

RESEARCH ARTICLE

Extreme freshwater events, scientific realities, curriculum inclusions, and perpetuation of cultural beliefs

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Abstract

The purpose of this research was to explore and open dialogue about possible connections between the scientific realities of extreme freshwater events (EFWE), a lack of EFWE-related curricular content in schools, and future teachers' awareness and perceptions of EFWE. In phase one, an analysis of existing weather data demonstrated ongoing moderate to severe EFWE in the two regions under investigation, Queensland, Australia and Saskatchewan, Canada, at the time of data collection. In phase two, a content analysis of school curricula in the two regions shows a dearth of mandatory content related to EFWE, though Queensland, Australia had slightly more mandated content than did Saskatchewan, Canada. In phase 3, a survey of pre-service teachers in the two regions showed a demonstrable lack of recognition of undergoing moderate to severe EFWE at time of data collection, along with a general satisfaction with the current level of curricular coverage of the topic. While respondents' overall concern was low, there were consistent regional differences. Queenslanders were more likely to recognize their lived experience with EFWE and perceived it to be a more important inclusion in school curricula than their Saskatchewanian counterparts. Taken together, results suggested that learned cultural truths were reflected in and perpetuated by school curricula. Results highlighted cultural denial of EFWE severity and a need to change false truths by increasing visibility of EFWE in mandated school curricula. The authors propose that results warrant further research and discussion as it relates to public policy and prioritizing EFWE in formal school curricula.

1. Introduction

There is currently a disconnect between the scientific realities of extreme freshwater events (EFWE) and how they are perpetuated by society through shared cultural beliefs. This research looks at formal school curricula as one possible cause of this disconnect in order to open dialogue about ways in which the gap may be closed.

Climate change is influencing the frequency and severity of extreme freshwater events (EFWE) such as heavy rainfall, floods, droughts and associated severe weather and water

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scarcity [1–3]. Evidence shows that every 0.5°C increase in global warming causes increases in frequency and severity of extremes including heavy precipitation (high confidence) and droughts (high to medium confidence) [3]. Even though freshwater is essential to much of life on Earth, it is also an extremely scarce resource. If all freshwater on the planet were equated to 100 L, usable freshwater amounts to only 0.003 L, equivalent to about half a teaspoon [4]. Due to the scarcity and critical need for freshwater, human societies and freshwater have historically coevolved.

Human systems have always had a highly complex relationship with water [5]. This long-term relationship has allowed water to shape societies while being shaped by societies [6–8]. Therefore, the consequences of EFWE necessitate that societies comprehend the historical values, expectations and policies that continuously emerge from humans' relationships with water. Farnum et al., [9] suggest cultural relationships with freshwater illustrate a plurality of discourses and ideologies that can influence how cultures engage with freshwater, each bringing about ecological and social benefits and problems. For example, in Western cultures, existing literature suggests that the formal values, expectations and education policies with education systems perpetuate dominant cultural beliefs [10,11]. Thus, if a particular society has not traditionally prioritized a particular topic (like EFWE) as important, it is reasonable to believe that it will not be reflected in its school curricula [12]. It has similarly been shown that cultural beliefs also influence what teachers believe should be included (and what gets ignored) in curricula and in their classrooms [13].

This paper seeks to explore 1) the extent to which societies recognize the realities of EFWE and 2) what role formal education plays in perpetuating that understanding. To address these questions, this paper investigates the three interrelated EFWE-related issues of occurrence, mandated school curricula, and educator perceptions within two water-vulnerable geographical regions of Australia and Canada. First, it offers scientific evidence as compiled from Government agencies to explain and describe the occurrence of EFWE in these two geographical regions. Second, this paper brings attention to what governments in these two geographical areas prioritize as important to teach and learn about EFWE within mandated school curricula. Finally, it explores the perceptions of 340 preservice teachers in these two geographical regions to examine their personal understanding of EFWE and their beliefs about addressing EFWE in the classroom. Taken together this research proposes that school curricula may serve to perpetuate a lack of recognition of the severity and importance of EFWE within the societies that they serve.

2. Literature review

The purpose of this research is to explore a potential disconnect between the scientific realities of EFWE and how cultural beliefs about EFWE are perpetuated through formal education. As such, the literature review will situate the research and its three parts as visualized in Fig 1.

2.1 The significance of EFWEs

The frequency and intensity of EFWE, such as catastrophic storms and long periods of drought, are increasing in many parts of the world [14]. Aggravated by climate change, environmental degradations and rapid urbanization, EFWE are having a disastrous impact on humanity, other species and the ecology. Raikes et.al. [15] outlines how intergovernmental communities characterize disaster as:

a serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one

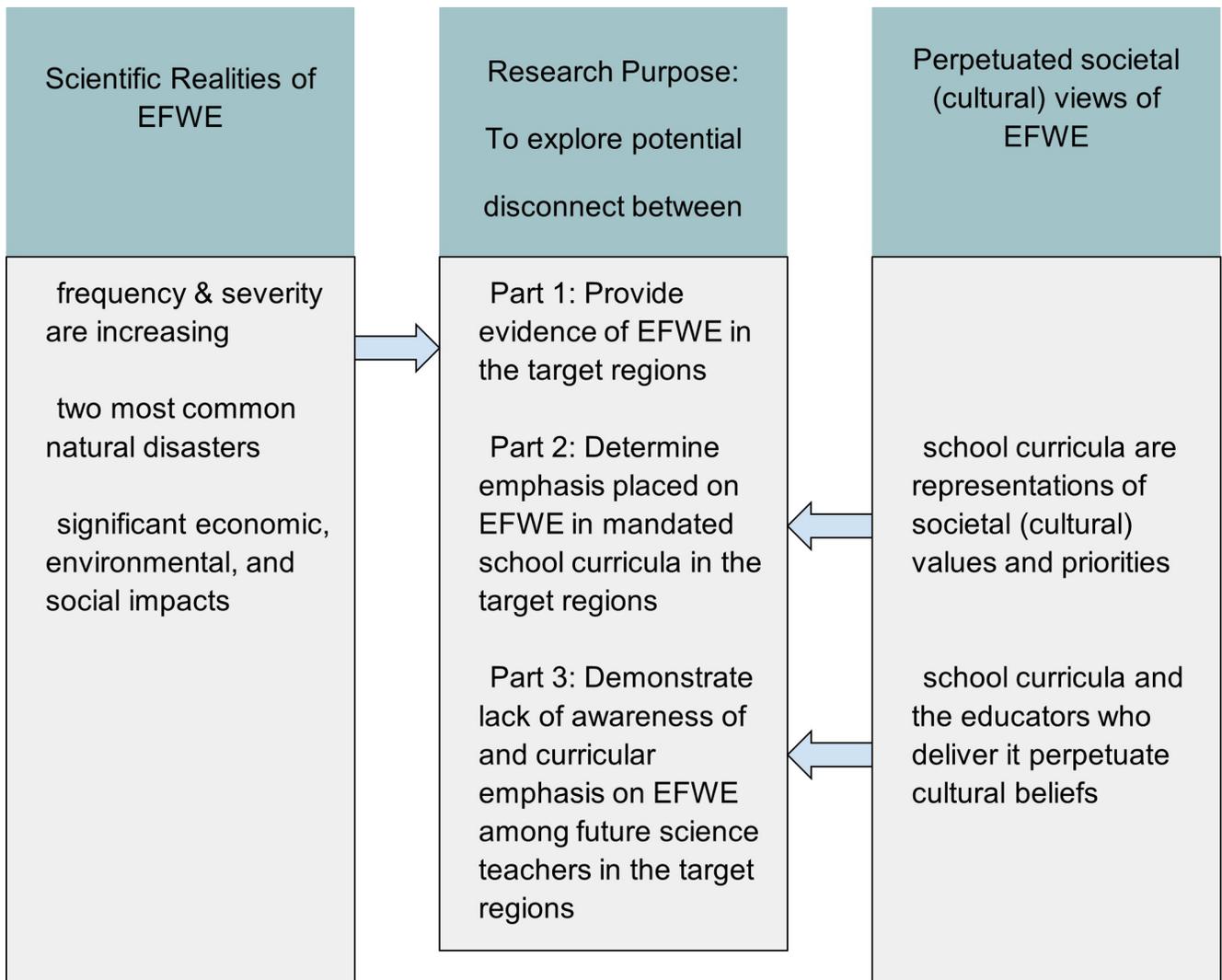


Fig 1. Relationship between reviewed literature and research purpose.

