Journal of Community Engagement and Scholarship

Volume 13
Issue 3 *Climate Change Knowledge Translation*

Article 4

March 2021

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Cover Page Footnote

Corresponding author. Email: bgunson@wlu.ca Website: www.resilientresearch.ca To access our research projects see: www.resilientresearch.ca Acknowledgements This research was supported in part by the following: Social Sciences and Humanities Research Council of Canada (SSHRC) through an Insight grant; Ontario Ministry of Agriculture, Food, and Rural Affairs (OMAFRA) though a New Directions research grant; Canada TREE (Tree Research and Education Endowment) fund though a Jack Kimmel research grant; Wilfrid Laurier University; an anonymous donor, and the Mountsberg Conservation area. Any opinions expressed in this work are those of the authors and do not necessarily represent those of the funding agencies, Wilfrid Laurier University, or Conservation Halton Mountsberg. We would like to thank Brenna Bartley (Mountsberg) for delivering the programming, Dr. David Morris and Dr. Jennifer Baltzer (WLU) who helped with project development, and all of the teachers, staff and students who helped deliver and participate in the program.

Knowledge Mobilization, Citizen Science, and Education

Bryce Gunson, Brenda L. Murphy, and Laura Jayne Brown

Abstract

While climate change project funders, community partners, and researchers are increasingly calling for robust knowledge mobilization plans, including knowledge translation and transfer, there are ongoing debates about how to design and measure the effectiveness of these efforts for specific target audiences. Climate Change S.O.S. – Save Our Syrup! is a knowledge mobilization program that brings high school students out to a working sugarbush in Ontario, Canada. This program was developed by drawing on the outdoor education expertise at the Mountsberg Conservation Area, forestry specialists' consultation, and the project team's work on previous community-based studies. Students also contribute to a citizen science project monitoring the health of the sugar maple ecosystem and learn about the impact of climate change on this ecosystem. Pretest and posttest surveys measured the knowledge mobilization program's effectiveness on the students' knowledge, attitudes, and behaviors. With 600 grade 9–12 participants in this project, this is one of the largest studies that the team could find that measures climate change knowledge mobilization effectiveness on high school students. Results indicate short-term positive changes in knowledge of climate change and maple syrup, and positive changes in students' attitudes regarding their ability to lessen their impact on climate change, but no statistically significant longer-term change to behavior. After highlighting some of the key issues and concerns around designing three projects and measuring effectiveness, the paper outlines how the program was developed, its key results and limitations and lessons learned. We argue that although single, targeted knowledge mobilization efforts can be effective, longer-term, multi-pronged approaches are likely necessary to contribute to sustained behavioral change.

Introduction

Since the 1992 Earth Summit in Rio de Janeiro, a proliferation of environmental research has been produced that has the potential to educate the public, enhance practice, and guide decision-making (Reed, Stringer, Fazey, Evely, & Kruijsen, 2014). To fulfill that potential across the social, economic, and environmental sectors, especially for complex problems such as climate change, research production and dissemination must involve ongoing and two-way information exchange among a project team with expertise spanning multiple spatial and temporal scales and disciplines (Murphy, 2011; Gunson & Murphy, 2015). It must also include societal expertise from those stakeholders most impacted by the problem such as practitioner, government, non-government, trade/business, Indigenous, gendered, or other perspectives (Murphy, Chrétien, & Morin, 2014). Moreover, to activate inter- and intra-generational climate change mitigation and adaptation, effective communication of research results requires purposefully translating, transforming, and transferring information to meet the needs of identified audiences. Both of these factors, two-way information exchange and targeted outreach, are essential to the process of knowledge mobilization (Levin, 2011).

One targeted opportunity to undertake knowledge mobilization is through sustainability education aimed at assisting learners in acquiring the knowledge and competencies that empower them to take action (Godemann & Michelsen, 2011). Citizen science is also becoming increasingly popular as a tool with which to both engage the public in large-scale scientific research while also attempting to achieve social and educational objectives (Brossard, Lewenstein, & Bonney, 2005; Crall, Jordan, Holfelder, Newman, Graham, & Waller, 2012; Eilam & Trop, 2012; Moss, Abrams, & Kull, 1998; Mueller & Tippens, 2012; Zoellick, Nelson, & Schauffler, 2012). Despite this potential, a review of citizen science and climate change studies by Groulx, Brisbois, Lemieux, Winegardner, and Fishback (2017) found that research focused on education or social mobilization is currently lacking and "the recognition that effective climate change communication and engagement may be a prerequisite to action is still comparatively novel" (p. 68). We argue that through citizen

science experiences and targeted education efforts, targeted knowledge mobilization has the potential to positively influence youth climate change knowledge raising awareness and providing information, attitudes impacting emotions and activating ecologically responsible values, and behaviors, e.g., instrumental, tangible changes to policy, practice, or actions.

As has been demonstrated across several concerted societal interventions (e.g., recycling, drinking and driving, seat belts), the roots of influencing positive change to knowledge, attitudes, and behaviors (KAB) can be established when embedded into the education of children and youth (La Trobe & Acott, 2000; Crall et al., 2012; Bogner, 2010). Despite this potential, documenting the impacts of environmental educational programming and citizen science experiences has been challenging because this highly interdisciplinary field of study has yet to develop clear criteria for defining and measuring program success (Brossard et al., 2005). Although some qualitative and quantitative studies have found that youth demonstrate positive changes primarily to knowledge acquisition and some attitudinal shifts, to date the authors could not find any large scale, quantitative studies focused on climate change knowledge mobilization to further corroborate these findings (Groulx et al., 2017; Thorn & Bogner, 2018).

In addition, despite the potential of youth-targeted climate change knowledge mobilization efforts, most studies gauging the outcomes of interventions focus primarily on program evaluation for educators and practitioners (Bogner, 1998; Reed et al., 2014; Thorn & Bogner, 2018). There is a paucity of research focused on evaluating youth KAB in the context of climate change education, and specifically, the project team could not find any research evaluating youth on climate change and forest-related consumer products such as maple syrup through a targeted outdoor education program tied to a high school curriculum.

Understanding the full breadth of outcomes resulting from knowledge mobilization programs is important for several reasons. First, given the money spent on program development and delivery, funders want to understand the broad impacts of the program on the participants (Thompson, Hoffman, & Staniforth, 2010). Second, understanding outcomes is necessary to develop theoretical frameworks to guide future research on the impact of knowledge mobilization on participants and society, and for improving methodologies in this emerging field (Bogner, 2010). Third, information on outcomes is valuable to professionals delivering the programming to improve existing projects, develop new programs, and reach new audiences (Thompson et al., 2010). Fourth, findings from these outcome studies improve the ability to set reasonable goals and objectives and suggest more evidence-based strategies for future knowledge mobilization program development (Bogner, 1998).

This paper reports on quantitative survey results aimed at the assessment of changes to youth environmental KAB from a combined citizen science and outdoor education three-year pilot knowledge mobilization program called Climate Change S.O.S.—Save our Syrup! (CCSOS!). The program, involving 600 youth in high school grades 9–12 (approximately ages 14–18), was developed from ongoing transdisciplinary research in Ontario, Canada. It focused on documenting the impact of climate change on maple syrup and identifying opportunities for effective mitigation and adaptation. For over a decade the research team (in various configurations and across several grants) has been working to understand the historic, economic, social, and environmental value of maple syrup as well as the impact of climate change on the sugar maple (*acer saccharum*) and associated biophysical and sociocultural "sugarbush" landscapes[1] Drawing on rural and Indigenous knowledges as well as a range of other expertise, the projects intentionally co-developed targeted, audience-specific knowledge mobilization outreach. CCSOS! draws together the results from our ongoing projects with expertise from the Mountsberg Conservation Area located in southern Ontario, Canada. The Mountsberg location is ideal because it includes a mature sugarbush used to produce maple syrup each spring as well as an outdoor education facility. The CCSOS! program consists of a pre-assembled classroom component delivered by the high school teacher in advance of the visit as well as on-site education modules and a citizen science experience delivered by Mountsberg staff.

