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REVIEW

Opinions of 12 to 13-year-olds in Austria and Australia on the concern, cause and imminence of climate change

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Abstract Early adolescence (12–13 years old) is a critical but under-researched demographic for the formation of attitudes related to climate change. We address this important area by exploring adolescent views about climate change. This paper presents opinions collected from surveys of 463 1st-year secondary school students (12–13 years old) in public secondary schools in inner-urban centres in Austria and Australia on whether climate change is (1) something about which to worry, (2) caused by humans and (3) happening now. Eligible respondents in both countries showed similar levels of agreement that climate change was probably or definitely something we should (1) worry about (84.6% Austria, 89.1% Australia), which is significantly higher than either country's adult population. Eligible respondents agreed that climate change probably or definitely is (2) caused by humans (75.6% Austria, 83.6% Australia) and that climate change is probably or definitely something that is (3) happening now (73.1% Austria, 87.5% Australia). Their response differed from the respective adult populations, but in opposite directions. Our results suggest that socio-cultural worldview may not have as much influence on this age group as it does on the respective adult populations and suggests that this age group would be receptive and ready for climate science education and engagement initiatives.

Keywords Climate change opinion · Climate science · Early adolescence · Worldview

INTRODUCTION

Despite more than 30 years at the forefront of the political and social agenda, meaningful climate change governance continues to exhibit disconnects between scientific knowledge, public knowledge and trust of climate science (Moser 2016). Aligning public opinions with the scientific consensus on the influence of anthropogenic climate change is an ongoing challenge for both science communicators and those who recognise the essential role the general public play in mitigation and adaptation (McBean and Hengeveld 2000; Moser 2016). Most studies (international and regional) ("Gallup: Social Series" 2017; Steentjes et al. 2017) that provide context for this disconnect and measure adult public opinions show marginal changes in public opinion over time. Public opinion research has shown that the influence of worldview (defined by Dilthey as "an overall perspective on life that sums up what we know about the world, how we evaluate it emotionally, and how we respond to it volitionally" (translated by Makkreel 1975)) is the primary predictor for why adults are so resistant to changing their opinions and attitudes (Cook et al. 2017). Interventions aimed at aligning adult opinions with the scientific consensus are likely to be ineffective and may even result in entrenching climate denialism and post-fact attitudes (Leviston et al. 2014). We need to reach individuals before their worldview bias prevents them from engaging with the topic of climate change in a pro-active and constructive manner. In so doing we may avoid cultivating further scepticism with the effect of delaying action to reduce global emissions. Since adolescence (12–24) is the age when individuals develop their attitudes and worldviews, this might be a period when interventions aimed at improving climate-friendly attitudes might be the most effective (Stevenson et al. 2014; Corner

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et al. 2015; Lee et al. 2020). The age range of adolescence is quite large and encompasses many significant physiological, social, emotional and intellectual changes. Selecting a suitable, more precise, age group to implement interventions depends, therefore, on obtaining an understanding of how opinions in this group alter over time (both as they age and as they change with time in this age group) and how this might correlate with worldview influence, e.g. the prevailing opinions of respective adults.

Research in older adolescents and adults indicates that, while there are differences in overall opinions (Harker-Schuch and Bugge-Henriksen 2013; Leiserowitz et al. 2011; Skamp et al. 2013), the degree of difference is not large. According to Corner et al. (2015), concern in the UK and Australia about 'the economy, employment opportunities and access to affordable education trump worries about issues like climate change for the people in 15–26 age range'. A 2011 report investigating US teenagers' opinions and knowledge of climate change (Leiserowitz et al. 2011) (13–17 years, $n = 517$) showed that 43% of teenagers think that climate change is something to be 'somewhat worried' or 'very worried' about, in comparison with 55% of adults; 57% of teenagers think climate change is anthropogenic compared to 50% of adults; and 54% of teenage think that climate change is happening compared to 63% of adults.

Differences between countries are also evident in opinions amongst older adolescents. A 2013 study exploring the opinions of 16–17-year-olds ($n = 188$) in Denmark and Austria (Harker-Schuch and Bugge-Henriksen 2013) showed that Danish students were considerably more worried about climate change (82%) than Austrian respondents (60%), were significantly more likely to think that climate change was caused by humans (Danish respondents: 90%; Austrian respondents: 73%) and somewhat more likely to think it was happening now (Danish respondents: 94%; Austrian respondents: 91%). Gender also plays a role in opinions related to climate change in adolescents. Harker-Schuch and Bugge-Henriksen (2013) found that older adolescent females are more likely to hold the opinion that governments and individuals are equally responsible for addressing the responsibilities of climate change than male students. With regard to perceptions of threat, a US study exploring the role of education in overcoming anti-climate attitudes in middle school students ($n = 378$), Stevenson et al. (2014) demonstrated that females perceive climate change to be more threatening than males. For opinions related to action-taking, Skamp et al. (2019) found in a cross-national study that early and middle secondary females students ($n = 12{,}627$) 'expressed more support for the four measures [of amelioration] which aligns with many studies that have found females express more 'environmental' concern'.

These differences in opinions across countries may be explained by the tendency of adolescents to mirror the same perceptions of risk and efficacy that are maintained by their parents (Lee et al. 2020), particularly in those families where indifference (low risk, low efficacy) and responsive (high risk, high efficacy) attitudes are familial norms (Mead et al. 2012). Taking data from 2013 for which we have data on both adults and 16–17-year-old adolescents, we find that 70% of Austrian adults, for example, are concerned about climate change (*Eurobarometer Climate change* 2017) compared to 60% of older adolescents who are also worried about climate change (Harker-Schuch and Bugge-Henriksen 2013). In Denmark in the same year, 73% of adults think that climate change is a threat compared to 82% of older adolescents.