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or more of the following: human, material, economic and environmental losses and impacts (p.1).

The significance of EFWE as part of extreme weather events can not be understated. Centre for Research on the Epidemiology of Disasters [16] describes floods and drought as the two most common natural disasters: with floods accounting for nearly half of all natural disasters from 1995 to 2015, while globally, *most* people have been affected by droughts.

The World Economic Forum [17] outlines how extreme weather events and natural disasters are becoming two of the most influential global risks, causing the largest economic, social, and environmental damage. This highlights the deep interconnections between physical and social systems. As an example, Caparros-Martinez et.al. [18] state:

Climate models that predict that by 2050 an increase of 1.5°C in the average global temperature of the planet could cause drought and habitat degradation that would make life difficult for 178 million people around the world, while the effect on the population of an increase of

between 2°C and 3°C would be significantly higher, affecting between 220 and 277 million people, respectively. On the other hand, the number of people at risk of flooding is expected to increase from 1.2 billion today to 1.6 billion in 2050 (about 20% of the world's population), which will cause the economic value of assets at risk to be about \$45 trillion by 2050, a growth of more than 340% compared to 2010) (p 1760).

Associated with EFWE, the diminishing freshwater resources along with an increase in the world's human population, has the United Nations World Water Assessment Programme [19] predicting the world will face a world freshwater crisis, altering all life on the planet.

Flooding is generally defined as an excess of water following extreme flows of precipitation or runoff. In Queensland, flooding predominantly occurs after sustained extreme rainfall. In Saskatchewan, floods can occur as a result of extreme rainfall, as well as rapid snowmelt across frozen land and glacial melt flow through riverine systems. It is possible to be experiencing drought and flood concurrently, since one has to do with extended periods of inadequate water supply and the other with a more localized (spatially and temporally) event of excess water supply, respectively. Two examples are the moderate drought in Queensland of 2018 during which some of the highest rainfall on record was experienced and the extensive drought in southern Saskatchewan in 2010 during which flooding occurred due to high volume rapid spring snowmelt.

The scientific definitions for droughts are more diverse and are often place-based or purpose-specific in terms of impact. Thus, there will commonly be references to agricultural drought, environmental drought, and socio-economic drought that are primarily associated with specific impacts and including qualitative impacts and categorization, as well as meteorological and hydrological droughts that are more purely quantitative in their definition. Drought is not simply a term used to convey periods of no to low precipitation, which is more correctly referred to as the aridity of a region characterized by low precipitation, such as a desert [20,21]. That is, desert regions are always arid, but not always experiencing drought. Drought, therefore, is a term more appropriately used to define rainfall deficiencies or moisture conditions in dry regions.

2.2 Impacts of climate change on frequency and severity of EFWEs

The impact of climate change on both scientific and societal responses to the availability of freshwater and the potential for changes in frequency and severity of EFWEs are becoming increasingly clear as increasing monitoring and analysis of freshwater systems are implemented. For more than 15 years, climate scientists have pointed to the likelihood of climate change exacerbating both the incidence and impacts of excessive moisture (flood) and a dearth of adequate moisture (drought) for supporting both societal and ecosystem function [22,23]. Active—and proactive—management of water resources requires an engaged, informed and educated society who are aware of and respect the deep connections between and amongst freshwater systems and the communities, ecosystems, and social-economic-political-health systems in which they exist [1,8,24].

Both Canada and Australia recently produced comprehensive reports on changing climate trends and projections, as well as connections to potential economic and agricultural impacts, namely Canada's Climate Change Report 2019 [25] and Australia's State of the Climate 2020 [26]. Both of the study regions in Canada and Australia have experienced demonstrated warming over the historical record (approximately 100 years in each case) and each is projected to experience further warming in accordance with the range of emissions scenarios and outputs for both regional climate model and global climate model [25,26]. Globally, increases in the

incidence and impacts of extreme precipitation are closely associated with warming temperatures [27]. Thus, excess precipitation is likely to become more prevalent and damaging in areas that are experiencing concurrent increases in temperature. The occurrence of flooding in those regions depends on both excess precipitation as well as localized flood control measures and infrastructure, and land use and urban design (e.g., amount of impervious cover).

2.3 The perpetuated societal view of EFWE

This research likens school curricula to notions of ‘truth’ that frame societal thoughts and conversations about EFWE and provides the opportunity to observe Foucault’s [28] concept of regimes of truth. This concept suggests that within all societies, historical evolving patterns of thought, classifications, and forms of knowledge, have become so normalized that they structure society’s perceptions of self and the world around them. This perceived legitimate knowledge holds so much power that it functions as ‘the truth’ in that social system. We propose that school curricula hold the legitimate power necessary to perpetuate these normalized notions of truth within societies.

Like any other concept, ‘the truth’ about EFWE becomes so entrenched in social systems that it has the potential for controlling conversations. Sammel and Hartwig [29] showed this to be the case when they conducted a review of 193 peer-reviewed research papers associated with EFWE in the two geographical regions explored in this paper, highlighting what could be viewed as ‘legitimate knowledge’ about EFWE in these regions. Their results found that EFWE were commonly perceived through a scientific lens and resulted from disturbances in the assumed normalcy of natural systems, mostly separate and distinct from human systems. Consistent with research advocating that water is dominantly interpreted as a natural resource, separate and distinct from human systems [30], EFWE were labelled as ‘natural disasters’ and ‘natural crises’. Further, these natural hazards were understood as causing major disruptions and negative consequences for social and economic systems and priorities, which reflected an anthropocentric (human centred) perspective. Sammel and Hartwig outlined that the dominant pattern of thought towards making sense of EFWE emphasized management, planning and preparedness as a means to avoid, reduce or mitigate negative EFWE consequences to human societies. This understanding, based upon historical evolving patterns of thought, classifications, and forms of knowledge, become so entrenched in social systems that they have the potential for controlling, limiting or closing down conversations about EFWE. However, it offers one conceptualization of a grand narrative of EFWE. With this as a starting point, we ask, to what degree have the curriculum documents influenced what people believe to be ‘true’ about EFWE? To what degree does this dominantly theorized perspective of EFWE disable other perspectives and considerations around EFWE within education?

2.4 School curricula as representations of society’s values and priorities

Drawing on British agendas of education, early educational infrastructures in Australia and Canada drew from questions of how and what to forge as the emerging nation’s identity. In this way, education has historically been an important site in the cultivation of both Australia’s and Canada’s social construction and identity with both built on the assumption that intelligence (as achieved from educational endeavors) is a means of measuring and attaining social standing and to the extreme, social superiority [31]. At the individual level, the cultural narrative promotes education as a lure for ‘higher earnings’. The desire to produce citizens who can understand the world from the frame of the formal government curriculum was based, in part, on advancing the achievements and agendas of the nation state. With the slow moving wheel of cultural change, education later focused on developing citizens, however, the agenda was,

and is, based upon introducing a child to the knowledge and culture as ascribed by the ruling government through centralized curricular.

So what agendas do governments have for education? In the era of neoliberal capitalism, increasingly, economists are involved in educational research, the evaluation of effective education and schools, and student performance of the skill based curriculum at a state/provincial, national and international levels [32]. At the international level, the OECD and World Bank, in combination with PISA and TIMSS, rank and sort countries by how their students achieve in completing hard skills, that being, the skills required for particular occupations. For example, this international involvement can be witnessed globally in science education as science is one of three subjects evaluated by the [Organisation for Economic Co-operation and Development](#) (OECD) through the implementation of PISA (Programme for International Student Assessment) testing. PISA's rankings and communication of Canada's and Australia's 15-year-old school students' scholastic performance in science education plays a role in influencing the normative directions of national conversations about these countries' competitive global performance [33,34]. International evaluations of national science education have instigated the injection of funding based upon demand for a more scientifically literate society and an increased number of students progressing towards scientific careers. Whereas soft skills, such as cooperation etc, are not prioritized [13]. The goal here is to appraise a country's human capital as a way to measure or predict a country's future economic growth, and to make larger economic decisions about the movement of money and risk management for those nation states. Education is thus in service of growing a nation's economy, through building the production capacities of students with the right information and skills to contribute to generating healthy economic growth.

