Trends in Youth Climate Change Research Highlight Strengths and Areas of Improvement in Canadian STEM Outreach Programs

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Climate change research and environmental activism are critical to the long-term health and safety of all people. Canadian populations face considerable risk from events such as coastal erosion, forest fires, droughts, and more. Youth climate activism is experiencing a zeitgeist which may positively impact research in this area. This paper explores publication trends in the Canadian Science Fair Journal to explore the locations, age groups, research topics and other key factors of science fair reports published between 2018 and 2022. From this analysis, we conclude that Canadian youth are keenly aware of how their research can generate solutions to climate change, and that they approach the issue from many perspectives. However, efforts must be made to further mobilize specific provinces, provide avenues for entrepreneurship, and increase networking to foster the next generation of Canadian climate scientists.

Introduction

Research into the multifaceted impacts of climate change has increased in the last decade. Scientists are increasingly exploring how climate change will impact human health and while researchers have studied trends in climate change in professional academics,[1] there has been less investigation into how youth scientists engage in this topic of research. Furthermore, it is important to consider how to encourage young students to maintain their passion for environmental activism through to careers in science.

Engaging in science, technology, engineering, and mathematics (STEM) extracurriculars positively influences students to choose a STEM major and increases student performance in these subjects.[2,3] However, there are few opportunities for youth (those under 18 years of age) to continue research past the project stage (e.g., pursue commercialization or further investigation).[4] One option is to pursue publication with The Canadian Science Fair Journal (CSFJ), a journal that offers a hybrid peer review/mentorship experience for Canadian youths between 8 and 18. Considering that early publication is critical to career success,[5-8] publishing a paper while still in elementary or high school could have a significant positive impact on the student's future.

This paper examines the publication history of CSFJ to explore trends in youth climate change research. The objective is to investigate how students engage in climate activism through science fair participation, trends in their research interests, and whether their activity is influenced by variables such as their province of origin or regional environmental interests.

Methods

General Trends

To examine general trends in youth climate change research by province, the number of climate change articles by province and Indigenous nations were obtained directly from the CSFJ (Figure 1). Manitoba First Nations (MB F.N.) is separate from Manitoba (MB) to honour how students identify with a specific national or cultural identity. Note that this specific identity was only selected from two authors from Manitoba. This data was further contextualized by the expected number of publications based on the population of each province (Figure 2). Expected publication numbers were calculated by multiplying the total number of environmental science papers by the

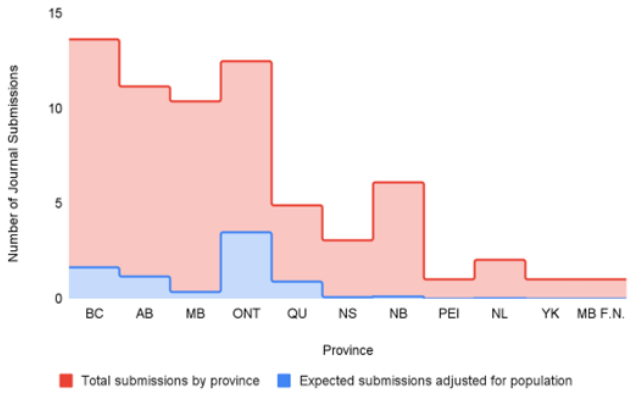


Figure 1 | Expected environmental/climate CSFJ publications by province/Indigenous Nation population (blue) and observed number of environmental/climate CSFJ publications (red).

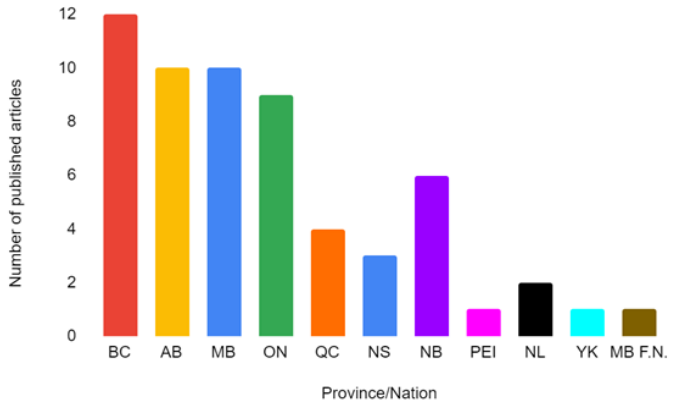


Figure 2 | Number of environmental/climate journal publications by province and Indigenous Nation.

total national population percentage of each province. Provincial and Indigenous Nation populations were obtained via Government of Canada,[9] and each divided by the national population. The resultant percentage was subsequently multiplied by the observed number of published environmental/climate CSFJ articles.