Following this introduction, the literature review provides a more in-depth discussion of knowledge mobilization and climate change followed by the details of the maple syrup study context. Next, the methods section describes the survey instrument and the subsequent results are

[1]To access our research projects, see www.resilientresearch.ca.

outlined in terms of the statistically significant changes to KAB using a pretest posttest survey design and the two sample Man Whitney statistical test. The paper then discusses key results and concludes with some final thoughts.

Climate Change, Knowledge Mobilization, and Maple Syrup

Measuring the Impacts of Educational Interventions

Today, climate change is one of the most prominent socioscientific issues of our time (Klosterman & Sadler, 2010); however, information about it provided by the media may or may not provide scientifically accurate information and can lead to public misconceptions about anthropocentric climate change and its potential impacts (Fortner, Lee, Corney, Romanello, Bonnell, Luthy, Figuerido, & Ntsiko, 2000). It is important, therefore, to develop audience-appropriate educational opportunities that provide accurate information about the multifaceted and complex phenomenon of climate change, especially its diverse consequences for ecosystems and human beings.

Modern climate change education often focuses on global-scale problems so large that it can overwhelm learners, a phenomenon that Klosterman and Sadler (2010) characterize as contributing to apathetic attitudes toward climate change. Recent research has also shown that school-aged students are influenced more by analyzing local problems rather than global examples of the impacts of climate change, resulting in more willingness to modify their own behavior and provide more support for governmental actions to address climate change (see, e.g., Bogner, 2010; Groulx et al., 2017; Sellmann & Bogner, 2013; Thornton & Leahy, 2012).

There is also a growing recognition that citizen science programs have the potential to enhance a participant's sense of environmental responsibility, promote social learning in informal environments, and contribute to finding answers to biological questions at unprecedented scales (Bonney, Ballard, Jordan, McCalley, Phillips, Shirk, & Wilderman, 2009; Brossard, et al., 2005, Crall et al., 2012; Groulx et al., 2017). Among other things, citizen science projects aim to increase participants' knowledge about science and the scientific process, and to change their attitudes toward science and the environment. Attitude changes ideally result in behavioral changes, which is the ultimate goal of environmental education (Dresner & Gill, 1994; Groulx et al., 2017; Van Liere & Dunlap, 1980).

According to the literature, self-esteem is an important variable influencing youths' abilities to develop and retain KAB. Self-esteem is an evaluation of self-worth that a person makes and maintains (Thøgersen, 2006). KAB research shows that fostering and encouraging higher self-esteem is important to help an individual feel capable of adopting pro-environmental attitudes and give them confidence in their abilities to change their behaviors (Haselton & Nettle, 2006; Thøgersen, 2006). Students learn best and are motivated when they feel comfortable, hopeful, and stimulated in the natural environment that allows them to feel free from the constraints of parents, school, and peers at home (Dresner & Gill, 1994). Environmental education programs in wilderness areas, such as this project's intervention at Mountsberg, have been shown to be a therapeutic tool for building positive self-perceptions (Dresner & Gill, 1994).

The experiences can build self-esteem, increase feelings of personal adequacy and worth, and bring about changes in participants' interpersonal skills, attitudes, and behaviors (Haselton & Nettle, 2006). The connection between self-esteem and agency, in terms of climate change action, is well supported in the literature (see Adger, Dessai, Goulden, Hulme, Lorenzoni, Nelson, Naess, Wolf, & Wreford, 2009) and is an important element of climate change education.

Research has shown that lower levels of self-esteem are associated with a perceived inability to act on problems. Adger et al. (2009) argues low self-esteem individuals consider themselves incapable of influencing climate change, and that on a broader scale this could hinder society's ability to act. Adger et al. (2009) notes that people who report greater understanding of climate change are generally more willing to act.

The literature on the influence of knowledge mobilization interventions on environmental KAB has generally shown that knowledge and attitudes are more easily shifted than behaviors. The paper by Leeming, Dwyer, Porte and Cobern (1993) was one of the first to publish about the difficulty in changing behaviors, with only five of the 34 studies they reviewed reporting changes in environmentally relevant behaviors. Seminal research by Bogner (1998) posited that increased knowledge ideally leads to favorable attitudes toward the environment, which in turn may lead to action promoting better environmental

quality. Yet, this body of literature continues to be controversial because behavioral changes are often not found by study results. Since then, reviews on this subject continue to suggest that outdoor education has many benefits such as allowing students to gain scientific knowledge, develop positive attitudes, and ideally, environmentally conscious behaviors (Bonney et al., 2009). Results from many studies, such as Jordan, Gray, and Howe (2011), found that content knowledge and awareness increased, but participation was insufficient to change participants' attitudes toward the environment and didn't translate into behavior changes. Similarly, Brossard et al. (2005) evaluated The Birdhouse Network to assess changes in science literacy, content knowledge, and attitudes. The program increased participants' knowledge of bird biology, an effect attributed to the emphasis placed on that subject throughout the program. This study, however, revealed no significant change in participants' attitudes toward science or the environment and no significant change in participants' understanding of the scientific process following participation.

The literature is somewhat contradictory regarding the additional changes to KAB that can be achieved through longer duration interventions. Some research found that more sustained programs (e.g., summer camps of one- to two-week outdoor education experiences) produced stronger knowledge gains and positive attitude changes (Ballantyne & Packer, 2002; Hashimoto-Martell, McNeill, & Hoffman, 2012; Thorn & Bogner, 2018). In contrast, one- to five-day ecology programs research by Bogner (1998) utilized a pretest, posttest evaluation to show that both programs fostered knowledge and attitude change, but a change in behavior was found only for the group in the five-day program. However, some suggest that change is more likely to occur in people who are already environmentally conscious and willing to spend longer times in such programs (Dresner & Gill, 1994; Crall et al., 2012).

Smaller scale student studies involving 20–30 participants have been common considering that public education classes in North America are often about that size and the researcher must comply with school board ethical restrictions (Bodzin, 2008; Sellmann & Bogner, 2013). Most KAB outdoor education literature (Arvai, Campbell, Baird, & Rivers, 2004; Brewer, 2006; Thorn & Bogner, 2018) is based on research involving voluntary programs such as after-school ecology clubs and summer camps that are not directly associated with school boards to overcome this constraint. At the larger scale, Brossard et al.'s (2005) The Birdhouse Network study involved 798 people from a relatively homogeneous group of older volunteer birdwatchers. Bogner's (1998) study included 700 students who participated in a long-established outdoor ecology program in a national park in the United States.

The pretest, posttest quantitative survey design is the most common KAB measurement approach in the literature and has been used since the early 1970s in the United States (Leeming et al., 1993). Although there are limitations (explained below), the pretest, posttest method is thought to be a good measure of KAB program effectiveness because it provides a baseline understanding of what students know before the program and allows for conclusions to be drawn about the persistence of KAB after the students have returned home (Jordan, et al., 2011; Brossard et al., 2005; Sellmann & Bogner, 2013). That said, formative research by Leeming et al. (1993) found that although several of the studies appeared to have found positive effects on environmental KAB, much of the utility of these findings was undermined by problems of weak or poorly described experimental design and data analysis processes using inappropriate statistical methods.

There is also some disagreement in the environmental education community about the completeness of the KAB model (Marcinkowski, 2003; Rickinson, 2001). The model is said to have conceptual limitations as it oversimplifies components and neglects the interactions of factors that may govern behavior (Leeming et al., 1993). Another methodological problem is that the vast majority of investigators use a new instrument constructed specifically for their current project. Thus, it becomes almost impossible to make meaningful comparisons of different techniques across studies because the comparability of the measurement instruments is unknown. Authors for many years (Leeming et al., 1993; Thorn & Bogner, 2018) have championed that researchers should feel some responsibility to use and further develop survey tools and inventories already in existence and believe that the development of a scale for measuring children's KAB about the environment (to be used as a comparable baseline measure) should be a high priority for future researchers (Thorn & Bogner, 2018).