With the goal of emphasizing hard skills needed for the workplace, what social narratives unfold within the formal educational curriculum and how do they align with the urgent and unfolding EFWE and freshwater crisis? It is essential to investigate understandings and conversations individuals, communities and societies are currently having around EFWE [9]. As formal education plays a key role in shaping a community's understanding of EFWE, this paper will explore how the social narratives within formal curriculum documents align to this urgent and unfolding freshwater future.

2.5 How school curricula perpetuate cultural beliefs

The previous section outlined various ways in which school curricula reflect societies' values and priorities. This section looks more at the mechanisms of *how* school curricula perpetuate cultural beliefs. Culture can be defined as a pattern of basic assumptions developed by a group that has worked well enough to be considered valid and to be taught to new members as the correct way to perceive, think, and feel [35]. This definition of culture aligns well with Foucault's [36] approach to conceptualizing regimes of truth. More simply, culture can be thought of as a series of shared meanings embraced by groups of people. Cultural beliefs, therefore, can be simply defined as "beliefs that are learned and shared across groups of people" [37 p. 574]. Beliefs are enduring sets of perceptions and cognitions about one's world [38]. Beliefs may be personal or shared by small groups, but are often commonly shared much more broadly by members of society and disseminated through institutional mechanisms such as schools [39].

At a macro level, the formal school curriculum is deeply influenced by culture [9,40] and school curricula reflect inarticulate cultural values [41]. Bourdieu [42] argued that one mechanism for groups within society to legitimize the meanings that they seek to impose as correct is through the formal education system. They do so by systemically ensuring cultural reproduction and preservation of their chosen, and arguably arbitrary, biases as the status quo through

curricula, leaving teachers to perpetuate that bias as neutral. Others go on to argue that as such chosen content becomes construed as school knowledge it becomes legitimized [43], that its presentation is unbiased and a-cultural renders its arbitrariness invisible [44], and that the more such perceived legitimacy becomes sanctified with time, the more it becomes taken for granted [45]. This curricular reinforcement of cultural views serves to perpetuate what is accepted as truth by a particular society [46]. As a result of such heavy cultural influence, Greene [47] asserts that teachers must view curricula through an anthropological lens of inquiry to become less complacent and more fully aware of the cultural contexts in which they teach.

At an individual micro level, teachers' cultural beliefs influence their teaching of curriculum [48]. Bryan's [49] review of science teacher beliefs and how they influence classroom practice uncovered that teachers' personal cultural beliefs influenced science teaching decisions. For example, Brickhouse [50] concluded that teachers' existing beliefs about science "influenced not only their explicit lessons but also an implicit curriculum about the nature of science" (p. 481). This "congruity thesis" was demonstrated among prospective teachers as well [49]. As such, pre-service science teachers' beliefs about school curricula carry with them the same level of cultural bias as the curricula they will teach [51].

This study considers cultural differences in formal curricular content and pre-service science teachers' perceptions of curricula as mechanisms to demonstrate differences in cultural beliefs about EFWE in Queensland, Australia and Saskatchewan, Canada. It is therefore critical to acknowledge as central to this work's chosen research methodology the known perpetuation of 1) cultural beliefs through curriculum, and 2) pre-service science teachers' cultural beliefs through curricular biases.

3. Methods

3.1 Ethics statement

The University of Regina Research Ethics Board (2018–047), University of Saskatchewan (via shared approval agreement with University of Regina), and Griffith University Human Research Ethics Committee (2014/386) approved the survey portion of this research. Participants provided informed consent in written form at the start of the survey (S1 Text) by reviewing the presented consent form and responding to the question "I understand and agree to participate".

This research seeks to explore the perpetuation of cultural beliefs. Because the type of longitudinal study that would be required to empirically test such a perpetuation was infeasible, the research was designed to explore the plausibility of such a perpetuation using cross-sectional evidence. It involved three parts. Part one used existing weather data to measure instances of EFWE, specifically floods and droughts, in the two target regions of Saskatchewan, Canada and Queensland, Australia. The purpose of part one was to verify the prevalence of EFWE in the two regions. Part two involved a content analysis of EFWE related terms within government mandated curricula in the two target regions. The purpose of this part was to explore the relative prevalence of EFWE related curriculum in the two regions, with the expectation that levels of EFWE prevalence and curricular coverage should be positively related. Part three involved a survey of pre-service teachers, measuring their lived experiences with and their beliefs about EFWE related content in school curricula. The purpose of this part was to attempt to link scientific reality to school curricula by exploring 1) the ability of these past students and prospective teachers to accurately identify their own experiences with EFWE, and 2) to determine the extent to which their experiences with EFWE were related to their beliefs about school curricula and the perpetuation of their cultural beliefs around EFWE. Taken together,

the combined information should paint a picture of the power of school curricula to perpetuate cultural beliefs that may not be in accordance with scientific reality.

These two locations were chosen for their similarities on several fronts. In Canada, we focus on Saskatchewan (SK); in Australia, we focus on Queensland (QLD), since each has experienced significant and largely unanticipated floods and droughts causing serious damage to property, communities, and social fabric over the past 8 years. The projections for EFWE in each region denote both drier and wetter climatic conditions, possibly simultaneously, as rainfall-driven regimes shift toward higher intensity, but less frequent rainfall events [26,52,53]. Within these scientific understandings and projections about EFWE, there is a need to further evaluate and enhance the political, education, and societal understandings and responses, leading to the second similarity. Canadian and Australian systems of education and government, investment into science and technology, and colonization of Indigenous populations, are similar and provide opportunities for synergistic and informative comparisons. Further, Saskatchewan and Queensland are considered Western cultures, within Commonwealth countries of similar size and standards of living, and both are considered to be major contributors to the agricultural and mining sectors of their countries' economies.

It is proposed that these two geographical regions in Canada and Australia (and arguably other places) have historically developed evidence-based cultural beliefs (or 'truths' as proposed by Foucault [36]) about EFWE which may serve to confine how EFWE could be understood or engaged with. This paper focuses on formal education as the mechanism for propagating those cultural beliefs, as it is tasked with integrating young people into a society's knowledge community with defined social understandings as prioritized by the Government who sets the curriculum. What is prioritized within education influences a society's ability to holistically understand EFWE, develop the confidence and skills to generate solutions, and the ability to know where and how to engage with community processes to respond to events that affect them directly. Formal education therefore, plays a key role in shaping the understandings and conversations individuals, communities and societies have around EFWE [54].

3.2 Part 1: Analysis of EFWE occurrences

This part measured instances of EFWE, specifically floods and droughts, in the two target regions of Saskatchewan, Canada and Queensland, Australia. The analysis was conducted in October 2019 and involved compiling, analysing, and comparing existing weather data gathered in the two regions between 2013 and 2018. These dates were chosen to encompass the five previous years and allow one extra year to account for the fact that seasons are reversed across the two hemispheres. The purpose of this part was to verify the recent ongoing and immediate prevalence of EFWE in the two regions.

The two regions report rainfall data differently, however, the purpose was to demonstrate occurrences of flood and drought as locally defined in each region rather than directly compare occurrence across the two regions. In Australia, the government reports rainfall decile data to represent rainfall deficiencies. Rainfall deciles are rankings associated with historically observed precipitation versus current to determine if current conditions are average, or are below or above average and by how much [55,56]. Essentially, all of the rainfall data over a given period of time is sorted from low to high quantities and then sorted into 10 equally sized groups to create deciles.

In Canada, the government uses a suite of available measures including the Climate Moisture Index (CMI) which is the difference between annual precipitation and potential evapotranspiration, Soil Moisture Index (SMI) which compares soil moisture conditions as related to historical norms, and the Palmer Drought Severity Index (PDSI) which represents the

deviation in moisture conditions from the ≥ 30 -year historical norm [20,56,57]. PDSI is used for this Canadian Prairies-related study as a standard communications method associated with the federal agriculture ministry, Agriculture and Agri-Food Canada (AAFC).

