 <sup>st</sup> block L (2.3) vs. 2 <sup>nd</sup> block L (1.8) 1 <sup>st</sup> block C (2.3) vs. 2 <sup>nd</sup> block C (1.8)	<.001 <.001
Recyclable Containers	Condition	$F(1,97)=0.51, p=.48, \eta_p^2=.005$	1 <sup>st</sup> block L (2.2) vs. 1 <sup>st</sup> block C (2.2)	.96
	Block	$F(1,97)=67.14, p<.001, \eta_p^2=.41$	2 <sup>nd</sup> block L (1.7) vs. 2 <sup>nd</sup> block C (1.9)	.08
	Interaction	$F(1,97)=0.13, p=.04, \eta_p^2=.04$	1 <sup>st</sup> block L (2.2) vs. 2 <sup>nd</sup> block L (1.7) 1 <sup>st</sup> block C (2.2) vs. 2 <sup>nd</sup> block C (1.9)	<.001 <.001
Paper	Condition	$F(1,98)=0.32, p=.58, \eta_p^2=.003$	1 <sup>st</sup> block L (1.8) vs. 1 <sup>st</sup> block C (1.9)	.93
	Block	$F(1,98)=67.14, p<.001, \eta_p^2=.41$	2 <sup>nd</sup> block L (1.5) vs. 2 <sup>nd</sup> block C (1.6)	.81
	Interaction	$F(1,98)=0.04, p=.84, \eta_p^2=.0004$	1 <sup>st</sup> block L (1.8) vs. 2 <sup>nd</sup> block L (1.5) 1 <sup>st</sup> block C (1.9) vs. 2 <sup>nd</sup> block C (1.6)	<.001 <.001
Garbage	Condition	$F(1,93)=4.67, p=.03, \eta_p^2=.05$	1 <sup>st</sup> block L (2.2) vs. 1 <sup>st</sup> block C (2.4)	.05
	Block	$F(1,93)=99.22, p<.001, \eta_p^2=.52$	2 <sup>nd</sup> block L (1.7) vs. 2 <sup>nd</sup> block C (1.9)	.03
	Interaction	$F(1,93)=0.04, p=.85, \eta_p^2=.0004$	1 <sup>st</sup> block L (2.2) vs. 2 <sup>nd</sup> block L (1.7) 1 <sup>st</sup> block C (2.4) vs. 2 <sup>nd</sup> block C (1.9)	<.001 <.001

Overall, results from Experiment 2 suggest that feedback in the learning condition improved sorting accuracy for all four bins, except that the effect was weaker for the paper bin. However, feedback did not optimize sorting motion, or sorting speed.

#### 4.6 Experiment 3

Both Experiments 1 and 2 were conducted in the lab where participants sorted items via a computer interface. While these results showed the immediate feedback increased sorting accuracy, the findings were limited to the artificial lab setting. To see whether the sorting game

influences actual sorting behaviour in real-world conditions, I introduce the game to students in one of the biggest residential buildings on UBC campus, and examine whether the game improved actual sorting accuracy and reduced contamination outside the lab.

#### **4.6.1 Participants**

Three high-rise towers from the UBC Marine Drive (MD) student residence were selected for the experiment, and randomly assigned to 2 conditions. Two towers were selected as game conditions, and the third tower was the control condition. The MD residence was selected for the study due to several reasons: the three hi-rise towers had a similar number of students, apartment units, and floors, and each building had a recycling room with a similar layout with the same amenities and recycling signage (see Appendix A.5). The residence complex also contains an industrial electronic measuring scale in the tunnels connecting the towers which was extremely useful for weighing of the compost bins. While all three towers look evenly spaced, door-to-door distance between them varies: distance between game tower 1 and control is 60m, and control and game tower 2 is 30m, and the distance between the two game towers is 95m. Since both control and the game buildings have the same recycling signage above each waste stream, the control building is testing the effectiveness of the posters alone, while the game buildings have posters plus the effectiveness of the sorting feedback game for those residents who end up playing. We recruited 334 residents to play the game, and had to exclude 25 responses due to technical problems or incompleteness, resulting in a total of 309 residents who completed the game (109 female, 112 male; mean age=20.7 years, SD=1.8) from the two game buildings. from the three buildings to play the sorting game. The average accuracy in the sorting game was around 68%. The detailed description of the buildings and game statistics are listed in Table 7.

Table 7. Building conditions, number of residents and rooms per building, and game statistics.

<b>Building condition</b>	<b>N of residents</b>	<b>N of units</b>	<b>% of residents who played the game</b>	<b>Mean game score (accuracy)</b>	<b>SD of game score (accuracy)</b>
Game	344	143	43.6%	68.2%	11.9%
Game	368	149	48.9%	67.4%	11.8%
No Game	405	180	-	-	-

#### 4.6.2 Stimuli

The sorting game in the pervious experiments involved 40 waste items and took at least 20 minutes to complete (with 80 trials in total). While more items in the game make it more comprehensive as a teaching tool, we needed to reduce the length of the game-time to maximize participation and game completion in the student residence. Therefore, we narrowed the items down to 28 (7 in each bin) with the lowest accuracy from lab experiments, which were also confirmed by UBC Campus Sustainability Office as the commonly miss-sorted items. This shorter version of sorting game was identical to the first block (with feedback) in the learning condition in Experiment 1, except it has 28 items, and participants clicked on the bin signage to sort the item in that waste stream. The sorting game took about five minutes to complete. Here is the sorting game link: [http://yuluo.psych.ubc.ca/studies/Sorting\\_MD](http://yuluo.psych.ubc.ca/studies/Sorting_MD)

#### 4.6.3 Procedure

The experiment ran for a total of 11 weeks from January to April, coinciding with the spring academic semester. The first two weeks served as the *baseline* period, followed by six weeks of *intervention* where we administered the game in the building lobby, with the final three weeks serving as the *post-intervention* period. During the intervention period, myself and the research

assistants (RAs) posted game advertising posters on every floor of the game buildings, including the elevator and on the bulletin board in the recycling room (see the poster in Appendix A.6). To solicit and engage students in game playing, every Tuesday, Wednesday, and Thursday at least two RAs and myself set up tables in the lobbies of each game building during 5-7pm when student traffic is high. We had a laptop computer and an iPad on which students could play the game, and decorate the table with the sorting game posters, and other recycling materials from UBC Campus Sustainability Office (Appendix A.6). We also had a big bowl of chocolates in the middle of the table as an incentive and immediate reward for participation. The RAs approached and invited students coming in and out of the building to play the sorting game and learn how to sort in 5 minutes. We always confirmed that they lived in the building before playing the game, and also offered a chance to win a \$25 UBC Food Services gift card as an additional reward for playing the game. We did not set up any posters or tables in the control building.

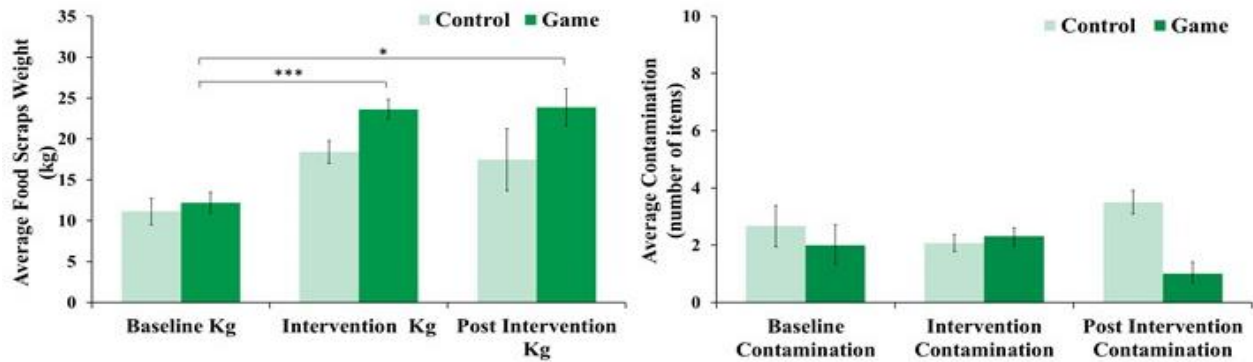
Every week of the study 11-week period, we coordinated with the building managers and custodial staff to hold all recycling and compost bins from study buildings in specific areas in the basement tunnels for measurements, usually one day before the scheduled collection pickup. Due to different pickup schedules, paper bin and recyclable containers bin were measured twice a week, and food scraps bins were measured three times a week. While each building had all 4 waste streams, we did not measure garbage due to the large size and weight of the garbage bins, including safety concerns of moving and searching through them. Thus, we only weighed food scraps, recycling containers, and paper bins. The bin dimension was about 22×24×40 inches. Before data collection had began, I trained each RA on the UBC sorting guidelines to ensure that

everyone was well-versed in campus waste sorting guidelines. For first few weeks I always accompanied RAs demonstrating the protocol, giving tips and pointers on best practices. We would weigh each bin with all the contents inside, subtracting the weight of an empty bin (12kg) from the total to record the material weight in kilograms (kg). All paper and recyclable containers bins were weighed by a digital DYMO® S250 shipping scale at the fixed location in the recycling room because we could use a portable scale when visiting each room. All food scraps bins were collected and weighed by a stationary Brecknell DS100 industrial scale situated in the residence complex tunnels. In addition to weight, we rummaged through the bins to count and record the number of contamination in each bin. Specifically, myself and RAs used thongs and gloves to visually search and inspect for all the items that did not belong in that waste stream. Thus, for every waste stream we had the weight (kg) and contamination (number of incorrect items) data in the food scraps, recycling containers, and paper streams in each building every week.

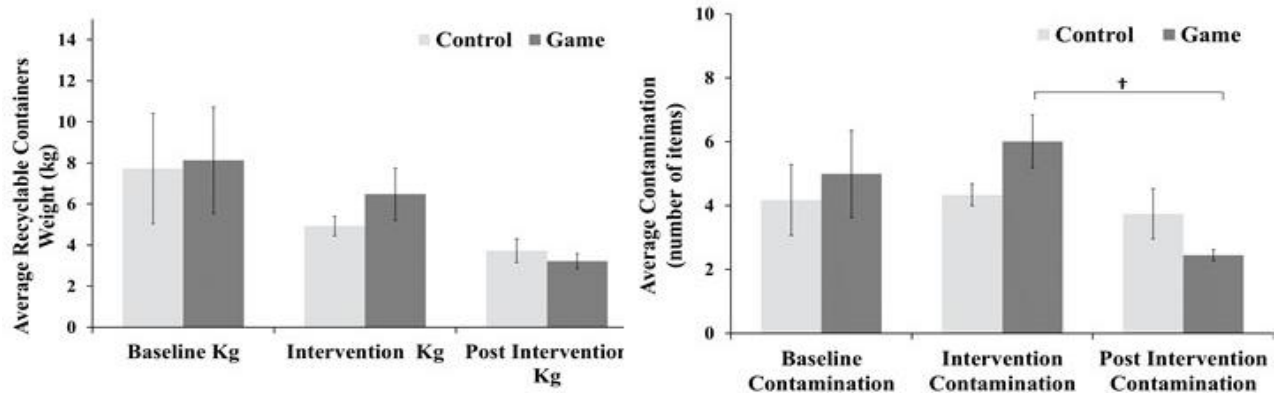
#### **4.6.4 Results and Discussion**

Since there were two buildings in the game condition, I first performed an independent-samples t-test between the two game buildings to see if the data were similar. With little difference between the two buildings in any stream and in any period, I combined the data to have one game condition data file. To examine the impact of the sorting game on sorting performance in the student residence, I used a 2 (building: game vs. control; between-subjects)  $\times$  3 (time: baseline, intervention, and post-intervention; between-subjects) ANOVA for each stream (food scraps, recyclable containers, and paper) and for each measure. The average weight and the average contamination in each stream per week are shown below in Figure 8.

**a) Food scraps weight (left) and contamination (right) per week**



**b) Recyclable containers weight (left) and contamination (right) per week**



**c) Paper weight (left) and contamination (right) per week**

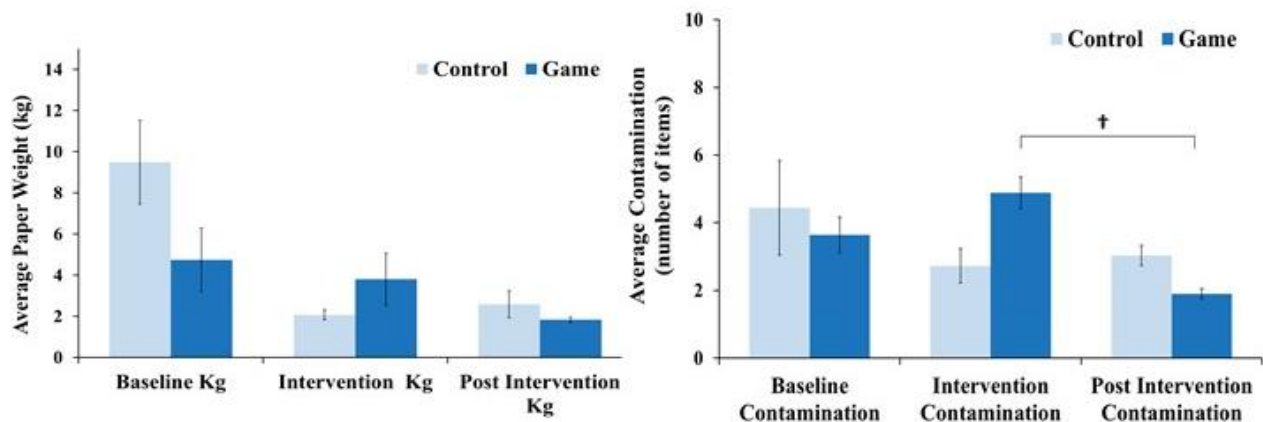


Figure 8. Experiment 3 results. Average weight (kg) and contamination (number of incorrect items) per week in the (a) food scraps bin, (b) recyclable containers bin, and (c) paper bin per week. The game building and the control building are compared in the baseline, intervention, and post-intervention period. (Error bars reflect  $\pm 1$  SEM; † $p < .1$ , \*\* $p < .01$ , \*\*\* $p < .001$ )

### *Food scraps weight (kg)*

The ANOVA analysis showed that there was a main effect of building [ $F(1,16)=8.2$ ,  $p=.01$ ,  $\eta_p^2=.34$ ] and time [ $F(2,16)=7.89$ ,  $p=.004$ ,  $\eta_p^2=.50$ ], but no significant interaction between building and time [ $F(2,16)=0.37$ ,  $p=.71$ ,  $\eta_p^2=.04$ ]. Tukey's HSD post-hoc test showed that in the game building the weight increased from baseline to intervention period ( $p=.047$ ). Additionally, the weight was significantly higher in the game building during intervention period ( $p=.02$ ) and post-intervention period ( $p=.04$ ) than the control building, but no difference between the game building and the control building during baseline ( $p=.99$ ). This suggests that the game increased the weight of food scraps when students were playing the game, and importantly, the effect remained after the game period.

### *Food scraps contamination*

For contamination, there was no effect of building [ $F(1,16)=1.64$ ,  $p=.22$ ,  $\eta_p^2=.10$ ], time [ $F(2,16)=0.04$ ,  $p=.97$ ,  $\eta_p^2=.004$ ], or interaction [ $F(2,16)=1.76$ ,  $p=.20$ ,  $\eta_p^2=.18$ ]. Tukey's HSD post-hoc test revealed no statistical differences between the control and game-playing buildings. Numerically, contamination in the control building increased while contamination in the game buildings decreased. Considering the weight of food scraps went up significantly in game-playing buildings during and after the intervention, it is encouraging to see it did not result in contamination increase during the same period.

### *Recyclable containers weight (kg)*

For recyclable container weight, there was no effect of time [ $F(2,16)=2.31$ ,  $p=.13$ ,  $\eta_p^2=.22$ ], no effect of building [ $F(1,16)=0.75$ ,  $p=.40$ ,  $\eta_p^2=.04$ ] or interaction [ $F(2, 16)=2.15$ ,  $p=.15$ ,  $\eta_p^2=.21$ ].

Tukey's HSD post-hoc test showed no significant pair-wise differences.

### *Recyclable containers contamination*

For contamination, there was no effect of building [ $F(1,16)=0.99$ ,  $p=.34$ ,  $\eta_p^2=.06$ ], time [ $F(2,16)=2.43$ ,  $p=.12$ ,  $\eta_p^2=.23$ ], or interaction [ $F(2,16)=2.28$ ,  $p=.14$ ,  $\eta_p^2=.22$ ]. Tukey's HSD post-hoc test showed a marginally significant decrease in contamination between the intervention period and the post-intervention period ( $p=.08$ ) in the game building.

### *Paper weight (kg)*

For paper weight, there was a main effect of time [ $F(2,16)=5.25$ ,  $p=.02$ ,  $\eta_p^2=.40$ ], but no effect of building [ $F(1, 16)=0.02$ ,  $p=.88$ ,  $\eta_p^2=.001$ ] or interaction [ $F(2,16)=2.59$ ,  $p=.11$ ,  $\eta_p^2=.24$ ]. Tukey's HSD post-hoc test showed only a significant decrease in weight of paper from baseline and the intervention period ( $p=.02$ ) in the control building.

### *Paper contamination*

For paper contamination, there was a marginal interaction between building and time [ $F(2,16)=3.18$ ,  $p=.07$ ,  $\eta_p^2=.28$ ], but no effect of building [ $F(1,16)=1.56$ ,  $p=.23$ ,  $\eta_p^2=.09$ ] or time [ $F(2,16)=1.75$ ,  $p=.20$ ,  $\eta_p^2=.18$ ]. Tukey's HSD post-hoc test showed a marginally significant decrease in contamination between the intervention period and post-intervention period ( $p=.09$ ) in the game building.

Overall, results from Experiment 3 show that weight of food scraps increased statistically in the intervention period as well as in the post-intervention period for game buildings. Data also shows that control building experienced a numerical increase in weight of food scraps, which could be due to existing signage and visual cues in the recycling room signaling to compost food waste. The increase of weight in game buildings was significantly higher than that of control, and this could be attributed to the combined effects of the game and recycling room posters. The increase of food scraps weight for the game buildings did not lead to an increase in contamination, if anything contamination decreased in the post-intervention period compared to the control. Regarding contamination, all three streams (food scraps, containers and paper) showed a numeric decrease in the post-intervention period compared to intervention. While this decrease was only marginal for containers ( $p=.08$ ) and paper ( $p=.09$ ), it shows a consistent trend for all three waste streams in game buildings compared to the control.

Unlike for the food scraps stream (whose weight of materials increased over the intervention period), it is interesting to note that the weight of containers and paper materials decreased for game and control buildings throughout the semester. This data seems to point that the game had no positive effects on the weight of paper and container streams. The contamination levels were the lowest during the post-intervention measurements, indicating that game's effects were the most noticeable in this period. This is likely due to the fact it took us six weeks to reach the critical mass of participants to play the game ( $n=334$ ), which was less than half of all the available residents from both game towers ( $N=712$ ).

## **4.7 Conclusion and General Discussion**

With the aim to answer the second research question of this dissertation, studies in this chapter examined if a sorting game with immediate feedback on sorting errors can facilitate acquisition of knowledge and improve sorting accuracy by correcting errors. We first identified the most problematic items where sorting mistakes occur most often in the pilot study. Targeting these items in particular, we designed the sorting game in the lab where participants manually sorted items into four bins (food scraps, recyclable containers, paper, and garbage) via a computer interface, and received immediate feedback on their performance. Participants sorted the items either by pressing a key to indicate to which bin the item belonged (Experiment 1), or manually dragging the item to the bin so their motion was tracked (Experiment 2). Beyond testing the game in the lab, I then implemented this game in student residences on campus and examined how the game influenced actual sorting behaviour in student residences (Experiment 3).

In Experiment 1, we found that participants have learned to sort more accurately after receiving immediate feedback after each trial in the first block, even when feedback was no longer provided in the second block, but the feedback had minimal impact on the sorting speed. In Experiment 2, we replicated most of the findings in Experiment 1, and found that feedback in the learning condition improved sorting accuracy for all four bins, except for the paper bin because sorting performance increased in the control condition in the second block for the paper bin. One explanation of this anomaly could be due to a campaign in the spring and summer terms on UBC campus when we collected the data for Experiment 2. The campaign specifically aimed to raise awareness that coffee sleeves should go to the paper bin. We speculate that in the first block in the control condition, participants may instinctively throw the coffee sleeves into the food scraps

bin or the garbage bin, but in the second block they may remember that coffee sleeves should go to paper bin from the campaign. To confirm this speculation, we examined the sorting accuracy of coffee sleeves and it indeed showed the largest improvement from the first block (70.0%) to the second block (83.0%), whereas the other paper items improved from 71.5% to 74.8%. Thus, this self-correcting behaviour based on the retrieval of prior knowledge could explain the improvement in sorting in the paper bin in the control condition of Experiment 2. It is important to note that feedback did not optimize sorting motion or speed in Experiment 2, except that the sorting speed improved only for the garbage items. One explanation is a possible ceiling effect in sorting speed in food, containers, and paper streams, so feedback could not improve the speed further. However, for the garbage items, the response time was the slowest, so feedback could improve the sorting speed. Once participants learned how to sort garbage items based on immediate feedback, their sorting speed for these items raised to the same levels as for the other streams.

In Experiment 3, I found that the sorting game increased the weight of food scraps when students were playing the game during the intervention period, and also in the post-intervention period. The weight increase in the food scraps bin was not associated with an increase in contamination, since the contamination in the game building marginally decreased in the post-intervention period compared to the control building. The sorting game decreased contamination in the recyclable containers ( $p=.08$ ) and paper ( $p=.09$ ) bins between the intervention period and post-intervention period in the game buildings. There are several reasons why the biggest effect was only seen in the food scraps bin. First, the weight and contamination of the containers and paper bins were more variable than that of the food scraps bin (Figure 8). This could be due to the fact

that mostly food items go to the compost bin, but many other types of items can go to the containers or the paper bin. Second, it is possible that our game did not capture all of the contaminants in the containers and paper bins, since contamination reduced in food scraps but remained high for the containers and the paper bins after the intervention. Taken together, these three experiments suggest that the sorting game with immediate feedback on performance can improve sorting accuracy even when the feedback is no longer provided. The sorting game provided an additional benefit and a novel intervention beyond the existing efforts to promote sorting. Both the control and the game buildings had the same sorting signage and infrastructure: a large sorting infographic poster on the wall, signage on the bin lid, and a transparent box (3D display) containing sample items that should go into the bin (Appendix A.5). These signs were present in every building in Experiment 3, and the sorting game was the only difference between buildings. Looking across Experiments 1 and 2 to compare different modes of sorting (e.g. key strokes and drag-and-drop gestures), data shows that overall sorting accuracy improved significantly from first block to second block in the learning condition compared to control. The learning effects were the most prominent in food scraps/ organics, containers and garbage. This shows that it was the immediate feedback on errors that improved sorting accuracy and not the mode of sorting gesture (keystroke and gestures). Sorting accuracy effects were consistent across the waste streams, although feedback did not optimize sorting motion, or sorting speed.

These studies are significant in three ways. First, we demonstrated that a digital sorting game which delivers immediate feedback to participants can improve sorting accuracy in the lab and in the field, even when feedback is no longer provided. Second, the current study provided a template for applying basic research to solve real-world problems, where we first identified the

most problematic items, designed the sorting game targeting these items, and examined the impact of the game using rigorous experimental methods. This approach can be applied to environmental problems beyond waste contamination. Third, the sorting game can be an effective education tool to teach people how to sort, minimize contamination, increase recycling and composting rates thereby contributing to resource management and sustainability goals. Environmental sustainability depends on not only people's intention to act, but also the accurate implementation of those intents and actions. Using a digital sorting game can help increase the accuracy of actions, facilitating behaviour change toward sustainability.

#### **4.8      Sorting Errors and Feedback**

Numerous sorting errors were identified during the study, showing that people had trouble sorting certain items. These errors could be driven by at least two reasons. First, people may categorize the item based on the physical properties of materials. For example, paper towels, napkins, and chopsticks were disposed incorrectly into paper bins, but should be in the food scraps bin instead. All three items shared similar physical properties of paper, which results in the error of sorting them as paper. Second, people may categorize the items based on the physical form of the items. For instance, broken glass bottles and styrofoam were disposed incorrectly into the recyclable containers bin, but should be in the garbage bin instead. Both items possess the form of a container, and therefore are categorized as containers, but broken glass is a safety hazard and styrofoam is not accepted in many systems due to its low resale value. These errors suggest that some recycling decisions are driven by intuition, where people categorize items based on physical properties or form, which are in direct contradiction to where the items ought

to go. This difference can be extremely detrimental in some cases: for example, a coffee cup with liquid still inside can contaminate a whole bin of clean paper, making it landfill bound.

The beneficial impact of feedback on sorting performance can be explained by at least three reasons. First, for incorrect trials, the feedback provided the correct response to the participants, rather than simply informing them whether their decision was incorrect. This correction allowed participants to know where the item should go instead, even if they made an error. This explains why sorting performance improved in the second block, or in the intervention or the post-intervention period after people have played the game. Such feedback provided sufficient information to allow people to acquire new knowledge, thus facilitating learning (Phye, 1979; Wentling, 1973). Second, since feedback was provided immediately after each trial rather than delayed to the end of the game, the learning process was efficient and rapid (Corbett & Anderson, 2001; Kulik & Kulik, 1988). Moreover, in some cases higher accuracy was already observed in the first block of the learning condition, compared to the control condition, suggesting that participants had learned to sort better with feedback (Keller, 1983; Mory, 2004). Third, feedback may facilitate the creation of new sorting concept in people's mind. For example, when the broken glass bottle was first disposed as container, and the feedback informed them it should go to garbage, participants may form a new concept that broken items must be disposed as garbage. Thus, providing immediate feedback when people need it can be an effective tool to build new knowledge and sustainable practices (Shute, 2008).

## **4.9 Limitations and Future Directions**

Although the effects in the lab were strong, the impact of the sorting game in the student residences was relatively weaker in Experiment 3. This could be due to several factors. First, the overall accuracy of the sorting game was around 68%, which suggests that participants do not know correct answers to all items, and therefore continue to make the same sorting errors when they dispose waste. In addition, our game only had 28 most common items to sort while in real life the number of household materials is larger and more complex. Second, less than half of all of the available residents (46%) played the sorting game in the two game buildings despite our efforts to recruit as many participants as possible, so the potential effect of the sorting game could only be seen in these residents, leaving the majority unchanged. Third, the effects in the lab were immediate, whereas the effects in the student residence were delayed. That is, in Experiments 1 and 2 the second block followed directly the first block after a 2-min break, but in Experiment 3, the actual sorting behaviour may occur anywhere from a few minutes to days or weeks after playing the game. Another key methodological distinction between the experiments involved different levels of data: Experiments 1 and 2 tested individual-level accuracies in a lab setting, while Experiment 3 measured the building-level sorting performance (in kg and contamination) without measuring individual-level accuracy. This difference likely influenced the results of Experiment 3 since only about half of the residents played the game. This said, we reason that the sorting game would have achieved stronger effects if we managed to reach every resident in the building. Finally, I did not have sufficient statistical power in Experiment 3, since we could only measure the bins for 11 weeks during the spring semester, with a few data points in each week. The experiment had to be completed at the end of the semester because students move out of the residence in April.