Similarly, the number of published environmental/climate CSFJ articles according to authors age was tallied directly from CSFJ publication data (Figure 3). It should be noted that authors aged 6-8 were participants in the Little Inventor's Protect Our Oceans Mini Challenge Project competition hosted by the National Sciences and Engineering Research Council of Canada (NSERC).

To explore trends in research subtopics, papers were assigned up to three subtopic areas based on the content of their publications (Figure 4, Table 1). Papers were further analyzed based on whether the student author was exploring the impact of climate change or proposing a solution to a climate change related problem (Figure 5). Papers were also coded based on whether students explicitly mentioned climate change topics despite having applications in this field (Figure 6).

Additionally, papers were coded based on how well the student author expressed the intent of their work via the title of the article. Titles were divided into those that 1) conveyed little to no information, 2) were either too generic or too technical, or 3) would be clear to both a casual and expert reader (Figure 7).

Publication Trends in Relation to Provincial Climate Change Events and Funding: The number of adverse weather events and youth climate change publications by province were plotted together to explore possible correlations (Figures 4 & 5). Incidents of drought, flooding, and heat events were pooled in the source data and as such could not be separated into distinct categories.[11] However, the 10-year forest fire average for each province was available from the Government of Canada and plotted accordingly.[11]

The number of overall CSFJ publications by province was compared to provincial education expenditures (Figure 6).[12-16]

Results

In terms of the overall number of climate change articles published in CSFJ, British Columbia (BC), Alberta (AB), and Manitoba (MB) slightly outperformed Ontario (ON) (Figure 2). This is interesting considering that Ontario's population is 2-3 times larger than the other three provinces. When article output is controlled by provincial population, all provinces outperform expectations based on population (Figure 1). New Brunswick (NB) surpassed expectations to the greatest extent, as NB possessed the greatest per capita number of journal submissions, while maintaining a small population relative to the other major provinces (BC, AB, ON). Quebec's (QC lower performance is also significant. While the climate change research publications by age (Figure 3) have a bimodal distribution, this data is influenced by the Little Inventors participants, who were specifically given a research prompt concerning ocean conservation.[10] If one excludes 6–8-year-olds, there is a normal distribution with a mean age of 16 years old

The three most popular research subtopics were acid rain and water conservation, climate-friendly agriculture and composting, and plastic pollution (Figure 4, Table

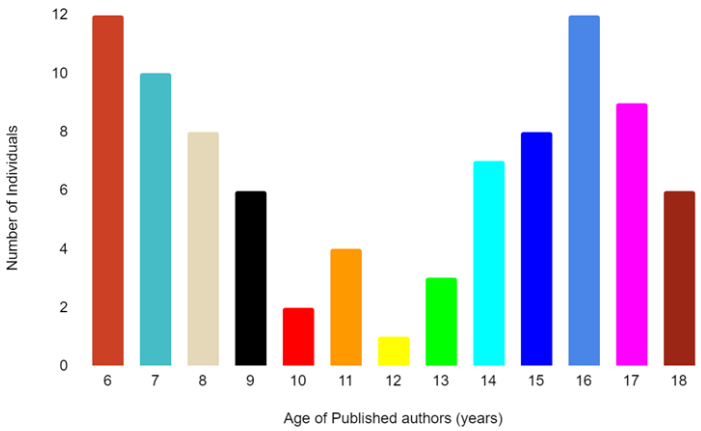


Figure 3 | Number of published environmental/climate CSFJ articles according to author's age.