Despite some shortcomings of the KAB approach it has continued to be used in the field of environmental education. It was adopted in the United States by the National Environmental Education Foundation (NEEF) to conduct surveys of environmental KAB administered by state natural resource departments to a sample of the general public each year from 1997 to 2002 (Robelia & Murphy, 2012). Each survey resulted in an environmental report card measuring a particular facet of environmental literacy of American citizens. The use of quantitative KAB measures by NEEF solidified the use of these measures as legitimate among many environmental education researchers (Robelia & Murphy, 2012; Thorn & Bogner, 2018).

The Study Context—Maple Syrup and Climate Change

For young Canadians, the potential loss of maple syrup due to climate change provides a tangible and uniquely Canadian opportunity to teach youth in an outdoor setting and influence their environmental KAB. The maple trees of Canada's forests have played an important role in the development of Canada, both commercially and culturally (Brown, Lamhonwah, & Murphy, 2015; Huron, 2014). Canada is the largest producer of maple syrup in the world, producing 71% of the world's supply with the remaining 29% coming from the United States (Government of Canada, n.d.). The maple syrup industry is an important part of the rural economy and in 2017 was worth an estimated $494 million. The maple leaf has been a symbol of Canadian identity since its likeness was placed on our national flag on February 15, 1965, and had been important at least since the 1700s (Murphy, Chrétien, & Brown, 2009). Maple syrup production from these trees each spring signals the impending ending of winter, celebrated by a number of maple syrup festivals and first-tap ceremonies (Chrétien, Murphy, Restoule, & Smits, 2014; Moody, 2015). Further, for Canada's First Nations and Métis peoples, maple trees and maple syrup have traditionally been vital to their societies, providing food and medicines and contributing economic benefits for hundreds of years (Chrétien, 2014; Huron, 2014). As well, maple syrup has featured prominently in their cultural and spiritual practices and is often seen as a tool to revitalize culture and as a basis of new community-owned businesses (Chrétien et al., 2014).

Climate change is affecting forests throughout the world, but the impacts of these changes vary by region (Murphy, et al., 2012; McGlade, 2015). Sugar maples are quite susceptible to the effects of climate change due to their shallow roots and sensitivity to changes in temperature and moisture (Colombo, 2008; Richardson, 2015). When mature trees were first established, the growing conditions were different than those created by the present or future climatic conditions; forest species may not be able to adapt quickly enough to these changes (Lindner, Maroschek, Netherer, Kremer, Barbati, Garcia-Gonzaloa, Seidl, Delzon, Corona, Kolstrom, Lexer, & Marchetti, 2010; Richardson, 2015). Given that maple trees need to be 40–50 years old before they can be tapped safely, and can live to be 300–400 years of age with an average life span of 150–200 years, the impacts of climate change (shifting precipitation and temperatures) are especially profound (Murphy et al., 2012). Maple syrup producers are facing a diversity of challenges from climate change that include potential range shifts in the maple resource, increasing variability in the timing, duration, and yield of sap flow and syrup operations, and a higher risk of invasive species, pests, and diseases (Snyder, Kilgore, Emery, & Schmitz, 2019).

CCSOS!: Intervention and Measurement

CCSOS! is a recently completed three-year pilot knowledge mobilization program at the Mountsberg Conservation Area geared toward grade 9–12 high school students highlighting the effect of climate change on sugar maple and maple syrup. Following the pilot, the program has continued to be offered on an ongoing basis as interest and funding allow.

Participants

Altogether, 600 students from seven secondary schools in the Halton District School Board in the cities of Oakville, Burlington, and Georgetown (Ontario) participated in our study, yielding 517 usable surveys. A total of 10 classes participated in the program. Classes included in this study attended the program during the spring semesters of 2013, 2014, and 2015, with one class attending in the fall semester of 2014. Classes included four Grade 9 classes (n=222), one Grade 10 class (n=10), two Grade 9 and 10 classes (n=75), and three Grade 10–12 classes (n=180). To fully maintain confidentiality, no demographic information was collected about the students. Participants

Figure 1. Youth walk to the Sugarbush at Mountsberg Conservation Area to Participate in CCSOS.

came from both urban communities (Burlington, Oakville) and a small town (Georgetown). The board required their own ethics approval for research to be conducted. Survey participants were included based on their class participation in the program, when teachers were willing to participate with their students, and when parents gave their permission to participate in the study (opportunity sample). Funding through our project allowed students from across Halton to participate by covering the bus costs, field trip costs, and program materials. This allowed the program to be free of charge, and thus more accessible for classes. Students from alternative learning programs such as STEP (Secondary Teen Education Program) and TEAM (Teen Education and Motherhood) particularly benefited from the opportunity to participate.

The Environmental Education Intervention

Conservation Halton promoted the program to the school boards. Participating teachers registered for the program with Halton staff and their school administration handled busing and other arrangements. Upon registration, information and lessons were mailed by Mountsberg staff to participating teachers. The materials, including insights from our ongoing maple syrup projects, were developed by Mountsberg educators and designed to align with the Ontario social science curriculum. The materials contain lessons on climate change, biodiversity, and more general environmental activities (e.g., recycling) with an overall focus on information associated with the sugarbush and maple syrup. Training information on the citizen scientist tools that are used on-site is also provided before the trip (e.g., how to use a clinometer and read a refractometer to measure the sugar content of sap and syrup) to maximize the time spent on-site. For the pilot, the CCSOS! program began with the administration of the survey pretest between 7–14 days prior to the visit to Mountsberg. The environmental education intervention then begins with the in-school lesson package delivered by the high school teacher before the students visit Mountsberg.

The on-site programming starts with a welcome to the Mountsberg Conservation Area (in the Discovery Centre). A "Science Scoop" video filmed at Mountsberg featuring Dr. Brenda Murphy from Wilfrid Laurier University introduces students to the problems of climate change and sugar maples. Students are then informed about the citizen science aspect of the experience, focusing on the need for student assistance to build a database to monitor the sugar maples to see if they are being affected by climate change.

Activity one invites students to sample and compare maple syrup to table syrup and participate in a discussion about the impacts of climate change on sugar maples. Activity two takes students outdoors, where they walk to the sugarbush and complete the citizen science project (Figure 1). Mountsberg educators encourage the students to critically examine the surrounding forest and ask them to watch for changes in the forest during the walk. Students are asked to indicate when they think they have entered the sugarbush, characterized by the differences between naturally occurring forests and a managed sugarbush. Students are introduced to the other interesting herbaceous species that are part of the sugar maple ecosystem (e.g., trilliums, jack-in-the-pulpit, wild leeks, maidenhair ferns).

For the citizen science project, groups of students are assigned a square-meter quadrant within a 25 square-meter study plot (demarcated by spray paint) where they undertake monitoring activities, specifically measuring tree health (height, diameter, canopy health, sap production), plot health (seed production, look for evidence of gall-inducing mites) and biodiversity (number of tree species, nests, tree cavities). Students use tools provided by Mountsberg to undertake the measurements (e.g., tape measures, refractometers, litter traps). They are taught the proper techniques

to take their measurements and are guided by the educators to ensure accuracy in completing their monitoring sheets. The study area plot, developed with the assistance of Wilfrid Laurier University experts, is located in a remote area of the Mountsberg sugarbush. All trees measuring over 5 cubic centimeters in diameter at breast height have been tagged and included in the monitoring project. A total of 33 trees were big enough to be included in the study; this group consists of 13 sugar maples (generally mature, canopy trees), 15 white ash (all young, understory trees), and 5 American beech (all young, understory trees).