During the field experiment, there is a possibility that residents of the control building may have seen the game posters or lobby events in the game buildings passing through or visiting friends. This may have increased their awareness and motivation to sort, or caused them to wonder why their building was not participating. Since all participants in the sorting game had to indicate which building they lived in, we found no participants outside of the two game buildings played the sorting game. As such there is no evidence that residents of the control building played the game and improved their sorting behaviour. Nevertheless, increased awareness or motivation in the control residents might have only increased the weight of bins but not necessarily the sorting accuracy, since the residents in the control building did not play the game. Indeed, our data shows that there was no statistically significant change in weight or contamination over time across streams in the control building, and it's unlikely that residents in the control building changed their sorting behaviour. Another limitation of Experiment 3 is that we heavily advertised the sorting game using posters and lobby events, and these efforts may have contributed to a heightened awareness of the recycling norm in students in these buildings. Experiment 3 could not discern how much of the results were driven by the sorting game alone versus the increased awareness and personal interaction with the residents during the game promotion. To address this issue, there are two arguments. First, lab Experiments 1 and 2 showed strong evidence that sorting performance improved in the second block in the learning condition when feedback was no longer provided. This suggests that the immediate feedback in the first block had a positive impact on subsequent performance. By this logic, participants who played the sorting game and received immediate feedback in Experiment 3 may also improve their sorting performance later. Second, the university is constantly running campaigns to promote sorting, and as a default there

are already many posters and signs in the recycling room. Thus, some students may be less sensitive to our efforts to promote the sorting game, and there are also residents who are simply not interested in the campaign for various reasons.

For future studies there are several recommendations to boost the impact of the sorting game based on the current study. First, the recruitment during intervention could be intensified with an attempt to recruit all of the residents in the building, and do so in a shorter time period. Second, the game can be played repeatedly (and with more items) to maximize the teaching benefits of the game as an education tool. Third, a follow-up questionnaire can be used before and after to examine whether people's attitude toward sorting and their intentions of sorting have changed after playing the game. Fourth, a limitation of the contamination measure in Experiment 3 was the inability to thoroughly inspect the bins when they were very full, especially in food scraps. We relied on visual inspection using tongs to move items around, but could not always reach the bottom 20% of the bin to identify all contaminants and deduce the true number of contamination. Other methods of contamination inspection (i.e., full audit to count all items in the bin, or new scanning and moisture sensing technology) could be more effective to measure full contamination in future research. Finally, these experiments are based on student population sample which is not representative of other communities and demographics. Future studies should investigate whether the game can also improve sorting accuracy in single households or multi-family residences in different communities to better generalize the findings.

## **Chapter 5: Sustainability Education in a Botanical Garden Promotes Environmental Knowledge, Attitudes, and Willingness to Act**

### **5.1 Introduction**

Over the past couple of centuries, human activity has caused adverse impacts on earth's ecosystems and created a myriad of environmental problems (Sathaye et al., 2007). In effect, human influence on the planet has reached such unprecedented levels that we have ushered a new geologic period: the Anthropocene (Zalasiewicz et al., 2010), signifying an era where human activity has been the most dominant influence on the earth's ecosystems and geology. More than 80 percent of earth's surface has been altered by human activity, two-thirds of major marine fisheries are overexploited (or depleted), and a global biodiversity crisis amidst the changing climate threatens the worst mass extinction since the loss of the dinosaurs 65 million years ago, triggering a potential widespread ecosystem collapse (FAO, 2013; Folke et al., 2004). Under current trends, the Convention on Biological Diversity forecasts a continued decline of biodiversity with serious (expected and unexpected) threats to all current and future populations (Secretariat of the Convention on Biological Diversity, 2014).

Given that human activity is at the center of environmental issues, sustainability critically depends on a change in human behaviour. However, creating behaviour change to mobilize global transitions into sustainability is one of the greatest challenges of the 21<sup>st</sup> century. Promoting public engagement and individual action remains a difficult challenge for governments, organizations and institutions worldwide (Gifford, 2011; Weber & Johnson, 2012; Whitmarsh et al., 2012). At the same time, individuals, communities, and organizations all

have the responsibility to address environmental problems and search for solutions to mitigate and adapt to the unprecedented rate of environmental change. With this responsibility is an opportunity for changemakers to look for effective and innovative ways to promote responsible consumption and resource management, and to implement sustainable strategies and practices in the private and public life (Lubchenco, 1998; Raskin et al., 2002). While extremely challenging, creating public engagement, discussions and action in sustainability is a fundamental component of the democratic process about what kind of a world we want to live in (Robinson, 2004; Whitmarsh et al., 2013).

## **5.2 Education in Nature: Botanical Gardens as a Venue for Sustainability Education**

Psychologists, anthropologists, and ecologists have long maintained that human connection with nature is a large determinant of people's worldview and behaviour (Bateson, 1979; Rees, 2002; Walker et al., 2004). In a culture where environmental problems have been brought on by a growing disconnection from the natural world (Suzuki & McConnell, 2007), botanical gardens are uniquely situated to provide a substantial contribution to sustainability education and global conservation while fulfilling their horticultural goals. While botanical gardens have traditionally focused on collecting and showcasing local or rare plants, majority of botanical gardens around the world already promote sustainability research, conservation, and public education through a range of courses, tours, and events (Dodd & Jones, 2010). Interest in education for sustainable development has grown with gardens around the world working to broaden audiences and diversify programs (Williams et al., 2015). With over 3300 botanical institutions and public gardens around the world receiving over 300 million visitors per year (BGCI, 2016), there is a tremendous, and yet untapped opportunity for gardens to re-connect a wide range of community

members with the natural world, illustrate the web of connections and motivate individual attitude and action toward a more sustainable future.

### **5.3 Factors Facilitating Behaviour Change**

Pro-environmental behaviour is defined as any action that enhances the quality of the environment, regardless of intent (Steg et al., 2014). Decades of research in pro-environmental behaviour has shown that human actions are determined by a number of internal and external factors such as knowledge, attitudes, social norms, culture and infrastructure (Gifford et al., 2011; Kahneman, 2011; Steg & Vlek, 2009; Weber & Johnson, 2012). While early behaviour change models emphasized powers of logic, reason and facts, work in behavioural economics has shown that humans have bounded rationality with emotions, shortcuts and biases playing a key role in influencing our behaviour (Kahneman, 2011; Kahneman & Tversky, 2001; McFadden, 1999). More specifically, research has shown that pro-environmental behaviour can be determined by a number of factors such as knowledge, attitudes, social norms, culture and infrastructure (DiGiacomo et al., 2018; Gifford et al., 2011; Kahneman, 2011; Namazu et al., 2016; Nolan et al., 2008; Steg & Vlek, 2009; Weber & Johnson, 2012; Wu et al., 2013). The natural environment also plays a role in shaping attitudes behaviour (Nisbett & Ross, 2011). Recent studies suggest that nature has beneficial effects on cognition, well-being, and behaviour (Berman et al., 2008; Chawla, 2015; Pretty, 2004; Wells & Evans, 2003; Zelenski et al., 2015). Building on past work on behaviour change (Jackson, 2005; Schultz et al., 1995; Stern, 2000), here I focus on how sustainability education in nature influences people's knowledge, attitudes, and pro-environmental behaviour.

## **5.4 Roles of Knowledge and Education**

Many models of behaviour change focus on information provision and education, with evidence that increases in knowledge are associated with pro-environmental actions (Darnton, 2008; Hines et al., 1986; Schwartz, 1992; Stern et al., 1999). Having the relevant knowledge can empower individuals to engage in pro-environmental actions. For example, knowledge about recycling programs and sorting guidelines has been associated with increased recycling behaviour (De Young, 1989; Schultz et al., 1995a). Knowledge in the form of consumption feedback has been effective in reducing household energy consumption (Allcott & Rogers, 2012; Nolan et al., 2008; Owens, 2000). Many behaviour change models are based on the assumption that to act pro-environmentally people must know how. However, it is important to note that the relationship between knowledge and behaviour can be bi-directional. That is: people who engage in pro-environmental behaviour (or have eco-centric values) may seek out relevant information and acquire new knowledge in order to guide their future actions (Darnton, 2008b).

Information alone may be insufficient to change behaviour (Blake, 1999), especially if there are strong external constraints such as inconvenience or financial costs (Steg & Vlek, 2009; Stern, 2000). Traditional methods of information delivery break down when they fail to consider limitations of people's cognitive capacities, interests and time (Kollmuss & Agyeman, 2002). Therefore, it is imperative that any new information is communicated effectively and that audiences can successfully and accurately comprehend and memorize it (Weber & Johnson, 2012). Moreover, trust in the source of information with poignant storytelling using relatable examples, or engaging hands-on activities, can significantly help engagement, comprehension, and retention of information (Jackson, 2005; McKenzie-Mohr, 2008).

## **5.5 Role of Environmental Attitudes**

The relationship between attitudes and behaviour has been a focus of social psychology for many decades (Ajzen, 1985; Bem, 1967; Jackson, 2005). A large body of research has shown that personal values, attitudes, and beliefs can determine the motivation to express concerns about the environment and the adoption of behaviours that are in line with those values and attitudes (Crompton, 2010; Schultz et al., 1995). People who engage in pro-environmental behaviour typically have pro-environmental attitudes (Bamberg & Möser, 2007), and people with strong pro-social values or biospheric values are more likely to engage in pro-environmental behaviour (Schultz et al., 2007; Stern et al., 1999). Strong environmental attitudes from the public can instigate legislative and infrastructural changes which can further reinforce these attitudes and behaviour change (Tibbs, 2011). However, similar to knowledge, environmental attitudes alone may not be sufficient to motivate all pro-environmental behaviours (Whitmarsh & O'Neill, 2010). For example, high-impact behaviours that have the biggest contributions to thwarting climate change, like vehicle use and diet (Wynes & Nicholas, 2017), are often entrenched in larger socio-technical systems and cultural contexts and are thus more difficult to change (Gifford et al., 2011; Steg & Vlek, 2009; Stern et al., 1999). As such, environmental attitudes and knowledge will have a varying effect on behaviour depending on social and geographic contextual factors (Braun et al., 2017).

## **5.6 Role of Nature**

Nature provides a range of goods and services: from provisioning (e.g., food, water), supporting and regulating (e.g., water and soil purification), to cultural, spiritual, and religious services, which are estimated to be valued around \$145 trillion per year (Chiesura, 2004; Costanza et al.,

2014; Daily et al., 1997). In addition, nature also provides psychological benefits for adults and children as a result of exposure (Cox et al., 2017; de Vries, Verheij, Groenewegen, & Spreeuwenberg, 2003; Ulrich et al., 1991). These benefits include reducing fatigue and stress (Berg & Berg, 2007; Gidlöf-Gunnarsson & Öhrström, 2007), and enhancing memory and attention (Barton & Pretty, 2010; Berman et al., 2008; Kaplan, 1995; Kaplan & Kaplan, 2011; Mackay et al., 2014; Pretty, 2004; Wells, 2000; Wilson et al., 2009). Moreover, exposure to nature can speed up hospital recovery time and reduce the use of painkillers (Bringslimark et al., 2009; Cohen-Cline et al., 2015; Maller et al., 2006; Ulrich, 1984). For all of these positive effects on people's mental, physical and social well-being, access to nature has been established as a critical component of a healthy, livable, and thriving city (City of Vancouver, 2012; de Vries et al., 2003).

Having a connection with nature is also associated with environmental attitudes, concern, and behaviour (Dunlap et al., 2000; Nisbet et al., 2009; Schultz et al., 2004), which are identified as one key factor in pro-environmental behaviour (Geng et al., 2015; Kollmuss & Agyeman, 2002; Stern et al., 1999). For example, a recent study with five botanical gardens in the UK found a positive relationship between ecological knowledge and environmental attitudes where the visitors showed stronger environmental attitudes after their visit to the gardens (Williams et al., 2015). Research with children also shows education in nature can have positive impacts on their knowledge, environmental attitudes, and behaviour (Chawla, 2015; Morgan et al., 2009; Sellmann & Bogner, 2013). In school food programs, integration of meals with school garden curriculum facilitated learning of healthy and sustainable food choices (Oostindjer et al., 2016).

## **5.7 Current Study**

The goal of the current study is to examine the impact of a sustainability education program delivered in a botanical garden on people's environmental knowledge, attitudes, intentions and willingness to act before and after their visit. Specifically, I evaluated the Sustainable Communities Field School (FS) program, which was developed in 2015 by the University of British Columbia (UBC) Botanical Garden and the Society Promoting Environmental Conservation (SPEC). SPEC is the oldest environmental non-profit organization in Canada, with more than 45 years of work in public education and policy advocacy on environmental protection. Established in 1916 as Canada's oldest university botanic garden, the UBC Botanical Garden has over 50,000 recorded plants, featuring 500 different types of rhododendrons, 95 maples, 75 magnolias, and a variety of mountain ash, woody vines and climber plants. Over the past 100 years, the mission of the garden has been to curate and maintain a documented collection of temperate plants for the purposes of education, research, conservation, community outreach and public display. Situated on a temperate rainforest peninsula directly overlooking the Pacific Ocean, mild climate allows for a wide diversity of plants to thrive year-round. With applied research and education as an integral part of the garden's programming, the UBC Botanical Garden provides a unique outdoor environment for sustainability education and community outreach via programs like the Field School.

The FS program is modeled after the United Nations Food and Agriculture Organization Farmer Field School, which started in the 1980s to help farmers reduce pesticide use, and improve land and water management. The Farmer Field School gained popularity with its focus on participation and empowerment to build farmers' capacity to make decisions that ultimately

reduce pesticide risks and improve farmer health (Friis-Hansen & Duveskog, 2012; Najjar et al., 2013; Settle et al., 2014). Inspired by this successful model of sustainability education, the FS program delivers verbal and interactive education to participants, featuring paired and group activities. Participants in the FS program are generally led by instructors on a nature tour and discuss four core sustainability topics: i) Sustainable food systems and choices, ii) Biodiversity conservation, iii) Water conservation, and iv) Waste reduction. Advertised as a corporate retreat event, the program delivers team-building activities aimed at promoting teamwork, creativity and fun in nature, using sustainability themes as context. As such the FS program is designed to engage employees of local businesses and organizations in topics of sustainability while immersed in nature, with a goal of fostering personal and group connections with nature that can lead to behaviour change toward sustainability. Since majority of botanical garden visitors often consist of local residents and tourists whose primary goal is to relax or pursue leisure activities (Connell, 2004; Wassenberg et al., 2015), the FS program aims to attract participants who might not have come to the garden otherwise. The following four sustainability topics provide the foundation of the FS curriculum: i) food systems and choices, ii) biodiversity conservation, iii) water conservation, and iv) waste reduction. These four domains were selected by local and global sustainability policy goals, as well as the available features of the botanical garden. The FS curriculum was inspired by the City of Vancouver Greenest City 2020 Action Plan, which includes zero waste (goal 5), clean water (goal 9), and local food (goal 10) (City of Vancouver, 2012). Expanding globally, these topics of the FS program also link to the Sustainable Development Goals of zero hunger (goal 2), clean water (goal 6), responsible consumption and production (goal 12), and life on land (goal 15) (United Nations Development Programme, 2018).

## **5.8 Methods**

### **5.8.1 Participants**

A total of 315 participants took part in the study. There were two distinct groups: Sustainable Communities Field School (FS) participants and regular garden visitors (GV) who did not receive the FS tour. There were 196 FS participants (47 males, 123 females, 26 undisclosed, mean age=40 years old, SD=15) who were employees from local businesses and organizations recruited through the FS marketing team. The FS participants reported the following levels of education: 12.5% completed high school, 12.2% college, 26.1% university and 12.7% had graduate degrees. Of this group, 90 FS participants filled out both pre-and post-visit surveys, but overall 146 FS participants completed the pre-visit survey and 140 FS participants completed the post-visit survey. As a control group, there were 119 regular garden visitors (30 males, 66 females, 23 undisclosed, mean age=39 years old, SD=17) who were recruited at the botanical garden during their visit. They reported the following levels of education: 18% completed high school, 10% college, 22% university and 21.7% graduate degrees. None of the garden visitors filled out both pre-and post-visit survey, resulting in 40 pre-visit surveys, and 79 post-visit surveys. As a result, I opted to use a between-subjects design for data analysis. The methods and research protocol was approved by UBC Behavioural Research Ethics Board (H17-01766). Participation in the surveys was voluntary and participants could withdraw at any time.

## **5.9 Survey Design**

The goal of this survey was to evaluate the impact of the Field School program on participants' environmental knowledge and attitudes, and their willingness to engage in pro-environmental

actions. The pre-visit and post-visit surveys can be found in Appendix B. The survey measured four components described below.

### *1. Environmental knowledge*

The Field School program involved four topics as a core of the curriculum: Sustainable food systems and choices, biodiversity conservation, water conservation, and waste reduction. As mentioned earlier, the rationale for selecting these topics in the curriculum was to connect the local goals of the Greenest City Action Plan, and the global UN Sustainable Development Goals, while incorporating them within the features available at the UBC Botanical Garden, such as the food demonstration garden, the water pond, and the Greenheart Canopy TreeWalk. To assess the environmental knowledge of participants, we took the following six questions from the Field School curriculum to test knowledge retention after the tour:

- 1) Name one of the local watersheds.
- 2) What percent of the food is wasted globally?
- 3) What are the main threats to biodiversity?
- 4) What is organic agriculture?
- 5) What is the shape of a honeycomb cell?
- 6) What role does a forest play in protecting water quality and supply?

These questions were only included in the post-visit survey and completed by both Field School participants and regular garden visitors.

### *2. Environmental attitudes and intentions to act*

To assess participants' environmental attitudes and intentions to act, we used well-established and commonly used psychometric scales (see Table 8). The Eco-Centrism (EC) scale measures the degree to which people are nature oriented and likely to engage in conservation behaviours

(Thompson & Barton, 1994). The Shortened Revised New Ecological Paradigm (NEP) is widely used for measuring general environmental attitudes through statements which assess a person's beliefs about humanity's ability to upset the balance of nature and the right to rule over the rest of nature (Dunlap et al., 2000). The Shortened Nature Relatedness (SNR) scale is designed to measure the strength of people's connection with nature which is associated with well-being and participation in ecologically sustainable behaviour. From the short-form Nature Relatedness Scale (NR-6) which has six items (Nisbet & Zelenski, 2013), we selected two statements which represent a self-identification and connection with nature. These items specifically assess two important dimensions directly relevant to the Field School program: the awareness of the impact of one's own actions on the environment, and one's relationship to nature. The final scale is the Intentions to Act (ITA) which examines people's willingness to take specific actions to address climate change (Bord et al., 2000).

Table 8. List of scales and statements used in the pre-visit and the post-visit surveys.

<p><b>Eco-Centrism</b></p> <ul style="list-style-type: none"> <li>• I need time in nature to be happy.</li> <li>• It makes me sad to see natural environments destroyed.</li> <li>• Humans are as much a part of an ecosystem as other animals.</li> <li>• Nature is valuable for its own sake.</li> </ul>	<p><b>Shortened Revised New Ecological Paradigm</b></p> <ul style="list-style-type: none"> <li>• The Earth is a spaceship with limited room and resources.</li> <li>• Humans are severely abusing the environment.</li> <li>• The so-called “ecological crisis” facing humankind is greatly exaggerated.</li> <li>• If things continue on their present course we will soon experience a major ecological catastrophe.</li> </ul>
<p><b>Shortened Nature Relatedness Scale</b></p> <ul style="list-style-type: none"> <li>• I always think about how my actions affect the environment.</li> <li>• My relationship to nature is an important part of who I am.</li> </ul>	<p><b>Intentions to Act</b></p> <ul style="list-style-type: none"> <li>• Concerns about environment guide my voting behaviour.</li> <li>• I try to use less air conditioning in summer and less heat in winter.</li> <li>• I intend to carpool and drive less by using public transport and bikes more often.</li> </ul>

The participants rated each statement on an 11-point Likert-scale, indicating how strongly they agree (10) or disagree (0) with each statement. Only one statement (The so-called “ecological crisis” facing humankind is greatly exaggerated) was reverse coded. We randomized the order of the 13 questions in the pre-visit and the post-visit surveys, and kept the same order for all participants, in order to minimize the chance of recalling their previous answers.

### *3. Willingness to engage in pro-environmental behaviours*

To examine whether the FS program can affect people’s willingness to act we included five actions per four sustainability domains (water, waste, food, and biodiversity) covered in the curriculum. The actions were based on past research at the garden and carefully selected to ensure they are relevant to the local context, Field School curriculum and available to most people. Participants were asked to select all actions they were most willing to do.

Table 9. List of actions in four sustainability domains (water, waste, food and biodiversity) in both pre-visit and post-visit surveys.

<p><b>Water Actions</b></p> <ul style="list-style-type: none"> <li>• Reduce shower time</li> <li>• Install low-flush toilet</li> <li>• Do less laundry</li> <li>• Turn off taps more often</li> <li>• Only do full-load laundry</li> <li>• Other_____</li> </ul>	<p><b>Waste Actions</b></p> <ul style="list-style-type: none"> <li>• Carry your own coffee mug or water bottle</li> <li>• Sort your waste for recycling and composting</li> <li>• Bring your own bag when shopping</li> <li>• Chose items with minimal packaging</li> <li>• Dispose of e-waste and batteries at designated drop-off depots</li> <li>• Other_____</li> </ul>
<p><b>Food Actions</b></p> <ul style="list-style-type: none"> <li>• Reduce meat consumption</li> <li>• Purchase organic food</li> <li>• Purchase fair-trade food</li> <li>• Grow your own food</li> <li>• Reduce food waste</li> <li>• Other_____</li> </ul>	<p><b>Biodiversity Actions</b></p> <ul style="list-style-type: none"> <li>• Sign a petition to save a forest</li> <li>• Buy FSC certified paper products</li> <li>• Volunteer for a local nature conservation group</li> <li>• Plant native plants or put up a bird feeder</li> <li>• Donate to a nature conservation group</li> <li>• Other_____</li> </ul>

#### *4. Demographics*

Previous studies have shown that demographic variables like gender, age, and education can correlate with environmental attitudes and some types of behaviour (Kollmuss & Agyeman, 2002; Williams et al., 2015). Thus, we collected information on gender, age, and education level. Since we wanted to track the same participant before and after their visit, I also collected answers on three additional questions (initials, name of the first street they lived on, and the name of their first pet) so that I could match the same participant from pre-visit to the post-visit survey. However, since not many participants provided this information I was only able to match 90 participants, and therefore opted for a between-subjects design. In the post-visit survey, we included a few questions on the feedback of the tour, which was only intended for the FS instructors and the data was not included in the analyses of this study.

#### **5.10 Procedure**

The Field School marketing team reached out to a number of local businesses and organizations in Vancouver advertising and inviting them to participate in the Field School program<sup>9</sup>. By the end of the summer there were seven groups (each ranging from 20 to 60 participants) with a total of 196 FS participants. Each group was led by two instructors (one from UBC Botanical Garden and one from SPEC) through the garden while receiving a verbal education about sustainability and participating in team-building activities. At the same time, I recruited 119 regular garden visitors who toured the botanical garden by themselves in groups of two to six. This group served as a control since they did not receive the FS curriculum or activities.

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<sup>9</sup> Field School is not a free program: it costs about \$30 per person to attend. This is one of the reasons we could not have a true FS control group because all participants expected to receive the same tour and activities.

### *Field School tour*

Electronic pre-visit surveys with the waiver form were emailed to participants a week before their visit (via [fluidsurveys.com](https://fluidsurveys.com)), but less than 5% of the participants filled out the online survey. Most participants completed a paper copy of the pre-visit survey upon arrival to the garden. After completing the pre-visit survey, the FS participants were introduced to the FS team (instructors and research assistants), the tour goals (refresh, reset & restore), and a brief agenda of the tour. When the group was more than 30 participants, they were split into two sub-groups to facilitate learning and interaction, with instructors switching between the groups. To ensure that each group received the same tour and curriculum, and to make the FS tour replicable by other researchers and gardens, I documented the instructor scripts, number of tour stops, and the activities during the tour with their locations in the garden (See Appendix B.2)

Figure 9 shows the map of the UBC Botanical Garden and the location of each stop during the tour. The tour started at the garden entrance marked by the red balloon sign. The entrance is also the exit of the garden, where the participants completed the pre- and post-visit surveys.

Participants were led by the instructors from stop 1 to stop 12. At each stop, the instructor delivered a verbal presentation of the discussion topics, engaged with questions and asked the group to participate in activities. In addition to the detailed script in Appendix B.2, Table 10 below provides a brief description of the stops, discussion topics and activities during a typical Field School tour.



Figure 9. Map of the garden with numbers highlighting the stops during the Field School tour.

When there were two sub-groups, both sub-groups went through stops 1 and 2 together, and then one sub-group went from stops 8 to 11, while the other sub-group went from stops 3 to 7.

Afterwards, the two sub-groups converged at stop 12 for discussions and activities, as well as quick snacks and a short break. Then, the two sub-groups switched routes, where one sub-group went to the other route that the other sub-group had just gone through. After the FS tour, participants completed the post-visit survey at the exit (the same location as the entrance), and then left the garden. Each tour lasted around 3 hours. The exact scripts that the instructors used, and description of all the activities with pictures are shown in Appendix B.2.

Table 10. A description of the stops, discussion topics, and activities during a typical Field School tour.

Location	Discussion Topics	Activities
Stop 1 - The Garden Entrance / Lam Rock	Acknowledge unceded Indigenous homelands of the Musqueam People. What is a botanical garden and how does it contribute to sustainability?	Heading to canopy (longer walk) or to Moon Gate: discuss in pairs what is the strangest food you ate.
Stop 2 - The Pond	What is biodiversity and why is it important? Talk about invasive species like the bullfrog that comes to the pond.	Sensory Activity: close eyes and use other senses to explore surroundings: what do you hear, smell? Share with the group.
Stop 3 – Moon Gate	What are the main threats to biodiversity? Discuss land use changes, agriculture, fragmentation, deforestation and impacts of development.	Point to the Eagle Tree and talk about migratory birds coming through and unique location of UBC Botanical Garden. Highlight the land-use change in the Garden.
Stop 4 – Garry Oak	Discuss First Nations use of plants for medicine and food, as well as drought tolerant nature of plants of the endangered Garry Oak ecosystem.	Ask people to ID Camas ( <i>Camassia quamash</i> ) and the Garry Oak ( <i>Quercus garryana</i> ).
Stop 5 – Taylor Plaza (The Food Garden)	What is organic agriculture and what are the benefits? Discuss the demonstration garden uses, how food is harvested by volunteers and then donated. People sample edible flowers and herbs from the garden.	Camera Activity: In pairs, one person is a camera and the other a photographer. Photographer guides the camera to an interesting place and camera takes a picture. Teams share back what image they captured.
Stop 6 – The Garden Compost Pile	How much food is wasted globally and what are ecological impacts? Share tips for meal planning and participating in organics collection.	Coffee Activity: The group unpacks a life-cycle of what goes into production of one cup of coffee through 60 cards from 7 different resource sectors. Each group starts with one sector and then they are all brought together.
Stop 7 – The Bee Hive	What is the shape of a honeycomb cell and why? Discuss honey bees the importance of native bees to ecosystems and how little we know.	Activity: Group is invited to sit and watch the resident bee keeper tend to the hive.
Stop 8 – Meyer's Glade	Small break with fruit snacks.	Team photo is taken.
Stop 9 - Canopy Walkway Entrance	What type of a forest are we in?	Groups are asked to think about the role of the forests in water quality and quantity.

<b>Location</b>	<b>Discussion Topics</b>	<b>Activities</b>
Stop 10 – Third Canopy Platform	Discuss how forests support water quality and quantity	Props: Sponge (flood and drought mitigation), umbrella (erosion mitigation), coffee filter (filtration and purification).
Stop 11 – Main Canopy Platform Six	Where does our tap water come from? How many liters do we use per person per day? Discuss misconceptions about water abundance and suggest ways to conserve water.	Using a map of the Metro Vancouver region ask participants to point out local watersheds.
Stop 12 – Meyer’s Glade Lawn	Talk about multiple users of water (household, agriculture, industry etc) that share a watershed.	Water-can activity: teams get a can filled with water, using strings which represent different users, they must transport the can across finish line without dropping. The team problem solves and cooperates in the management of a shared resource.