3.3 Part 2: Content analysis of school curricula

To appreciate the extent to which the Australian and Saskatchewan Governments seek to invest in the teaching and learning of EFWE, it is important to examine the curriculum mandates teachers' are to focus on in relation to EFWE. As such, part two involved a content analysis of EFWE related terms within government mandated curricula in the two target regions. For the purposes of this initial exploration, analysis was limited to formal mandated school curricula because it outlines what a government prioritizes as important enough for all citizens to learn. Content analysis was used to search for and evaluate use of EFWE related terms within government mandated curriculum for all K-10 discipline areas operating in Queensland (the national based, Australian Curriculum) and Saskatchewan (the provincially based Saskatchewan Curriculum). These documents were first searched for the occurrence of the term 'water'. Each year level within the K-10 Science, Social Studies, and Geography curricula within the Australian and Saskatchewan curricula was canvassed to see how often the search categories of flood, drought, water scarcity and severe weather appeared in the content descriptions, elaborations, outcomes or indicators. These terms were chosen due to their association pre-service teachers' perceptions from theme 2. The year level and context of each inclusion was recorded.

In Queensland, elementary and secondary School education aligns with a national curriculum. The Australian Curriculum guides the content taught at each discipline and year level from kindergarten (referred to as Foundation Year) to Year 12. Within each discipline there are content descriptors that outline the specific mandatory "knowledge, concepts, skills and processes that teachers are expected to teach and students are expected to learn" [58]. Supporting these content descriptors are elaborations which provide examples but these suggestions are not mandatory to implement. In comparison, the Canadian curriculum mandates are organized provincially, rather than nationally. Similar to the Australian content descriptors and elaborations, the Saskatchewan curriculum offers mandatory outcomes, supported by suggested indicators of what could be taught to achieve each outcome [59]. It is compulsory for all Australian and Saskatchewan teachers to teach their respective content descriptors or outcomes and for graduating pre-service education students to understand the competency requirements for their discipline areas.

3.3.1 Part 3: Survey of pre-service teachers. Finally, a survey (S1 Text) was conducted that was in part designed to determine pre-service teachers' beliefs around EFWE education, and how those perceptions may be coloured by one's lived experience with EFWE.

Data were collected from pre-service science educators studying at universities in Queensland, Australia and Saskatchewan, Canada. Pre-service science teachers were chosen as the target population because they had lived experience with their own school curricula while being tasked with perpetuating them through the curricula they teach in future. Science education students were recruited to complete a brief on-line survey during class time early in courses taken during the first semester of the 2018 academic year (February for Queensland and September for Saskatchewan). Sampling was purposive and designed to achieve national representativeness. It was instead designed to maximize comparability between two pre-selected, geographically similar yet culturally different, international regions. As such, the most important elements of sampling were 1) to select universities within the two regions where respondents were living through EFWE conditions at time of data collection, and 2) to ensure that

respondents were early enough in their programs to maximize consistency in what they had learned to date before starting to take disparate elective courses. The classes during which to collect data were chosen at each university to ensure virtually all new science education students would be enrolled. Total sample size was limited by the number of first year science education students enrolled in Saskatchewan's only two universities with education programs. In Saskatchewan, sampling would closely mimic a census of students in early science education classes. An effort was made to collect a similar number of responses in Queensland as in Saskatchewan. In Queensland, only one university was needed to establish a similar response rate to that of the Saskatchewan sample. Participation was entirely voluntary and the survey took approximately 10 minutes to complete.

As part of a larger study, the surveyed pre-service teachers were first asked two open ended questions about water-related curriculum. The first asked about the top three things that they remembered learning about water during their own schooling. The second asked about the top three most important concepts to teach children about water in school. These qualitative questions were the first questions posed in the survey, so respondents had not been exposed to any sort of list of topics to potentially bias results. Thematic coding looked for references to droughts, floods, natural disasters, severe weather, and water scarcity. These terms were consistent with curriculum content analyzed as part of step 2. Coding was manually to ensure that themes were captured even in the absence of specific keywords. Due to the simplicity and objectivity of the coding involved, only one expert coder was employed.

The next set of survey questions sought to examine perceptual differences around EFWE related curricula. The two parallel questions asked "As a future science educator, to what extent do you agree that water related curriculum adequately deals with each of the following?" and "As a future science educator, to what extent do you feel adequately prepared to teach each of the following?". The questions were followed by a list of water related topics that included "flood/drought planning" and "flood/drought warning systems" both as a single item on 5-point scales from strongly disagree (1) to strongly agree (5).

The last set of questions were designed to assess the scientific accuracy of pre-service educators' beliefs about EFWE in their areas. Respondents were asked the two parallel yes/no questions "To the best of your knowledge, have you ever experienced living through drought/flood conditions?"

4. Results

4.1 Part 1: Incidents of drought and flood in the study regions

Part one used existing weather data to measure instances of EFWE, specifically floods and droughts, in the two target regions of Saskatchewan, Canada and Queensland, Australia.

The long-term average rainfall for the Brisbane area is 1011.5mm per year (Fig 2; [55]). Over the past 6 years, 3 years have experienced lower than average rainfall, with statistically significant deviations of up to 20% below the norm. One year (2015) also experienced a significant deviation with observed rainfall accumulation of 143% above the norm.

Within the 5-year period of 2014–2018, Australia experienced below average rainfall more extensively in the east, with more moderate and higher than average rainfall in the west. However, there were moderate drought conditions, including below and very much below average rainfall in Brisbane and Gold Coast, Queensland at the time that survey data was collected. The rainfall deviation from the norm for 2018, for instance, constitutes approximately 85% of normal rainfall in a climate normal year [21]. In Canada, the government uses a suite of available measures including the Climate Moisture Index (CMI) which is the difference between annual precipitation and potential evapotranspiration, Soil Moisture Index (SMI) which

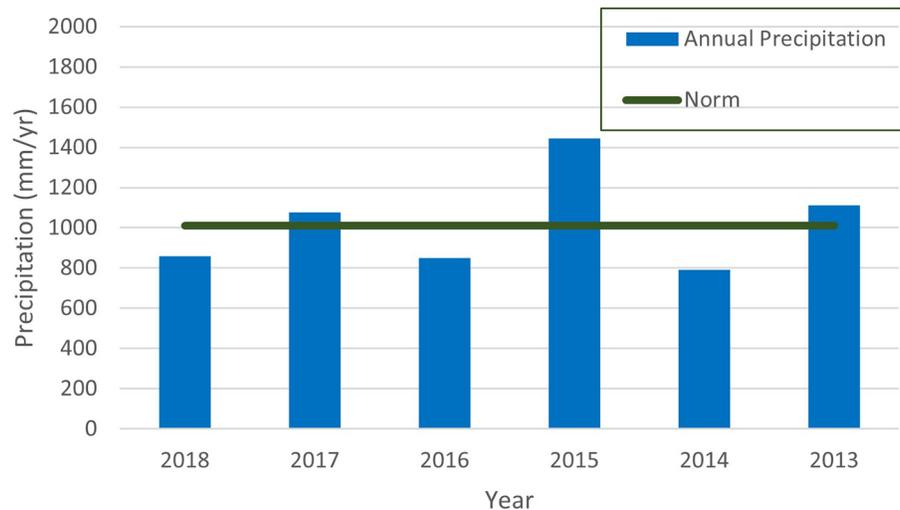


Fig 2. Total precipitation (rainfall only) for Brisbane between 2013 and 2018 (BOM, 2019b).

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compares soil moisture conditions as related to historical norms, and the Palmer Drought Severity Index (PDSI) which represents the deviation in moisture conditions from the ≥ 30 -year historical norm [20,56,57]. PDSI is used for this Canadian Prairies-related study as a standard communications method associated with the national agriculture ministry, Agriculture and Agri-Food Canada (AAFC).