Upon completion of activity two, students walk back to an open space outside of the Discovery Centre to participate in activity three, titled "Tipping Point," which focuses on value chains. Tipping Point encourages students to think about the maple syrup production process as well as identify all the links along the maple syrup value chain. The value chain is an environmental/societal/economic ecosystem beginning with the land-base, and involving producers, retailers, consumers, and regulators (Murphy, et al., 2014). To simulate the value chain, students stand in a circle shoulder-to-shoulder holding a tree branch vertically (like a walking stick). The instructor then asks that participants quickly switch sticks with their neighbor, which requires them to catch it before it falls. The instructor then stresses the circle by reading statements such as "A summer drought has limited the maple harvest. Take two steps back." This expands the circle, which makes it harder to catch the sticks. Dropped sticks indicate value chain problems caused by environmental stresses. The circle can be made bigger or smaller depending on the statement read by the instructor.

The final activity of the day is called the "I can change climate change" (IC4) activity. IC4 is an established program regularly offered by Mountsberg staff that is designed to equip students with the skills required to be environmentally responsible consumers. Using a culinary theme, students are informed that food purchasing decisions have an impact on climate change. They are encouraged to think about how maple syrup fits into the local food picture in Ontario by preparing a menu using the Foodland Ontario calendar which outlines seasonally available local foods. Students are encouraged to think about how their purchasing decisions locally can make a difference globally. This concludes the on-site education portion of the program.

Measurement of the Knowledge Mobilization Intervention

Many psychological pretest, posttest studies across a wide range of topics use a control group to compare changes between the control and those receiving the intervention, and some KAB studies follow this model. For instance, Bogner (1998) utilized a control group of students who participated in the in-class learning but did not attend the on-site program as a means of measuring the impact of the experiential component. However, as is often the case in KAB research (Brossard et al., 2005; Sandhaus, Ramirez-Andreotta, Kilungo, Wolf, Sandoval, & Henriquez, 2018), we could not use a control group for this study due to ethics restrictions imposed by the school board. Instead, the goal of this research was to measure student KAB changes prior to and after this intervention.

The survey package was tested and refined with input from a teacher before the program began, which resulted in some refinements, such as using different colored surveys (white pretest, pink posttest) to help teachers easily administer the survey. As per ethics protocols, students read and signed the informed consent forms. The forms describe the purpose of the project, identify the risks and benefits of participation, and provide information on confidentiality, feedback, and publication. They also contain the researchers' contact information. These same forms were read and signed by their parent/guardian and returned to the research team. The study was voluntary, and students could withdraw at any time without penalty. To accommodate students who chose not to participate we included a maple syrup-themed word search to work on while participants completed the survey. The pretest and posttest surveys (Table 1) and associated ethics and permission forms were mailed to each participating teacher prior to the site visit, along with instructions on how to administer the surveys. The pretest survey was administered in-class by the teachers about 7–14 days before the in-class educational information was taught. After visiting Mountsberg, teachers were asked to administer the posttest survey within seven days, and mail both surveys back to the research team; this led to a pretest, posttest window of 14–21 days. There is much debate around how much time should pass before delivering the posttest, with some researchers advocating for as long as 21–30 days after the pretest (Bogner, 1998). There is concern, on the one hand, that students

completing the posttest too soon will remember their pretest responses and answer the posttest in the same way. On the other, with a lengthy delay, students may have forgotten what they learned.

As is standard in this type of research, the same survey was administered before and after the learning experience. The responses were anonymous, and the research team was not involved in administering the survey. The evaluation had to be as brief as possible because the respondents are young students and the surveys had to be administered by teachers during class time. The questionnaire was created from insights gathered from other KAB studies in different contexts during the literature review phase. For example, some questions were adapted from the New Environmental Paradigm (NEP) scale, which is designed for adults but has successfully been adapted for use by young people (see, e.g., Dunlap, Van Liere, Mertig, & Jones, 2000). We did not test for reliability and validity as the ethics agreements limited the amount of time we could request from teachers to administer the survey.

The school board ethics agreements granted us only 20 minutes of class time for the students to complete both surveys. The survey consisted of 18 Likert scale statements (six statements per KAB category) aimed to test students' KAB both before

Table 1. Questionnaire

Measurement Category	Statements
Environmental Knowledge	1. Changes in climate temperature are so small and so gradual that plants and animals can adapt.
	2. Biodiversity is essential to the health of ecosystems.
	3. Climate change is affecting the timing of the maple syrup collection season.
	4. Climate change may result in more storms or droughts.
	5. Carbon dioxide is removed from the atmosphere by trees through photosynthesis.
	6. The maple syrup "value chain" involves producers, distributors, retailers, and customers.
	Likert Scale Responses Strongly Agree – Agree – Neutral – Disagree – Strongly Disagree
Environmental Attitudes	1. I am concerned about climate change and how it may impact my life.
	2. Using more resources than we need is a serious threat to the health and welfare of future generations of people.
	3. I don't think there is very much I could do to lessen the impacts of climate change.
	4. I like maple syrup and would be willing to make some personal changes to prevent the impacts of climate change.
	5. I believe it is important to buy products that are environmentally friendly, even if they are more expensive.
	6. I believe I should recycle because it helps lessen my impact on the environment.
	Likert Scale Responses Strongly Agree – Agree – Neutral – Disagree – Strongly Disagree
Environmental Behaviors	1. I consciously turn off the tap to conserve water.
	2. When I shop I choose natural or chemical-free products whenever I can (e.g., snacks, clothing, shampoo).
	3. I talk to others about climate change and the environment.
	4. I walk whenever I can because I know cars contribute to climate change.
	5. I encourage my family to purchase locally grown food (e.g., grown in Ontario).
	6. I recycle because I know it helps lessen my impact on the environment.
	Choose One Response Always – Sometimes – Rarely – Never

and after participating in the program (Table 1). Students had five Likert scale options (strongly agree, agree, neutral, disagree, strongly disagree) to circle for the knowledge and attitudes statements, and four options (always, sometimes, rarely, never) to circle for behavioral statements. The five-point Likert scale has been widely used and validated by a panel of researchers in the field of environmental knowledge and attitudes (Brossard et al., 2005; Dunlap et al., 2000). We purposefully provided one less option to choose for the behavioral statements to follow best practices of Sellmann and Bogner (2013) and Bogner (1998), who state that measuring environmentally conscious behaviors is best accomplished with a four-option scale. Behavioral change is the hardest measure to change, so Sellmann and Bogner (2013) argue that less ambiguous options are needed in questionnaires as behaviors are more of a "yes" or "no" change verses attitudinal or knowledge changes, which are better suited to a five-option scale that can capture more nuanced shifts.

This project follows the suggestions of authors such as Brossard et al. (2005), who indicate that roughly half of knowledge statements should be focused on environmental processes (e.g., climate change may lead to more storms or droughts) and half of the statements should be fact-based (e.g., the maple syrup "value chain" involves producers, distributors, retailers, and customers). Attitude toward the environment was assessed with a subset of the most frequently used measures of public environment concern such as recycling, resource use, and climate change, along with statements focused on assessing their willingness to change (e.g., "I like maple syrup and would be willing to make some personal changes to prevent the impacts of climate change.") (Brossard et al., 2005; Thorn & Bogner 2018). Behavioral statements were formulated in-line with such authors as Bogner (1998) and Brossard et al. (2005), who emphasize that behavioral statements must be simple, actionable, and tailored to the age and abilities of the participants. The statements aimed to measure behavioral actions (e.g., "I consciously turn off the tap to conserve water") that students could easily make at home while also including statements that attempt to discover if students had become more environmentally conscious (e.g., "I talk to others about climate change, and the environment").

Statistical analysis to assess whether participation in the knowledge mobilization activities influenced the participants' environmental KABs was carried out using RStudio (version 1.1.456). To test the null hypothesis that the two populations (pre and post) have the same response distribution, we employed a two sample Mann-Whitney-Wilcoxon test at the 95% confidence level. The test is used to test for two independent samples, such as our pooled pretest, posttest samples, which was appropriate since we could not track changes to individual participants, but rather amalgamated responses to each test into one set of data. In addition, this test has been successfully used in other pretest, posttest projects (Bogner, 2010; Ballantyne & Packer, 2002) to measure changes in student KAB resulting from a learning program. This allowed us to go beyond the descriptive statistics used by some authors in this field (Klosterman & Sadler, 2010; Sadler & Zeidler, 2004; Bodzin, 2008).