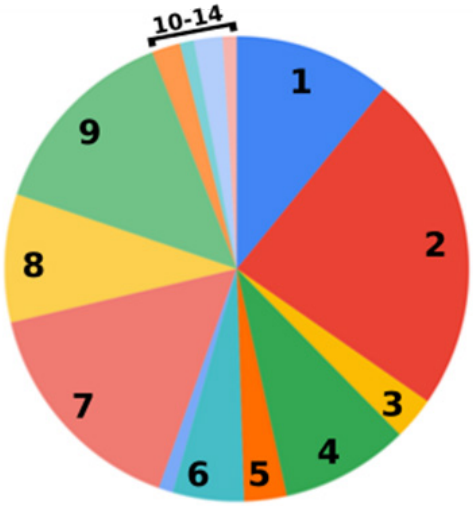


Figure 4 | Pie chart of CSFJ environmental/climate publications according to their respective category (Table 1).

Table 1 | Category and associated percentage of total CSFJ climate/environmental submissions of figure 6.

Number	Category	Percentage (%)
1	Ecosystems	10.9
2	Acid rain & water conservation	23.8
3	Invasive Species	3.0
4	Food waste & insecurities	8.9
5	Carbon fixation	3.0
6	Weather changes	1.0
7	Oil spills	5.0
8	Climate-friendly agriculture and compost	15.8
9	Alternative fuels	8.9
10	Plastic pollution	13.9
11	Forest fires	2.0
12	Pollution/climate change and human health	1.0
13	Flooding	2.0
14	Air pollution	1.0

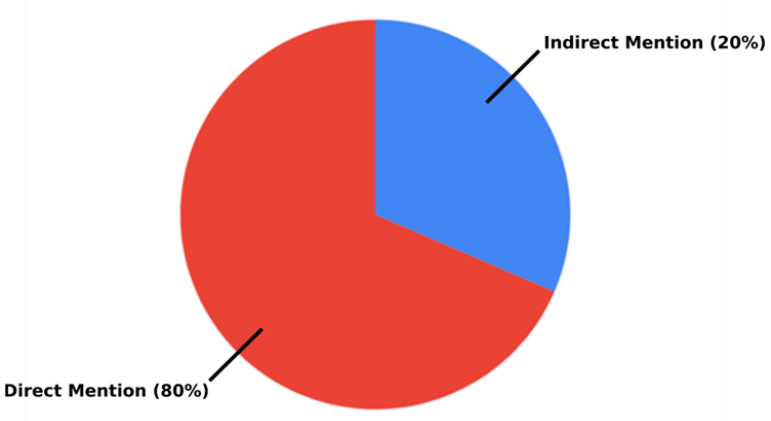


Figure 5 | CSFJ environmental/climate publications categorized according to whether climate change was directly mentioned in the paper (red, 80%) or indirectly implied (blue, 20%).

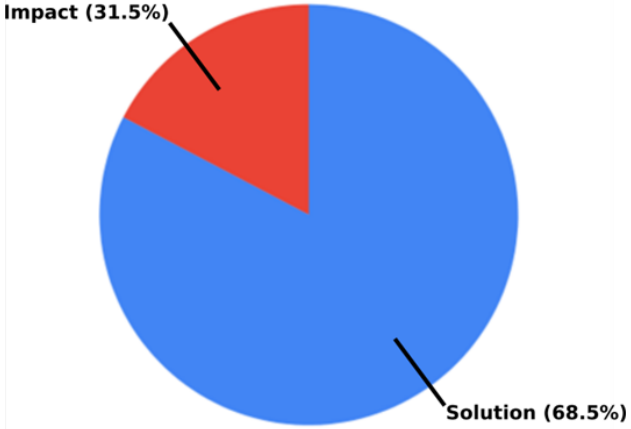


Figure 6 | CSFJ environmental/climate publications categorized according to whether their research measured the impact of climate change (red, 31.5%) or proposed a solution to climate change (blue, 68.5%).