Both Regina and Saskatoon, Saskatchewan, Canada typically receive less than 0.5mm/day of precipitation for between 121–140 days per year [60]. The region is defined as semi-arid with total precipitation (rainfall and snow) norms of 389.7 and 353.7mm/yr, respectively [61]. Between 2013 and 2018, total precipitation events were both above and below the normal ranges for each study location (Fig 3).

The Saskatchewan-based preservice teacher surveys were conducted during periods of significant drought, resulting from both below average rainfall and snowfall in 2017 and 2018. These totals are 39 and 52% of normal total precipitation, leading to depletion of groundwater reserves, lowering of the water table, and limited surface water supplies. The impacts of this 2-year significant deviation from the norm resulted in PDSI values between -3.99 and -3.00, defined as experiencing “severe drought” [56,57].

Flooding is an excess of water following extreme precipitation flows. In Queensland, this predominantly refers to extreme rainfall. In Saskatchewan, floods can occur as a result of extreme rainfall, as well as rapid snowmelt across frozen land and glacial melt flow through riverine systems. It is possible to be experiencing drought and flood concurrently, since one has to do with extended periods of inadequate water supply and the other with a more localized (spatially and temporally) event of excess water supply, respectively. An example is the moderate drought in Queensland of 2018 during which some of the highest rainfall on record was experienced (Fig 4).

Similar data for Canada demonstrates these same phenomena during the study period and in the Canadian locations under review (Table 1). Both observed water availability and regional climate models for Saskatchewan indicate that the frequency and duration of periods

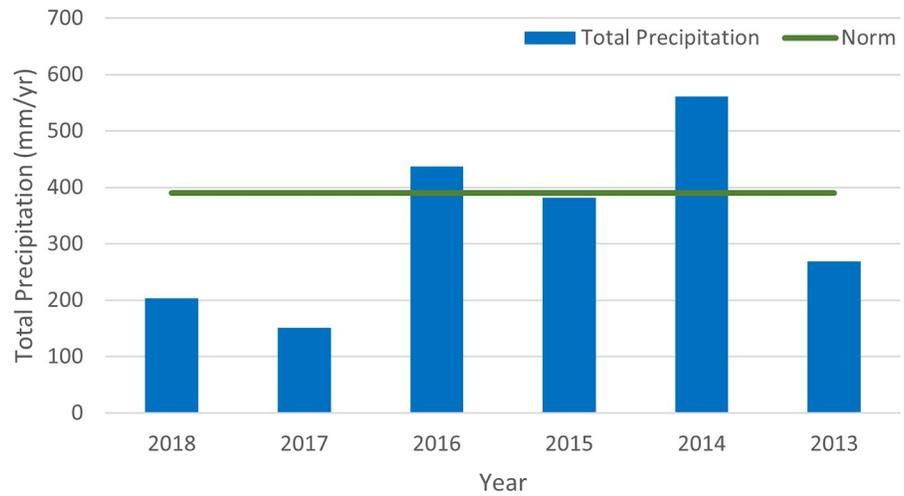


Fig 3. Total precipitation (rainfall + snow) for Regina between 2013 and 2018 (Government of Canada, 2019).

<https://doi.org/10.1371/journal.pclm.0000020.g003>

of low precipitation and drought are increasing alongside less frequent, high intensity rainfall [62,63]. In 2014 and 2016, significant flood events were recorded in Saskatchewan. Each required evacuation of communities and resulted in damage to infrastructure. In 2014, 68 municipalities declared local states of emergency as a result of approximately 240mm of precipitation in less than 2 days. The 2014 flood was in close proximity to the city of Regina,

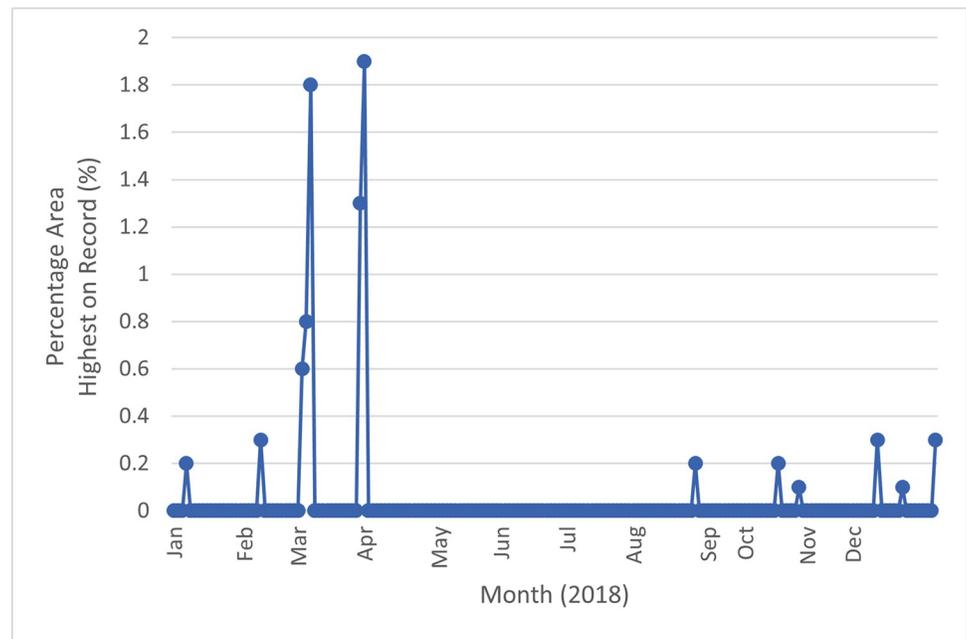


Fig 4. Daily extreme rainfall that fell above the highest on record in Queensland for 2018 (source: BOM, 2019c).

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Table 1. Regina 1-day maximum precipitation, in mm, projections and observations, 2013–2018.

YEAR	RCP 2.6 (low)	RCP 4.5 (median)	RCP 8.5 (high)	Recorded Maximum	Recorded Fit with Model	Date of Maximum
2013	24.23	37.27	56.41	32.1	Low-Median	20-Jun-13
2014	21.82	34.03	40.47	79.9	High+	24-Jun-14
2015	18.23	32.23	44.01	78.2	High+	27-Jul-15
2016	21.83	31.38	43.1	25.9	Low-Median	10-May-16
2017	24.96	29.41	51.47	16.9	<Low	14-Jun-17
2018	18.44	29.9	42.2	22.4	Low-Median	1-Jun-18

RCP2.6, RCP4.5, and RCP8.5 refer to three emissions scenarios representing different atmospheric concentrations of greenhouse gases. Each scenario output includes reporting of low, median and high projections. The low scenario is defined by the 10th percentile of the given model; median values represent the 50th percentile; the high scenario refers to the 90th percentile of the given model. For the purposes of this table, the minimum (RCP2.6 low) and maximum (RCP8.5 high) are provided to illustrate the extremes of the projections model ensemble.

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occurring 2 weeks prior to the recorded 1-day maximum rainfall of nearly 80mm on 24 June 2014. The 2016 flood occurred at the Red Earth First Nation, which is located in closer proximity to Saskatoon. In that case a total of four communities or municipalities declared local states of emergency.

This data provides foundational evidence to support that the two regions of Australia and Canada under investigation had been similarly affected by EFWE in the recent past. Droughts and floods had occurred in both Queensland and Saskatchewan in the five years prior to the study's survey of pre-service teachers. More notably, Queensland was experiencing moderate drought conditions combined with flash flooding and Saskatchewan was experiencing severe drought conditions at their respective times of data collection. As such, all respondents were living through EFWE at the time of survey completion.

4.2 Part 2: EFWE and school curricula in Queensland and Saskatchewan

Part two involved a content analysis of EFWE related terms within government mandated curricula in the two target regions. The Australian Geography curriculum yielded the most instances of including the word 'water' (66 references), with Science (31 references) second, with zero to fourteen references for all other discipline areas. In Saskatchewan, the Grade 1–10 Science curricula had a total of 132 references to water, while the Social Studies curricula had a total of 28 references, other discipline areas ranged between zero and eleven references.