Data analysis began with quality checking each survey manually to ensure they were completed correctly and to remove any incomplete surveys. Next, a random number generator was used to remove surveys from each high school data set so that the number of pretest and posttest survey groups were equal. This resulted in 517 surveys being included in the pretest and in the posttest. To ensure that the random removal of data sets did not affect the distribution of responses, histograms were generated using the percentage of Likert scale responses and compared for both the initial and edited data for each statement by group. By doing so it was determined that the random removal of surveys did not alter the distribution of responses from each high school. Finally, the data from all the schools' surveys were combined by statement and pooled into two groups, pretest and posttest.

Drawing from previous research (e.g., Bonney et al., 2009; Bogner, 1998), we hypothesized that this study would demonstrate statistically significant positive changes in knowledge, may or may not result in statistically significant positive changes in attitudes, and would not lead to statistically significant changes in behavior.

The general direction of the participants' responses was ascertained by summing the agreement (Likert scale values 1 and 2) and disagreement (Likert scale 4 and 5) answers to the knowledge and attitude statements in the pretest and posttest surveys. For the behavior statements the "never" and "rarely" responses were summed and compared with the "sometimes" and "always" responses.

Table 2. Summary of the Responses to the Knowledge Statements and Results of Mann-Whitney Tests

Knowledge Statements	K1		K2		K3		K4		K5		K6	
	Pre%	Post%	Pre%	Post%	Pre%	Post%	Pre%	Post%	Pre%	Post%	Pre%	Post%
1=Strongly Agree	5	6	26	37	12	48	17	25	23	23	17	36
2=Agree	33	19	47	46	64	41	61	55	38	40	55	43
3=Neutral	25	20	25	13	19	8	17	16	29	28	24	15
4=Disagree	31	40	2	1	5	1	4	2	7	6	3	2
5=Strongly Disagree	6	14	0	3	0	2	1	2	3	3	0	3
p-value	***<.001***		***<.003***		***<.001***		*.055*		*.845*		***<.001***	

Note: A P-value of less than 0.05 indicates a statistically signficant change in pre- and post-test responses.

Table 3. Summary of the Responses to the Attitude Statements and Results of Mann-Whitney Tests

Attitude Statements	A1		A2		A3		A4		A5		A6	
	Pre%	Post%	Pre%	Post%	Pre%	Post%	Pre%	Post%	Pre%	Post%	Pre%	Post%
1=Strongly Agree	15	21	31	32	4	5	9	9	9	19	38	36
2=Agree	52	49	50	47	21	21	46	47	45	38	52	49
3=Neutral	25	23	13	73	28	18	36	35	33	33	9	12
4=Disagree	6	4	4	2	40	36	9	8	11	9	0	3
5=Strongly Disagree	3	3	1	2	6	20	1	1	2	2	0	2
p-value	*0.104*		*0.995*		***<0.004***		*0.609*		*0.089*		*0.239*	

Note: A P-value of less than 0.05 indicates a statistically signficant change in pre- and post-test responses.

Table 4. Summary of the Responses to the Behavior Statements and Results of Mann-Whitney Tests

Behavior Statements	B1		B2		B3		B4		B5		B6	
	Pre%	Post%	Pre%	Post%	Pre%	Post%	Pre%	Post%	Pre%	Post%	Pre%	Post%
1=Never	2	4	25	21	42	44	10	11	32	28	4	4
2=Rarely	6	6	32	33	37	34	26	21	36	31	8	10
3=Sometimes	25	26	34	34	17	19	40	46	18	30	27	26
4=Always	67	64	9	12	4	3	25	22	14	12	62	61
p-value	*0.410*		*0.376*		*0.820*		*0.977*		*0.119*		*0.669*	

Note: These P-values indicate no statistically signficant change in pre- and post-test responses.

Results

The results of the data analysis on the 517 completed pretest and posttest survey sets are presented by statement group, Knowledge (K), Attitudes (A) and Behaviors (B). Of the three statement groups, the participants' knowledge was most influenced by the knowledge mobilization intervention with four of the six statements in this group having statistically significant changes at the 95% confidence level (Table 2) as indicated by the bold italics. Only one of the statements within the Attitudes group demonstrated a statistically significant change (Table 3) and none of the behaviors statements results were statistically significant (Table 4). Histograms are provided only for the statements where a statistically significant change was found.

Knowledge

Statement K1 (Figure 2) and K2 (Figure 3) are concerned with broader climate change and biodiversity concepts. Statement K1 is worded in the negative, so the statistically significant (P-value < 0.001) shift from the "Agreement" end of the Likert scale in the pretest responses toward the "Disagreement" end in the posttest responses indicates a knowledge gain. This result demonstrated that students more fully understood the impact of climate change on plants and animals (pretest 37% to posttest 53%). In K2, the responses shifted toward the "Agreement" end of the scale, indicating that students learned the connection between biodiversity and ecosystem health. This statistically significant change in the distribution of responses for K2 (p-value = 0.003) was the result of a shift from "Neutral" (pretest 27% to posttest 14%) to "Strongly Agree" (pretest 26% to posttest 37%) (Figure 3).

Statement K3 (Figure 4) focused on climate change and maple syrup production. The change from pretest to posttest survey responses was statistically significant (p-value = <0.001) and again shifted from "Neutral" (pretest 21% to posttest 7%) toward the "Agreement" end of the scale (pretest 75% to posttest 90%) suggesting that students gained some tangible knowledge about the way in which climate change is impacting maple syrup production.

In statement K4, focused on climate change and extreme weather, both the pretest and posttest distribution of responses indicate that most of the students' answers clustered at the "Agreement" end of the scale (pretest and posttest ≈ 79%), with the results not statistically significant (p-value = 0.055). For statement K5, the focus was on the removal of carbon dioxide through photosynthesis. With close to 30% in both the pretest and posttest responding with "Neutral" and approximately 60% at the "Agreement" end of the scale, this indicated that there wasn't a significant knowledge gain (p-value = 0.845).

Statement K6, focused on knowledge of the maple syrup value chains, the test results (p-value = <0.001) indicate that there was a statistically significant shift in the responses from "Neutral" (pretest 24% and posttest 15%) toward the "Agreement" end of the scale (pretest 71% posttest 80%) (Figure 5).

Attitudes

The next set of results pertains to the statements regarding the student attitudes about climate change and the role they can play in this global issue. Of the six statements in this section only one, A3, showed a significant shift in responses (Table 3).

Statement A1 asked students to indicate their concern about the impact of climate change on their lives. There was no significant change in their attitudes after the program with close to

Figure 2. Responses to Statement: "Changes in Climate Are So Small Plants and Animals Can Adapt"