### *Regular garden visitor tour*

As a control group, 119 regular garden visitors were recruited for the study on a voluntary basis at the botanical garden. A table was set up at the entrance /exit during mid-day hours throughout the summer, mostly on weekends, in the same seasonal period as the Field School tours to recruit people who just arrived or were about to leave the garden. The table displayed the surveys, garden advertisements, and various education materials on plants and birds to draw people’s attention. I also offered organic apples and chocolate snacks as a reward to participants who took part in the survey. Upon agreeing to participate, I asked the visitors to first indicate whether they had just arrived, or finished their visit. For those who had finished their visit, I asked whether they had gone through the food garden and the canopy TreeWalk. The majority of visitors who completed the post-visit survey had gone through the food garden and the canopy TreeWalk (i.e., they had gone through stops 1 to 12). This ensured that both the Field School participants and the

garden visitors had similar exposure to the natural environment in the garden, and the biggest systematic difference between the two groups was the Field School program. During the study there was limited signage throughout the garden, with only Latin names of plants available, so the GVs could not have gleaned answers to the knowledge questions on the survey<sup>10</sup>.

## **5.11 Results**

The goal of the analysis was to examine the impact of the Field School program on people's environmental knowledge, attitudes, and intentions to act. I used a between-subjects 2 (time: pre-visit vs. post-visit) x 2 (group: Field School participants vs. garden visitors) ANOVA to examine each of the following measures. Since we also had 90 matched FS participants (the same person who filled out both pre-visit and post-visit surveys), I also ran the within-subject analysis for the FS participants, with results presented in Appendix B.3. All data was analyzed in R (R Core Team, 2017).

### **5.11.1 Environmental Knowledge**

To examine participants' environmental knowledge, I coded a correct answer to a knowledge question as 1 and incorrect as 0, and calculated the percent of correct answers for each question within the FS participants and GV (see Figure 10) Since the knowledge questions were only included in the post-visit survey, I used a Chi-square non-parametric test with Yates correction to assess any differences between the two groups.

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<sup>10</sup> Since the study, the Garden has invested in infrastructural improvements and installed dozens of interpretative signs and decals throughout the grounds, including two education pods.

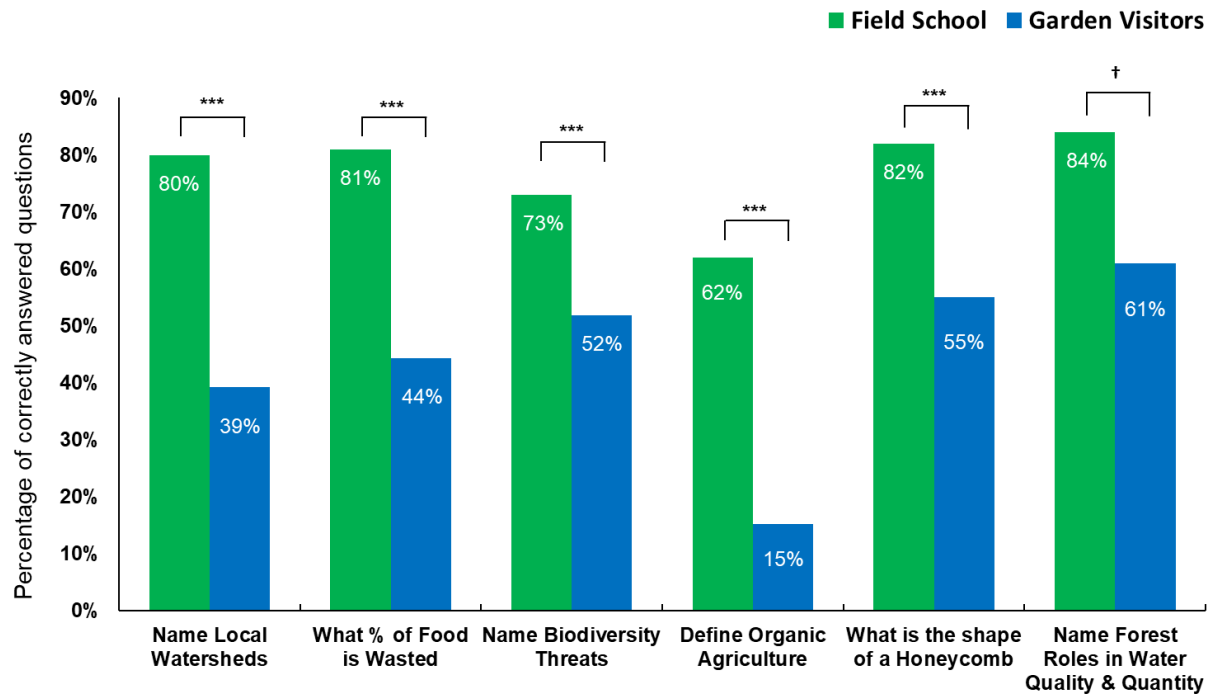


Figure 10. Knowledge measured as percentage of participants who correctly answered each question among the Feld School participants and regular garden visitors. († $p < .1$ , \*\*\* $p < .001$ )

As Figure 10 shows, significantly more FS participants answered the knowledge questions correctly than garden visitors. The difference between the groups was significant for five questions: naming local drinking watersheds [ $\chi^2(1)=35.25$ ,  $p < .001$ ], percentage of food waste [ $\chi^2(1)=30.32$ ,  $p < .001$ ], main biodiversity threats [ $\chi^2(1)=9.60$ ,  $p < .001$ ], defining organic agriculture [ $\chi^2(1)=43.07$ ,  $p < .001$ ], and the shape of a honeycomb cell [ $\chi^2(1)=17.54$ ,  $p < .001$ ]. For the final question “Name forest roles in water quality and quantity”, the difference between the two groups was marginally significant [ $\chi^2(1)=10.90$ ,  $p = .09$ ]. This result shows that the Field School participants were leaving the Garden with higher knowledge of the FS curriculum than regular garden visitors who did not receive the FS program.

### 5.11.2 Environmental Attitudes and Intentions to Act

To examine participants' environmental attitudes and intentions to act, we conducted a 2 (time: pre-visit vs. post-visit) x 2 (group: Field School participants vs. garden visitors) between-subjects ANOVA on the ratings of the four scales. The average ratings in each group on each scale are shown in Figure 11. The internal reliability of the scales was examined via Cronbach's alpha. All four scales had an acceptable reliability: Eco-Centrism  $\alpha=.68$ , New Ecological Paradigm  $\alpha=.65$ , Shortened Nature Relatedness  $\alpha=.71$ , and Intention to Act  $\alpha=.65$ .

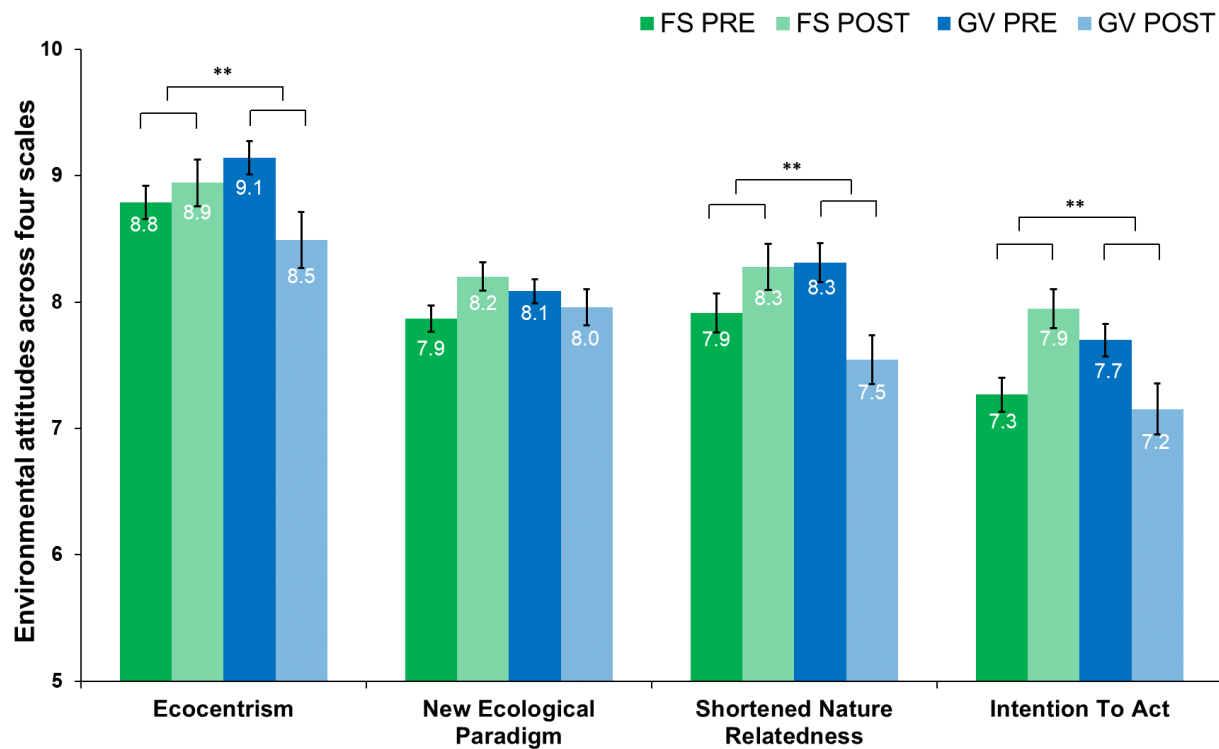


Figure 11. Average ratings on the four scales between the two groups before and after the visit. FS=Field School participants, GV=garden visitors, PRE=pre-visit, POST=post-visit. (Error bars reflect  $\pm 1$  SEM; \*\* $p<.01$ ).

For Eco-centrism, there was no main effect of time [ $F(1, 396)=0.29, p=.58, \eta_p^2=.0007$ ] or group [ $F(1, 396)=1.44, p=.23, \eta_p^2=.003$ ], but there was a significant interaction between time and group

[ $F(1, 396)=9.07, p=.002, \eta_p^2=.022$ ]. This suggests that the Field School participants showed an increase in eco-centrism after the tour, but the garden visitors showed a decline in eco-centrism after the tour. For the New Ecological Paradigm, there was no main effect of time [ $F(1, 396)=1.52, p=.21, \eta_p^2<.001$ ], condition [ $F(1, 396)=0.02, p=.86, \eta_p^2=.003$ ], or interaction between time and group [ $F(1, 396)=1.48, p=.22., \eta_p^2=.002$ ]. For the Shortened Nature Relatedness scale, there was no main effect of time [ $F(1, 397)=0.10, p=.74, \eta_p^2<.001$ ], but a marginal effect of group [ $F(1, 397)=2.83, p=.09, \eta_p^2=.002$ ], and a significant interaction between time and group [ $F(1, 397)=9.73, p<.001, \eta_p^2=.009$ ]. This suggests that the Field School participants showed an increase in nature relatedness after the tour, but the garden visitors showed a decline in nature relatedness after the tour. Finally, for the Intentions to Act scale, there was no effect of time [ $F(1, 397)=3.63, p=.05, \eta_p^2=.009$ ], or the group [ $F(1, 397)=1.89, p=.16, \eta_p^2=.004$ ], but a significant interaction between time and group [ $F(1, 397)=9.11, p=.002, \eta_p^2=.022$ ]. Once again, this suggests that the Field School participants showed an increase in intentions to act after the tour, but garden visitors showed a decline after the tour. Within subjects t-test analysis of 90 matched FS participants (Appendix B3, Figure B3-1) shows a significant increase in environmental attitude scales post visit compared to pre-visit for all four scales. Similar to the knowledge results, there is a consistent pattern emerging from attitudinal data: Field School participants were more eco-centric, more related to nature, and more likely to act after the Field School tour, than before coming to the garden, and also compared to the regular garden visitors who did not experience the Field School tour.

### 5.11.3 Willingness to Engage in Pro-Environmental Behaviours

To examine people's willingness to engage in sustainable actions, I used a Chi-square test with Yates correction to assess differences between the groups. For water conservation (Figure 12), only one action (do less laundry) showed a difference between the pre and post visit, with FS participants displaying a significant increase in willingness to do this action after the visit [ $\chi^2(1)=5.16, p=.02$ ], while for the GV the increase was marginal [ $\chi^2(1)=2.91, p=.08$ ].

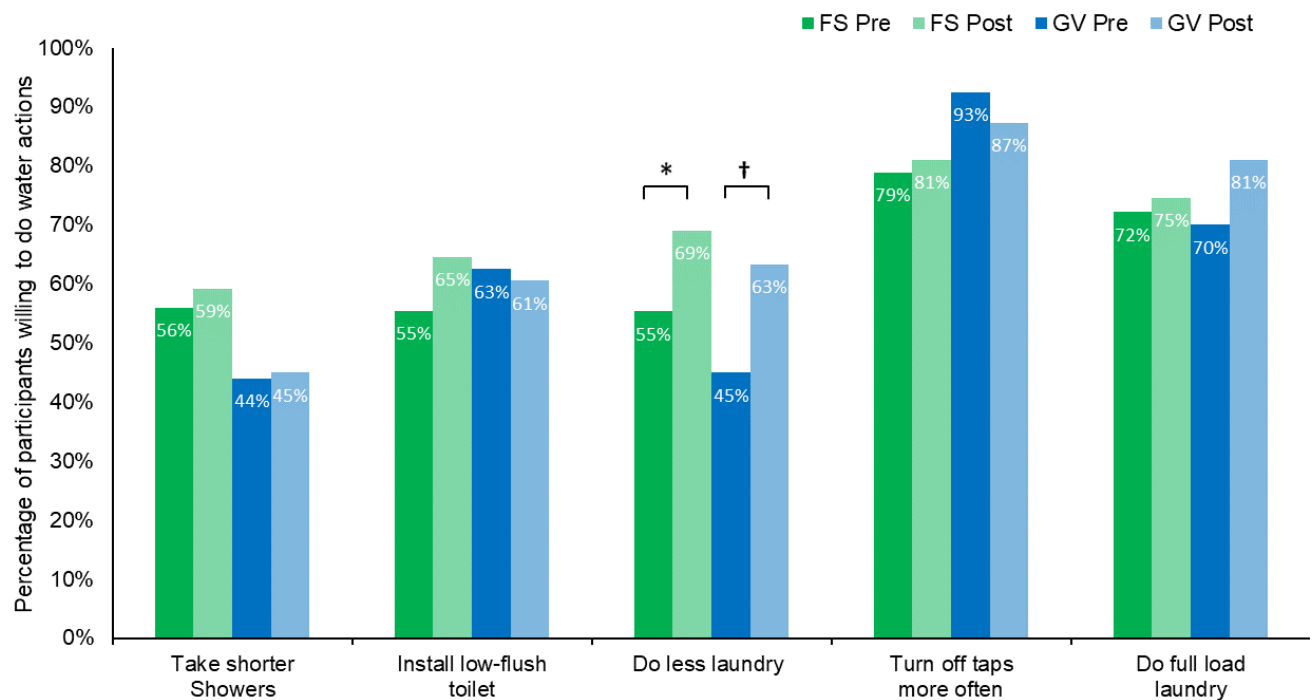


Figure 12. Percentage of participants willing to do water conservation actions. FS=Field School participants, GV=garden visitors, Pre=pre-visit, Post=post-visit. († $p<.1$ , \* $p<.05$ ).

Regarding waste reduction (Figure 13), only one action (choosing items with low packaging) showed a significant change in willingness for the FS group after the tour [ $\chi^2(1)=5.03, p=.02$ ], but the garden visitors showed a numerical decline in willingness to buy items with low packaging after their visit.

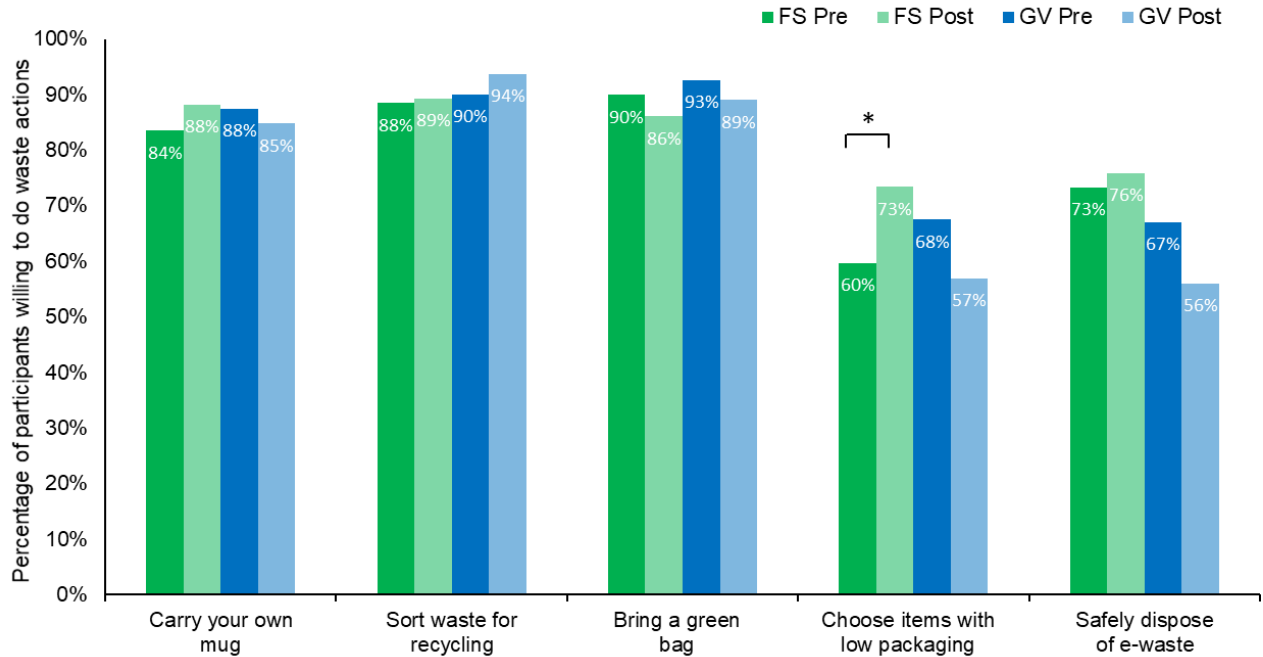


Figure 13. Willingness of participants to engage in actions to reduce waste. FS=Field School participants, GV=garden visitors, Pre=pre-visit, Post=post-visit. (\* $p < .05$ ).

Regarding sustainable food choices (Figure 14), only one action (grow your own food) showed a difference between the groups, where FS participants marginally increased their willingness [ $\chi^2(1)=2.77, p=.09$ ] after the tour, and GV marginally decreased their willingness [ $\chi^2(1)=3.28, p=.06$ ] to do this action after their visit.

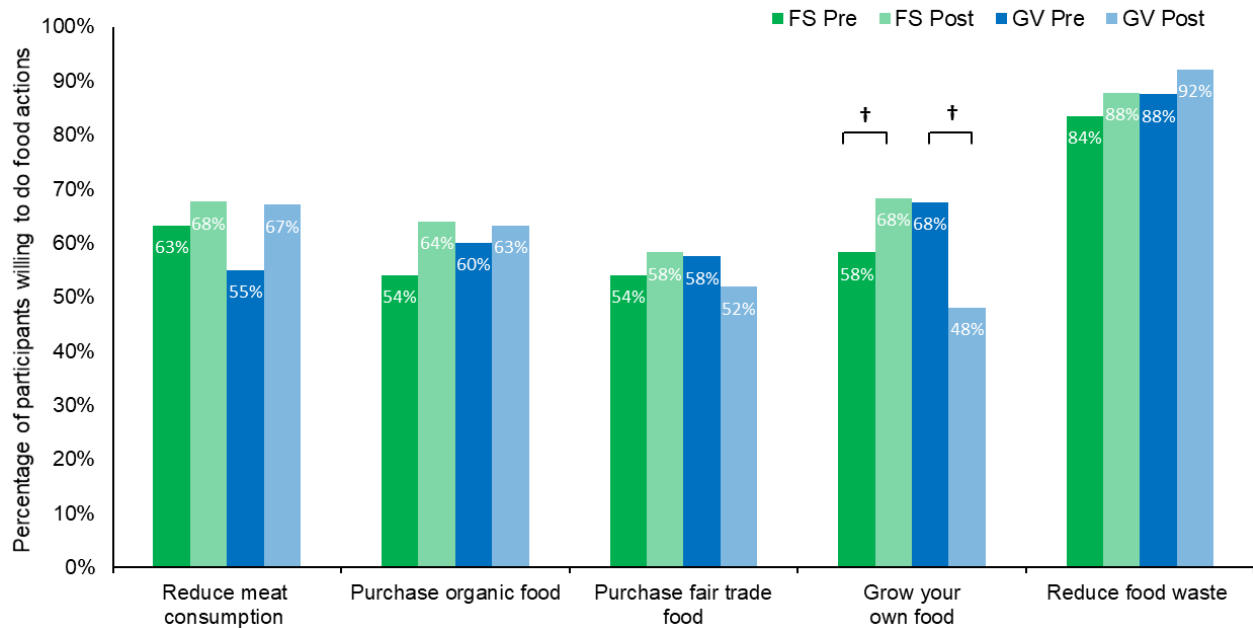


Figure 14. Willingness of participants to make sustainable food choices. FS=Field School participants, GV=garden visitors, Pre=pre-visit, Post=post-visit. († $p < .1$ ).

For biodiversity conservation (Figure 15), marginally more FS participants were willing to buy forestry certified paper after the tour [ $\chi^2(1)=1.91, p=.1$ ], compared to GV whose willingness decreased after the visit [ $\chi^2(1)=3.93, p=.04$ ]. Moreover, marginally more FS participants were willing to volunteer for a nature group [ $\chi^2(1)=2.76, p=.09$ ], and significantly more FS participants were willing to donate to nature conservation [ $\chi^2(1)=5.76, p=.01$ ] after the tour.

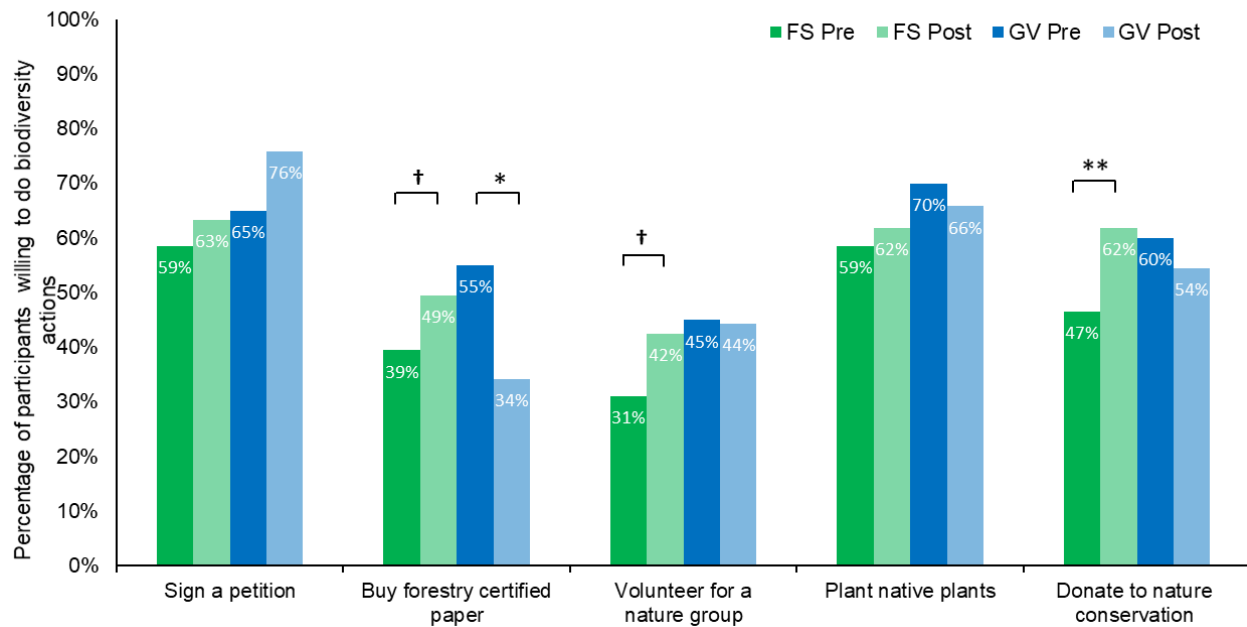


Figure 15. Willingness of participants to do biodiversity conservation actions. FS=Field School participants, GV=garden visitors, Pre=pre-visit, Post=post-visit. († $p<.1$ , \* $p<.05$ , \*\* $p<.01$ ).

Looking at percentages for all 20 actions across the 4 domains (Figures 12-15), the waste reduction domain elicited the highest rate of willingness to act. The lowest rate of willingness was found in the biodiversity conservation domain. A separate analysis of 90 matched FS participants (Appendix B3, Figures 2-5), where the same person filled out a pre-and post-visit survey, showed a significant increase in willingness to engage in 15 out 20 sustainable actions, which can be attributed to FS tour experience.

#### 5.11.4 Regression Analyses

To further understand what factors may determine people's willingness to engage in pro-environmental behaviours, I conducted regression analyses using demographic variables (gender, age, and education), conditions (group and time), and ratings from the four scales (Eco-Centrism, Shortened Revised New Ecological Paradigm, Shortened Nature Relatedness, and Intentions to

Act) to predict people's willingness to engage in actions in each domain (water, waste, food and biodiversity). Table 11 presents the regression analyses.

Table 11. Regression analysis using demographics (gender, age, and education), conditions (group and time), and ratings from the four scales (EC=Eco-Centrism, NEP=New Ecological Paradigm, SNR=Shortened Nature Relatedness, ITA=Intentions to Act) to predict willingness to engage in sustainable actions in each domain. (\* $p < .05$ , \*\* $p < .01$ , \*\*\* $p < .001$ )

<b>Dependent Variable</b>	<b>Predictors</b>	<b><math>\beta</math></b>	<b><math>SE</math></b>	<b><math>t</math> value</b>	<b><math>p</math> value</b>
All domains combined	Gender (Male as reference)	-1.69***	0.49	-3.42	<.001
	Age	0.02	0.01	1.34	0.18
	Education	0.58*	0.24	2.39	0.02
	Group (GV as reference)	-0.27	0.53	-0.51	0.61
	Time (Pre-visit as reference)	-0.22	0.45	-0.49	0.62
	EC	0.39	0.24	1.58	0.11
	NEP	0.13	0.19	0.67	0.50
	SNR	0.38*	0.19	1.96	0.05
	ITA	0.43**	0.17	2.46	0.01
Water domain	Gender (Male as reference)	-0.28*	0.14	-2.09	0.03
	Age	0.01*	0.00	2.22	0.02
	Education	0.16**	0.07	2.48	0.01
	Group (GV as reference)	-0.26	0.14	-1.79	0.07
	Time (Pre-visit as reference)	0.11	0.12	0.91	0.36
	EC	0.09	0.07	1.39	0.16
	NEP	-0.03	0.05	-0.50	0.62
	SNR	0.01	0.05	0.23	0.81
	ITA	0.16***	0.05	3.29	<.001
Waste domain	Gender (Male as reference)	-0.37*	0.16	-2.34	0.02

Dependent Variable	Predictors	$\beta$	SE	t value	p value
	Age	0.00	0.00	0.55	0.58
	Education	0.20**	0.08	2.52	0.01
	Group	0.00	0.17	0.03	0.97
	(GV as reference)				
	Time (Pre-visit as reference)	-0.24	0.15	-1.61	0.10
	EC	0.14	0.08	1.76	0.07
	NEP	0.01	0.06	0.17	0.86
	SNR	0.12*	0.06	1.96	0.05
	ITA	0.03	0.06	0.55	0.58
Food domain					
	Gender (Male as reference)	-0.85***	0.17	-5.14	<.001
	Age	0.00	0.01	0.09	0.93
	Education	0.12	0.08	1.52	0.13
	Group	-0.02	0.18	-0.10	0.92
	(GV as reference)				
	Time (Pre-visit as reference)	-0.10	0.15	-0.67	0.50
	EC	0.01	0.08	0.11	0.91
	NEP	0.10	0.06	1.55	0.12
	SNR	0.22***	0.07	3.39	<.001
	ITA	0.05	0.06	0.82	0.41
Biodiversity domain					
	Gender (Male as reference)	-0.19	0.20	-0.95	0.34
	Age	0.01	0.01	1.40	0.16
	Education	0.08	0.10	0.86	0.39
	Group (GV as reference)	0.02	0.21	0.11	0.91
	Time (Pre-visit as reference)	-0.06	0.18	-0.33	0.74
	EC	0.12	0.10	1.24	0.21
	NEP	0.02	0.08	0.27	0.79
	SNR	0.06	0.08	0.72	0.47
	ITA	0.19***	0.07	2.77	<.001

In all domains combined, gender predicted willingness to act with male participants less willing to act than females ( $\beta=-1.7$ ,  $p<.001$ ). Higher levels of education ( $\beta=.57$ ,  $p=.02$ ), and attitudinal

measures of nature relatedness ( $\beta=.37, p=.05$ ), and intentions to act ( $\beta=.42, p=.01$ ) predicted willingness to engage in the 20 sustainability actions.