[Table 2](#) illustrates that in Australia there are four mandatory requirements to teach EFWE within the content descriptors of the F-Year 10 curricula. However, in one of these requirements, teachers may choose bushfires or flooding. Within the elaborations, there is also one suggestion to teach about droughts, floods or bushfires. Even though we argue EFWE are underrepresented in the Australian curricula, it seems it is better than the Saskatchewan curricula, as there are no specific mandatory requirements to teach about EFWE in grades K-10. There are five teaching suggestions but these are shared with other teaching suggestions, such as avalanches and tropical cyclones (in a geographical region without mountains and not considered topical). As such, there are no stand alone places within the Saskatchewan curriculum that requires teachers to focus on EFWE.

Through an examination of the Saskatchewan and Australian curricula (from Year F-10 in all discipline areas) it can be argued that students may be offered a strong base for understanding water as historical and contemporary tool for shaping Earth's landscape, as a necessity for all living things, as well as a valuable resource that needs to be conserved [12,54]. However,

Table 2. Content analysis of school curricula.

Curriculum	Grade or Year level & theme	Mandated teaching	Suggested teaching
Australian Science	9 Biological science	Ecosystems consist of communities of interdependent organisms and abiotic components of the environment; matter and energy flow through these systems (ACSSU176)	Investigating how ecosystems change as a result of events such as bushfires, drought and flooding
Australian Humanities and social sciences	5 Geography	The impact of bushfires or floods on environments and communities, and how people can respond (ACHASSK114)	Mapping and explaining the location, frequency and severity of bushfires or flooding in Australia Researching how the application of principles of prevention, mitigation and preparedness minimises the harmful effects of bushfires or flooding
Australian Geography	7 Water in the world	Causes, impacts and responses to an atmospheric or hydrological hazard (ACHGK042)	Explaining the physical causes and the temporal and spatial patterns of an atmospheric or hydrological hazard through a study of either droughts , storms, tropical cyclones or floods Explaining the economic, environmental and social impacts of a selected atmospheric or hydrological hazard on people and places, and describing community responses to the hazard
Australian Geography	7 Water in the world	The nature of water scarcity and ways of overcoming it, including studies drawn from Australia and West Asia and/or North Africa (ACHGK040)	Investigating the causes of water scarcity (for example, an absolute shortage of water (physical), inadequate development of water resources (economic), or the ways water is used) Discussing the advantages and disadvantages of strategies to overcome water scarcity (for example, recycling ('grey water'), stormwater harvesting and re-use, desalination, inter-regional transfer of water and trade in virtual water, and reducing water consumption)
Australian Geography	9	Challenges to food production, including land and water degradation, shortage of fresh water , competing land uses, and climate change, for Australia and other areas of the world (ACHGK063)	Exploring environmental challenges to food production from land degradation (soil erosion, salinity, desertification), industrial pollution, water scarcity and climate change
Saskatchewan Science	4	Analyze how weathering, erosion, and fossils provide evidence to support human understanding of the formation of landforms on Earth (RM4.3)	Examine the effects of natural phenomena (e.g., tidal wave, flash flood , hurricane, tornado, earthquake, mud slide, forest fire, avalanche, and meteor impact) that cause rapid and significant changes to the landscape.
Saskatchewan Science	5	Investigate local, national, and global weather conditions, including the role of air movement and solar energy transfer (WE5.2)	Describe the characteristics of severe weather events, such as hurricanes, tornadoes, blizzards, hailstorms, droughts , and tropical cyclones, including the role of air movement and solar energy transfer in those events.
Saskatchewan Science	5	Analyze the impact of weather on society and the environment, including technologies that help humans address weather conditions (WE5.3)	Explain the effects of different types of severe weather on people, communities, and the environment, including personal safety preparations for various severe weather events.
Saskatchewan Social sciences	7	Appraise the impact of human habitation on the natural environment in Canada, and in a selection of Pacific Rim and northern circumpolar countries (DR7.2)	Examine the effects of humans and their technology on the natural environment in Canada, and in a selection of Pacific Rim and circumpolar countries, including the consequences for indigenous peoples who inhabit those regions (e.g., over harvesting of salmon fishery, increased incidence of severe weather , influence of logging industry on the natural world and ecosystems, effects of deforestation and coral removal, and efforts to reclaim shorelines and restore the natural barriers).
Saskatchewan Science	8	Analyze the impact of natural and human-induced changes to the characteristics and distribution of water in local, regional, and national ecosystems (WS8.1)	Identify possible personal, societal, economic, and environmental consequences of natural changes and human practices and technologies that pose threats to surface and/or groundwater systems in Saskatchewan (e.g., vegetation removal, water and sewage treatment plants, timber harvesting, over-application of fertilizers, agricultural and urban irrigation, impervious ground cover, land alterations, mining, introduction of invasive species, shoreline erosion, fluctuating lake levels, flooding , draining and/or channelling of surface water features, and damming of rivers).

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when it comes to extreme freshwater events, such as droughts and floods, very little is included as mandatory content.

4.3 Part 3: Survey of pre-service teachers

Part three involved a survey of pre-service teachers, measuring their lived experiences with and their beliefs about EFWE related content in school curricula. Of the 340 complete responses gathered, 197 were from Queensland and 143 were from Saskatchewan. The response rates were 82% for Queensland students and 86% for Saskatchewan students across all classes. University enrolment statistics were used in place of survey questions to describe the demographics of the samples under investigation, and indicated that the majority of students enrolled in the education programs at the surveyed universities were local domestic students from the regions under investigation.

4.3.1 Lived experience with EFWE. In order to assess the scientific accuracy of pre-service educators' beliefs about EFWE in their areas, respondents were asked whether they remembered having ever experienced living through drought and flood conditions. Recall that at the time of data collection, both regions were experiencing moderate to severe drought, and the Queensland region had also experienced very recent flash flooding.

Despite the number of EFWE to have occurred in the two regions over the previous five years and the EFWE occurring in the two regions at the time of data collection, only 80% of Australians and 40% of Canadians reported ever having experienced living through either drought or flood conditions. Overall, the surveyed Queensland pre-service educators were significantly more aware of ever having experienced living through either type of EFWE than their Saskatchewan counterparts (sig of Chi $p = .000$, Phi = .425). Only 22.5% of Saskatchewan pre-service educators reported experiencing drought conditions compared to 65% of Australians (sig of Chi $p = .000$, Phi = .419). Given that Saskatchewan's drought was more severe than the one in Queensland, this result was unanticipated. Similarly, only 31% of Canadians reported having lived through flood conditions compared to 65% of Australians (sig of Chi $p = .000$, Phi = .336).

The tendency for the Australian pre-service educators to be over twice as cognizant of having experienced EFWE as their Canadian counterparts suggested that there must be some reason behind the difference. Recall that the purpose of survey results was to draw connections between the scientific realities of EFWE and how they are reflected in school curricula. Further recall that Australia had more instances of mandatory EFWE in its school curriculum than did Saskatchewan. As such, one potential explanation for differences in pre-service teachers' recognition of living through EFWE may be because Queenslanders were more likely to be taught to recognize them.

4.3.2 Curricular beliefs. The first two questions were open ended questions and about water education in general rather than being EFWE specific. There were very few mentions of memories of having been taught about EFWE in school (see Table 3). While the question limited responses to the top three topics respondents remembered being taught, only about 4% of respondents mentioned extreme water events in their lists. When asked about the top three most important concepts to teach children about water, response ratios nearly doubled, rising to 8% from 4% of all respondents referencing EFWE as important curricular content. This question was posed after the question asking respondents to rate the extent to which current curriculum adequately deals with a range of water-related topics, which did not seem to bias perceptions of its importance relative to other issues. It is interesting to note that Queenslanders were more likely to name specific EFWE as being important, while Saskatchewanians anchored more generally on the importance of water scarcity.

Table 3. Open-ended responses referencing extreme freshwater events.

	What top three things do you remember learning about water in school?		What do you believe are the three most important concepts to teach children about water?	
	Australia	Canada	Australia	Canada
flood	3	0	8	4
drought	4	2	6	2
natural disaster	2	2	2	4
water scarcity	1	3	3	8
total respondents*	8/197 (4%)	7/143 (5%)	14/197 (8%)	16/143 (10%)
total also experiencing flood or drought	7/8 (88%)	3/7 (43%)	11/14 (79%)	7/16 (44%)

* mentions may not equal respondent totals because some respondents may have mentioned multiple terms.