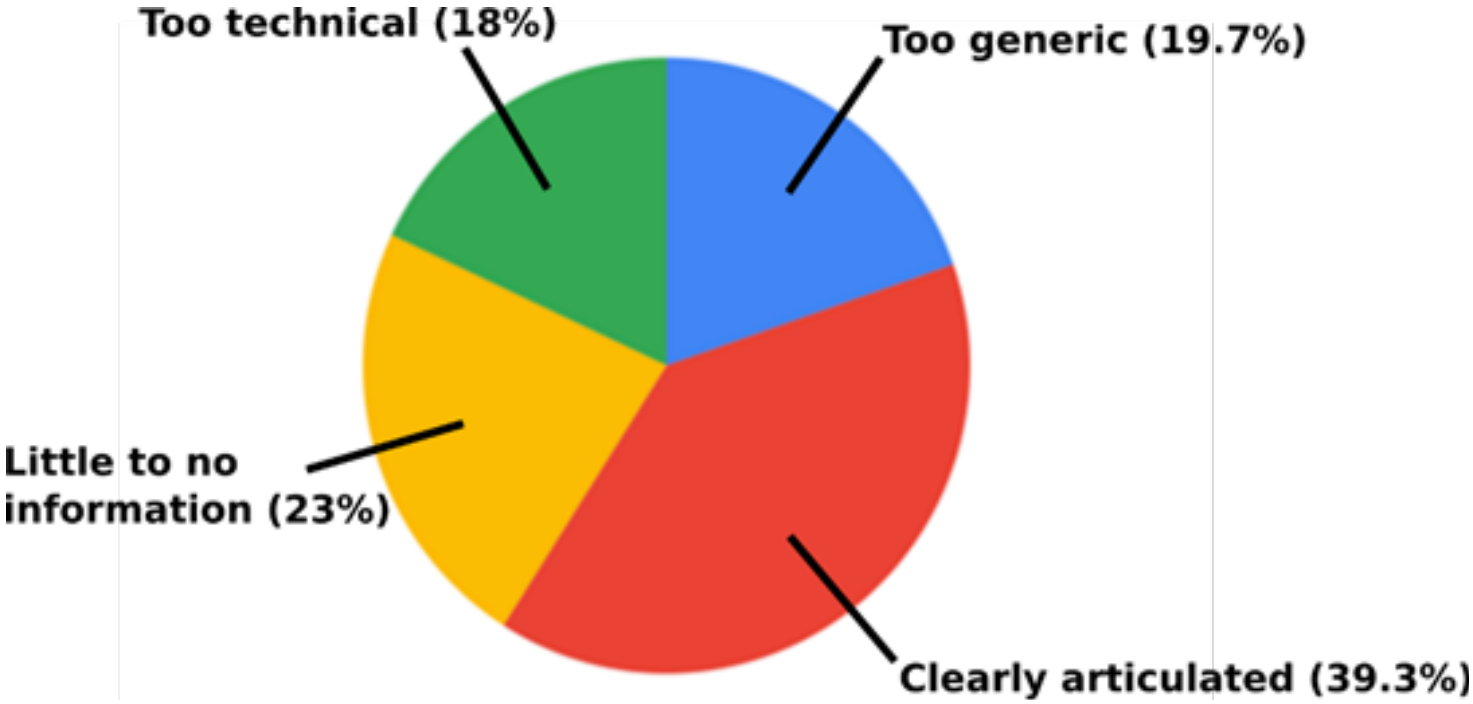


Figure 7 | Title of journal submissions and associated clarity of title to solution. 39.3% of titles clearly illustrated the topic for both lay and technical audiences (e.g., Pristine waters: A pioneering project in Yukon River microplastic research) (red). 23% of titles (yellow) provided little to no information on the experiment (e.g., The Air Pick-Up). Generic titles (e.g., The Trouble with Green Crabs) represented 19.7% of titles (blue). 18% of titles were too technical (e.g., The polyhaeophyceae method: The development of an algae based LPDE equivalent) (green).

1). There were no significant trends in subtopics based on province (i.e., coastal provinces did not produce more ocean conservation papers). 82.7% of papers directly mentioned climate change or environmental studies in their paper, indicating that the majority of student authors were intentionally engaging in the research topic. 39.3% of student authors had a clearly articulated title that provided sufficient information for both lay audiences and experts (Figure 5 and 7), further demonstrating that students understood the material and were able to communicate their research. Although 23.0% of students had titles which conveyed little to no information about their project, this was largely seen in the 6–8-year-old demographic. There was a marginal tendency for students to favour too technical titles over generic titles (19.7% vs. 18.0%). 68.5% of student papers proposed solutions to climate change (Figure 6), indicating that youth scientists are engaging in critical problem solving.