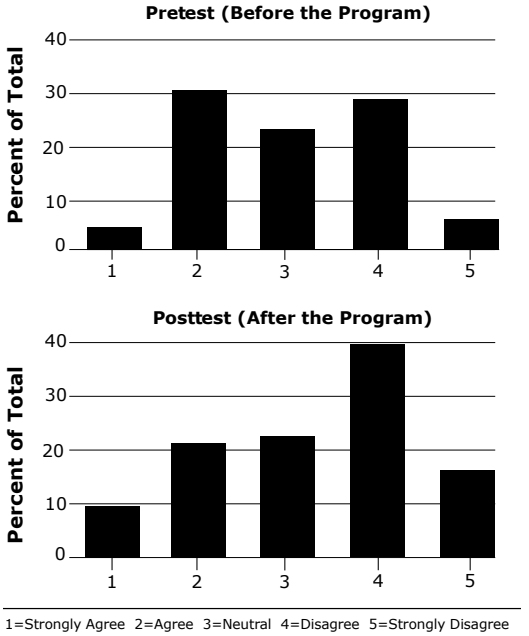
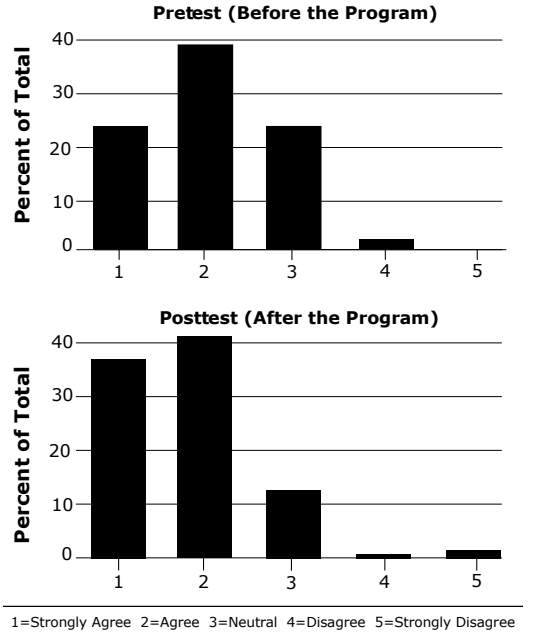


Figure 3. Responses to Statement: "Biodiversity Is Essential to the Health of Ecosystems"



25% of the responses remaining "Neutral" and the majority (about 70%) of students in "Agreement" that climate change will impact their lives (p-value = 0.104). Statement A2 focused on the overuse of resources and how this might threaten future generations' health and welfare. Again, there was no significant change in the students' attitudes measured by their pretest and posttest responses with approximately 80% at the "Agreement" end of the scale (p-value = 0.995).

Statement A3 focused on attitudes toward self-efficacy and the ability to "do" something to lessen the impact of climate change. Since this statement was worded in the negative, responses shifting significantly (p-value = 0.004) from "Neutral" (pretest 28% and posttest 19%) toward the "Disagreement" responses (pretest 45% to posttest 56%) suggested a positive change in the students' attitudes related to self-efficacy (Figure 6).

Statement A4 asked if the students liked maple syrup and would be willing to personally make changes to protect it from climate change. The majority of pretest and posttest responses (about 55%) indicate "Agreement" and close to 33% remained "Neutral," so there wasn't a significant shift in their attitude (p-value = 0.609). Statement A5 was: "I believe it is important to buy products that are environmentally friendly, even if they are more expensive." And the responses remained predominantly in "Agreement" at about 55% for both the pretest and posttests, with around 32% remaining "Neutral" (p-value = 0.089). Statement A6 asked about the student's attitude regarding recycling to benefit the environment. The responses showed strong "Agreement," with about 87% in both the pretest and posttest surveys (p-value = 0.239).

Behavior

The next set of results pertains to statements regarding the students' climate change-related behaviors and the role they can play in this global issue. None of the six statements in this section showed a significant shift in responses (Table 4).

Statement B1 asked if students practiced water conservation by deliberately turning off the tap. The majority reported "Always" (65%) and another about 25% "Sometimes" doing so in both the pretest and posttest surveys (p-value = 0.410). Statement B2 focused on student purchasing habits of natural or chemical-free products and again showed no change between the pretest and posttest surveys. Close to 55% reported "Rarely" to "Never" to deliberately buying these products (p-value = 0.376). B3 asked if they talked about climate change and the environment to others. The majority reported "Rarely" to "Never" (combined about 78%) in both the pretest and posttest surveys (p-value = 0.820). The B4 statement focused on students' willingness to walk because they know a car's exhaust contributes to climate change. The majority (about 45%) reported "Sometimes" with another 22% reporting "Always" in both surveys (p-value = 0.977). Statement B5 focused

Figure 4. Responses to Statement: "Climate Change Is Affecting the Timing of the Maple Syrup Collection Season"

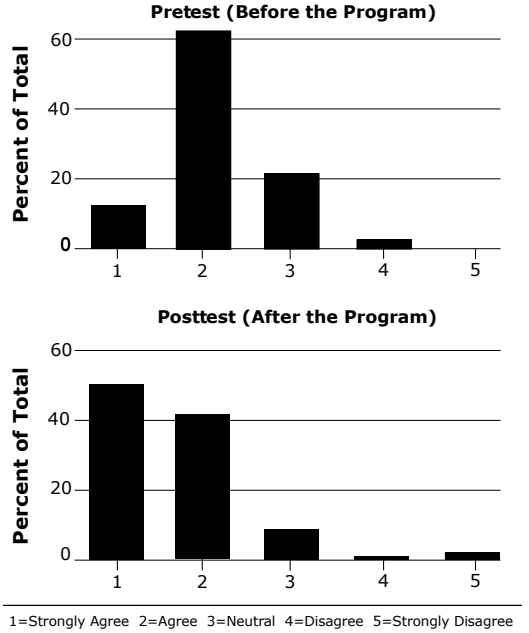


Figure 5. Responses to: "The Maple Syrup 'Value Chain' Involves Producers, Distributors, Retailers, and Customers"

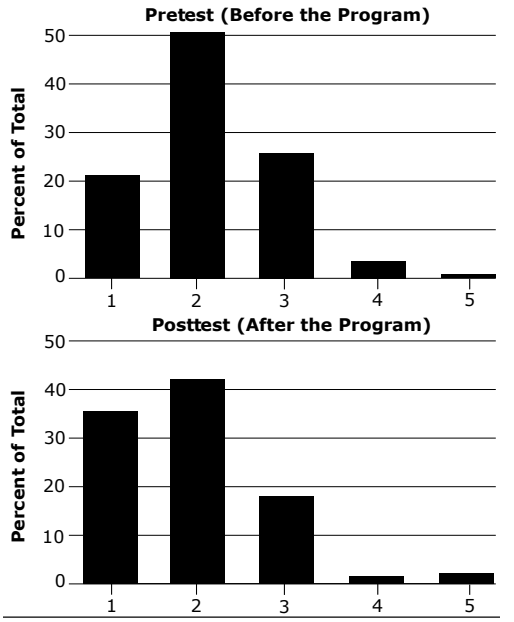
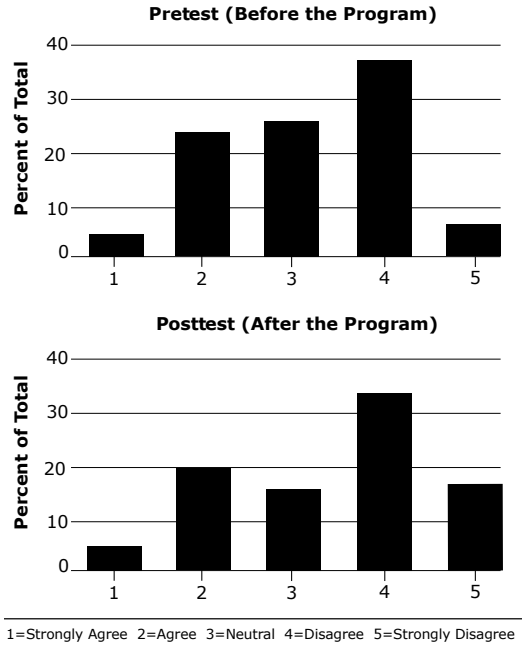


Figure 6. Responses to: "I Don't Think There Is Much I Could Do to Lessen the Impacts of Climate Change"



on whether students encouraged their families to shop locally. The majority of responses for both tests were either in the "Rarely" or "Never" categories with a combined percentage of 68% in the pretest and 58% in the posttest (p-value = 0.119). The final statement B6, was concerned with assessing if students recycled to lessen their impact on the environment. Again, there was no change between the pretest and posttest responses with 62% responding that they "Always" and another 27% that they "Sometimes" recycle to reduce the impact on the environment (p-value = 0.669).