Looking at specific domains, gender predicted willingness to act in water conservation actions with male participants less willing than females ( $\beta=-.28, p=.03$ ). Participants with higher age ( $\beta=.01, p=.02$ ), education ( $\beta=.16, p=.01$ ), and intentions to act ( $\beta=.15, p=.001$ ) also predicted willingness to engage in water conservation actions. In the waste domain, gender predicted willingness to act with male participants less willing than females ( $\beta=-0.37, p=.02$ ). Higher education ( $\beta=.19, p=.01$ ) and intentions to act ( $\beta=.12, p=.05$ ) also predicted willingness to engage in waste reduction actions. In the sustainable food domain, gender predicted willingness to act with male participants less willing than females ( $\beta=-0.85, p<.001$ ), along with the attitudinal measure of nature relatedness ( $\beta=.22, p<.001$ ). In the biodiversity domain, the intention to act attitude scale predicted willingness to engage in biodiversity conservation actions ( $\beta=0.19, p<.001$ ).

## **5.12 Conclusion and General Discussion**

The goal of the current study was to examine the impact of the Sustainable Communities Field School program on people's environmental knowledge, attitudes, intentions and willingness to engage in pro-environmental behaviours. I surveyed FS participants before and after the tour, as well as regular garden visitors who went through the garden but did not receive the FS education as a control group. Overall, the results show that after their visit the FS participants gained environmental knowledge, increased their environmental attitudes, and showed greater willingness to engage in specific pro-environmental behaviours than garden visitors who did not

go through the FS tour. These results suggest that the Field School program can be an effective sustainability education model to increase the willingness of people from local businesses and organizations to engage in pro-environmental behaviours.

The increase in environmental knowledge in FS participants was not surprising because instructors specifically discussed the six questions and provided answers during the tour, whereas garden visitors did not receive such information. It is still encouraging to see that the FS participants could recall most of the concepts and were leaving the garden having possibly gained new knowledge. The differences between FS participants and GV on knowledge answers were quite varying. The FS participants showed the biggest difference (41%) in the local watershed question and in the organic agriculture question (47%), and the smallest differences were in the biodiversity threats question (21%) and the forest roles question (23%). The names of local watersheds and the definition of organic agriculture do require more specific knowledge, in which case the Field School curriculum could be more useful, whereas biodiversity threats and forest roles are general knowledge and can be reasoned.

Regarding environmental attitudes, three out of four scales showed significant difference between the FS and GV post-visit to the garden. Since the Field School program contained a number of discussions of sustainability topics, and included group activities, and interactions between group members, it is currently not possible to tease apart which factors explained the changes in knowledge, attitudes, intentions and willingness to act. An unexpected result was the decline in the attitude measures and intention to act (Figure 11) for the garden visitors after the visit. This decline could indicate that after visiting the botanical garden, people felt less nature-

oriented or connected to nature, and showed lower intentions to act, compared to before their visit. While it is possible that without the tour the garden visitors may become more complacent with nature after their visit, and thus become less concerned about the environment and less motivated to act, it is also possible that sampling differences of the visitors (different visitors who filled out the pre-visit and post-visit surveys) can account for the decrease in these measures. Although we cannot explain this decline, the results suggest that merely accessing nature may not be enough to raise environmental awareness and promote public actions. The fact that GV showed some decline in the attitude scales likely attenuated the difference between the groups and the benefits of the FS experience. Regarding the ITA scale, it is interesting to note that although the instructors made no mention of voting, use of air conditioning and heating, or carpool and use of public transport during the tour, FS participants showed agreement and intent to engage in these behaviours.

Among the 20 pro-environmental actions identified for the water, waste, food, and biodiversity domains, FS participants showed an increase in the willingness to engage in six actions compared to garden visitors. The six actions were: do less laundry, choose items with low packaging, grow your own food, buy forestry certified paper, volunteer for a nature group, and donate to a nature conservation group. Within group analysis of 90 matched FS participants (Appendix B3, Figures 2-5), where the same person filled out a pre-and post-visit survey, showed a significant increase in willingness to engage in 15 out 20 sustainable actions. The increase in willingness can be explained by the FS curriculum and activities. This can be explained by the FS curriculum and activities. For example, the goal of the coffee cup activity was to unpack the amount of energy and materials that go into the production of a to-go cup of

coffee, so participants may be more willing to buy items with low packaging because of this activity. Discussing the benefits of organic food practices and learning about food waste in the food garden, and sampling of edible flowers, may have motivated participants' willingness to grow their own food and reduce food waste. Discussion of the ecosystem services forests provide on the canopy walk may have increased participants' willingness to buy forestry certified products. Learning about the work SPEC does and the fact that one of the instructors was from that organization may have increased their willingness to volunteer for a nature group and donate to nature conservation.

It is important to acknowledge that actions in the willingness to act measure were not equal in terms of the cost and effort involved, which could determine the impact of the FS program. For example, more FS participants were willing to do less laundry after the FS tour in the water domain, which required less cost and effort. However, this was not the case for the other domains. More FS participants were willing to grow their own food after the FS tour in the food domain, which would require more effort and cost. This increase in willingness may be driven by the food garden tour. More FS participants were willing to buy forestry certificated paper, volunteer for a nature group, and donate to nature conservation after the FS tour in the biodiversity domain, which again requires more effort and cost. This increase in willingness may be driven by the activity on the roles of forest and the mention of the partnership with a non-profit organization in the FS curriculum. Across the four behavioural domains, regression analyses revealed that gender (being female), higher education, nature relatedness, and intentions to act predicted greater willingness to engage in pro-environmental behaviours. These findings are consistent with past research that showed gender, education, and nature relatedness are

associated with stronger environmental attitudes and behaviour (Dunlap et al., 2000; Kollmuss & Agyeman, 2002; Nisbet et al., 2009; Schultz et al., 2004; Williams et al., 2015).

Many gardens already incorporate education and community outreach within their other horticultural goals, which makes gardens unique spaces for nature education. While this study demonstrates that the UBC botanical garden can provide a useful platform to engage local communities on sustainability issues, it is important to acknowledge the diversity of botanical gardens around the world and various forms they can take: from lush garden ecosystems of Kirstenbosch with local or exotic plants, to more stylized European Botanic Gardens such as Leiden in the Netherlands. Similarly, botanical gardens are mini curated representations of nature (Heyd, 2006), and this diversity of plants and other garden features can have varying impacts on visitor experiences, their connection with nature and understanding of biodiversity.

### **5.13 Limitations and Directions for Future Research**

The current study had several limitations. First, we could not employ random assignment between the two groups, since FS tours were arranged and recruited from the organizations ahead of time, whereas the garden visitors spontaneously visited the garden and paid the entrance fee themselves. As a better control group, future studies should randomly assign participants to serve in the FS condition or the control condition and compare their responses afterwards. Second, we could not control for the group sizes and visit durations between the FS participants and GV. Field School group sizes were often much larger, and the participants stayed in the garden for at least three hours, whereas garden visitors tend to show up in smaller groups and had a shorter visit in the garden. Third, the FS participants were all employees from the same

organization, whereas garden visitors tend to be family members. The difference may change the dynamics of the interactions or the experiences of the visit for FS participants and garden visitors. It is unclear whether garden visitors would show the same effects after the FS tour because they may come to the garden for leisure and not education purposes. Future programs should standardize the sizes and duration between the two groups for a more like-to-like comparison. Fourth, a very important limitation is that current study did not measure actual behaviour since all measures were self-reports regarding willingness to act. Finally, we need to address the possibility that the differences observed between the groups may be due to a combination of priming and social desirability bias since FS participants were there with their employer or fellow peers. Given the study design, this is difficult to tease out, and future studies should try to control for this factor, or incorporate into the study design.

While difficult to coordinate and implement, a key recommendation for future studies is to measure actual behaviours in one or more sustainability domains. For example, measure the use of resources while at the garden or at the place of employment (such as increased waste sorting), formation of sustainability committees, volunteering, financial donations or signing of actual petitions for environmental conservation. Fifth, the current study only measured changes right after the tour, so it's unclear how long any of the effects will last. Future studies should examine the longevity of the effects of the FS program, following up with the participants weeks after their visit. Sixth, not many participants completed both pre-and post-visit surveys. This could be due to a number of reasons, including a lack of general willingness to complete surveys, a rush to leave the garden, missing answers on the surveys, or not providing demographic details so that I could match their surveys. Future studies should make the survey shorter to save time, or provide

larger incentives for completing the survey. Future studies should also include a pre-visit knowledge test to ensure that the two groups were not different before the tour, and to be able to assess if FS groups learned new knowledge. Making the survey shorter might help increase pre-visit survey completion rates while standardizing survey completion time. Finally, I cannot say which aspect of the FS program caused which effects. Future research should test each component of the FS program separately in order to identify their impact on participants' environmental knowledge, connection with nature or their willingness to act. For example, an impact of an education tour with or without the team-building activities and the excitement of the TreeWalk Canopy could be an interesting new direction for the Garden to study.

Given the growing demand for nature excursions and team-building activities, and gardens' mandate to educate and research, this study suggests that community education programs like the Field School could be an effective way satisfy both groups while informing and engaging people in topics of sustainability. Consistent with the 2030 Sustainable Development Goals, community-based research collaborations can provide important opportunities for botanical gardens and nature-based educational organizations to have a direct contribution to local and global sustainability education.

## **Chapter 6: Conclusion and General Discussion**

### **6.1 Summary of Chapters**

The goal of this dissertation is to explore theory and practice behind solutions to motivate and engage individuals and communities in pro-environmental behaviour. While first two research chapters specifically deal with strategies that reduce contamination in consumer and household waste streams, the third examines willingness to act in other sustainability domains, of which waste is one. Past studies on recycling and composting have often focused exclusively on participation, but since contamination of waste streams can often undermine the positive intent of participation, my studies make a novel contribution to literature by examining participation and contamination while testing multiple interventions with theoretical and practical implications for effective design of future interventions. My specific focus on waste was borne out of the fact that most of the waste created in North America is still sent to landfill, even though majority of it can be recycled and used as a resource (Geyer et al., 2017; Hottle et al., 2015). In addition, strategies that can help in this domain may have relevance to other similar pro-environmental actions.

While various elements, such as convenience or social norms, may motivate people to use the recycling and composting bins instead of garbage, they do not guarantee the accuracy of sorting. Since contamination of waste streams has the potential to cancel out the positive intent of participation, there is a tangible research need for strategies that can motivate people to recycle more frequently and accurately. With this goal in mind, the first two research questions of this dissertation focus on strategies to improve the accuracy of sorting in private and public domains through use of active and passive prompts, and immediate feedback on errors through a computer game. The third research question expands the behavioural analysis to examine willingness to act in four behavioural domains: waste, water, food and biodiversity. Together

they aim to contribute to best practices in the study of waste diversion, community engagement and design of pathways to motivate long-term pro-environmental behaviour change.

### **6.1.1 Chapters 3 and 4: The Waste Sorting Challenge**

Chapters 3 and 4 of this dissertation addressed the first two research questions examining strategies for effective public waste sorting participation (i.e. using their recycling and compost bins instead of throwing everything in garbage), and accuracy of sorting (i.e. reduction of contamination) across the waste streams. More specifically, Chapter 3 set out to compare effectiveness of visual prompts and volunteer guidance on waste participation and accuracy during a popular UBC public festival. Previous studies had shown promising benefits of prompts, visual cues and use of volunteers, but not compared all of them at once. This study's contribution is in testing multiple interventions at once to determine how they compare to each other, especially in case of visual cues (3D items) which is missing in the literature. The interventions differ in the level of convenience they afford, and the effort required by participants to correctly sort, which has theoretical implications for pro-environmental research regarding convenience and effort people are able or willing to exert. A randomized control trial was conducted at the Apple Festival to examine impact of four conditions and three interventions. The results showed that volunteer staff significantly reduced contamination in all waste streams, compared to the other interventions of 2D and 3D signage, as well as the control. Since most waste management schemes require front-end sorting which relies on individuals to sort waste at the bins, using volunteers offers a teaching opportunity to give feedback to people on how to sort. Receiving training before the festival, dozens of volunteers were able to reduce contamination by 96% in the organics bin, 97 % in the recyclable containers bin, 97% in the

paper bin, and 85 % in the garbage bin. No other condition had a significant effect on the contamination across streams, with analysis showing that the BT3D display was not the second-best condition for all streams. BT3D had second-least contamination in organics and paper streams, but control performed better in recyclable containers, and BT reduced contamination better in garbage stream. It is unclear why there is such difference of performance across streams. It is likely due to a mix of factors including that the BT3D display was not clear, with a mix of 2D and 3D items creating an information overload.

While the finding that volunteer staffed bins had the lowest amount of contamination is unsurprising, this study provides further empirical evidence that in order to effectively reduce contamination of recycling bins and ensure diversion of useful materials away from the landfill, the event organizers should have trained staff direct and help people participate correctly in the behaviour we want them to do. A surprise finding from my data is how poorly the bin top 3D display performed compared to just signage. I had hypothesized that using real colourful items obtained from the festival vendors as examples on top of bins should have performed better than the 2D inanimate signs, since real items would draw attention as visual cues signalling exactly in which bin to put which item. However, there was no significant difference between the 2D and 3D interventions, as there was a waste stream (containers) where the control performed better than 3D and 2D display in reduction of contamination. This shows limitations of passive communicative material to educate and guide more accurate sorting (and similar pro-environmental behaviour), which match the behavioural economics and other literature critical of information provision campaigns covered in Chapter 2.

Regarding weight of materials in the bins no intervention had a significant impact on weight, although there was a significant impact of waste stream type on the weight of bins, with compost the most highly generated waste stream at the festival across conditions. This makes sense as food leftovers are often heavier than other materials, and this was a food related event. Results of this study demonstrate that events and festivals can generate a large amount of waste which needs to be properly sorted to help achieve zero waste goals, which UBC is committed to. If events simply rely on existing signage and standard bin set up without active guidance of volunteer or staff, they risk severe contamination of recycling and compost bins which will likely result in all of the contents sent to the landfill. Chapter 3 demonstrated difficulty of devising clear and effective cues and prompts as a passive method of education and feedback. This in part due to the diversity of take-out materials in the marketplace, along with people's reliance on intuitive thinking and inability to parse through all of the information to make the most accurate decisions. When 3D items (real life materials) are used as exemplars on top of the bins, their appearance, neatness and clarity is very important. Using a clear plastic box for the items display might be beneficial as indicated in some campus pilots (Foster, 2016). This will hopefully signal that the items are visual cues of materials allowed in the bin, and prevent people from putting additional items next to it, which had complicated and compromised the visual display in my study.

While Chapter 3 examined waste contamination in a public setting and compared passive vs active prompts to give people information on correct sorting, Chapter 4 focused on household recycling behaviour in a more private setting – student residences. Building on the hypothesis that people need knowledge and feedback to sort better, Chapter 4 contains three experiments

that study the impact of an online sorting game (with immediate feedback if a player gets it right or wrong) on sorting behaviour and if accuracy can improve. More specifically I examine the game's influence on people's knowledge and sorting accuracy over time, compared to a game with no feedback, and standard signage available in recycling rooms. Given the effectiveness of immediate feedback on learning, an unexplored question is whether immediate feedback facilitates the acquisition of recycling and composting knowledge and improves sorting accuracy by correcting recycling errors immediately. Experiment 1 of Chapter 4 showed that participants in the lab learned to sort more accurately after receiving immediate feedback after each trial in the first block, even when feedback was no longer provided in the second block. The feedback had minimal impact on the sorting speed. In Experiment 2, using motion tracking technology instead of keys, results from Experiment 1 were replicated, showing that feedback in the learning condition improved sorting accuracy for all four bins, except that the effect was weaker for the paper bin. To test the benefits of feedback in under real-world condition, Experiment 3 deployed the game in the field setting of a large student residence and compares it to a building where residents did not play the game. Both experimental conditions (game and no game buildings) had standard recycling signage in the recycling rooms. Results showed that the weight of food scraps increased significantly in the game building compared to the control but the weight increase did not result in an increase in contamination compared to the control. The sorting game also marginally decreased contamination in the paper ( $p=.09$ ) and recyclable containers ( $p=.08$ ) between the intervention period and post-intervention period in the game building, compared to the control building that did not play the game.

Looking across Experiments 1 and 2 to compare different modes of sorting (e.g. key strokes and drag-and-drop gestures), data shows that overall sorting accuracy improved statistically from first block to second block in the learning condition compared to control. The learning effects were the most prominent in food scraps/ organics, containers and garbage. This shows that it was the immediate feedback on errors that improved sorting accuracy and not the mode of sorting gesture (keystroke and gestures). Sorting accuracy effects were consistent across the waste streams, although feedback did not optimize sorting motion, or sorting speed. Taken together, these findings suggest that the sorting game with immediate feedback on accuracy of sorting decisions can help reduce contamination of waste streams and improve sorting accuracy over time, when knowledge alone is the main factor in accurate sorting. Even when feedback was removed, lab tests showed that knowledge remained, as the accuracy was higher than in the control condition. Conversely, the effects of the game in the field experiment were less pronounced than the lab tests. This can be due to several factors and research limitations which will be discussed in greater detail in the next section, but it mainly demonstrates that recycling and composting behaviours (like most pro-environmental actions) depend on more than just knowledge.

### **6.1.2 Chapter 5: Education in Nature**

Chapter 5 expands the behavioural scope and focuses on the third research question of this dissertation to evaluate the impact of a community-based sustainability education program on people's knowledge, attitudes, and willingness to act in 20 pro-environmental behaviours. The Sustainable Communities (FS) Field School program is delivered at the UBC botanical garden in collaboration with Society Promoting Environmental Conservation (SPEC), one of Canada's

oldest environmental organizations. Participants of the FS program were surveyed before and after the tour, and their answers compared to the regular garden visitors (GV) who went through the garden on their own and did not receive the education tour or hands-on activities. The results showed that compared to the GVs, the FS participants were better able to answer curriculum knowledge questions, showed an increase in connection to nature, and willingness to engage in certain pro-environmental behaviours after the tour. FS participants scored much higher on environmental knowledge questions (about water, waste and biodiversity) compared to the control group, however this is not too surprising given that instructors specifically discussed or answered the six questions during the tour. Regarding environmental attitudes, after the visit the FS participants showed a significant increase in three out of four scales (Ecocentrism, Shortened Nature Relatedness, and Intention to Act) compared to their pre-visit surveys. Additionally, the FS participants increase in self-reported measure was also higher compared to the regular GV who did not receive the 3-hour education nature tour with team activities. Within-subject analysis of matched FS participants (N=90) confirmed the positive trend seen in across group analysis with GVs. After their visit, the matched FS participants reported an increase in all four attitude scales, with willingness to do 15 out of 20 environmental actions compared to their pre-visit surveys (Appendix B.3). Across the 20 actions in the four sustainability domains, the waste reduction domain elicited the highest rate of willingness to act, while the lowest rate was found in the biodiversity conservation domain.

The key component of the FS program is to engage community members from local businesses in team-building activities and discussions using prompts and stories that highlight benefits of ecosystem services and their importance for water and food provision, waste management and

biodiversity protection. It is currently difficult to tease out which part of the FS tour experience affected which component of the participants' post-visit knowledge, attitude or willingness to act. However, positive changes in FS participants' self-reports, compared to their pre-visit surveys and GV post-visit surveys, suggest that FS program can be an effective way to educate and engage public in topics of sustainability. Regular garden visitors who did self-guided tours showed lower environmental attitudes and less willingness to act post visit, compared to their pre-visit counterparts. Unlike the Field School participants where the same person filled out both pre and post visit surveys, the regular garden visitor groups who completed my surveys are not the same individuals. Therefore, the decrease could be due to many factors, such as group differences between those arriving and leaving, fatigue, hunger, and distraction toward upcoming tasks, as opposed to nature visit backfiring. Still, the finding is puzzling, and should be investigated further because it suggests that just having access to nature does not automatically translate to increased connection to nature, and willingness to act more sustainably. Nature based organizations, like gardens and parks, should engage their visitors more directly in topics of sustainability, either through guided tours, hands-on activities, interactive visual displays, or other methods, if they want to ensure their guests leave with specific message or motivation. At the same time, similar to the insights from my waste-sorting chapters, it takes more than information to galvanize pro-environmental actions. Factors like convenience, social norms and available infrastructure can all derail or support the behavioural pathways, and if we are only focused on improving people's knowledge and not conscious of the whole ecosystem (or contexts) where the action takes place, it is unlikely that majority of people will be able to act sustainably. I discuss theoretical and practical implications of these studies in section 6.3.

## **6.2 Research Limitations**

This dissertation and research studies presented have several limitations. In Chapter 3, I could not control the foot traffic near each experimental condition, and there was variability in how convenient the bins were to access throughout the day. This variability may have contributed to the large error bars. Additionally, I don't know the long-term benefits of the volunteer feedback because we did not track participants after they left the festival. The null effects of bin tops and bin tops with 3D displays do not necessarily mean that signage does not work. This only highlights the need to develop more effective signage to guide sorting at events. Finally, Chapter 3 did not find evidence that volunteer staff increased waste diversion from landfill since the weight of the bins did not change. This raises the limits of volunteer guidance on sorting.

Chapter 4 lab and field studies are testing different levels of data, where one tests individual sorting accuracy immediately after playing the game, and the field experiment tested actual sorting behaviour which may take place days and weeks after playing the game. Real world circumstances of household sorting include many more items than were represented in the game. In Chapters 3 and 4 dependant variables were kilogram of materials and the number of contaminants per bin. Unlike in Chapter 3 where I could empty-out all of the bin's contents to thoroughly count contaminants, I was not able to do so in Chapter 4 field experiment. Likewise, in the field experiment I was unable to measure and inspect garbage waste stream in the student residences for safety reasons, which would have allowed me to systematically compare game effects with the lab results. The inability to thoroughly inspect all of the contents of recycling and food scraps bins is a limitation, since there was no convenient or hygienic way to offload the materials while examining the bins, and myself and research assistants had to rely on visual

inspection using tongs to move materials around. This was especially problematic for the container and food scraps bins when they were more than 70% full. Another limitation of the Chapter 4 field Experiment 3 is that we were only able to reach about half of all the available residents to play the game, which means our results measured combined sorting abilities of residents who played the game and those who did not. Finally, I did not have sufficient statistical power in Experiment 3, since we could only measure the bins for 11 weeks during the spring semester, with a few data points in each week. The experiment had to be terminated at the end of the semester because students moved out of the residence.

Chapter 5 Field School study had the following limitations: First, I could not employ random assignment between the two groups (FS & GV), since FS tours were arranged and recruited from the organizations ahead of time, whereas the garden visitors spontaneously visited the garden and paid the entrance fee themselves. As a better control group, future studies should randomly assign participants to serve in the FS condition or the control condition, and compare their responses afterwards. Second, I could not control for the group sizes and visit durations between the FS participants and GV. Field School group sizes were much larger and the tour was around three hours, whereas garden visitors tended to show up in small groups and spent less time in the garden. Third, FS participants were all employees from the same organization, whereas garden visitors tend to be family members or groups of friends. It is unclear whether garden visitors would show the same effects after the FS tour because they may come to the garden for leisure and not education purposes. Fourth, we did not measure actual behaviour and all measures were self-reports. Fifth, the study only measured changes after the tour, so it's unclear how long the effects last. Sixth, not many participants completed both pre-and post-visit surveys. This could

be due to a number of reasons, including a lack of willingness to complete surveys, a rush to leave the garden for home, and missing answers on the survey so we could not match their responses. I also do not know which aspect of the FS program (e.g. canopy walkway, group activities, guided tour, etc.) impacted the attitudes or willingness to act. Finally, we also need to address the possibility that the differences observed between the groups may be due to a combination of priming and social desirability bias since FS participants were there with their employer or fellow peers. Given the study design, this is difficult to tease out, and future studies should try to control for this factor or incorporate into the study design.

### **6.3 Theoretical and Practical Implications**

Literature review in Chapter 2 highlighted many decades of behavioural research and insights which have shown that human actions are determined by a large range of internal and external factors, and there is no silver bullet intervention and prescriptions that work for all types of sustainability actions and all types of contexts due to the variability of factors. That said, there are methods and strategies that seem to apply to many environmental behaviours, such as waste sorting or water conservation, and they include education and knowledge dissemination, social influence of peers, availability of materials, economic or technological policies, or convenience of infrastructure. In next sections I draw out some of the key findings from each chapter and provide some thoughts on how these findings enrich our theoretical understanding of the antecedents of pro-environmental behaviour, while providing recommendations for planners and policy makers.

Chapter 3 adds to the pro-environmental research literature by testing multiple recycling interventions at the same time to determine how they compare to each other, especially in case of visual (3D) prompts which has not been tested empirically. The interventions differ in the level of convenience they afford, and the effort required by participants to correctly sort, which has theoretical implications for pro-environmental research regarding convenience and effort people are able or willing to exert. The data from this study matches behavioural insights by demonstrating the ineffectiveness of passive methods of information dissemination (such as 2D and 3D signage), since none of them had nearly as good of an effect on contamination levels as having trained volunteers help people sort. While this finding is not too surprising, I did hypothesize that 3D display intervention would perform better than 2D alone, given that visual cues of real life items should have in theory signalled to people where their waste should go. However, there was no significant difference between the 2D and 3D interventions, which could be due to several factors: perhaps my display was not clear enough, festival goers didn't have the time or interest to correctly sort, or too many take-out items created a confusion and information overload. At any rate, inability of passive prompts adds to the argument that knowledge alone (without a direct social norming factor) is simply not a significant motivator of action.

These findings confirms that information focused interventions are not enough to motivate behaviours like correct waste sorting if the environmental conditions are complex, messy, and require individual agency and environmental attitudes to fight against the systems designed to make unsustainable behaviour more convenient and prevalent. We must always remain mindful of the fact that people's attention and cognitive capacities are limited, they may or may not have previous pro-environmental experiences or attitudes, and at the same time, we have inconvenient

and inconsistent infrastructure which often conflicts with people's intuitive decision-making and desire for convenience. In contrast, having a trained staff member or volunteer direct people where to sort items provided more than just information: that person is reducing complexity into clear direction, offers convenience as well as social influence about prevalent norms and attitudes. Posters, flyers, and other visual prompts can still be a part of the education strategy, and there are new methods of improvement being continually devised to make them more useful and easy to comprehend. However, as we look for more engaging methods of education and feedback, the social influence of peers and neighbours is an inescapable powerful component that comes out of all three of my research chapters. While I did not specifically set out to study the social elements and influence on behaviour, its priming and motivating features were unavoidable, given that behavioural research inevitably involves studies of people, and people are parts of social networks. For example, in Chapter 4 with the sorting game, I noticed that people were more likely to stop and play the sorting game when they saw their neighbours at our desk. Similarly, in Chapter 5 the Field School tours are steeped in social influence since participants were brought to the gardens by their employers. While on one hand these social components cannot be easily teased out due to my study design, observations from my research match the literature insights from social psychology and socio-cultural studies discussed in Chapter 2 about the importance of social and cultural values that prime environmental contexts and motivate people's willingness to act.