There do not appear to be any overarching trends in the incidents of drought, flooding and heat events compared to the number of climate change publications per province (Figure 4 and 6). Similar results were obtained when comparing climate publications to the 10-year forest fire average (Figure 8). Similarly, provincial education expenditure was not correlated with the number of journal submissions (Figure 9). For example, New Brunswick's provincial education expenditures are in the millions, much smaller than the billions spent by British Columbia, Alberta, Manitoba and Ontario, yet this province produced 7 publications relative to the 10 to 12 papers from the others.

Discussion

While the Canadian Science Fair Journal (CSFJ) is a national academic journal geared toward K-12 students, environmental/climate related submissions were largely submitted from five provinces (Figure 2). Although Ontario, British Columbia and Alberta constitute 38%, 13% and 11% of the Canadian population respectively,[9] and could be expected to submit a proportionate number of environmental/climate change papers, Manitoba and New Brunswick exceeded their expected number of submissions relative to population. This surprising result is compounded by the average four-year funding toward K-12 education by province, with the total number of submissions from New Brunswick significantly exceeding its relative amount of funding and that of the other four greatest CSFJ submitting provinces (Figure 9). This may suggest that greater educational

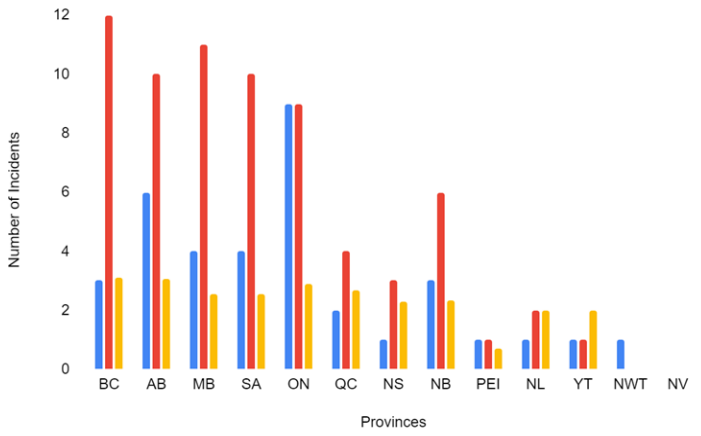


Figure 8 | Incidents of drought, heat events and flooding (blue), CSFJ environmental/climate change submissions (red) and log10 of 10-year average (yellow) of forest fires.

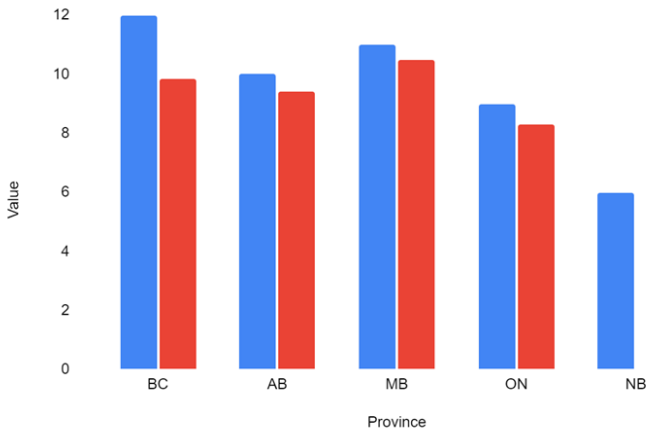


Figure 9 | Number of environmental/climate CSFJ publications from five greatest author home province (blue), and average education funding from 2018 - 2022 by province (log10) (red).

funding is not correlated to higher academic output. It is possible that youth researchers in New Brunswick are more keenly aware of the impact of climate change due to their physical location. Coastal communities and the fishing industry are two groups most at-risk for the negative impacts of climate change.[17] It is also possible that there are more environmental campaigns aimed at children within New Brunswick, although this is not immediately apparent from a cursory search of available data. It is also possible that New Brunswick's high output is due to it hosting the 2019 Canada Wide Science Fair, which representatives of CSFJ attended. However, representatives also attended or contributed to the 2018 fair in Ontario without observing an overrepresentation in papers from this province.