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Once again, heightened awareness of EFWE among Queensland respondents was reflected in beliefs about curricular importance. Australians who had experienced an EFWE were twice as likely to raise the issue of EFWE as being important to teach (80%) than Canadians who reported having experienced an EFWE (40%). This difference can be explained by differences in cultural truths between the two countries, as reflected in school curricula, where the significance of EFWE has been more strongly ingrained in the Australian way of life.

Australians thought the existing curriculum more adequately dealt with disaster planning and emergency warning systems than did Canadians (see Table 4). Australians similarly felt more prepared to teach about disaster planning and emergency warning systems than did Canadians. These findings were consistent with earlier findings regarding the more frequent occurrences of EFWE in Australia's existing curricula and Queensland respondents' superior ability to identify occurrences of EFWE. These findings reinforced important cultural differences between the two countries, with the Australians placing more weight on EFWE as an important issue to be taught and addressed than their Canadian counterparts.

4.4 Parts 1–3 results summary. The literature demonstrates that 1) EFWE are increasing, 2) formal education perpetuates cultural beliefs, 3) educators are key actors in that cultural perpetuation. Results from 4.1 demonstrated that all respondents were living through EFWE at the time of survey completion. Results from 4.2 demonstrated that EFWE are not well represented in mandated school curricula in either region, though it had slightly more coverage in the Australian curriculum. Results from 4.3 demonstrated that far fewer Saskatchewanian than Australian pre-service teachers 1) were aware that they were living through EFWE at the time of data collection, and 2) identified EFWE related issues as being important to teach in school. This research uses existing findings in the literature and primary findings to propose that the differences noted between Canada and Australia may be at least partially explained by school curricula and school teachers perpetuating cultural beliefs about the importance of EFWE in their respective regions.

Table 4. Perceptions of teaching around extreme water events.

(1—strongly disagree to 5—strongly agree)	Australians	Canadians	Sig of t
perceived adequacy of curriculum			
flood/drought planning	3.68	3.31	.002
flood/drought warning systems	3.58	3.22	.002
perceived preparedness to teach			
flood/drought planning	3.22	2.88	.004
flood/drought warning systems	3.10	2.80	.011

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5. Discussion

Cultural beliefs relate to ideas so ingrained in one's culture that one often doesn't perceptually acknowledge their existence. The literature shows that cultural beliefs are indeed embedded in both codified school curricula and in educators' curricular beliefs. Results of this research as they relate to differences in importance of EFWE in school curricula across the two locations are consistent with what one would expect based on this literature and cultural relevance. Thus, it is *reasonable* to conclude that any differences noted between the two regions may be explained by cultural differences in beliefs about the significance of EFWE between the two societies. The intention of this research, however, is not to *prove*. Instead, it is to offer a possibility for further study and to start a dialogue about how to effect change in the face of beliefs that are so ingrained that they go unquestioned.

There were clear differences in existing curricular emphasis and pre-service science teacher beliefs about future curricular emphasis on EFWE between Queensland and Saskatchewan. Those differences could not be explained by issues of lived experience or immediacy, as both regions were experiencing EFWE at time of data collection.

Both Australian curriculum and pre-service science teachers' cultural beliefs demonstrated a stronger emphasis on the importance of EFWE to society. Topics related to EFWE were more heavily embedded in Queensland curriculum than in Saskatchewan curriculum, suggesting that EFWE was a more salient issue for Australians than for their Canadian counterparts. While survey results indicated that neither culture highly prioritized EFWE as an issue of importance, Queenslanders recognized the occurrence and importance of EFWE more strongly than their Saskatchewanian counterparts. This consistently higher Australian emphasis implied that a higher level of cultural significance was placed on EFWE in Queensland, Australia than Saskatchewan, Canada.

6. Managerial implications

Government departments responsible for formal curriculum development can use these results to reconsider their existing curricula as they relate to EFWE and whether expansion is warranted. EFWE relevant content can span a variety of subject areas including science, social studies, and geography. By adding required EFWE related curricula, societies will be more cognizant of the causes, consequences, and management of EFWE. Governments may also choose to reflect on cultural beliefs as they relate to other important societal issues that may not be appropriately reflected in formal school curricula.

Post-secondary teacher education programs should also update their curricula to specifically address cultural bias in the classroom. Pre-service science teachers should be trained to be cognizant of the cultural biases they bring to classrooms and ways to correct for them when choosing how to teach mandated topics and what to include as discretionary content. This should help future teachers to better adapt toward teaching highly relevant emergent topics and reduce the likelihood of perpetuating existing cultural biases and experiences in their classrooms.

Inclusion of teachers with such training in ongoing curricular updates and design may further reduce the perpetuation of historical cultural bias in curricula and help to increase emphasis and EFWE and other emerging climate and sustainability related subjects.

Of course, EFWE should also continue to be addressed at a variety of levels through fora including but not limited to informal education, public service campaigns, public policy, and civic participation. However, until EFWE curriculum is added to classrooms, governments will continue to signal that they do not believe them to be of core social significance.

7. Broader societal recommendations

This research was intended to explore possible relationships between formal education and cultural beliefs about EFWE and to open a dialogue around and future research into possible ways to more strongly emphasize and thus change cultural beliefs about the severity and impacts of EFWE within society. We recommend that such a dialogue encompass the three major themes of 1) society's existing sense of abundance and denial of the severity of EFWE, 2) the realities of the natural crisis that we face, and 3) recognition of the relationship between school curricula and cultural beliefs about important topics like EFWE.

7.1 Abundance and denial

Emerging from part one of the research is the reality that both the Queensland and Saskatchewan governments reported moderate to severe EFWE for years prior to, and during, the time of the survey. However part three illustrates, to a variety of degrees, that this reality was not recognizable to the participating future teachers. At the time of the survey, Saskatchewan participants were living through a severe drought, but only 22.5% believed they had *ever* experienced a drought, as compared with 65% of the Queenslanders who were living through a moderate drought. With freshwater being critical to all life on this planet, and the wide ranging consequences of moderate to severe drought, it would be assumed that this issue would preoccupy public and political conversations and be foremost in people's minds. However, this study illustrates that this assumption is not the case. It seems the severity of the situation does not translate into a discourse of public concern.

Even though every participant had, and were, experiencing a drought, we argue their lack of recognition has a cumulative effect that more widely enforces this ignorance. That being, this lack of knowledge sustains a wider social narrative endorsed by the ideal of past abundance. The perception of the abundance of freshwater is endorsed in many people's everyday experiences as large populations in Canada and Australia live in cities where natural systems may be rendered invisible and the infinite ways humans are supported by what science classifies as 'nature' can be ignored or discredited. This narrative hides the reality of droughts from city populations, where the target universities were located and the majority of Queensland's and Saskatchewan's populations live, and presents the rural experience of droughts as isolated incidents. Continuation of this abundance narrative obstructs or minimizes interventions to illuminate the reality of the situation.

The narratives or social 'truth' of abundance feeds the denial of droughts. Cohen [64] describes denial as a tactic to cope with guilt, anxiety or other negative feelings about the reality of a situation. Cohen explains that denial can be "understood as an unconscious defence mechanism" (p. 4) that is not limited to individuals but can be a collective mechanism, highly organised and calculated, that enforces a regime of truth. Cohen [64] identifies three types of denial. The first is *literal* denial, where there is blatant denial that an assertion is not true. The second is *interpretative* denial. This is when facts are not denied, but are given another interpretation, usually one to suit the dominant narrative. *Implicatory* denial is more organized, structured and embedded in social narratives. It also doesn't necessarily deny the facts, but denies or minimizes the significance or implications of the situation. Implicatory denial is reflective of an 'official or political denial', where manipulation or spin doctoring of facts minimize implications to victims [social or environmental] while protecting perpetrators. We argue that if any denial mechanisms go unchallenged, denial will remain the dominant narrative, perpetuating social ignorance, prioritizing economic interests over environmental concerns, and worsening the effects of climate change induced EFWE.