Chapters 3 and 4 made practical and theoretical contributions demonstrating that immediate feedback and active guidance can lead to significant improvements in accuracy of sorting across all waste streams, in particular under controlled environments (like a lab) or when knowledge is

the only component missing. At the same time, these chapters point out that complexity of environmental conditions and inconvenience are insurmountable barriers to recycling and composting behaviours, which cannot be overcome by more information and feedback. For example, having staff or volunteers help sort waste at the front or back end makes a tremendous impact on how well waste was sorted, and therefore active guidance should be employed whenever possible. That said, this strategy might be too expensive or impractical for all contexts. Likewise, the sorting game with immediate feedback on errors significantly improved accuracy compared to no feedback condition, but it took us several weeks of boothing in the lobbies of residences to engage half of building participants, and the effects were much better in the lab than in the student residences. Real-world conditions involve many more items than were featured in the game, and require skills and materials that go beyond knowledge of the sorting guidelines.

Since many pro-environmental behaviours depend on people's active participation, and yet people vary in their ability and willingness to act, policy makers, designers and change-makers need to spend time and money to design and build systems that can motivate action through the powers of convenience, simplicity and positive social norms. When people's individual agency or ability to act is low, the surrounding systems need to bear the brunt of the work (cost or effort) to enable behaviour to take place through defaults, choice architecture, positive feedback and social influence. When people see their peers act, it can further motivate their own attitudes and willingness to act, creating a positive feedback loop. Over time, as people engage in behaviours they will likely build more knowledge and behaviour supporting attitudes, providing social modeling for others, and entrenching sustainability practices within their local contexts.

Numerous sorting errors were identified in waste studies Chapters 3 and 4, showing that people had trouble sorting certain items, especially if they conflict with our intuitive way of classification. These errors could be driven by at least two reasons. First, people may categorize the item based on the physical properties of materials. For example, paper towels, napkins, and chopsticks were disposed incorrectly into paper bins, but should be in the food scraps bin instead. All three items shared similar physical properties of paper, which results in the error of sorting them as paper. Second, people may categorize the items based on the physical form of the items. For instance, broken glass bottles, and styrofoam were disposed incorrectly into the recyclable containers bin, but should be in the garbage bin instead. Both items possess the form of a container, and therefore are categorized as containers. Similarly, compostable containers (made of paper and look like they have a plastic lining) can be found in paper and container bins, instead of compost bins.

These findings match behavioural insights that many recycling decisions are driven largely by intuition, and people can incorrectly categorize items based on physical properties or form. Since human decision-making relies on both conscious and unconscious elements, with preferences for simplicity and convenience, it is crucial that recycling and composting processes synchronize their efforts and work with people's intuitive systems. Otherwise, errors will persist and so will the loss of resources and revenue. For these reasons, Chapter 3 highlights the importance of planning for zero-waste events and festivals ahead of time, since variety of materials at the event made it difficult to set up clear and simplified 2D and 3D signage. It would help immensely if the event organizers can work with the vendors ahead of time to simplify and standardize take-out materials given out to public, while ensuring they are acceptable in the local recycling or

composting system. A suggestion by the UBC Senior Planning and Sustainability Engineer Bud Fraser is: anything that touches solid food should be compostable, and anything you drink from is recyclable. Policy makers, designers and planners must work across municipalities and industries to simplify the sorting conditions (signage, infrastructure, material packaging) so that recycling behaviour can follow people's instinctual tendencies for convenience and consistency.

Chapter 5 demonstrated that Field School nature tours were successful in raising participants' environmental knowledge, connections with nature and willingness to act in topics of sustainability. Previous studies have shown that education in nature can have a positive impact on people's physiological and emotional state of being, and this study contributes to the literature by combining benefits of nature exposure with engaging education tours to raise awareness and motivate pro-environmental action. Since botanical gardens and other nature-based organizations receive thousands of visitors each year, they can positively influence people's attitudes, knowledge and willingness to act by setting up programs and public tours like the Field School. Regular garden visitors who did not go through the education tour showed less willingness to act. While this may be due to various factors it may also show that simply accessing nature does not have a significant impact on people's attitudes, knowledge and willingness to act may, unless the ecological connections are explicitly made, and visitors directly engaged. Engagement can take many forms, either through story-telling, prompts and visual aids, to group or paired activities. That said, while engaging nature tours can raise general awareness and willingness to act, it is unclear what percentage will lead to actual behaviour once individuals depart the idyllic botanical garden environment and return to the busy and complex environments of their everyday lives where sustainable actions are often difficult or expensive to do.

These three studies in aggregate show while on one hand we can intervene in some aspects of people's lives, such as impact their knowledge or environmental awareness, since most pro-environmental behaviours depend on numerous interconnected elements which come together to support the behaviour over time, education and awareness raising strategies need to be incorporated and aligned within contextual elements to facilitate and enable behaviour to take place. In some instances, contextual factors need to be completely changed, and we need to examine the whole ecosystem of contexts where the behaviour takes place, at home or in the public, where systems of provision and very day life are designed to enable people's individual and collective agency to act sustainably.

#### **6.4 Future Research Directions**

There are a few pro-environmental studies examining long-term effects of interventions, especially in residential settings. Such studies would be invaluable to test the persistence of interventions (such as sorting game or door to door feedback), and also provide an indication of general improvements in participation or accuracy over time. Because student residences have a relatively high yearly turn-over of inhabitants, it can be difficult to track the same population of students. However, measuring waste participation and contamination during a long-term study, can aid an investigation whether some 'knowledge' or 'practice' can persist over time even as residential make-up changes. It would also show whether there is any long-term improvement in contamination reduction, and especially waste diversion. Future studies on waste and contamination should always try to measure the garbage stream as well, to discern the rate of consumption and true landfill diversion. One of the research limitations for my waste related studies has been a conceptualization of severity of contamination per bin. Contamination can be

difficult to discern from a simple count number (especially when relying on visual inspection), and there is a research need to develop better methods to inspect, measure and compare severity of contamination per bin per waste stream, so that studies and interventions can be better compared to each other.

Waste-related research experiments in this dissertation examined effectiveness of various education strategies, with an emphasis on active guidance, prompts, infrastructure and feedback. While these are necessary components of waste sorting behaviour, there are many other elements that facilitate pro-environmental action. A meta analysis of 36 studies using 70 psychological interventions to promote household recycling by Varotto and Spagnolli (2017) revealed that social modeling and environmental alterations have the potential for the biggest impacts. They also point out under-studied areas of recycling behaviour that involve contextual and socio-demographic determinants, such as characteristics and location of bins, product (materials) characteristics, environmental attitudes, sense of community, recycling experience and demographic factors (Varotto & Spagnolli, 2017). Studies that address these research gaps would help provide a richer understanding of the recycling and pro-environmental behaviour, and lead to more effective strategies for participation and contamination reduction.

Multi-unit residential buildings (MURBs), such as student residences, are one of the sectors with lowest participation in the household recycling program. Unlike single family homes, where a lack of a blue or green bin for weekly collection signals non-compliance, in MURBs it can be much harder to target and motivate residents that do not recycle since it is not always possible to identify and reach them. One of the ways property managers and UBC Student Housing and

Hospitality Services can address this issue is to try to engage residents at the move-in period, as some past research has shown there are opportunities for behaviour change when people move homes or change jobs (Darnton et al., 2011; McKenzie-Mohr, 2000). For student residences, this often implies summer months, especially August and September when the move-in is at its height, and new residents may be more willing to follow social influence of others and form new habits. This may also be a good time to ensure all rooms have a compost and recycling bins, since some students claimed their room did not have these items. Similarly, when residence advisers (RAs) do visits and organize welcome events, they should incorporate sustainability within their programming to demonstrate desired social norms, provide tools, and information. Future studies can also investigate what kind of set up people have in their suite to recycle materials, and how it effects whether they even participate, and how correctly. For example, some people might have several bags or bins inside their homes to pre-sort items before dropping them off in recycling bins, while others may collect everything in one bag or bin and have to re-sort things once inside the recycling room. It could also be interesting to see if different modes of sorting inside the unit and in the building/ homes can facilitate better sorting participation and accuracy - do these different set ups and conveniences facilitate behaviour in aggregate, and if so, how can we streamline and simplify systems and processes to allow pro-environmental action to take place automatically?

The Field School chapter demonstrated the difficulty of measuring people's actual behaviours and the long-term benefits of the FS experience. Since I only measured changes after the tour, it's unclear how long the effects will last. A key recommendation for future studies of this kind is to measure actual behaviours in the four sustainability domains, whether while they are at the

gardens, at home or at work, and examine the longevity of the effects through follow-up surveys. Future studies should also make the survey shorter to save time, and provide more rewards to completing both pre-and-post visit survey. If conducting a knowledge test, future surveys should also include a pre-visit knowledge test to ensure that the two groups (FS and GV) were not different before the tour. Since we do not know which aspect of the FS program (i.e. being in nature, group activities, sustainability curriculum or the canopy walk) caused which effects (i.e. knowledge, attitude or willingness to act), future research should unpack and test each component of the program to identify the changes in knowledge, attitudes, intentions and willingness to act.

Another interesting query regarding pro-environmental behaviour and its relationship with attitudes and knowledge is how much do attitudes matter to act sustainably, and which comes first? For example, literature review in Chapter 2 has shown that the interaction can go both ways and be reinforcing, that is action and experience results in higher levels of attitudes and knowledge, which further leads to action (Bem, 1967; Sussman, 2015). This indicates that there is an ongoing iterative process with positive and negative feedback loops, and that for the most part, it all starts with the behaviour/ action itself. In other words, engaging in behaviour (because it is made convenient and easy) can strengthen behaviour supporting attitudes and improve knowledge over time. This claim is also supported through the theory of cognitive dissonance (Festinger 1957), where individuals strive for consistency between attitudes and behaviour, because the inconsistency (or dissonance) produces great mental discomfort. As such, if a person with low environmental attitudes engages in pro-environmental behaviour in one context because it is made convenient or due to social norms, they can develop behaviour-supporting

environmental attitudes and knowledge as a result of engaging with the behaviour. Cognitive biases discussed in the earlier, such as confirmation and recency bias, can provide feedback loops which can prevent willingness and ability to change if people are not engaging in a specific behaviour, but once the desired behaviour has taken place, these same biases become beneficial and strengthen pro-environmental behaviours, attitudes and knowledge. Since behaviour is often the hardest component to change, and we prefer a harmony between our actions and attitudes, people often bring their attitudes in line to match the behaviour. Researchers and policy-makers should therefore focus on interventions that help make behaviour take place through infrastructural, technical, political and economic factors, and study attitudinal or social norm changes, and how they further entrench and normalize pro-environmental action. Doing so can enhance the power of individual and collective agency, help people engage in behaviour and bring with it attitudes, meanings and knowledge that reinforces behaviour in a positive feedback loop.

## **6.5 Advancing Behavioural Sustainability**

While individuals and communities are at the center of the behavioural challenge, at the same time they are only a part of other systems of multi-directional influences that also involve economics, technology, institutions and culture, which all affect and reinforce human behaviour over time. As we try to motivate individuals and communities into sustainable action we must remember that their personal agency is often severely restricted by factors beyond their understanding or capacity. Most people do not set out to be unsustainable, but are implicated in ecologically disruptive practices set up by powers out of their control, where often, their intentions to be sustainable may clash with other lifestyle desires and goals (Steg & Vlek, 2009;

Whitmarsh et al., 2013). Pro-environmental strategies can range from more effortful (cognitively or physically) for individuals and communities, since not everything can be simplified or standardized, looking for opportunities to simplify environmental context to allow sustainable actions to take place by default. In other words, there are instances when we need to communicate information effectively and educate people (such as using interactive games with feedback), but there are also opportunities when choice architecture is more suitable to change defaults and options, so the sustainable actions can take place automatically.

Even when we design visually stimulating posters to get people's attention and inform them which items should go in which bin, if they lack the infrastructure inside the apartment or have to go through three doors and two sets of keys to get to the recycling room, it is very unlikely that the information alone will generate any meaningful change in their behaviour. Recycling infrastructure and the waste materials are instrumental in waste sorting behaviour because no amount of information can compensate for infrastructure which is inconvenient, messy, or badly run. If the recycling systems around people are complex and not conducive to help sustainable action take place, the information and awareness campaigns will likely only reach the already interested recycling keeners, which make a minority of the population. As many authors have pointed out most people don't engage in unsustainable lifestyles on purpose but are implicated in the existing systems that make it hard to be sustainable (Gatersleben et al., 2002; Jackson, 2005; Shove, 2003; Whitmarsh & O'Neill, 2010). Similarly, people don't get persuaded to act more sustainably by science and facts, but do so when the 'green' options become more readily available which allow them to maintain their quality of life while being sustainable. Since the source of our individual and collective un-sustainability is often traced to the overarching social

and physical systems which shape our behaviour over time, we need to examine the individual sphere of agency as embedded in the larger systems and help make pro-environmental behaviour take place by default.

One of the central problem of sustainability (and thus unsustainability) is in incompatibility of socio-technical and economic growth (both human inventions) and how nature's ecological systems actually operate (Levin, 2005; Robinson, 2004). Just as sustainable development principles should be grounded in ecological sciences as to what Earth systems can support, our pro-environmental behaviour design should be informed by behavioural sciences insights as to how people think and act. Similarly, while psychology and behavioural elements are fundamentally indispensable to sustainable behaviour research, incorporation of other disciplines (such as sociology or cultural theories) in an inter-disciplinary research could lead to interesting perspectives and solutions when studying these complex problems that touch on practically every facet of private and public life. Tied with the responsibility to mitigate and adapt to challenges of global climate change and responsible resource management, there is a tremendous potential to study and implement behavioural strategies that address these key mechanisms toward sustainable social change. Since human behaviour and sustainability challenges are extremely complex phenomena that cut across numerous disciplines and realms of public and private life, we will require multi disciplinary approaches to have any real ability to solve large-scale issues such as climate change or zero waste. This will require working with multiple stakeholders and actors as well as across multiple scales (Sathaye et al., 2007), disciplinary orientations of researchers and policy-makers, and their underlining assumptions about what the problem is and how to solve it.

As a leader in sustainability education and research, UBC offers an example of a successful model for other schools and institutions to follow. With a history of environmental activism and its geopolitical location, UBC has fully committed to climate change agreements and zero waste goals, including a diversion of 80% of operational waste from landfill. Doing so has provided tangible targets and an incentive to act and deliver on the commitment, and to that end, UBC has invested a significant amount of financial resources into standardizing recycling infrastructure throughout the campus. Every academic building now has standardized bins and signage, with outdoor stations and student residences following suit. However, with a policy commitment and desire to meet climate targets, the University had to earmark over 1 million dollars for the infrastructure and education campaigns. Change is not cheap or easy, and institutions need to be willing to lead by example and set up sustainability pathways to motivate the change in their communities.

The UBC Campus Sustainability Office is a part of the Campus and Community Planning Department which gives it power and ability to request compliance with zero waste policies, work collaboratively with Food Services and Student Residences, and spread zero waste principles throughout the campus. Aware of its role as a Change Agent, UBC is creating a strong institutional framework supportive of sustainability principles via projects and initiatives such as Campus as a Living Lab, Centre for Interactive Research on Sustainability, and the University Sustainability Initiative. This integration goes beyond the operational landscape to include research and teaching. For example, UBC has established Sustainability Learning Pathways where any student regardless of their disciplinary major can add a minor in sustainability to their program. There are currently 450-plus courses that have sustainability related content. Similarly,

since 2001 SEEDS Sustainability Program helps advance campus sustainability strategies such as Zero Waste Action Plan, Climate Action Plan and Green Building Plan by connecting students, researchers, operational staff and faculty to work together on innovative and impactful research projects. To date they have engaged over 7,500 graduate and undergraduate students with faculty, staff and community partners, on 900 sustainability projects in over 200 courses, generating a useful library and a list of resources (UBC Sustainability, 2018). These partnerships and cross-collaboration, along with tangible international commitments on climate and sustainability, are some of the ways to institutionalize and move forward on sustainability goals. Located within British Columbia, a province with a strong history of environmental activism, and Metro Vancouver which has Greenest City goals, is a huge advantage for UBC. Policy backing and organizational structure on sustainability matters, like waste, means green initiatives will not face unreasonable road-blocks, and sustainable partnerships are more likely to be cooperative and fruitful.

To move forward we must accept the premise that people's agency is limited, and that sustainability is extremely complex and dependant on other socio-technical and economic factors. We are facing a difficult (if not impossible) battle trying to solve unsustainable behaviours through appeals to people's individual agency, reason and sacrifice. Sustainability has thus far been framed with an uninspiring narrative of limits and constraints, which is increasingly being linked to growing apathy and denial, in stark contrast to the desired outcome of wide spread change across scales. By stressing the limits to growth, these discourses are often based on 'less harm' or 'net zero' solutions and as a result the call for 'doing less harm' is being embedded in a wide range of international policies and regulations (Robinson & Cole 2015). Not

to mention, such response fails to go far enough to counteract current unsustainable trends. The problem, as Ehrenfeld notes, is that the current notion of sustainable development is merely a modification of the current process of economic development since our current strategies are barely sufficing to help cope with the forces of unsustainability, but not enough to allow life to thrive (Ehrenfeld, 2008). Piece meal actions can have impacts when they are targeted and impact a significant component of a sub-system, but as long as the upstream systems of provision are set up to make unsustainability convenient, common and embodied within other goals or interests, the weight of the influence will be against long-term sustainability. Therefore, a system thinking (cradle-to-cradle) approach to pro-environmental behaviours, such as waste diversion, is essential because otherwise we are destined to tinker with piece-meal solutions that may work for a short period, but never connect to the source of unsustainability.

Similarly, we need to study pro-environmental behaviours under specific contexts where we can test how a particular intervention works (such as immediate feedback while sorting), while at the same time examining human behaviour as just one system operating within a larger even more complex system of provision, technology, commerce and culture. While this is a significant undertaking, it brings optimism and a promise that we can tackle sustainability problems at their source, instead of constantly trying to keep up with the symptoms of the problem downstream. As such, while we should continue to mobilize individuals and communities, at the same time we also need to swim upstream to design and build systems of resources and material provision that support human desires for goods and services, and does so in a way that is consistent with sustainable development goals, and enables pro-environmental behaviour to take place more automatically.

While there are limits to human agency and ability to steer or control complex systems, there are instances and examples where communities come together and organize successfully. Such approaches are often influenced by past events, geography and institutions that help entrench sustainability within the public and private life, and it is a constantly evolving ongoing process. For zero waste goals this process inevitably includes policies, market economy, technology, e.g. the manufacturing corporations and products in the marketplace, their ability to be recycled and composted in the recycling plants, and the policies that enable and support the whole enterprise. One waste study has highlighted that the outsourcing of compostable biopolymer is often driven by organizational sustainability goals, while the ability to compost depends on local waste management legislation and available infrastructure (Meeks et al., 2015). In some ways local policy and environmental attitudes can drive the use of more ‘green’ options, like compostable food containers, but the ability to process it depends on local infrastructure, which may not be yet available. Many places in the Metro Vancouver area, including UBC, do not accept plastic bags and other low-grade plastics including styrofoam, straws or soft-plastics, and yet they are inescapable and prevalent, pollute the environment and contaminate recycling and compost streams. Yet recently in light of the growing awareness and media attention, many communities in Canada and the world are organizing in the battle on un-necessary consumer plastics. The Vancouver City Council has voted to approve a ban on straws and polystyrene foam cups and containers, with the ban on distribution set for June 2019 (Chan, 2018). Initiatives like this, through a concerted, synergistic and methodological tactic can help reduce the dispersion of deleterious effects of waste in the environment, while introducing possible channels of innovation, with benefits for all stakeholders, human and non-human. Policy makers, designers, manufacturers and retailers must continue to collaborate and implement zero waste (closed-

system) principles throughout the whole process to ensure materials can be re-used and recycled. This involves extending consumer responsibility to manufacturers and corporations (as has been done in Germany and British Columbia) and working with economic markets, so the financial and ecological costs of landfill or recycling process are not borne out by municipalities or consumers. Sustainability transition will inevitably require a widespread systemic change, with significant leadership in various levels of governments, institutions and businesses leading by example and designing policies and infrastructures that work with people's need for convenience and provisions, while supporting long-term sustainability.

## Bibliography

- Abrahamse, W., & Steg, L. (2013). Social influence approaches to encourage resource conservation: A meta-analysis. *Global Environmental Change*, 23(6), 1773–1785.
- Ajzen, I. (2001). Nature and Operation of Attitudes. *Annual Review of Psychology*, 52, 27–58.
- Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behaviour*. Englewood-Cliffs, NJ: Prentice-Hall.
- Allcott, H., & Rogers, T. (2012). *The Short-Run and Long-Run Effects of Behavioural Interventions: Experimental Evidence from Energy Conservation* (Working Paper 18492). Cambridge. Retrieved from <http://www.nber.org/papers/w18492>
- Amel, E., Manning, C., Britain, S., & Koger, S. (2017). Beyond the roots of human inaction: Fostering collective effort toward ecosystem conservation. *Science*. <https://doi.org/10.1017/S0376892900018178>
- Anderson, R. C., Kulhavy, R. W., & Andre, T. (1971). Feedback procedures in programmed instruction. *Journal of Educational Psychology*, 62, 148-156.
- Andrews, A., Gregoire, M., Rasmussen, H., & Witowich G. (2013). Comparison of recycling outcomes in three types of recycling collection units. *Waste Management*, 33, 530-535.
- Ariely, D. (2008). *Predictably Irrational: The Hidden Forces That Shape Our Decisions*. Harper Perennial.
- Armitage, C. J., & Conner, M. (2001). Efficacy of the Theory of Planned Behaviour: A meta-analytic review, *Social Psychology*, 40(4), 471–499.
- Bamberg, S., & Möser, G. (2007). Twenty years after Hines, Hungerford, and Tomera: A new meta-analysis of psycho-social determinants of pro-environmental behaviour. *Journal of Environmental Psychology*, 27(1), 14–25. <https://doi.org/10.1016/j.jenvp.2006.12.002>
- Barton, J., & Pretty, J. (2010). What is the best dose of nature and green exercise for improving mental health- A multi-study analysis. *Environmental Science and Technology*, 44(10), 3947–3955. <https://doi.org/10.1021/es903183r>
- Bateson, G. (1979). *Mind and Nature: A Necessary Unity*. Bantam Books.
- Becker, G. (1976). *The Economic Approach to Human Behaviour*. Chicago Press.
- Bem, D. J. (1967). Self-perception: An alternative interpretation of cognitive dissonance phenomena. *Psychological Review*, Vol 74(3), 183–200.
- Ben-Bassat, T., & Shinar, D. (2006). Ergonomic guidelines for traffic sign design increase sign

- comprehension. *Human Factors*, 48, 182-195.
- Berg, A., & Berg, A. (2007). Preference for Nature in Urbanized Societies: Stress, Restoration, and the Pursuit of Sustainability. *The Journal of Social Issues*, 63(1), 79–96.
- Berman, M.G, Jonides, J, & Kaplan S. (2008). The Cognitive Benefits of Interacting With Nature. *Psychological Science*, 19(12), 1207-1212
- Best, H., & Kneip, T. (2014). Curbside Collection and Participation in Household Waste Recycling: A Causal Analysis Max Planck Institute for Social Law and Social Policy Discussion Paper No. 15-2014
- Blake, J. (1999). Overcoming the ‘value-action gap’ in environmental policy: Tensions between national policy and local experience. *Local Environment*, 4(3), 257–278.  
<https://doi.org/10.1080/13549839908725599>
- Bohm, R. A., Folz, D. H., & Kinnaman, T. C., Podolsky, M. J. (2010). The costs of municipal waste and recycling. *Resources, Conservation and Recycling*, 54, 864-871.
- Bord, J.R., O'Connor, R.E., Fisher, A. (2000). In what sense does the public need to understand global climate change? *Public Understanding of Science*. 9(3), 205-218
- Botanic Gardens Conservation International. (2018). Plants for the Planet. Retrieved from <http://www.bgci.org/about-us/index>
- Braun, T., Cottrell, R., & Dierkes, P. (2017). Fostering changes in attitude, knowledge and behaviour: demographic variation in environmental education effects. *Environmental Education Research*, 4622 (November), 1–22.  
<https://doi.org/10.1080/13504622.2017.1343279>
- Bringslimark, T., Hartig, T., & Patil, G. G. (2009). The psychological benefits of indoor plants: A critical review of the experimental literature. *Journal of Environmental Psychology*, 29(4), 422–433. <https://doi.org/10.1016/j.jenvp.2009.05.001>
- Butler, A. C., Karpicke, J. D., & Roediger III, H. L. (2007). The effect of type and timing of feedback on learning from multiple-choice tests. *Journal of Experimental Psychology: Applied*, 13, 273.
- Capra, F. (1996). *The web of life: a new scientific understanding of living systems*. New York: Anchor Books.
- Chan, K. (2018). Vancouver approves ban on plastic straws, foam cups and containers. *Daily Hive*. Retrieved from <http://dailyhive.com/vancouver/vancouver-approves-ban-plastic-straws-foam-cups-containers-may-2018>
- Chawla, L. (2015). Benefits of Nature Contact for Children. *Journal of Planning Literature*,

30(4), 433–452.

Chung, E. (2018). Many Canadians are recycling wrong, and it's costing us millions. *CBC News*. Retrieved from <http://www.cbc.ca/news/technology/recycling-contamination-1.4606893>

Cialdini, R. B. (1993). *Influence: Science and Practice* (Third Edit). HarperCollins College Publishers.

Cialdini, R. B. (2003). Crafting normative messages to protect the environment. *Current Directions in Psychological Science*, 12(4), 105–109. <https://doi.org/10.1111/1467-8721.01242>

City of Vancouver. (2012). *Greenest City Action Plan 2020*. City of Vancouver. Retrieved from <http://vancouver.ca/files/cov/Greenest-city-action-plan.pdf>

City of Vancouver. (2016). *Greenest City Action Plan, Goals and Targets: Zero Waste*. Retrieved from <http://vancouver.ca/green-vancouver/zero-waste.aspx>

Cohen-Cline, H., Turkheimer, E., & Duncan, G. E. (2015). Access to green space, physical activity and mental health: a twin study. *Journal of Epidemiology and Community Health*, 69(6), 523–529. <https://doi.org/10.1136/jech-2014-204667>

Connell, J. (2004). The purest of human pleasures: The characteristics and motivations of garden visitors in Great Britain. *Tourism Management*, 25(2), 229–247. <https://doi.org/DOI:10.1016/j.tourman.2003.09.021>

Connor, S. (2015). Gulf Stream is slowing down faster than ever, scientists say. *Independent*. Retrieved from <http://www.independent.co.uk/environment/gulf-stream-is-slowing-down-faster-than-ever-scientists-say-10128700.html>

Connolly, T. M., Boyle, E. A., MacArthur, E., Hainey, T., & Boyle, J. M. (2012). A systematic literature review of empirical evidence on computer games and serious games. *Computers and Education*, 59(2), 661–686.

Costanza, R., de Groot, R., Sutton, P., van der Ploeg, S., Anderson, S. J., Kubiszewski, I., ... Turner, R. K. (2014). Changes in the global value of ecosystem services. *Global Environmental Change*, 26(1), 152–158. <https://doi.org/10.1016/j.gloenvcha.2014.04.002>

Corbett, A. T., & Anderson, J. R. (2001, March). Locus of feedback control in computer-based tutoring: Impact on learning rate, achievement and attitudes. In Proceedings of the SIGCHI conference on Human factors in computing systems, 245-252. ACM.