Although CSFJ submissions were received from every province and territory, excluding Northwest Territories (NWT) and Nunavut; journal submissions from Quebec and Saskatchewan were considerably below expectations relative to their respective populations. This phenomenon could be addressed through outreach programs, tailored to the specific characteristics of Quebec and Saskatchewan's K-12 population. While the CSFJ has a pipeline to publish journal submissions in French, it is predominantly an anglophone journal. As such, circulating CSFJ memos through Quebec's K-12 schools and extracurricular activities (i.e., cadets, hockey, and soccer teams) and increasing Francophone journal editors may bring the number of submissions from Quebec in line with its anglophone counterpart: Ontario (Figure 2). To increase the number of CSFJ submissions from Saskatchewan, outreach could target the local indigenous populations, which account for nearly 15% of the province.[9] Moreover, targeting outreach toward Indigenous schools/students could yield a positive impact upon a marginalized group. One such method of outreach targeting to reach the Indigenous population would utilize the historical and cultural ties of Indigenous communities with the environment, further increasing the number of environmental/climate CSFJ submissions.

Although it may be anticipated that certain subtopics would be more popular in specific provinces, no such trends emerged. This may be due to the relatively small sample size. Interestingly, the possible effects of provincial political identity (e.g., Quebec and Alberta) did not seem to influence this perspective.[18,19] For some areas of Canada, climate change poses more obvious risks. For example, our oceans become more acidic and less oxygenated, threatening coastal provinces.[20] However, it may also optimistically indicate that Canadian youth consider climate change from a national or global perspective, rather than a provincial one. As climate change poses a tremendous threat to all of Canada,[20] it is inspiring to think that youth scientists understand our shared need for climate change interventions and are contributing to academic discourse on this issue.

As previously mentioned, youth engagement in STEM outreach and science fairs plays a critical role in encouraging students to enter STEM professions.[2-4] Additionally, early publication is critical to long-term success in academics.[5-8] Publishing youth climate change research may have the additional benefits of providing peer role models for other students interested in environmental activism. Peers play an important role

in inspiring students to form a personal connection to the mission and become intrinsically motivated by the cause.[21] For example, the "Greta Thunberg Effect" has resulted in youths exposed to Thunberg having higher intentions of taking collective actions to reduce global warming.[22] It has been argued that children make the best environmental advocates because they will be the primary victims of climate disruption and occupy a moral high ground.[23] Encouraging Canadian youth to engage in climate change research and providing a platform through which they can disseminate their findings and meet like-minded peers could help to mobilize students to fight for their environmental future.

In this context, it is important to consider both current strengths of youth climate change research, and weaknesses. Generally, CSFJ authors understand their research and its implications, as demonstrated by the vast majority (80%) directly identifying climate change as the 'problem' they were trying to solve. As 68.5% of students developed solutions to climate change (e.g., algae as carbon fixation, or ways to repurpose food waste as biofuel), it might be worthwhile to invest in entry level entrepreneurship organizations to provide mentorship and funding for students to scale these ideas. Similarly, some students produced similar projects (multiple papers using algae for biofuel, plastics, or carbon fixation). Facilitating youth networking could help foster a community of young climate activists. However, there are areas of improvement. The title of scientific papers is a critical variable in determining readership. As only 39% of students had titles that could appeal to a broad spectrum of readers,[24] greater teaching resources focusing on how to write effective titles and abstracts would be useful.

There were several limitations to the present work. Due to the complexity of the dataset, predicted publication numbers were based on the total population of provinces rather than age range-specific information. The level of indigenous scholarship is difficult to ascertain as we did not provide students the opportunity to self-declare their status beyond their geographical location. Finally, the categorization of papers by topic matter, impact vs. solution, etc. was performed by the researchers and may therefore suffer internal bias. To combat these issues in the future, more robust, optional questionnaires will be available to participating students.