Discussion

This project's knowledge mobilization intervention was designed to actively engage students in an informal environment, foster self-esteem, provide understandable, accurate climate change information, link the impact to a local seasonal forest product (maple syrup), and undertake messaging about positive environmental attitude and behavior shifts. Our project with 600 students participating through a program tied to the Ontario curriculum and sanctioned by school boards is a distinctive contribution to this literature. Although the outdoor experience for our program was conducted on one day, as Bogner (1998) recommended, we added a prior in-class teacher-led module to help better prepare the students for their day in the sugarbush and to further the likelihood of shifting environmental KABs. The project also blended in-school/out-of-school learning with citizen science as an integrated approach designed to increase the positive impact on students' KABs, without being able to engage in a longer-term program. As research shows having students complete the KAB surveys in an identical environment pretest and posttest is important (e.g., Bogner, 1998; Thorn & Bogner, 2018), we had teachers in our study administer the survey in their classroom before the trip, and once they returned. Our knowledge mobilization project also utilized resources and findings provided in Brossard et al. (2005), who recommended that the process of evaluation must be both brief and engaging for this age group as participants in these kinds of projects view it as a recreational experience, so the survey was developed with short, plain-language statements tailored to program content.

The CCSOS! program was an opportunity to undertake knowledge mobilization through sustainability education. The goal of this project was to maximize the potential positive KAB changes through a combination of outreach activities and measure the KAB shifts using a survey instrument and statistical method based on literature best practices (e.g., Brossard et al., 2005; Bogner, 1998; Thorn and Bogner, 2018). A second goal was to provide a clear and complete reporting of the methodology, thereby permitting comparison to other studies (e.g., Brossard et al., 2005) and providing these details for future projects. The study makes a distinctive contribution to research focused on large-scale quantitative measurement knowledge mobilization interventions (e.g., Crall et al., 2012) by involving several distinctive factors, particularly the combination of student experiences with the focus on a locally relevant and threatened environmental resource, maple syrup.

This project's knowledge mobilization intervention combined a high school classroom, teacher-led module with four on-site learning components including two delivered in the outdoor education center (introduction and IC4), and two experiential modules (citizen science and the "tipping point" game). The impact of the intervention was measured using a pretest, posttest survey. As is often seen among KAB environmental research, we did not use a control group, instead pooling the data into two groups and using the two group Mann-Whitney test to assess statistical significance. Delivering the

pretest and posttest 14–21 days apart did result in some statistically significant changes; however, we had no way to judge if a longer time frame would have yielded similar results, or ultimately, for what duration the students retained these gains.

In terms of the generalizability of the results, there are three important considerations. Given that the study had both regular and alternative high school classes in the program, we were able to test across a diversity of learners in this age group (14–18). We still obtained some statistically significant results despite this diversity, indicating that the methodology was fairly robust and worth considering by other researchers. This diversity might also have meant that our study had less of a bias toward participants already being more environmentally conscious (e.g., involved in optional after-school ecology programs). Yet, since this knowledge mobilization intervention was voluntary and had to be approved by parents if the student was under 16 years old, there may well be some unknown bias toward environmental-minded participants in the results. Further, we also did not have any way to parse results according to age groups. It could very well be the case that younger students may have chosen different answers than their older peers. In addition, the team had no way to assess whether or not some other intervening factors (e.g., time spent on the in-school lesson, changing social media access or media events such as Earth Day) might have contributed to, or dampened the KAB results (Leeming et al., 1993). Though our results are promising, there needs to be some caution in inferring a direct cause and effect relationship with this sort of knowledge mobilization intervention or in generalizing these results to the likely impacts of other knowledge mobilization interventions with other groups of students.

It is important that researchers recognize that working with in-school children can be time consuming and add a layer of complexity to the project. It could mean writing two ethics proposals and adhering to two different research ethics committees (in our case the university's ethics committee and the school board's ethics committee). Work with students enrolled in the school system tends to require considerable restrictions and additional steps. For instance, in addition to the 20–minute time restriction, complete lack of access to the classroom environment, and the inability to collect demographic information, we were asked to provide a word search for students in the classroom who did not attend the program or who chose not to participate, so these students would not feel out of place while their peers completed the survey. The school boards are understandably protective of their teachers' time and students' safety and privacy. It is therefore important to allow sufficient time to meet all criteria and school board timelines and carefully scope the survey and paperwork to meet these standards.

Knowledge Gain

Our results indicate positive environmental knowledge gains in four of the six statements the students ranked and it is where the knowledge links and experiences were the most explicit that we found the statistically significant knowledge gains. The results of CCSOS! reinforce Brossard et al.'s (2005) finding that projects must make explicit to participants the issues that they are experiencing and link all learning clearly to the topic. Our results also mirror findings from other studies that indicate students of this age are better able to deal with statements related directly to what they have learned, but that they struggle with concept-based statements (Dresner & Gill, 1994; Sellmann & Bogner, 2013). The four statistically significant statements in this section (K1 "Changes in climate temperature are so small and so gradual that plants and animals can adapt"; K2 "Biodiversity is essential to the health of ecosystems"; K3 "Climate change is affecting the timing of the maple syrup collection season"; K6 "The maple syrup value chain involves producers, distributors, retailers, and customers") were all specifically addressed during the school trip and the statements are more directly tied to this knowledge. However, (K4 "Climate change may result in more storms or droughts"; K5 "Carbon dioxide is removed from the atmosphere by trees through photosynthesis") dealt with more technical topics, which, although addressed in the in-class teaching materials, was more tangential to the outdoor experience.

The challenge of learning concepts is not exclusively an age issue as noted by Brossard et al. (2005), who found that mature adult birdwatching participants quite readily learned scientific facts about birds but struggled to understand concepts such as the scientific method. There is no "one-size fits all" approach to facilitating concept learning as it takes time and multiple interventions to develop these skills (Bogner, 1998). Literature in this field

suggests that longer-duration outdoor learning experiences (summer camps, nature courses, etc.) can assist in developing understanding of environmental concepts (Dresner & Gill, 1994). The CCSOS! program, using a combination of an in-class component and a one-day outdoor experience, did result in significant knowledge gains, but it cannot be expected that students would gain a complete understanding of complex environmental issues in such a short time. It is unknown if the one-day experience, on its own, would have yielded similar results, but considering that the experiential component dominated the statistically significant results, it may be that the in-class component was less impactful than the outdoor experience. This dovetails with Bogner's (1998) study showing that students experiencing both in-class and outdoor components show more KAB changes than control group receiving only the in-class component.

Attitude Changes

Only one statement in this section, A3 ("I don't think there is very much I could do to lessen the impact of climate change"), yielded a statistically significant attitudinal shift toward an increase in students' perceptions that they could do something to lessen the impact of climate change. This result is both ambiguous and promising. The ambiguity stems from the nature of the statement since we do not know what "doing" meant to the students. The promise lies in the perceived increased in self-efficacy.

It is clear from the literature that today's children are under enormous pressures and often say that they feel overwhelmed about the plight of the planet (see, e.g., Andersson & Wallin, 2000; Arvai et al., 2004). Students often feel confused because adults seem unable to resolve environmental problems. Furthermore, urban life tends to insulate children from the natural environment. Many activities of urban children encourage attitudes of anonymity and passivity. Authors such as Louv (2011) discuss the growing body of evidence suggesting that significant changes in children's experiences in nature have occurred over the past several decades. According to Louv (2011) there are strong indicators of an absence of direct experience with the natural world in many children's everyday lives. Thus, the attitude change in A3 is promising. One explanation for this finding is given by Dresner and Gill (1994), who state that a clarity of purpose develops during outdoor education programs when children are called on to take active roles. Attitudes that promote active involvement in changing the world are critical to combating despair in the face of environmental problems. Children may exhibit new, environmentally responsible attitudes and behaviors when they learn about the variety of positive, responsible actions and have opportunities to practice them (Thorn & Bogner, 2018; Sellmann & Bogner, 2013).