Cox, D., Shanahan, D., Hudson, H., Fuller, R., Anderson, K., Hancock, S., & Gaston, K. (2017). Doses of Nearby Nature Simultaneously Associated with Multiple Health Benefits. *International Journal of Environmental Research and Public Health*, 14(2), 172. <https://doi.org/10.3390/ijerph14020172>

- Crompton, T. (2010). *Common Cause: The Case for Working with our Cultural Values*. WWF UK.
- Crompton, T., & Thøgersen, J. (2009). Simple and Painless? The Limits of Environmental Spillover in Environmental Campaigning. *Journal of Consumer Policy*, 32(2), 141-163
- Daily, C. G., Alexander, S., Ehrlich, R. P., Goulder, L., Lubchenco, J., Matson A. Pamela, Mooney, A. H., ... Woodwell, M. G. (1997). Ecosystem Services: Benefits Supplied to Human Societies by Natural Ecosystems. *Issues in Ecology*, 2, 1-18.
- Darnton, A. (2008). *GSR Behaviour Change Knowledge Review. Reference Report: An overview of behaviour change models and their uses Development*. Government Social Research Unit, UK
- Darnton, A., Verplanken, B., White, P., & Whitmarsh, L. (2011). *Habits , Routines and Sustainable Lifestyles: A summary report to the Department for Environment, Food and Rural Affairs*. London.
- De Leon, I. G., & Fuqua, R. W. (1995). The effects of public commitment and group feedback on curbside recycling. *Environment and Behaviour*, 27, 233-250.
- de Vries, S., Verheij, R. A., Groenewegen, P. P., & Spreeuwenberg, P. (2003). Natural environments - Healthy environments? An exploratory analysis of the relationship between greenspace and health. *Environment and Planning A*, 35(10), 1717-1731.  
<https://doi.org/10.1068/a35111>
- De Freitas, S. (2006). Learning in immersive worlds: a review of game-based learning. Retrieved from [http://www.jisc.ac.uk/media/documents/programmes/elearninginnovation/gamingreport\\_v3.pdf](http://www.jisc.ac.uk/media/documents/programmes/elearninginnovation/gamingreport_v3.pdf)
- De Young, R. (1989). Exploring the difference between recyclers and non-recyclers. *J. Environmental Systems*, 18(4), 341-351. <https://doi.org/10.2190/FBQC-5V5D-HHVC-V6X8>
- De Young, R., Boerschig, S., Carney, S., Dillenbeck, A., Elster, M., Horst, S., ... & Thomson, B. (1995). Recycling in multi-family dwellings: Increasing participation and decreasing contamination. *Population & Environment*, 16, 253-267.
- Dewis, G., & Wesenbeeck, P. Van. (2016). Trash talking - Dealing with Canadian household e-waste, Statistics Canada, available at <https://www150.statcan.gc.ca/n1/pub/16-002-x/2016001/article/14570-eng.htm>.
- Dietz, T., Gardner, G. T., Gilligan, J., Stern, P. C., & Vandenberg, M. P. (2009). Household actions can provide a behavioural wedge to rapidly reduce US carbon emissions. *Pnas*, 106(4), 18452-18456. <https://doi.org/10.1073/pnas.0908738106>

- DiGiacomo, A., Wu, D. W.-L., Lenkic, P., Fraser, B., Zhao, J., & Kingstone, A. (2017). Convenience improves composting and recycling rates in high-density residential buildings. *Journal of Environmental Planning and Management*, 0(0), 1–23. <https://doi.org/10.1080/09640568.2017.1305332>
- Dihoff, R. E., Brosvic, G. M., & Epstein, M. L. (2003). The role of feedback during academic testing: The delay retention effect revisited. *The Psychological Record*, 53, 533–548.
- Dodd, J., & Jones, C. (2010). *Redefining the Role of Botanic Gardens - Towards a New Social Purpose*. Research Centre for Museums and Galleries. Leicester. Retrieved from <http://www.bgci.org/public-engagement/socinc/?sec=education&id=socinc>
- Duffy, S., & Verges, M. (2008). It Matters a Hole Lot: Perceptual Affordances of Waste Containers Influence Recycling Compliance. *Environment and Behaviour*, 41(5), 741–749. <https://doi.org/10.1177/0013916508323737>
- Dunlap, R. E., Van Liere, K. D., Mertig, A. G., & Jones, R. E. (2000). New Trends in Measuring Environmental Attitudes: Measuring Endorsement of the New Ecological Paradigm: A Revised NEP Scale. *Journal of Social Issues*, 56(3), 425–442. <https://doi.org/10.1111/0022-4537.00176>
- Duprè, M., & Meineri, S. (2016). Increasing recycling through displaying feedback and social comparative feedback. *Journal of Environmental Psychology*, 48, 101–107. <https://doi.org/10.1016/j.jenvp.2016.07.004>
- Ehrenfeld, J. R. (2008). *Sustainability by Design: A Subversive Strategy for Transforming Our Consumer Culture*. New Haven and London: Yale University Press.
- Environment and Climate Change Canada. (2014). Municipal Solid Waste and Greenhouse Gases. Retrieved from <http://www.ec.gc.ca/gdd-mw/default.asp?lang=En&n=6f92e701-1>
- Environmental Protection Agency. (2013). Municipal solid waste generation, recycling, and disposal in the United States: Facts and figures. Retrieved from <https://archive.epa.gov/epawaste/nonhaz/municipal/web/html/>
- Estes, J.A, Terborgh J, Brashares J.S, Power M.E, Berger J, Bond W.J, Carpenter S.R, Essington T.E, Holt R.D, Jackson J.B.C, Marquis R.J, Oksanen L, Oksanen T, Paine R.T, Pikitch E.K, Ripple W.J, Sandin S.A, Scheffer M, Schoener T.W, Shurin J.B, Sinclair A.R.E, Soule M.E, Virtanen R, Wardle D.A. (2011). Trophic Downgrading of Planet Earth. *Science*. 333:301–306. <https://doi.org/10.1126/science.1205106>
- FAO. (2013). *Fast Facts: The State of the World's Land and Water Resources (SOLAW) - Managing Systems at Risk*. London and Rome. Retrieved from <http://www.fao.org/docrep/017/i1688e/i1688e00.htm>

- Fishbein, M., & Ajzen, I. (1975). *Belief, Attitude, Intention and Behaviour: an introduction to theory and research*. Reading, MA.: Addison-Wesley.
- Folke, C., Carpenter, S., Walker, B., Scheffer, M., Elmqvist, T., Gunderson, L., & Holling, C. S. (2004). Regime Shifts, Resilience, and Biodiversity in Ecosystem Management. *Annual Review of Ecology, Evolution, and Systematics*, 35(1), 557–581. <https://doi.org/10.1146/annurev.ecolsys.35.021103.105711>
- Foster, K. (2016). *The Effectiveness of 3D Display Cases In The AMS Nest*. <https://doi.org/doi:http://dx.doi.org/10.14288/1.0343156>
- Friedman, M., & Savage, L. (1948). The Utility Analysis of Choices Involving Risk. *Journal of Political Economy*, 56, 279–304.
- Friis-Hansen, E., & Duveskog, D. (2012). The Empowerment Route to Well-being: An Analysis of Farmer Field Schools in East Africa. *World Development*, 40(2), 414–427. <https://doi.org/10.1016/j.worlddev.2011.05.005>
- Gagnon Thompson, S. C., & Barton, M. A. (1994). Ecocentric and anthropocentric attitudes toward the environment. *Journal of Environmental Psychology*, 14(2), 149–157. [https://doi.org/10.1016/S0272-4944\(05\)80168-9](https://doi.org/10.1016/S0272-4944(05)80168-9)
- Gatersleben, B., Steg, L., & Vlek, C. (2002). Measurement and Determinants of Environmentally Significant Consumer Behaviour. *Environment and Behaviour*, 34(3), 335–362. <https://doi.org/10.1177/0013916502034003004>
- Geng, L., Xu, J., Ye, L., Zhou, W., & Zhou, K. (2015). Connections with nature and environmental behaviours. *PLoS ONE*, 10(5), 1–11. <https://doi.org/10.1371/journal.pone.0127247>
- Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. *Science Advances*, 3(7), 25–29. <https://doi.org/10.1126/science.1252826>
- Gidlöf-Gunnarsson, A., & Öhrström, E. (2007). Noise and well-being in urban residential environments: The potential role of perceived availability to nearby green areas. *Landscape and Urban Planning*, 83(2–3), 115–126. <https://doi.org/10.1016/j.landurbplan.2007.03.003>
- Gifford, R. (2011). The dragons of inaction: psychological barriers that limit climate change mitigation and adaptation. *The American Psychologist*, 66(4), 290–302. <https://doi.org/10.1037/a0023566>
- Gifford, R., Kormos, C., & McIntyre, A. (2011). Behavioural dimensions of climate change: drivers, responses, barriers, and interventions. *Wiley Interdisciplinary Reviews: Climate Change*, 2(6), 801–827. <https://doi.org/10.1002/wcc.143>
- Goldenhar, L. M., & Connell, C. M. (1991). Effects of educational and feedback interventions on

- recycling knowledge, attitudes, beliefs, and behaviours. *Journal of Environmental Systems*, 21, 321-333.
- Gram-Hanssen, K. (2011). Understanding change and continuity in residential energy consumption. *Journal of Consumer Culture*, 11(1), 61–78.  
<https://doi.org/10.1177/1469540510391725>
- Hargreaves, T. (2010). *Towards a phronetic approach to pro- environmental behaviour: Seeking context, interaction and power in behaviour change processes*.
- Hargreaves, T. (2011). Practice-ing behaviour change: Applying social practice theory to pro-environmental behaviour change. *Journal of Consumer Culture*, 11(1), 79–99.  
<https://doi.org/10.1177/1469540510390500>
- Hershkowitz, A. (1998). In Defense of Recycling. *Social Research*, 65(1), 141–218.  
<https://doi.org/10.1177/0090591706286470>
- Heyd, T. (2006). Thinking through Botanic Gardens. *Environmental Values*, 15, 197–212.  
<https://doi.org/10.1353/Im.2005.0025>
- Hines, J., Hungerford, H., & Tomera, A.N. (1987). Analysis and Synthesis of Research on Responsible Environmental Behaviour: A Meta-Analysis. *The Journal of Environmental Education*. 18. 1-8. 10.1080/00958964.1987.9943482.
- Hjorth, P., & Bagheri, A. (2006). Navigating towards sustainable development: A system dynamics approach. *Futures*, 38(1), 74–92. <https://doi.org/10.1016/j.futures.2005.04.005>
- Holland, L. (2000). Recycling domestic waste: A proxy for environmental sustainability? *International Journal of Sustainable Development and World Ecology*, 7(3), 271–276.  
<https://doi.org/10.1080/13504500009470047>
- Hoornweg, D., Bhada-Tata, P., & Kennedy, C. (2013). Waste production must peak this century. *Nature*, 502(7473), 615–617. <https://doi.org/10.1038/502615a>
- Hottle, T. A., Bilec, M. M., Brown, N. R., & Landis, A. E. (2015). Toward zero waste: Composting and recycling for sustainable venue based events. *Waste Management*, 38(1), 86–94. <https://doi.org/10.1016/j.wasman.2015.01.019>
- Huber, M. Z., & Hilty, L. M. (2015). Gamification and sustainable consumption: Overcoming the limitations of persuasive technologies. *Advances in Intelligent Systems and Computing*, 310, 367–385.
- Humes, E. (2012). *Garbology: Our Dirty Love Affair with Trash*. Avery.
- Jackson, T. (2005). *Motivating Sustainable Consumption: A review of evidence on consumer behaviour and behaviour change*. Sustainable Development Research Network.

- Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., ... Law, K. L. (2015). Plastic waste inputs from land into the ocean. *Science*, 347(6223).
- John, P., Cotterill, S., Moseley, A., Richardson, L., Smith, G., Stoker, G., & Wales, C. (2011). *Nudge, Nudge, Think, Think: Experimenting with Ways to Change Civic Behaviour*. Bloomsbury Academic.
- John, P., Smith, G., & Stoker, G. (2009). Nudge Nudge, Think Think: Two Strategies for Changing Civic Behaviour. *Political Quarterly*, 80(3), 361–370. <https://doi.org/10.1111/j.1467-923X.2009.02001.x>
- Kahneman, D. (2011). *Thinking, Fast and Slow*. Farrar, Straus and Giroux.
- Kahneman, D., & Tversky, A. (2001). Judgment under uncertainty: heuristics and biases, 185(4157), 1124–1131.
- Kaiser, G. F., Wolfing, S., & Fuhrer, U. (1999). Environmental attitude and ecological behaviour. *Journal of Environmental Psychology*, 19, 1–19.
- Kaplan, R., & Kaplan, S. (2011). Well-being, reasonableness, and the natural environment. *Applied Psychology: Health and Well-Being*, 3(3), 304–321. <https://doi.org/10.1111/j.1758-0854.2011.01055.x>
- Keller, J. M. (1983). Motivational design of instruction. Instructional design theories and models: An overview of their current status, 1, 383-434.
- Knol, E., & DeVries, P. W. (2011). EnerCities, a serious game to Stimulate Sustainability and Energy Conservation: Preliminary Results. Retrieved from [https://www.openeducationeuropa.eu/sites/default/files/legacy\\_files/asset/In-depth\\_25\\_4.pdf](https://www.openeducationeuropa.eu/sites/default/files/legacy_files/asset/In-depth_25_4.pdf)
- Kollmuss, A., & Agyeman, J. (2002). Mind the Gap : why do people act environmentally and what are the barriers to pro-environmental behaviour? *Environmental Education Research*, 8(3). <https://doi.org/10.1080/1350462022014540>
- Kulhavy, R. W. (1977). Feedback in written instruction. *Review of Educational Research*, 47, 211-232.
- Kulik, J. A., & Kulik, C. L. C. (1988). Timing of feedback and verbal learning. *Review of Educational Research*, 58, 79-97.
- Levin, S. A. (2005). Self-organization and the Emergence of Complexity in Ecological Systems, *AIBS Bulletin*, 55(12), 1075–1079.
- Levin, S. A. (2014). Multiple Scales and the Maintenance of Biodiversity. *Ecosystems*, 3(6),

498–506. <https://doi.org/10.1007/s100210000044>

- Levine, J., Chan, K. M. A., & Satterfield, T. (2015). From rational actor to efficient complexity manager: Exorcising the ghost of Homo economicus with a unified synthesis of cognition research. *Ecological Economics*, 114, 22–32. <https://doi.org/10.1016/j.ecolecon.2015.03.010>
- Loewenstein, G., Bryce, C., Hagmann, D., & Rajpal, S. (2014). Warning: You Are About to be Nudged. *Behavioural Science & Policy*, 1(1), 35–42.
- Lubchenco, J. (1998). Entering the Century of the Environment: A New Social Contract for Science. *Science*, 279(5350), 491–497. <https://doi.org/10.1126/science.279.5350.491>
- Lucas, K., Brooks, M., Darnton, A., & Jones, J. E. (2008). Promoting pro-environmental behaviour: existing evidence and policy implications. *Environmental Science & Policy*, 11(5), 456–466. <https://doi.org/10.1016/j.envsci.2008.03.001>
- Lutzenhiser, L. (1993). Social and Behavioural Aspects of Energy Use. *Annu. Rev. Energy Environ.*, 18, 247–89.
- Lutzenhiser, L., Cesafsky, L., Chappells, H., Gossard, M., Moezzi, M., Moran, D., Vine, E. (2009). *Behavioural Assumptions Underlying California Residential Sector Energy Efficiency Programs*.
- Maller, C., Townsend, M., Pryor, A., Brown, P., & St Leger, L. (2006). Healthy nature healthy people: “contact with nature” as an upstream health promotion intervention for populations. *Health Promotion International*, 21(1), 45–54. <https://doi.org/10.1093/heapro/dai032>
- Marshall, G. (2014). *Don't Even Think About It: Why Our Brains Are Wired to Ignore Climate Change*. Bloomsbury.
- Martinho, G., Gomes, A., Ramos, M., Santos, P., Gonçalves, G., Fonseca, M., & Pires, A. (2017). Solid waste prevention and management at green festivals: A case study of the Andanças Festival, Portugal. *Waste Management*, 71, 10–18. <https://doi.org/10.1016/j.wasman.2017.10.020>
- McDonough, W., & Braungart, M. (2002). *Cradle to cradle: Remaking the way we make things*. Farrar, Straus and Giroux.
- McFadden, D. (1999). Rationality for Economists? *Journal of Risk and Uncertainty*, 19(1), 73–105.
- McKenzie-Mohr, D. (2008). Fostering Sustainable Behaviour: Beyond Brochures. *International Journal of Sustainability Communication*, 3, 108–118.
- McKenzie-Mohr, D. (2000). Fostering sustainable behaviour through community-based social

- marketing. *The American Psychologist*, 55(5), 531–537. <https://doi.org/10.1037/0003-066X.55.5.531>
- McKenzie-Mohr, D. (2000). Fostering sustainable behaviour through community-based social marketing. *American Psychologist*, 55(5), 531–537. <https://doi.org/10.1037/0003-066X.55.5.531>
- Meadows, D. (2002). Dancing With Systems. *The Systems Thinker*, 13(2). Retrieved from <http://www.gperform.org/Meadows.pdf>
- Meeks, D., Hottle, T., Bilec, M. M., & Landis, A. E. (2015). Compostable biopolymer use in the real world: Stakeholder interviews to better understand the motivations and realities of use and disposal in the US. *Resources, Conservation and Recycling*, 105, 134–142. <https://doi.org/10.1016/j.resconrec.2015.10.022>
- Miller, N. D., Meindl, J. N., & Caradine, M. (2016). The Effects of Bin Proximity and Visual Prompts on Recycling in a University Building. *Behaviour and Social Issues*, (25), 4–10. <https://doi.org/10.5210/bsi.v.25i0.6141>
- Miller, T., Wiek, A., Sarewitz, D., Robinson, J., Olsson, L., Kriebel, D., & Loorbach, D. (2014). The future of sustainability science: A solutions-oriented research agenda. *Sustainability Science*. <https://doi.org/10.1007/s11625-013-0224-6>
- Mitchell, A., & Savill-Smith, C. (2004). The use of computer and video games for learning. A review of the literature. ULTRALAB. Learning and Skills Development Agency. Retrieved from <http://dera.ioe.ac.uk/5270/>
- Moore, J., & Rees, W. E. (2013). Is Sustainability Still Possible? In *State of the World 2013*. The Worldwatch Institute.
- Mory, E. H. (2004). Feedback research revisited. *Handbook of research on educational communications and technology*, 2, 745–783.
- Morawski, C. (2009). *Understanding economic and environmental impacts of single-stream collection systems*. Container Recycling Institute Report.
- Morgan, S., Hamilton, S. L., Bentley, M. L., & Myrie, S. (2009). Environmental education in botanic gardens: Exploring Brooklyn Botanic Garden's Project Green Reach. *The Journal of Environmental Education*, 40(4), 35–52. <https://doi.org/10.3200/JOEE.40.4.35-52>
- Najjar, D., Spaling, H., & Sinclair, A. J. (2013). Learning about sustainability and gender through Farmer Field Schools in the Taita Hills, Kenya. *International Journal of Educational Development*, 33(5), 466–475. <https://doi.org/10.1016/j.ijedudev.2012.06.004>
- Nelles, M., Grünes, J., & Morscheck, G. (2016). Waste Management in Germany – Development to a Sustainable Circular Economy? *Procedia Environmental Sciences*, 35, 6–14.

<https://doi.org/10.1016/j.proenv.2016.07.001>

- Nisbet, E. K. L., Zelenski, J. M., & Murphy, S. A. (2009). The Nature Relatedness Scale: Linking individuals' connection with nature to environmental concern and behaviour. *Environment and Behaviour*, 41, 715-740
- Nisbet, E. K., & Zelenski, J. M. (2013). The NR-6: A new brief measure of nature relatedness. *Frontiers in Psychology*, 4(NOV), 1-11. <https://doi.org/10.3389/fpsyg.2013.00813>
- Nisbett, R. E., & Ross, L. (2011). *The Person and the Situation: Perspectives of Social Psychology* (2nd ed.). Pinter & Martin Ltd.
- Nolan, J. M., Schultz, P. W., Cialdini, R. B., Goldstein, N. J., & Griskevicius, V. (2008). Normative social influence is underdetected. *Personality & Social Psychology Bulletin*, 34(7), 913-23. <https://doi.org/10.1177/0146167208316691>
- Oostindjer, M., Aschemann-Witzel, J., Wang, Q., Skuland, S. E., Egelanddal, B., Amdam, G. V., van Kleef, E. (2016). Are School Meals a Viable and Sustainable Tool to Improve the Healthiness and Sustainability of Children's Diet and Food Consumption? A Cross-national Comparative Perspective. *Doi.Org*, 00-00. <https://doi.org/10.1080/10408398.2016.1197180>
- Owens, S. (2000). 'Engaging the public': Information and deliberation in environmental policy. *Environment and Planning*, 32(7), 1141-1148. <https://doi.org/10.1068/a3330>
- Paben, J. (2017, February). Germany's recycling rate continues to lead Europe. *Resource Recycling*. Retrieved from <https://resource-recycling.com/recycling/2017/02/07/germanys-recycling-rate-continues-lead-europe/>
- Pashler, H., Cepeda, N. J., Wixted, J. T., & Rohrer, D. (2005). When does feedback facilitate learning of words? *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 31, 3.
- Phye, G. D. (1979). The processing of informative feedback about multiple-choice test performance. *Contemporary Educational Psychology*, 4, 381-394.
- Preiss, J. (2015). 4,000 Staff Lunch, One Small Bag of Garbage. Retrieved from <https://sustain.ubc.ca/stories/4000-staff-lunch-one-small-bag-garbage>
- Pretty, J. (2004). How nature contributes to mental and physical health. *Spirituality and Health International*, 5(2), 68-78. <https://doi.org/10.1002/shi.220>
- R Core Team. (2017). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from <https://www.r-project.org/>
- Rabinovich, A., Morton, T. A., Postmes, T., & Verplanken, B. (2012). Collective self and individual choice: The effects of inter-group comparative context on environmental values

- and behaviour. *British Journal of Social Psychology*, 51(4), 551–569.  
<https://doi.org/10.1111/j.2044-8309.2011.02022.x>
- Raskin, P., Banuri, T., Gallopin, G., Gutman, P., Hammond, A., Robert, K., & Swart, R. (2002). *The Great Transition: The Promise and Lure of the Times Ahead*. Stockholm Environment Institute - Boston.
- Reckwitz, A. (2002). Toward a Theory of Social Practices: A Development in Culturalist Theorizing. *European Journal of Social Theory*, 5(2), 243–263.  
<https://doi.org/10.1177/13684310222225432>
- Rees, W. E. (2002). Globalization and Sustainability: Conflict or Convergence? *Bulletin of Science, Technology & Society*, 22(4), 249–268.  
<https://doi.org/10.1177/0270467602022004001>
- Rittel, H., & Webber, M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, 4(2), 155–169.
- Robinson, J. (2004). Squaring the circle? Some thoughts on the idea of sustainable development. *Ecological Economics*, 48, 369–384.
- Robinson, J., Burch, S., Talwar, S., O'Shea, M., & Walsh, M. (2011). Envisioning sustainability: Recent progress in the use of participatory backcasting approaches for sustainability research. *Technological Forecasting and Social Change*, 78(5), 756–768.  
<https://doi.org/10.1016/j.techfore.2010.12.006>
- Robinson, J., & Cole, R. J. (2015). Theoretical underpinnings of regenerative sustainability. *Building Research & Information*, 43(2), 133–143.  
<https://doi.org/10.1080/09613218.2014.979082>
- Sathaye, J., Najam, A., Cocklin, C., Heller, T., Lecocq, F., Llanes-Regueiro, J., ... R. Schaeffer, Y. Sokona, R. Swart, H. W. (2007). Sustainable Development and Mitigation. In B. Metz, O. R. Davidson, P. R. Bosch, R. Dave, & L. A. Meyer (Eds.), *Climate Change 2007: Mitigation* (Contributi, p. 54). Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. <https://doi.org/10.1057/palgrave.jba.2950072>
- Schlossberg, T. (2017, July 19). The Immense, Eternal Footprint Humanity Leaves on Earth: Plastics. *The New York Times*. Retrieved from <https://www.nytimes.com/2017/07/19/climate/plastic-pollution-study-science-advances.html>
- Schultz, P. W., Nolan, J. M., Cialdini, R. B., Goldstein, N. J., & Griskevicius, V. (2007). The constructive, destructive, and reconstructive power of social norms. *Psychological Science*, 18(5), 429–34. <https://doi.org/10.1111/j.1467-9280.2007.01917.x>
- Schultz, P. W., Oskamp, S., & Mainieri, T. (1995). Who recycles and when? A review of

- personal and situational factors. *Journal of Environmental Psychology*, 15(2), 105–121.
- Schultz, P. W., Shriver, C., Tabanico, J. J., & Khazian, A. M. (2004). Implicit connections with nature. *Journal of Environmental Psychology*, 24(1), 31–42. [https://doi.org/10.1016/S0272-4944\(03\)00022-7](https://doi.org/10.1016/S0272-4944(03)00022-7)
- Shin, N., Sutherland, L. M., Norris, C. A., & Soloway, E. (2012). Effects of game technology on elementary student learning in mathematics. *British Journal of Educational Technology*, 43(4), 540–560.
- Shute, V. J. (2008). Focus on formative feedback. *Review of Educational Research*, 78, 153–189.
- Schultz, W. (2002). Knowledge, information, and household recycling: Examining the knowledge-deficit model of behaviour change. In T. Dietz & P. C. Stern (Eds.), *New tools for environmental protection: Education, information, and voluntary measures* (pp. 67–82). Washington, DC: The National Academies Press.
- Schwartz, S. H. (1992). Universals in the Content and Structure of Values: Theoretical Advances and Empirical Tests in 20 Countries. *Advances in Experimental Social Psychology*, 25, 1–65. [https://doi.org/10.1016/S0065-2601\(08\)60281-6](https://doi.org/10.1016/S0065-2601(08)60281-6)
- Secretariat of the Convention on Biological Diversity. (2014). *Global Biodiversity Outlook 4*. Montréal: Global Biodiversity Outlook 4. <https://doi.org/10.1093/aje/kwq338>
- Sellmann, D., & Bogner, F. X. (2013). Effects of a 1-day environmental education intervention on environmental attitudes and connectedness with nature. *European Journal of Psychology of Education*, 28(3), 1077–1086. <https://doi.org/10.1007/s10212-012-0155-0>
- Seto, K. C., Güneralp, B., & Hutyra, L. R. (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences of the United States of America*, 109(40), 16083–8. <https://doi.org/10.1073/pnas.1211658109>
- Settle, W., Soumare, M., Sarr, M., Garba, M. H., & Poisot, A.-S. (2014). Reducing pesticide risks to farming communities: cotton farmer field schools in Mali. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, 369, 20120277. <https://doi.org/10.1098/rstb.2012.0277>
- Shove, E. (2003). *Comfort, cleanliness and convenience: the social organization of normality*. Oxford: Berg Publishers.
- Shove, E. (2010). Social theory and climate change: questions often, sometimes and not yet asked. *Theory, Culture & Society*, 27(2–3), 277–288. <https://doi.org/10.1177/0263276410361498>
- Shove, E., & Pantzar, M. (2005). Consumers, Producers and Practices: Understanding the