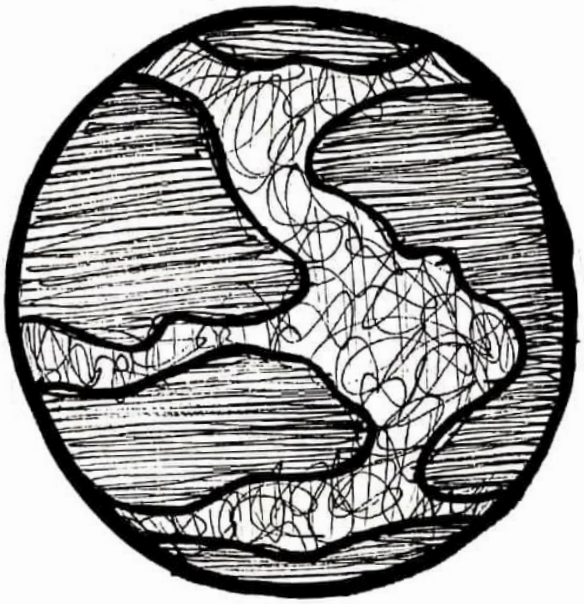
Conclusion

This paper has examined the trends within youth climate change research published in the Canadian Science Fair Journal. Overall, youths across Canada demonstrate a high level of engagement in researching solutions to the effects of climate change and are aware of the potential impact of their work. Our analysis has highlighted that some provinces (such as New Brunswick) are outperforming expectations, while also suggesting areas which are in need of greater engagement (i.e., Quebec and Saskatchewan). We conclude that youth scientists are passionate about climate change and understand the implications of their research. However, there are several ways that we can better equip them to become climate activists, including networking opportunities and more guidance on effective title and abstract writing. Ultimately, Canadian youth scientists show a high level of commitment to environmental research, which may positively contribute to the growing youth climate change activism movement within the country.

References

1. Harper SL, Cunsolo A, Babujee A, Coggins S, De Jongh E, Rusnak T, et al. Trends and gaps in climate change and Health Research in North America. Environmental Research. 2021;199:111205.
2. Sahin A. Stem clubs and science fair competitions: Effects on post-secondary matriculation [Internet]. Journal of STEM Education: Innovations and Research. [cited 2022Mar27]. Available from: https://www.jstem.org/jstem/index.php/JSTEM/article/view/1781
3. Freeman S, Eddy SL, McDonough M, Smith MK, Okoroafor N, Jordt H, et al. Active learning increases student performance in science, engineering, and Mathematics. Proceedings of the National Academy of Sciences. 2014;111(23):8410–5.
4. Ng R, Slivitzky K, Webster R, McNally D. Extending the science fair project beyond the walls of the gymnasium with the Canadian Science Fair Journal. Communications Biology. 2019;2(1).
5. Sekara V, Deville P, Ahnert SE, Barabási A-L, Sinatra R, Lehmann S. The chaperone effect in scientific publishing. Proceedings of the National Academy of Sciences. 2018;115(50):12603–7.
6. New products. Science. 2018;359(6379):1062–.
7. Sinatra R, Wang D, Deville P, Song C, Barabási A-L. Quantifying the evolution of individual scientific