While we did not see attitudinal shifts in the other five statements, the results are still interesting. In both the pretest and posttest results for A1 and A2, related to climate change impacts and the overuse of resources, students already have strong concerns for these issues, with agreement ranging from 70–79%. Similarly, A6, focused on recycling, had at least 85% agreement both pretest and posttest suggesting that messaging on this issue has already been quite successful. Recycling was included in the environmental attitudes section because it is a fundamental concept taught in the sustainability and stewardship strand of the Ontario school curriculum's science and technology program (Ontario Ministry of Education, 2019). Recycling is an important value that is central to stewardship and is one of the first environmentally conscious acts children can perform at an early age (Stauch, 2012). With the first curbside recycling program debuting in Kitchener, Ontario in 1981 (and expanding to 150 countries around the world since then), recycling is generally well understood in the Ontario context (Stauch, 2012). Although it is not directly linked with climate change or maple syrup, the question served to capture potential attitudinal changes using a well comprehended concept. Students demonstrated that they came into this knowledge mobilization intervention with some already formed pro-environment attitudes; it may be difficult to increase this level much higher with a short intervention.

The results for A5, asking about attitudes associated with buying environmentally friendly products, was not the central focus of the intervention, so lack of a shift may be related to this context. A4, however, presents a somewhat puzzling result as the whole student experience was very much focused on maple syrup and preventing the impacts of climate change on sugarbush ecosystems; this topic was not tangential as was the case for some of the other statements. It could be that students did not like maple syrup, the statement was too general (e.g., what is meant

by "personal changes"?) or, as other researchers have noted, one-day programs often don't provide the sustained interaction needed to shift attitudes (Thorn & Bogner, 2018).

We postulate that another reason we did not see significant changes in A4 and A5 could be that these statements are focused on issues of personal power and lifestyle choices in areas over which students might not yet have full decision-making control. Since older students (grades 11 and 12) may have more personal control, it might be the case that their answers would have demonstrated this self-reliance, while this was less likely to be the case for the younger students (grades 9 and 10). Students of this age may not be purchasing their own products, so they are perhaps less willing to be concerned with decisions over which they do not have control (Thøgersen, 2006).

Behavioral Changes

No statistically significant changes in students' environmental behaviors were identified; yet the patterns already described above were also found for these statements. B1 (turning off the tap) and B6 (recycling) demonstrated strong pre-existing positive environmental behaviors; 90% and 87% posttest respectively when combining "Sometimes" and "Always." B2 (choosing chemical free products; responses spread among "Sometimes," "Never" and "Rarely") and B5 (buying local; answers clustering toward "Never" and "Rarely"), are statements related to lifestyle choices that may be beyond the student's control. B3 (talking about climate change) and B4 (walking to reduce climate change) would likely be somewhat within the personal power of these students; yet we still did not find a shift. Interestingly, the B3 responses stayed firmly with "Never" and "Rarely" (78% posttest), and B4 answers were 65% pretest and 68% posttest for the "Sometimes" and "Always" responses suggesting that a sizable group of students were already adjusting their behavior to mitigate their carbon footprint.

Overall, our results support the findings from other studies that have attempted to identify behavioral changes through self-reporting measures in youth-aged participants, with many authors explaining the difficulty in describing and quantifying behavioral changes (Bogner 1998; Sellmann & Bogner 2013; Thornton & Leahy 2012). In general, this disconnect between awareness and action supports earlier research as well, which showed that an increase in knowledge and awareness alone does not necessarily promote pro-environmental behaviors (Hashimoto-Martell, McNeill & Hoffman 2012; Bowers, Newman, Brawdy & Egan, 2001; Corburn, 2005). One of the best practice suggestions was to scope the planned activities to focus on a local, tangible issue, rather than a global problem (Sellmann & Bogner, 2013). We had hoped that the focus on a locally relevant commodity and landscape might break through this barrier, but no shift in behaviors occurred.

We posit four possible reasons for the lack of change in environmental behaviors. First, limits to youth self-efficacy and self-esteem may have contributed to the intractability of their behaviors. Youth of this age don't typically run the household and talking about climate change might not feel safe or be a popular discussion topic among this peer group (Rickinson, 2001). Second, apathy related to ongoing dominant societal narratives about the global scale of climate change are not likely overturned by a brief intervention. Ongoing educational initiatives are probably necessary. Third, the environmental justice literature argues that students might be more easily spurred to action from understanding how their own urbanized ecosystem affects their personal lives directly (such as understanding urban environmental health issues are related to increased pollution) rather than learning about something that may be seen to only affect rural communities (Hashimoto-Martell, et al., 2012; Bowers et al., 2001; Corburn, 2005). Fourth, and here is the good news, two tested behaviors (turning off taps, recycling) already align with environmental goals, while one other (walking to reduce climate change impacts) also seems to denote a behavior supportive of environmental values. These results would suggest that interventions and initiatives prior to our knowledge mobilization outreach have had a positive impact on environmental behaviors. In particular, our results confirm what has already been well documented in regard to the change in recycling behavior through ongoing societal influences starting at a very young age (Ballantyne & Packer, 2002).

Conclusions

Research on the impact of knowledge mobilization interventions is necessary because, increasingly, funding agencies and program implementation teams want to use evidence-based strategies and calibrated measurement metrics for existing programs and to reach new

audiences. Further, Groulx et al. (2017) assert that currently, there is a "lack of social science studies that have examined citizen science in the context of climate change" (p. 67). With the impact of climate change and other environmental issues intensifying, academics need to further develop the theoretical frameworks and measurement tools required to better understand how scientific knowledge can be transferred and translated for public audiences. This research contributes to this body of literature with a specific focus on youths. This study was designed to build on several best practices in the sustainability education and measurement literature. It combined in-school and on-site experiences, focused on a locally relevant environmental resource, and used Mann-Whitney statistical analysis of pre- and posttest surveys to measure the effectiveness of the knowledge mobilization. This project had a distinctive focus on evaluating youth KAB in the context of climate change education using quantitative measurement within an in-school group of youth. As hypothesized, the citizen science experiences and targeted education efforts of this knowledge mobilization intervention were found to positively influence youth environmental knowledge, while attitudes and behaviors were harder to shift. The statistically significant knowledge gains appear to be correlated with more heavily emphasized student experiences and with statements focused on facts rather than concepts.

The relatively large sample size and quantitative focus of this study increases the confidence in, and generalizability of, the results, albeit with the caveats outlined in the discussion section. Despite these efforts, the project results demonstrate both the complexity and difficulty of measuring and shifting environmental KABs. Simply providing information and measuring knowledge gain is insufficient. Instead, experiential interventions that promote an emotional connection to nature and place, enhance feelings of empowerment and provide insight into the participants' own values and interests are needed to more deeply shift KABs (Groulx et al., 2017). Longer term interventions also seem to have the potential to lead to more substantive shifts (e.g., five-day programs). As was demonstrated by the strong positive pretest and posttest results around recycling in this study, sustained and ongoing societal efforts can have a profound impact on shifting KABs. This study expands the understanding of KAB in the context of climate change, and we believe this approach (and the lessons learned) can be successfully applied in different contexts. Our conclusions and recommendations can be used by decision makers when designing outdoor education programs to quantify program effectiveness for funders. Given the highly competitive nature of funding acquisition, having a strong knowledge mobilization plan that is measurable using the KAB approach may provide a competitive advantage.

Areas of future research should build on these foundations and focus on how to further shift attitudes and change environmental behaviors, as well as continue to improve measurement approaches. Research should also continue to focus on how to design and measure the effectiveness of knowledge mobilization plans (including knowledge translation and transfer) as there remains ongoing debates about these efforts. The CCSOS! program continues to be offered as resources and interest allows and this project has provided some evidence regarding the value of such outdoor education experiences. In an era of neo-liberal spending cuts and a focus on the bottom line, it will be important to continue championing, funding, and documenting the success of these enhanced opportunities to provide ongoing sustainability education as today's youth are the leaders and decisionmakers of tomorrow.

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