- invention and reinvention of Nordic Walking. *Journal of Consumer Culture*, 5, 43–64.
- Shove, E., Pantzar, M., & Watson, M. (2012). *Dynamics of Social Practice: Everyday life and how it changes*. London: SAGE Publications.
- Simon, H. (1982). *Models of Bounded Rationality. Vols 1 and 2*. MIT Press.
- Simon, H. A. (1996). *The Sciences of the Artificial* (3rd edition). Cambridge, MA.: MIT Press.
- Sloman, S. A. (1996). The empirical case for two systems of reasoning. *Psychol. Bull.*, 119, 3–22.
- Statistics Canada. (2013). Waste Management Industry Survey: Business and Government Sectors: 2010. *Minister of Industry*, (16), ii-38. <https://doi.org/16F0023X>
- Statistics Canada. (2014). Disposal and diversion of waste, by province and territory. Retrieved from <http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/envir32b-eng.htm>
- Steg, L., & Vlek, C. (2009). Encouraging pro-environmental behaviour: An integrative review and research agenda. *Journal of Environmental Psychology*, 29(3), 309–317. <https://doi.org/10.1016/j.jenvp.2008.10.004>
- Steg, L., Bolderdijk, J. W., Keizer, K., & Perlaviciute, G. (2014). An integrated framework for encouraging pro-environmental behaviour: The role of values, situational factors and goals. *Journal of Environmental Psychology*, 38, 104–115.
- Stern, P. (2000). Toward a Coherent Theory of Environmentally Significant Behaviour. *Journal of Social Issues*, 56(3), 407–424.
- Stern, P. C., Dietz, T., Abel, T., Guagnano, G. A., & Kalof, L. (1999). A value-belief-norm theory of support for social movements: The case of environmentalism. *Human Ecology Review*, 6(2), 81–97. <https://doi.org/10.2307/2083693>
- Stern, P. C., Dietz, T., & Guagnano, G. A. (1995). The new ecological paradigm in social-psychological context. *Environment and Behaviour, Sage Publications*, 27(6), 723–743.
- Sussman, R. (2015). *Paved with Good Environmental Intentions: Reconsidering the Theory of Planned Behaviour*. University of Victoria.
- Sussman, R., & Gifford, R. (2011). Be the change you want to see in the world. *Environment and Behaviour*, 45(3), 323–343. <https://doi.org/10.1177/0013916511431274>
- Sussman, R., Greeno, M., Gifford, R., & Scannell, L. (2013). The Effectiveness of Models and Prompts on Waste Diversion: A Field Experiment on Composting by Cafeteria Patrons. *Journal of Applied Social Psychology*, 43(1), 24–34. <https://doi.org/10.1111/j.1559-1816.2012.00978.x>

- Suzuki, D., & McConnell, A. (2007). *The Sacred Balance: Rediscovering Our Place in Nature*. Greystone Books.
- Tammemagi, Y. H. (1999). *The Waste Crisis: Landfills, Incinerators, and the Search for a Sustainable Future*. Oxford University Press.
- Thaler, R., & Sunstein, C. (2008). *Nudge: Improving Decisions About Health, Wealth, and Happiness*. New Haven & London: Yale University Press.
- Thomas, C., & Sharp, V. (2013). Understanding the normalisation of recycling behaviour and its implications for other pro-environmental behaviours: A review of social norms and recycling. *Resources, Conservation and Recycling*, 79, 11–20.  
<https://doi.org/10.1016/j.resconrec.2013.04.010>
- Tibbs, H. (2011). Changing cultural values and the transition to sustainability. *Journal of Futures Studies*, 15(3): 13 - 32
- Tüzün, H., Yilmaz-Soylu, M., Karakuş, T., Inal, Y., & Kizilkaya, G. (2009). The effects of computer games on primary school students' achievement and motivation in geography learning. *Computers and Education*, 52(1), 68–77.
- UBC. (2015). *Annual Sustainability Report. 2014-2015*. Retrieved from [https://sustain.ubc.ca/sites/sustain.ubc.ca/files/uploads/CampusSustainability/CS\\_PDFs/PlansReports/Reports/2014-2015-Annual-Sustainability-Report-LoRes.pdf](https://sustain.ubc.ca/sites/sustain.ubc.ca/files/uploads/CampusSustainability/CS_PDFs/PlansReports/Reports/2014-2015-Annual-Sustainability-Report-LoRes.pdf)
- UBC Communications & Marketing. (2017). Recycling and Waste. Retrieved from <https://www.ubc.ca/stories/2017-spring/recycling-waste.html>
- UBC Communications and Marketing. (2014). *Recycling and Composting Attitudes and Behaviours*. Campus Report.
- Ulrich, R. (1984). View through a window may influence recovery from surgery. *Science*, 224(4647), 420–421. <https://doi.org/10.1126/science.6143402>
- Ulrich, R. S., Simonst, R. F., Lositot, B. D., Fioritot, E., Milest, M. A., & Zelsont, M. (1991). Stress Recovery During Exposure To Natural and Urban Environments 1. *Journal of Environmental Psychology*, 11, 201–230. Retrieved from [http://ac.els-cdn.com/S0272494405801847/1-s2.0-S0272494405801847-main.pdf?\\_tid=5b3fd6c6-3734-11e7-94b2-00000aab0f26&acdnat=1494608546\\_ac2e3b3fff9febb768d491f62610cb4a](http://ac.els-cdn.com/S0272494405801847/1-s2.0-S0272494405801847-main.pdf?_tid=5b3fd6c6-3734-11e7-94b2-00000aab0f26&acdnat=1494608546_ac2e3b3fff9febb768d491f62610cb4a)
- UNEP. (2015). *Global Waste Management Outlook*. <https://doi.org/10.1177/0734242X15616055>
- United Nations Development Programme. (2018). Sustainable Development Goals. Retrieved from <http://www.undp.org/content/undp/en/home/sustainable-development-goals.html>

- Varotto, A., & Spagnolli, A. (2017). Psychological strategies to promote household recycling. A systematic review with meta-analysis of validated field interventions. *Journal of Environmental Psychology*, 51, 168–188. <https://doi.org/10.1016/j.jenvp.2017.03.011>
- Walker, B., Holling, C. S., Carpenter, S. R., & Kinzig, A. (2004). Resilience, Adaptability and Transformability in Social-Ecological Systems, *Ecology and Society*, 9(2)[5].
- Wassenberg, C. L., Goldenberg, M. A., & Soule, K. E. (2015). Benefits of botanical garden visitation: A means-end study. *Urban Forestry & Urban Greening*, 14(1), 148–155. <https://doi.org/10.1016/j.ufug.2015.01.002>
- Weber, E. U. (2008). Doing the Right Thing Willingly: Using the Insights of Behavioural Decision Research for Better Environmental Decisions. In In: E. Shafir (Ed), *The Behavioural Foundations of Policy*. Princeton University Press (pp. 380–397).
- Weber, E. U., & Johnson, E. J. (2012). *Psychology and behavioural economics lessons for the design of a green growth strategy* (No. WPS 6240). Washington, DC: Retrieved from <http://documents.worldbank.org/curated/en/747971468157507040/Psychology-and-behavioural-economics-lessons-for-the-design-of-a-green-growth-strategy>
- Wells, N. M. (2000). Effects of Greenness on Children’s Cognitive Functioning. *Environment and Behaviour*, 32(6), 775–795. <https://doi.org/10.1177/00139160021972793>
- Wells, N. M., & Evans, G. W. (2003). Nearby Nature: A Buffer of Life Stress among Rural Children. *Environment and Behaviour*, 35(3), 311–330.
- Whitmarsh, L. (2009). Behavioural responses to climate change: Asymmetry of intentions and impacts. *Journal of Environmental Psychology*, 29(1), 13–23. <https://doi.org/10.1016/j.jenvp.2008.05.003>
- Whitmarsh, L., Lorenzoni, I., & O’Neill, S. (2012). *Engaging the public with climate change: Behaviour change and communication*. Routledge.
- Whitmarsh, L., & O’Neill, S. (2010). Green identity, green living? The role of pro-environmental self-identity in determining consistency across diverse pro-environmental behaviours. *Journal of Environmental Psychology*, 30(3), 305–314. <https://doi.org/10.1016/j.jenvp.2010.01.003>
- Whitmarsh, L., Saffron, O., & Lorenzoni, I. (2013). Public Engagement with Climate Change: What do we know, and where do we go from here. *International Journal of Media & Cultural Politics*, Volume 9(1), 7–25(19). [https://doi.org/http://dx.doi.org/10.1386/macp.9.1.7\\_1](https://doi.org/http://dx.doi.org/10.1386/macp.9.1.7_1)
- Whitmarsh, L., Seyfang, G., & Neill, S. O. (2010). Public Engagement with Carbon and Climate Change: To what extent is the public ‘carbon capable’? *Global Environmental Change*, Volume 21(1), 56–65. <https://doi.org/http://dx.doi.org/10.1016/j.gloenvcha.2010.07.011>

- Williams, S. J., Jones, J. P. G., Gibbons, J. M., & Clubbe, C. (2015). Botanic gardens can positively influence visitors' environmental attitudes. *Biodiversity and Conservation*, 24(7), 1609–1620. <https://doi.org/10.1007/s10531-015-0879-7>
- Wilson, N., Ross, Killoran, M., Lafferty, K., & Jones, R. (2009). A review of ecotherapy as an adjunct form of treatment for those who use mental health services. *Journal of Public Mental Health*, 7(3), 23–36.
- World Economic Forum. (2016). *The New Plastics Economy: Rethinking the future of plastics*. Retrieved from <https://www.weforum.org/reports/the-new-plastics-economy-rethinking-the-future-of-plastics>
- Wu, D. W. L., DiGiacomo, A., Lenkic, P. J., Wong, V. K., & Kingstone, A. (2016). Being in a “green” building elicits “greener” recycling, but not necessarily “better” recycling. *PLoS ONE*, 11(1), 1–13. <https://doi.org/10.1371/journal.pone.0145737>
- Wynes, S., & Nicholas, K. A. (2017). The climate mitigation gap: education and government recommendations miss the most effective individual actions. *Environmental Research Letters*, 12(7). <https://doi.org/10.1088/1748-9326/aa7541>
- Zalasiewicz, J., Williams, M., Steffen, W., & Crutzen, P. (2010). The new world of the Anthropocene. *Environmental Science and Technology*, 44(7), 2228–31.
- Zelenika, I., & Pearce, J. M. (2012). The Internet and other ICTs as tools and catalysts for sustainable development: innovation for 21st century. *Information Development*, 29(3), 217–232. <https://doi.org/10.1177/0266666912465742>
- Zelenski, J. M., Dopko, R. L., & Capaldi, C. L. (2015). Cooperation is in our nature: Nature exposure may promote cooperative and environmentally sustainable behaviour. *Journal of Environmental Psychology*, 42, 24–31. Retrieved from <https://doi.org/10.1016/j.jenvp.2015.01.005>

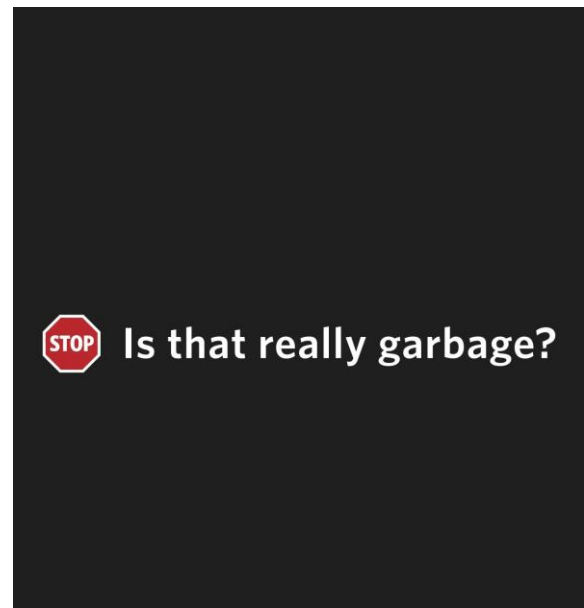
## Appendices

### Appendix A Supporting Materials for Chapter 4

#### A.1 80 Items Used in the Pilot Study with Mean Sorting Accuracy

Food Scraps	Containers	Paper	Garbage
 15.4%	 53.8%	 40.4%	 19.2%
 23.1%	 55.8%	 50.0%	 28.8%
 28.8%	 55.8%	 73.1%	 30.8%
 30.8%	 57.7%	 78.8%	 30.8%
 34.6%	 63.5%	 80.8%	 34.6%
 36.5%	 69.2%	 84.6%	 34.6%
 63.5%	 73.1%	 86.5%	 36.5%
 73.1%	 80.8%	 88.5%	 40.4%
 78.8%	 80.8%	 88.5%	 42.3%
 94.2%	 82.7%	 90.4%	 55.8%
 94.2%	 84.6%	 94.2%	 55.8%
 94.2%	 84.6%	 94.2%	 61.5%
 96.2%	 84.6%	 94.2%	 65.4%
 96.2%	 86.5%	 94.2%	 69.2%
 96.2%	 94.2%	 96.2%	 75.0%
 96.2%	 96.2%	 94.2%	 75.0%
 96.2%	 98.1%	 96.2%	 75.0%
 98.1%	 98.1%	 96.2%	 76.9%
 98.1%	 98.1%	 98.1%	 82.7%
 98.1%	 100%	 100%	 82.7%
<b>72.1%</b>	<b>79.9%</b>	<b>86.0%</b>	<b>53.7%</b>

## A.2 Signage for the UBC Waste Stream Bins



### A.3 Image Set 1 in One Block:

Food Scraps



Containers



Paper



Garbage



### A.4 Image Set 2 in Another Block:

Food Scraps



Containers



Paper



Garbage



## A.5 Bin Layout in the Game Buildings



## A.6 Sorting Game Posters and Lobby Set-up.

Posters (left) placed on every floor and in recycling rooms in the game buildings; table in the lobby (right) in game buildings inviting students to play the game.



## Appendix B Supporting Materials for Chapter 5

### B.1 Pre-visit and Post-visit Surveys

Pre-visit survey, page 1



#### Field School Pre-Event Survey

Please choose an answer that most accurately reflects your personal feelings or opinions. There is no right or wrong answer. Your information will be kept strictly confidential.

Q1. The Earth is like a spaceship with limited room and resources.

0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree

Q2. I need time in nature to be happy.

0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree

Q3. I always think about how my actions affect the environment.

0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree

Q4. It makes me sad to see natural environments destroyed.

0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree

Q5. Humans are as much a part of the ecosystem as other animals.

0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree

Q6. Concerns about environment guide my voting behavior.

0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree

Q7. Nature is valuable for its own sake.

0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree

Q8. Humans are severely abusing the environment.

0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree

Q9. I try to use less air conditioning in the summer and less heat in the winter.

0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree

Q10. The so-called "ecological crisis" facing humankind has been greatly exaggerated.

0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree

Q11. I intend to carpool and drive less by using public transport and bicycles more often

0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree

Q12. My relationship to nature is an important part of who I am.

0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree

Q13. If things continue on their present course we will soon experience a major ecological catastrophe.

0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree

Q14. What environmental issues are the most pressing and urgent to you? Please rank (1-5) with the most pressing items (1) and least urgent (5).

- \_\_\_\_\_ Waste and pollution
- \_\_\_\_\_ Water scarcity
- \_\_\_\_\_ Food security
- \_\_\_\_\_ Climate change
- \_\_\_\_\_ Species extinction



Pre-visit survey, page 2

Which pro-environmental actions below are you most willing to do? Please circle all actions that apply in each category.

#### Q15. Water

1. Reduce shower time
2. Install a low-flush toilet
3. Do less laundry
4. Turn off taps more often
5. Only do full-load laundry
6. Other \_\_\_\_\_

#### Q17. Food

1. Reduce meat consumption
2. Purchase organic food
3. Purchase fair-trade food
4. Grow your own food
5. Reduce food waste
6. Other \_\_\_\_\_

#### Q16. Waste

1. Carry your own coffee mug or water bottle
2. Sort your waste for recycling and composting
3. Bring your own bag when shopping
4. Chose items with minimal packaging
5. Dispose e-waste and batteries at designated drop-off depots
6. Other \_\_\_\_\_

#### Q18. Biodiversity

1. Sign a petition to save a forest
2. Buy FSC certified paper products
3. Volunteer for a local nature conservation group
4. Plant native plants or put up a bird feeder
5. Donate to a nature conservation group
6. Other \_\_\_\_\_

The following questions are for general purposes. Your responses will be kept strictly confidential and will never be linked to your personal information.

Q19. What are your initials? \_\_\_\_\_

Q20. What's the name of the first street you lived on as a child? \_\_\_\_\_

Q21. What's the name of your first pet? \_\_\_\_\_

Q22. Gender: ☐ Male ☐ Female ☐ Other

Q23. Age \_\_\_\_\_

Q24. What is your role in your company or organization? \_\_\_\_\_

Q25. What's the highest level of education have you completed?

- ☐ Some high school ☐ High school ☐ College  
☐ University ☐ Graduate degree

*Thank you for your time!*

## Post-visit survey, page 1



### Field School Post-Event Survey

Please answer the following questions to the best of your knowledge:

- Q1. Name one of the local watersheds: \_\_\_\_\_
- Q2. What percent of the food is wasted globally? \_\_\_\_\_
- Q3. What are the main threats to biodiversity? \_\_\_\_\_
- Q4. What is organic agriculture? \_\_\_\_\_
- Q5. What is the shape of a honeycomb cell? \_\_\_\_\_
- Q6. What role does a forest play in protecting water quality and supply? \_\_\_\_\_

Please choose an answer that most accurately reflects your personal feelings or opinions. There is no right or wrong answer. Your information will be kept strictly confidential.

- Q7. Concerns about environment guide my voting behavior.  
0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree
- Q8. I try to use less air conditioning in the summer and less heat in the winter.  
0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree
- Q9. Nature is valuable for its own sake.  
0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree
- Q10. Humans are severely abusing the environment.  
0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree

- Q11. The Earth is like a spaceship with limited room and resources.  
0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree

- Q12. I need time in nature to be happy.  
0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree

- Q13. I always think about how my actions affect the environment.  
0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree

- Q14. It makes me sad to see natural environments destroyed.  
0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree

- Q15. My relationship to nature is an important part of who I am.  
0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree

- Q16. I intend to carpool and drive less using public transport and bicycles more often.  
0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree

- Q17. The so-called "ecological crisis" facing humankind has been greatly exaggerated.  
0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree

- Q18. If things continue on their present course we will soon experience a major ecological catastrophe.  
0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree

- Q19. Humans are as much a part of the ecosystem as other animals.  
0.....1.....2.....3.....4.....5.....6.....7.....8.....9.....10  
Strongly Disagree Strongly Agree



## Post-visit survey, page 2

Q20. What environmental issues are the most pressing and urgent to you? Please rank (1-5) with the most pressing items (1) and least urgent (5).

- \_\_\_\_\_ Waste and pollution  
\_\_\_\_\_ Water scarcity  
\_\_\_\_\_ Food security  
\_\_\_\_\_ Climate change  
\_\_\_\_\_ Species extinction

Which pro-environmental actions below are you most willing to take? Please circle all actions that apply in each category.

#### Q21. Water

1. Reduce shower time  
2. Install a low-flush toilet  
3. Do less laundry  
4. Turn off taps more often  
5. Only do full-load laundry  
6. Other \_\_\_\_\_

#### Q22. Food

1. Reduce meat consumption  
2. Purchase organic food  
3. Purchase fair-trade food  
4. Grow your own food  
5. Reduce food waste  
6. Other \_\_\_\_\_

#### Q23. Waste

1. Carry your own coffee mug or water bottle  
2. Sort your waste for recycling and composting  
3. Bring your own bag when shopping  
4. Chose items with minimal packaging  
5. Dispose e-waste and batteries at designated drop-off depots  
6. Other \_\_\_\_\_

#### Q24. Biodiversity

1. Sign a petition to save a forest  
2. Buy FSC certified paper products  
3. Volunteer for a local nature conservation group  
4. Plant native plants or put up a bird feeder  
5. Donate to a nature conservation group  
6. Other \_\_\_\_\_

Giving constructive feedback will help us to make our classes even more awesome!

Q25. What did you like the best about this tour?

Q26. On a scale of 1 to 5 please circle the most appropriate response.

The garden tour facilitators were:

#### Knowledgeable:

- 1.....2.....3.....4.....5  
No, Yes,  
Not at all Strongly Agree

#### Well-prepared:

- 1.....2.....3.....4.....5  
No, Yes,  
Not at all Strongly Agree

#### Approachable:

- 1.....2.....3.....4.....5  
No, Yes,  
Not at all Strongly Agree

The following questions are for general purposes. Your responses will be kept strictly confidential and will never be linked to your personal information.

Q27. What are your initials? \_\_\_\_\_

Q28. What's the name of the first street you lived on as a child?  
\_\_\_\_\_

Q29. What's the name of your first pet? \_\_\_\_\_

Q30. Gender: ☐ Male ☐ Female ☐ Other

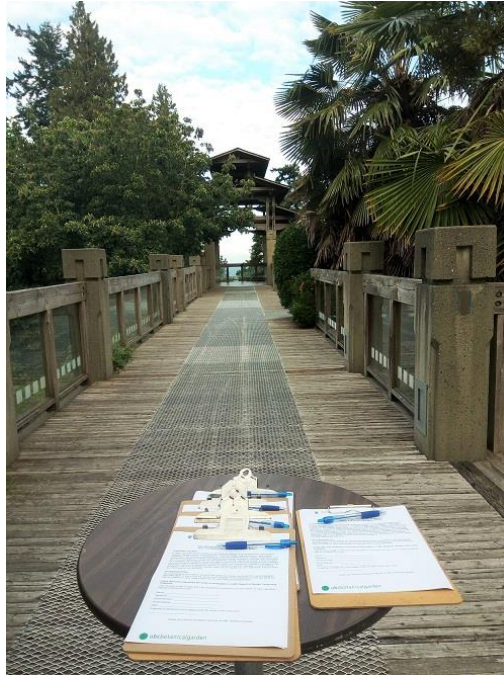
Q31. Age \_\_\_\_\_

Q32. What's the highest level of education have you completed?  
☐ Some high school ☐ High school ☐ College  
☐ University ☐ Graduate degree

Thank you for your time!

## B.2 Instructor Scripts and Photos of the Field School Tour

### Welcome to UBC Botanical Garden (Entrance)



**Description:** Upon arrival the guests are ushered toward reception center to fill out the Treewalk waivers and surveys. After that the guests gather at the entrance to UBC Botanical Garden Shop and are greeted by members of the Field School team. They are asked to fill out 2 forms: a waiver for the TreeWalk and the pre-survey.

**Guide 1:** Hello and welcome to UBC Botanical Garden! May I have a show of hands of people of been here before? *Guests respond.* Thank you. I'm always excited to host tours at the garden with people who have never been here before, and I love to see people who are returning to the space once again.

My name is Eagle Guide this is my colleague Falcon Guide from SPEC which is a local non-profit called the Society Promoting Environmental Conservation.

**Guide 2:** SPEC is the oldest environmental non-profit in Canada. Our work focuses on urban sustainability. We work in the areas of urban agriculture, water conservation, clean energy and waste reduction. For this program, we partner with the UBC Botanical Garden to engage businesses and community groups in sustainability education in nature. We also partner to run the research component of the program which looks at measuring the impact field school tours have on participants.

**Guide 1:** You are here today to enjoy the Sustainable Communities Field School. This program is designed to engage people in fun and engaging teambuilding activities in nature. I'd like to also introduce our team of students involved in teaching and working on this project: *students are introduced*. The goal of today is for you to come outside and “Reset, Refresh and Restore”. Ultimately, we hope that you have fun here today in the garden and with your colleagues.

An overview of the day's agenda is the following: we're going to start here at the beginning of the Botanical garden and will divide the group into two. Half of you will come with me to the food garden and the other half will go with Oliver to the Greenheart TreeWalk. About half way through the tour we'll all meet again to have a snack, then the groups will switch, and will all meet back here for our final activity.

### **Stop 1: Botanical Gardens - Museums of Living Plants**



**Guide:** Who knows what a botanical garden is?

**Audience:** *Responses are shared.*

**Guide:** *Keywords from the responses are repeated back to the audience.*

**Guide:** *Show one of the plant labels.* Botanical gardens are museums of living plants collected from around the world. Our goal is to collect, grow and document plants. You will see here (*show plant label*) and throughout the garden labels that identify where the plants are from, their scientific name, where the plant was collected from, and its accession/record number. Like a gallery that collects pieces of art, we collect plants that are wild collected as either seeds or

cuttings, and are then brought back here to be propagated and grown-up in our nursery. When the plants are big enough they are transferred into our living collection.

## **Stop 2: First Nations Land Acknowledgment Beside the Pond**



**Guide:** UBC Botanical Garden is located on the unceded territory of the Musqueam People who have lived on this coast and on these cliffs for thousands of years.

**Guide:** I'm going to invite you to close your eyes and take a deep breath as our Grounding Activity. We're going to close our eyes for about 30 seconds, and during that time try to breathe deeply - accessing your senses - smell, hearing and touch to connect to the place. Imagine your feet are the roots growing down into the ground connecting you to this place. *30 seconds passes* *guide says* I'll invite you to take one more deep breath and when you're ready open your eyes. Tell me what did you smell what did you hear, smell and experience?



*Grounding Activity*

**Audience:** *The group shares back:* Sound of water, wind blowing through the trees, insects, birds chirping, cars on a nearby road, etc.

**Guide:** A large role we aim to play at the botanical garden is encourage celebration of biodiversity. As we walk to the next stop can you think about how we might define or characterize biodiversity and why is it important?

### **Stop 3: Moon Gate Tunnel to the Food Garden – Threats to Biodiversity**



**Guide:** Please gather here and circle up - we're going to make our way over into our food garden. But before we go I wanted to highlight our eagle tree which is the oldest tree in the garden. I asked you to think about the question of: what is biodiversity and what is impacting it? Can you tell me what do you think are the greatest impacts of biodiversity?

**Guide:** *Feedback received from the audience.* What do you think are the greatest threats to biodiversity?

**Guide:** Agriculture is considered the key driver to biodiversity loss through land use change. For example, when we clear forest to make way for a farm or pastureland, not only is biodiversity lost through destruction of habitat, but surrounding waterways are affected by farm inputs such as pesticides, herbicides, and fertilizers.

As we go through the tunnel we will see that the garden has undergone its own land use change. At one point, the garden was all connected until the highway was put in, cutting the space in half. As we walk through this tunnel we will experience the difference ecosystems created by this land use change. The forest ecosystem of the Asian garden is a clear contrast to the Gary oak ecosystem on the other side.

#### Stop 4: Garry Oak Endangered Ecosystem and Indigenous Food Plants



**Guide:** Is anyone familiar with Garry Oak ecosystems and if so can you describe them?

**Audience:** responses received

**Guide:** First Nations in British Columbia have a long and amazing relationship with food and wild edible plants. *Camassia* is a bulb that grows similar to a potato. It is an important staple food crop for first Nations of this area. *Camassia* was grown and managed by First Nations using controlled burning. This ecosystem is considered a water wise area because plants have undergone adaptations to withstand the typical wet winters and dry summers. Plants adaptations to low water and dry conditions includes deep roots, specific leaf shapes, coating or waxes that prevent water loss, and spines and hairs to reflect heat.

## Stop 5 & 6: Food garden



**Guide:** A food garden is a perfect place to get people thinking about their food. Where it comes from, how it is produced, who produces it, and how can consumers get active to support just and sustainable food systems. Here we showcase food and agriculture plants for learning of all ages. A wide variety of foods are grown by our horticulturalists and then harvested by our volunteers. All food harvested is donated to charity.

**Guide:** What is organic agriculture?

**Audience:** responses received

**Guide:** Organic agriculture includes practices that prohibit the use of genetically engineered plants or animals, synthetic pesticides and fertilizers.

Group walks over to the Compost Pile. Showcase how at UBC we process all of our organic waste at our own facility which produces mulch and compost which is used for landscaping.