impact. Science. 2016;354(6312).
8. Laurance WF, Useche DC, Laurance SG, Bradshaw CJ. Predicting publication success for Biologists. BioScience. 2013;63(10):817–23.
9. Government of Canada, Statistics Canada. "Population Estimates, Quarterly." Population Estimates, Quarterly, Government of Canada, Statistics Canada, 17 Mar. 2022, https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1710000901.
10. Yamoah M, Mendes S. NSERC [Internet]. Little Inventors. [cited 2022Mar27]. Available from: https://nserc.littleinventors.org/
11. Canada E and CC. Government of Canada / gouvernement du Canada [Internet]. Climate. Government of Canada / Gouvernement du Canada; 2022 [cited 2022Mar27]. Available from: https://climate.weather.gc.ca/historical_data/search_historic_data_e.html
12. Government of Ontario. Education funding, 2021-22 [Internet]. Untitled Document. Government of Ontario; [cited 2022Mar27]. Available from: http://www.edu.gov.on.ca/eng/policyfunding/funding.html
13. Education Mof. Operating grants [Internet]. Province of British Columbia. Province of British Columbia; 2021 [cited 2022Mar27]. Available from: https://www2.gov.bc.ca/gov/content/education-training/k-12/administration/resource-management/k-12-funding-and-allocation/operating-grants
14. K to 12 education funding framework [Internet]. Alberta.ca. [cited 2022Mar27]. Available from: https://www.alberta.ca/k-12-education-funding-framework.aspx#:~:text=In%20September%202020%2C%20we%20implemented,distributed%20through%20base%20instruction%20funding.
15. Education and early childhood learning [Internet]. Finance and Statistics | Manitoba Education and Early Childhood Learning. [cited 2022Mar27]. Available from: https://www.edu.gov.mb.ca/k12/finance/schfund/index.html
16. Draper E. New Brunswick Board of Education / 2021-2022 [Internet]. New Brunswick Public Schools. [cited 2022Mar27]. Available from: https://www.nbpschools.net/boe/financereports
17. Government of Canada. Canada's top climate change risks [Internet]. Canada Climate Action. Government of Canada; 2019 [cited 2022Mar29]. Available from: https://cca-reports.ca/wp-content/uploads/2019/07/Report-Canada-top-climate-change-risks.pdf
18. Levinson-King R. Wexit: Why some Albertans want to separate from Canada [Internet]. BBC News. BBC; 2019 [cited 2022Mar29]. Available from: https://www.bbc.com/news/world-us-canada-49899113
19. Quebec separatism [Internet]. Encyclopædia Britannica. Encyclopædia Britannica, inc.; 2022 [cited 2022Mar29]. Available from: https://www.britannica.com/place/Canada/Quebec-separatism
20. Government of Canada, Environment and Climate Change Canada. "Canada's Changing Climate Report." Canada in a Changing Climate: Advancing our Knowledge for Action, Government of Canada, 2019. https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/Climate-change/pdf/CCCR_FULLREPORT-EN-FINAL.pdf
21. Pearce, NJ and Larson, RW. How Teens Become Engaged in Youth Development Programs: The Process of Motivational Change in a Civic Activism Organization. Applied Developmental Science. 2006;3:121-131. https://www.tandfonline.com/doi/abs/10.1207/s1532480xads1003_2
22. Sabherwal, A, Ballew, MT, van der Linden, S, Gustafson, A., Goldberg, MH, Maybach, EW, Kotcher, JE, Swim, JK, Rosenthal, SA, and Leiserowitz, A. The Greta Thunberg Effect: Familiarity with Greta Thunberg predicts intentions to engage in climate activism in the United States. Journal of Applied Social Psychology. 2021;51(4):321-333. https://onlinelibrary.wiley.com/doi/full/10.1111/jasp.12737
23. Cherry, L. The power of positive role models: youth climate activism in films. Journal of Environmental Studies and Sciences. 2021;11:212-216. https://link.springer.com/article/10.1007/s13412-021-00663-8
24. Why the title of your paper matters [Internet]. Nature News. Nature Publishing Group; 2021 [cited 2022Mar29]. Available from: https://www.nature.com/articles/s41562-021-01152-2



Catching Earth | ***Jasleen Jagayat***

Catching Earth reflects the influence humans have on the state of our world. This piece depicts a hand throwing the globe in the air similar to a ball, representing the negligence we may treat the world with. If we catch our failures towards creating a sustainable world, we may be able to handle them and prevent the world from falling. At the same time, keeping our Earth safe is also dependent on how well we are able to support it. This also represents the control our actions have on the state of the world and how we decide to treat it.

Breeze of Resiliency | ***Jasleen Jagayat***

Breeze of Resiliency reflects the effect of climate change through the delicate form of the dandelion. With climate change and the detrimental effects that come along with it, the Earth has shown to be resilient, working against powerful forces. With even the slightlest breeze the pappi of dandelions fly away and create new roots elsewhere. The delicate form of these white, fluffy pappi sail away with the air and germinate elsewhere. This delicate process allows the seeds to sprout more dandelions representing rebirth and growth, in which we see all throughout mother nature.