7.2 Natural crisis

All participants more commonly associated EFWE as an act of nature rather than a result of human induced climate change. Although, Queensland participants did show more awareness of the existence and complexity of the human-relatedness of EFWE than Saskatchewanian participants. When EFWE are understood as a 'natural force' or a 'natural event' they are perceived as being separate and distinct from human systems [65,66]. Under this belief, EFWE are perceived as unaffected by social or political agendas or actions. It is assumed humans can not directly influence floods or droughts, but can only endure them and hope to control or manage risks. This aligns with Sammel and Hartwig [29] findings that the contemporary narrative of peer reviewed, academic papers depict EFWE natural disturbances to expected routine or normal quantities of water. EFWE are not viewed as an inevitable part of the circulation of freshwater within living, fluctuating systems [67]. The focus is on the anthropocentric aftermath of these events, and their management (through scientific knowledge and engineering solutions), with little recognition of the complex historical and contemporary social policies, agendas and actions that are deeply interconnected and influenced by human existence and practices. With the focus on mitigation and management, it may be easy to abdicate any responsibility for their occurrence in the first place. It also silences conversations about how water is not external to humans, as humans are mostly water [68] (Neimanis 2017).

We argue that the teaching and learning of EFWE needs to transition away from a mindset of being perceived as 'nature based' or 'negative' towards the understanding that emphasizes the deeper dialectical relations society and water hold. These future teachers need to explore, alongside their students, concepts associated with EFWE and help them understand EFWE from multiple lenses and prioritize understanding the complex relationships humans have with freshwater within their watershed. We believe students need to understand the science of EFWE as well as complex socio-political interactions that work to mitigate or enhance the impact of changes to the water levels in watersheds. This process would develop competencies in accessing community specific, factual knowledge of history and government processes, and encourage students to take part in practices that stimulate public discussions and debate. Further enhancing and enriching students' identity within their community through civic participation.

7.3 Curriculum links

By reviewing both the Saskatchewan and Australian curricula, part two highlights there are *no* mandatory places in the Saskatchewan curriculum where teachers must include *any* knowledge of EFWE, whereas the Australian curriculum advocates four mandatory inclusions on water scarcity and water hazards, such as floods and droughts. The effects of this lack of mandatory inclusion of EFWE in the Saskatchewan curriculum may be reflective of the facts that none of the Saskatchewan participants indicated remembering learning about floods. Less than 5% of all Saskatchewan and Queensland participants indicated learning about droughts and water scarcity in schools. This number is extremely low. The Queensland participants were more likely to identify EFWE as being important for inclusion in their future teaching and learning activities. This discernment of the importance of teaching EFWE is essential if teachers are to prioritize this concept. It is critical that future teachers [and citizens] see the need for their students [future voting citizens] to appreciate the complex processes that occur when there are changes in: the quantity of freshwater; the uses of freshwater; power relations associated with freshwater; and cultural framings of freshwater. It is important for citizens to recognize how these changes have the potential for producing and sustaining social and environmental inequities and injustices that impact their communities. Understanding these

processes also allows for people to identify places when specific interventions may produce more ecologically and socially favourable outcomes for their communities.

Future curricula must mandate the inclusion of EFWE and illustrate the complexity of our social relationships *with* water. Future teachers must have the skills, confidence and holistic insights into the scientific, social, economic, political, and health interconnections associated with EFWE to better support the next generations of citizens to respond and support their communities through predicted changing water patterns. Teachers need to be community leaders able to cultivate literate citizens who can understand and apply what they learn. Rather than just possessing discipline knowledge, students must be helped to find personal and community connections to issues associated with EFWE. Therefore, the teaching and learning of EFWE needs to move from simply detailing decontextualized content knowledge, to actively helping students to critically understand and examine the complex and dynamic relationships between EFWE and associated community issues (both present and future), and their own lives. This is especially critical as both Queensland and Saskatchewan are experiencing frequent EFWE brought about from a changing climate, and the implications of this will continue to have an impact on all living in these regions.

Even though formal school curriculum does not represent the totality of knowledge taught or learned within a society, it does represent the knowledge that is systematically prioritized as being essential for the next generation of citizens. Reflecting on legitimized cultural truths embedded within these documents, it becomes apparent that narratives around EFWE are marginalized or excluded. By not prioritizing EFWE in these documents, the governments are complicit in *implicatory* denial. That is, they may not necessarily deny the facts that both places are experiencing moderate or severe droughts, or the reality that this is likely to continue with climate change, but they do directly ignore the significance or implications of the situation by omitting or minimizing it within their curricula. To a large degree, governments currently perpetuate the invisibility of EFWE within these societies.

Improving the visibility of EFWE within these curricula is a key part to improving societal understandings of EFWE. This implies that teachers (and future teachers) need to reflect on their prior beliefs about EFWE and be open to unlearning and building capacities to see these invisible beliefs embedded within curricula. This necessitates challenging existing beliefs and ideas about what societies deem as 'normal' knowledge about EFWE. It means being responsible for our individual and collective openness to change, learning to hear and listen to the 'voices' of those silenced by our current regimes of truth around EFWE and generating shifts that go beyond promoting behavioural change.

Overcoming the invisibility towards EFWE is not just about ensuring it is in the curriculum, that is a start, but it also encompasses reorganizing the social, political and economic narratives that underpin these cultural truths, so this knowledge is made visible and engaged with, rather than being 'invisible in plain sight'. As such, we argue that EFWE needs to be reframed and prioritized within both society *and* curricular documents. By reframing EFWE in societies and school systems, education can move beyond approaches that promote denial, and advance dialogues for collectively reimagining how societies make sense of EFWE and leverage this future thinking to promote a more relational way of thinking. Without this work, the realities of climate induced EFWE may be avoided or evaded in the formal education sector, maintaining ignorance that supports denial.

8. Limitations

This research was designed to explore whether cultural beliefs about EFWE are reflected in school curricula. In order to do so it relies on previous research to establish the relationships

between 1) school curricula as perpetrators of culture, and 2) pre-service science teachers' cultural beliefs and perpetuation of culture. This paper's research was not designed to re-test those findings, but instead to use them as a starting point for looking at a specific curricular area, around which two societies have existing beliefs and curricula.

While the study demonstrates differences as they relate to EFWE curricula and beliefs that follow the trends anticipated by the propositions of the research, results are correlational, not causal, and thus we cannot claim that the relationships identified were not caused by some other mechanism. However, the purpose of this study was to explore a possibility, open a dialogue, and encourage further research into possible causes and consequences of such potential perpetuation.

This study employed three different methods, all of which came with limitations. Part 1 studied meteorological data from two countries which measure flood and drought differently. Providing explanations of the differences and separate visual representations were necessary. Part 2 involved a content analysis of school curricula that were developed by different levels of government and with different structures. Keyword searches were used to maintain consistency and comparability. Part 3 involved a survey of pre-service science educators. Saskatchewan's low population meant that a census technique was used to recruit participants. Pre-service teachers were used because they are the teachers of tomorrow, but the research could be redone using existing science educators to test replicability. While the survey design relied on respondents' memories and perceptions, memory and perception are the foundations for cultural beliefs and part of the purpose of the study was to demonstrate that perception may be more relevant than reality when shaping school curricula.

9. Future research

One area for potential future research is to examine the extent to which non-mandatory and informal education (e.g., university programs, public service campaigns) around EFWE are able to supplement formal school curricula, as they do not necessarily reach all members of society. It would also be useful to know the extent to which these levels and types of education can override the culturally set notions of EFWE and perpetuated through popular and social media, popular culture entertainment fora, and other community-based communication channels.

Another area of research is to study teachers' professional development opportunities and how they may be used to reduce perpetuation of cultural biases and increase recognition and understanding of EFWE. Similarly, conducting a study of how societies design and update curricula, and how they include teachers and scientific experts in that process may further identify ways to enhance representation of EFWE and other important emergent issues to school curricula.

Such studies would also open a door to study this issue longitudinally. A multi-generational study that examined differences between science educators of all ages could help to add insight to the dialogue proposed. Looking at the evolution of school science curricula over time as it relates to the study of EFWE, water, and climate more generally may also serve to build on this work.

Supporting information

S1 Text. Water education questionnaire qualtrics.
(PDF)

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