**Guide:** Does anyone know how much food is wasted globally?  
(Answer 30-40%)



**Camera Game in the Food Garden:** *Introduce the activity.* Get people to pair up. In their pair - one person is the camera and one person is the photographer. The photographer is the lead. This person walks around the Garden to find something that catches their eye. They go back to the camera and the camera closes their eyes. The photographer leads the camera to the object to take the 10 second picture (time when the camera opens eyes) and then leads the camera with eyes closed back to the group. The group is asked to share what they saw in their picture.



**Coffee Cup Activity:** *Introduce the coffee cup game.* Break the team up into 2 groups and each group gets 3 supply chains. Tell them to put the supply chains together. How much work does it take to get a coffee into the customer's hand? The team has 10 minutes to put the chains together. Bring them all back together and ask them to put it all together. How did it go, how did they organize? What worked? What didn't work?

Looking at this complex coffee activity allows us to explore resource use along the supply chains and how these chains could be improved. For instance, how would this supply chain be different if it were organic with fairly traded coffee? What about not needing the takeaway cup? What do we lose when we throw out a cup of coffee in garbage: what resources are wasted that we might not think about?



**Flower Tasting:** *Invite the group to take a nasturtium flower which tastes like a pepper and eat it. The Guide demonstrates this and ask for groups did you like it what did it taste like. Explain how many flowers can be added to salads.*

### **Stop 7: Bee Hives**



**Guide:** If we were to fly in a drone up into the air and looked down we would see that the food garden is a particular shape. It's a shape that bees are typically associated with anyone know what that shape is?

**Audience:** responses received

**Guide:** The hexagon is an important structure for bees and in nature. *The guests are invited to sit watch the beehive.* Honey bees have amazing social structures that are led by Queens. Bees are a super organism. They communicate plant locations through dancing (waggle dance), they see in UV light, they are attracted to purples, blues, yellow and white. Most bees in a hive are female. Only the females have a stinger so good insect identifiers can pick up males and hold them. In the Fall, the workers kick out all the male drones so that they don't have to feed them

over the winter. The only job of the male drones is to mate with the Queen. She has only 1 mating flight in early spring.

**Guide:** Where do honey bees come from?

**Audience:** responses received

**Guide:** These are European bees that are originally from Italy and now commercial bee keepers transport bees all over the world. 1 in 3 bites of food come from the pollination services of bees. At UBC Botanical Garden we have been focusing our research and education on raising awareness of native bees in the Garden. We know we have a diversity of native bees. 80% of bees are not social insects but solitary insects. We know that there are somewhere between 50-150 native bee species in the Lower Mainland.

### **Stop 8: Meyer's Glade**

The group is assembled and we have a small break with organic fruit snacks.

Team photo is taken beside (and on top) of a 24-ton granite boulder, deposited by glacial ice.

### **Stop 9: Forest walk entrance**

By the time we arrive at the entrance of the TreeWalk we've mentioned Coastal Western Hemlock, Western Red Cedar, Douglas Fir and Grand Fir.

**Guide:** Can you name some of the most common trees found in this coastal rainforest region?

**Audience:** responses received.

**Guide:** Welcome to the Greenheart TreeWalk. The walkway is approximately 300 meters long and has 9 platforms. Maximum height over the forest floor is 22.5 meters. You are not obliged to do the walk. You are welcome to walk along the forest trails below the canopy walk and meet us at the exit. You can also give the TreeWalk a try and decide what to do once you've reached the first platform. Please walk with your hands free as the walk way is wobbly. The platforms are more stable. As we start our walk please start thinking about the role that forests play in protecting our local water supply, both quantity and quality. We will discuss at platform 3. Any questions?

**Audience:** Ask questions.

**Guide:** Let's go.



### **Short Stop: Treewalk Platform 1**

**Guide:** Are we all OK? If you prefer to head back and walk on the forest floor with a guide, this is the time to do it. Can you guess what tree this is?

**Audience:** Responds.

**Guide:** It is a Grand Fir. Typically, there are three ways to differentiate trees. You can look at the bark, at the needles or leaves, and at the cones. Please observe how the platforms are attached to the trees. There are two systems in place, the hugging system and the kissing system. The one at your feet is the kissing system. The rods with rubber ends lean against the tree without damaging it. The rods are pulled back as the tree grows thicker. If you look up the trunk you will notice a system of cables that wraps around the tree. This is the hugging systems. The system works like a finger trap. The more you pull or the stronger the pressure, the tighter the cables wrap around the tree. When the pressure is released, when we walk off the platform, the cables also release the pressure from the tree.

Let's continue walking. We will pass a tree with a bluish color. It's called a Taiwanese Coffin Tree. It was used to make coffins. It's a high elevation tree and the bluish tint on its leaves is a protection against UV rays. It is a threatened species in its native regions of Asia.



*Field School group on the TreeWalk*

### Stop 10: Treewalk Platform 3 – Forests and Water Activity



**Guide:** So, I asked you to think about the role that forest plays in protecting our water supply. Now I'm going to ask you to break out into three groups. I will assign one prop to each group. These props (a sponge, a coffee filter and an umbrella) represent one of the functions/roles that the forest plays to protect our water supply. You now have 2 minutes to discuss as a group and then you will present to the rest of us.

**Audience responds and guide helps by filling in gaps:** (They discuss in groups and then present). Group 1 (umbrella): the umbrella represents the Canopy that protects the forest from erosion during rainfall. It also provides shade for the wildlife and plants. Group 2: (coffee filter): the filter represents the natural filtration that the forest provides. A healthy soil and root system cleans water as it drains through it and cleans it before it reaches the reservoir. Group 3: (sponge) the sponge represents how forests can regulate water flowing into the reservoir by holding water during flash storms and wet periods and by gradually releasing the water during dry periods.

**Groups return props.** We continue our walk through two more platforms and stop at platform 6. On the way there, the guide asks the group to think about where our tap water comes from and about how many liters per person per day we consume in Metro Vancouver.

## Stop 11: Treewalk Platform 6 – Watersheds in Metro Vancouver



**Guide:** Can anyone tell me where our tap water comes from?

**Audience responds:** Audience members point out where our local drinking watersheds are. Capilano, Seymour and Coquitlam.

**Guide:** these are unique watersheds as they are forested and protected. No agriculture, forestry, industry or residential activity happens in the three watersheds. They are fully dedicated to water supply. It is quite unique to be able to rely on three watersheds that are mostly gravity fed and very close to the urban environment they feed. So How many liters of water do we use per person per day at a household level? This does not take into account the water used to make the products we buy. How many liters do we use at home for showering, washing clothes, toilets, etc., including leaks in the home piping?

**Audience:** they guess numbers.

**Guide:** answer is 330 liters approximately. Same as the Canadian average. It's the second highest in the world after the US. Some developed countries in Europe use less than half of that. So, what is going on?

**Audience:** water is too inexpensive here, no metering, we live in a rainforest, we live in a culture of overconsumption (among other answers).

**Guide:** Because we live in a rainforest the perception that we have enough water is difficult to overcome. We receive a lot of rain and snow in the watersheds in the Fall and Winter but about 90% is not caught by the reservoirs (it "overflows") so when we get to the drier periods we are relying on the water in the reservoir and on snow melt. Climate change is also complicating things as snow melt is happening earlier, rain patterns are less predictable. The growing population (we expect another 1 million people by 2040) is also putting pressure on our water sources. What can we do about this?

**Audience:** charge more for water, meter household consumption, educate people, use water efficiency infrastructure, build another dam or make current dams bigger.

**Guide:** Yes, all these are possible solutions. They all have trade-offs. For example, building a new dam would cost tax payer money and will have a large environmental cost. You can take action by conserving water at home and at the workplace. You can also make sure you consider this topic when you vote for your government representatives. Any questions?  
Ok, now we will continue walking to the exit. Check out the last platform. What tree is it on?

### **Short Stop: Treewalk Platform 9 – Cedar the Tree of Life**

**Guide:** What tree is this?

**Audience:** Cedar

**Guide:** and what was/is cedar used for, especially by indigenous people of the region?

**Audience and guide:** clothing, roofs, canoes, totem poles, medicine, baskets, hats, etc.

**Guide:** I hope you enjoyed the TreeWalk, we will now do the water can activity and then we will meet up with the other group to do a group photo and share a snack. Any questions?

### **Stop 12: Water Can Race on Meyer's Glade**



**Guide:** In this activity, 1 or 2 teams of up to 8 participants each have to carry a can of water from point A to point B. The cans have a set of strings connected to the rubber band which is bound around the can. Water is poured into the can and the participants must use the strings to pick up and transport the can (they cannot touch the can itself while it is lifted from the ground). They must try to avoid spilling the water. The can represents their community's watershed and each string represents a water user (industry, agriculture, recreation, households, etc.). If water is spilt, the facilitator adds more water to the can to make sure it does not become easier for the team (the less water the easier it is to transport it). In between point A and B there will be obstacles such as a rope that the team has to go under while carrying the can. This obstacle represents climate change and a growing population (variables that put pressure on local water systems). The activity is about team communication, coordination, planning, problem solving, and working under pressure. It also invites the team to reflect on what it means to share a key resource (such as water) in a community.

## Final Activity – The Web of Connections



Getting all team members in a large circle, questions will be asked and whoever answers correctly the yarn ball will be passed or thrown to that person. Make sure that the person who threw the yarn holds an end of the thread to keep the web growing. Keep asking questions and passing the yarn to those who respond and have different people answer and hold a piece of yarn. Questions from the tour are asked until everyone is holding a piece of the yarn. The purpose is to build a web of connections while sharing the knowledge and experiences as a group.

### GENERAL QUESTIONS ASKED

Q: What does SPEC stand for?

A: Society Promoting Environmental Conservation

Q: What did you enjoy the most about the day?

Q: In terms of taking action, what area feels more challenging?

### FOOD CHOICES

Q: What is organic agriculture?

A: Agriculture production that does not permit the use of synthetic fertilizers and pesticides nor the use of genetically engineered organisms.

Q: What is one reason experts believe honey bee populations are collapsing?

A: Pesticides, transportation, colony collapse disorder, varroa mites

Q: Out of every three bites of food we eat, it is thought that bees are integral to how many?

A: 1 out of 3.

## **FOREST**

Q: What type of tree is the “Eagle Tree”?

A: Douglas Fir

Q: What are three things that First Nations use Cedar trees for?

A: Roofs, cooking, weaving, tools

Q: Where are red alders often found?

A: after wind, fire or disease caused disturbances.

Q: What bio geoclimatic zone do we live in?

A: Coastal Wester Hemlock

## **WATER**

Q: What are the reservoirs that provide water for Vancouver?

A: Capilano, Seymour, Coquitlam.

Q: Describe one way that climate change could negatively affect our water supply?

A: drier summers, more rain in winters, increased frequency of storms, less snow melt due to warmer temperatures,

Q: Describe one way we can better conserve water in our homes?

A: wash less, shorter showers, decrease lawn sprinkling, drip irrigation for gardens, car wash infrequently and at a car wash place.

Q: What key roles do forests play in our water supply?

A: Filtration, Erosion mitigation, water supply regulation.

## **WASTE**

Q: How much food is wasted globally?

A: Estimates vary but between 30-50

Closing remarks and reflections: (Reception Centre Lawn)

Thank your group for joining on the tour today. Have your guests reflect back on their experience. What did they like, learn, and would like to see more of?

### B.3 Within-Subjects Analysis of the FS Participants

Since we had 90 matched Field School participants, where the same person filled out both the pre-visit and the post-visit surveys, we compared their pre- vs. post-visit attitudes and willingness to act. This offers another way to measure the effectiveness of the FS tours within subjects.

#### *Environmental Attitude Scales*

Paired t-test analysis of the attitude scores (Figure B3-1) shows that post-visit FS participants reported significantly higher scores compared to pre-visit in all four scales: New Ecological Paradigm [ $t(89)=4.49, p<.001$ ], Eco Centristism [ $t(89)=3.57, p<.001$ ], Shortened Nature Relatedness [ $t(89)=3.28, p<.001$ ], and Intention to Act [ $t(89)=5.84, p<.001$ ].

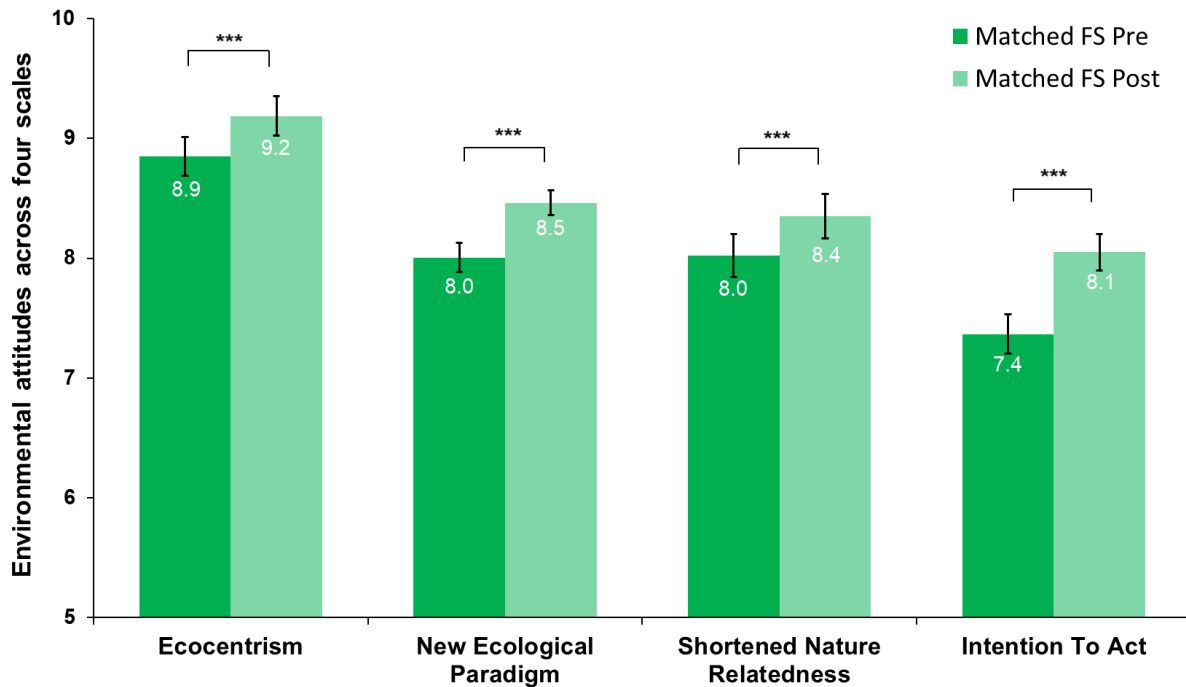


Figure B3-1. Average ratings on the four scales for matched FS participants before and after the visit. FS=Field School participants, Matched=same person, Pre=pre-visit, Post=post-visit. (Error bars reflect  $\pm 1$  SEM; \*\*\* $p<.001$ ).

### *Willingness to Act*

The McNemar chi square test was conducted to compare matched Field School participants willingness to engage in pro-environmental behaviours pre-visit vs. post-visit. We found that FS participants' willingness to engage in water conservation (Figure B3-2) increased for three behaviours: Take shorter showers [ $\chi^2(1)=10, p=.001$ ], Do less laundry [ $\chi^2(1)=12, p<.001$ ], and Do full load laundry [ $\chi^2(1)=4, p=.045$ ].

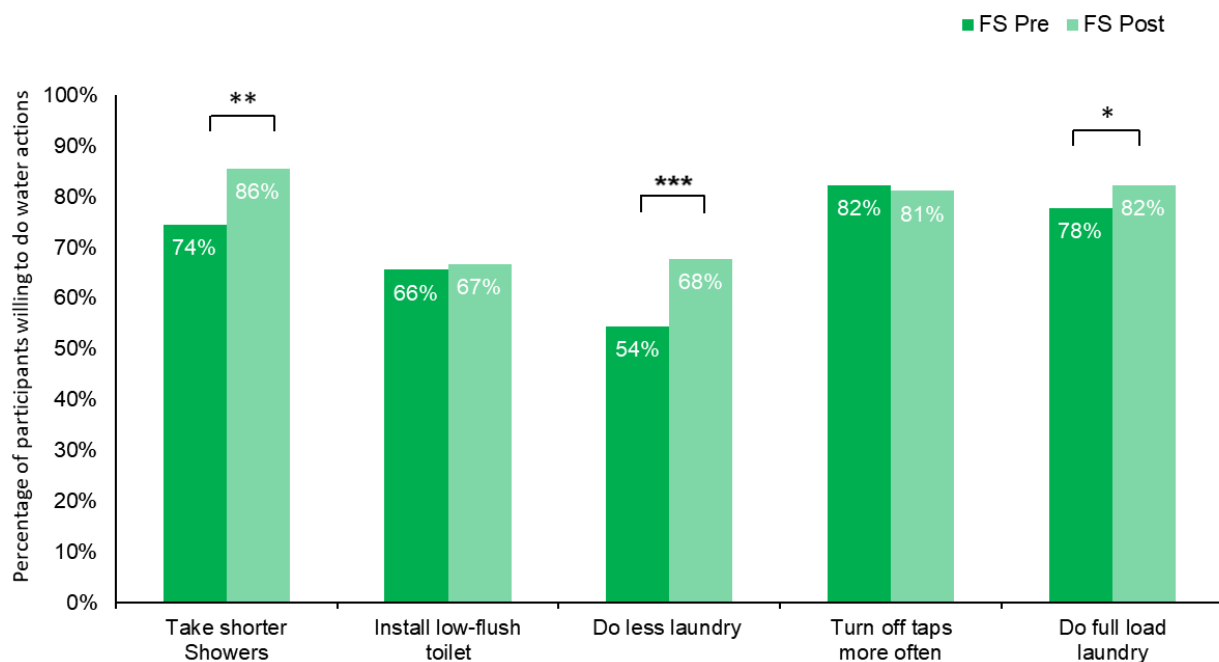


Figure B3-2. Percentage of matched FS participants willing to engage in water conservation actions. FS=Field School participants, Pre=pre-visit, Post=post-visit. (\* $p<.05$ , \*\* $p<.01$ , \*\*\* $p<.001$ ).

Willingness of matched FS participants to do waste related actions (Figure B3-3) increased in post-visit surveys for two actions: Bring your own bag when shopping [ $\chi^2(1)=4, p=.045$ ] and Chose items with low packaging [ $\chi^2(1)=10, p=.001$ ]. Dispose of e-waste safely increased marginally [ $\chi^2(1)=3, p=.083$ ].

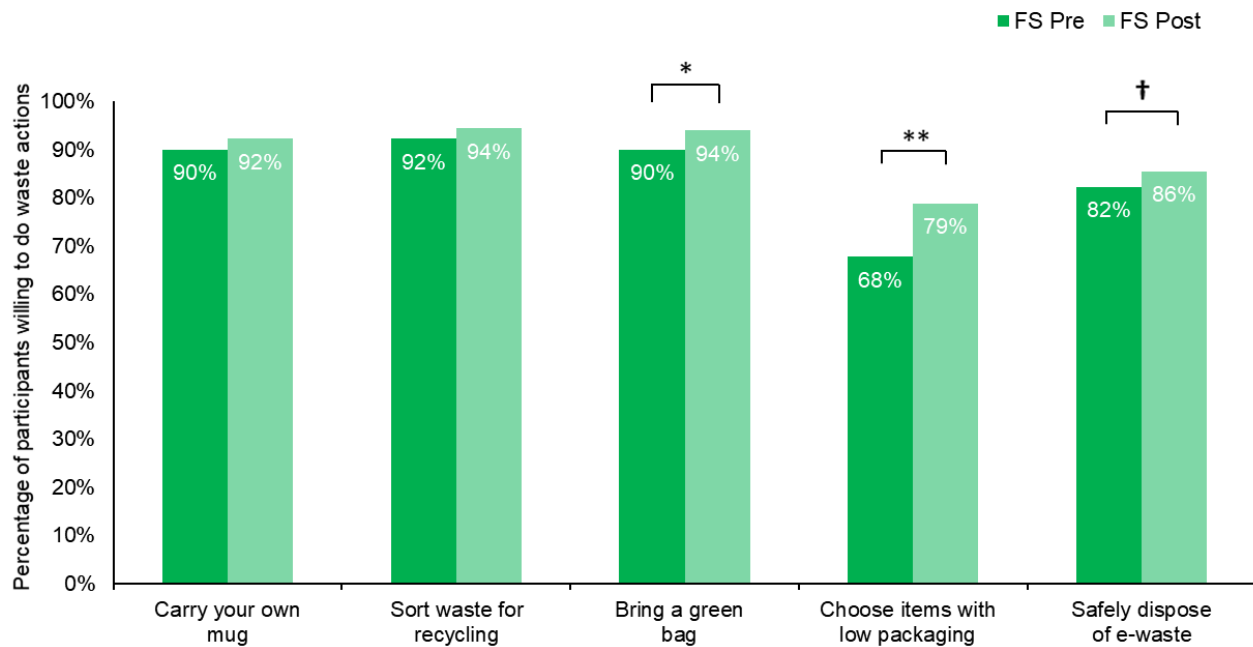


Figure B3-3. Percentage of matched FS participants willing to engage in waste conservation actions. FS=Field School participants, Pre=pre-visit, Post=post-visit. († $p<.1$ , \* $p<.05$ , \*\* $p<.01$ ).

Willingness of matched FS participants to do sustainable food actions (Figure B3-4) increased for all five behaviours: Reduce meat consumption [ $\chi^2(1)=4, p=.045$ ], Purchase organic food [ $\chi^2(1)=12, p<.001$ ], Purchase fair trade food [ $\chi^2(1)=6.54, p=.01$ ], Grow your own food [ $\chi^2(1)=4, p=.045$ ], and Reduce food waste [ $\chi^2(1)=4, p=.045$ ].

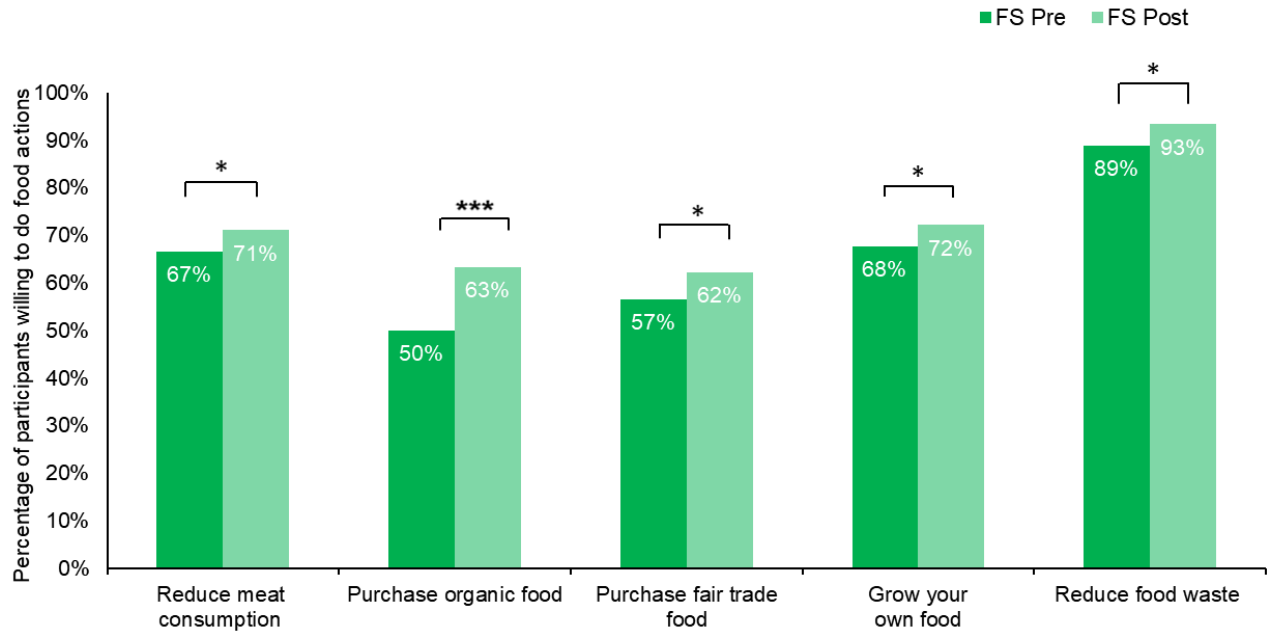


Figure B3-4. Percentage of matched FS participants willing to engage in sustainable food actions. FS=Field School participants, Matched=same person, Pre=pre-visit, Post=post-visit. (\* $p < .05$ , \*\*\* $p < .001$ ).

Willingness of matched FS participants to do biodiversity conservation actions (Figure B3-5) increased significantly for three actions and marginally for two: Sign a petition to save a forest [ $\chi^2(1)=3$ ,  $p=.083$ ], Buy sustainable forestry certified paper [ $\chi^2(1)=13$ ,  $p<.001$ ], Volunteer for a nature group [ $\chi^2(1)=7$ ,  $p=.008$ ], Plant native plants [ $\chi^2(1)=7$ ,  $p=.008$ ], and Donate to nature conservation organizations [ $\chi^2(1)=11$ ,  $p<.001$ ].

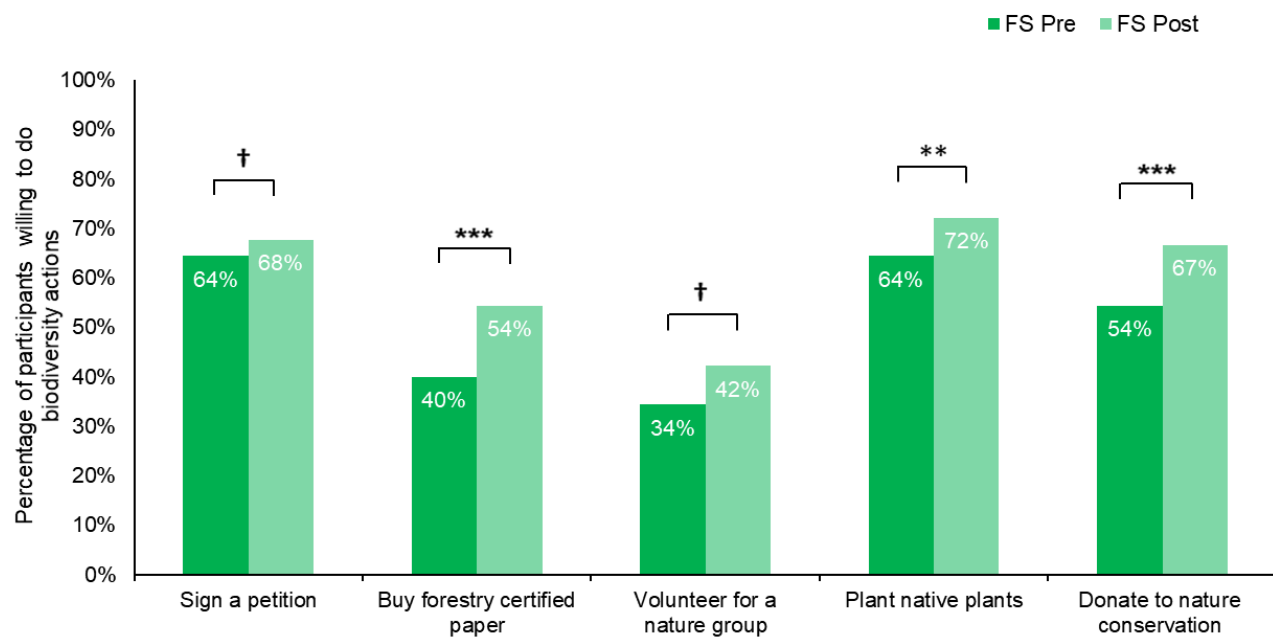


Figure B3-5. Percentage of matched FS participants willing to engage in sustainable biodiversity actions. FS=Field School participants, Pre=pre-visit, Post=post-visit. († $p<.1$ , \*\* $p<.01$ , \*\*\* $p<.001$ ).