However, research suggests that the influence exerted by adults on the younger population may be diminished due to an inherent plasticity arising from their intellectual and social development that may make them less susceptible to worldview influences than adults (Stevenson et al. 2014; Corner et al. 2015; Harker-Schuch 2020). Contrary to studies in adults which show the influence of worldview on adult attitudes to climate change, Stevenson et al. (2014, p. 293) found that climate change knowledge of middle school students in the USA ($n = 387$) was positively correlated to acceptance of anthropogenic global warming which may arise, as they argue, 'because worldviews are still forming in the teenage years'. This is further supported by Lee et al. (2020, p. 11) who in a narrative synthesis of the literature on youth perceptions on climate change tentatively argued that 'younger children's thinking about climate change is less reflective of worldview and cultural values than older children's [thinking]'.

While this is a positive indication for knowledge deficit interventions, there is little further evidence, as overall research in the adolescent age group is lacking and fragmented (Stevenson et al. 2014; Corner et al. 2015; Nature Editorial 2018; Lee et al. 2020), let alone research associated with climate opinions (a recently published narrative synthesis by Lee et al. (2020) is a notable exception). This is further exacerbated by climate change being a contentious issue in the broader public arena (Brechin and Bhandari 2011; Poortinga et al. 2011; Capstick et al. 2014), which may reduce the number of willing participants, difficulties in obtaining necessary research approvals and gaining all necessary consents (i.e. departments of education, the school, the teachers, the parents and the students themselves).

Finally, while we have information on climate opinions from older adolescents, there is little specific opinion data from early adolescents. With opinions between older adolescents and adults showing some alignment, there is a need to examine climate opinions in younger age groups.

From such examinations, we can develop an understanding of this critical age group and, potentially, identify the age at which views on climate change become the subject to the influence of worldview.

This paper aims to provide further context in the realm of climate opinions in adolescence and focuses on a significant but hitherto under-researched group: the early adolescent (Nature Editorial 2018). This age group may provide a unique and previously unexplored avenue for climate science communication (Harker-Schuch 2020); offering as-yet uncharted access to early worldview construction and, more critically, intellectual development pathways.

Why early adolescents matter

The early adolescent age group is the largest group of climate-vulnerable people on Earth and the group with the biggest portion of responsibility (Nature Editorial 2018; UNICEF 2015). In addition to their suitability for targeted climate interventions (Harker-Schuch 2020), they possess vital characteristics that play a major role in an individual's ability to comprehend the foundations of the climate change issue (Piaget 1972; Case 1985; Jensen and Nutt 2015; Harker-Schuch 2020) which may play an important role in civic action and responsibility (Field et al. 2015). The characteristics are (I) that their brains are undergoing a new intellectual development phase (Case 1985; Jensen and Nutt 2015), (II) their worldview has only just begun to form (Corner et al. 2015), (III) their high level of social trust (Wray-Lake et al. 2010), (IV) they are uniquely vulnerable to the impacts of climate change and (V) they have a budding self-determination and social activism (Piaget 1972; Case 1985; Jensen and Nutt 2015) which will eventually drive their socio-political identity and help them secure social capital and community. These characteristics of the second critical phase of development arise as a result of physiological changes in the human brain that begin shortly before the age of 12 to ensure that healthy individuals will develop the skills they need to enter and manage adult life (Jensen and Nutt 2015).

The intellectual development (I) that takes place in this age group allows adolescents to begin to process higher-order executive functions (Case 1985) and develop abstract reasoning. The mechanisms and processes that underlie climate change—particularly its 'wickedness' (Levin et al. 2012)—require an individual to intellectually perceive the scale and connectedness of those processes and mechanisms. These perceptions are usually only possible once the brain begins this developmental phase (Piaget 1972; Case 1985; Jensen and Nutt 2015).

As well as triggering executive function processing, the brain begins to form socio-political/-cultural worldviews (II) (Case 1985; Corner et al. 2015). In conjunction with the abstract-reasoning process, a proto-self-determination arises which is necessary for worldview development—making this age group an ideal 'starting point' for fact-based worldview development (Field and Hoffman 1994; Rosso et al. 2004). There is a very short window of opportunity in this age group (Harker-Schuch and Bugge-Henriksen 2013; Stevenson et al. 2014; Kahan 2015) and recent research also indicates that embedding critical reasoning at this age may cultivate a worldview that is more open to consideration of evidence (Shi et al. 2015) as opposed to one that is, for example, suspicious of knowledge institutions or dismissive of information that challenges unfettered economic growth.

In addition to improvements in intellectual reasoning and the development of worldview, early adolescents also show stronger social trust (III) than older adolescents do (Flanagan and Stout 2010). This social trust is defined as a 'beliefs that people are generally fair and trustworthy' (ibid) and is important to civic stability and the functioning of democratic societies.

As well as being vulnerable (IV) to climate change in comparison with older age groups (UNICEF 2015), adolescents are aware of this vulnerability (Thew et al. 2020). They lack political and social agency (aside from that in their homes) and the right to influence their shared future or participate as key stakeholders (ibid).

However, young people also tend to have high levels of social activism (V) and this activism can lead to significant change throughout all levels of society (Checkoway et al. 2005; Lawson et al. 2019). Aside from radical social adjustments, young people also implement gradual change as they secure relationships, find employment and exercise their rights as adults (Checkoway et al. 2003; Silva Dias and Menezes 2014). Teaching them about climate change—both as a science and as a wicked problem—will ensure they are prepared to engage with it successfully and could also drive much-needed social coalescence on this issue (Crayne 2015). For example, the recent #Fridays4Future movement, according to Fisher (2019), is associated with an increase in parental activism and engagement. This is further supported by a recent study involving 238 families in North Carolina, in the USA, which demonstrated that children may '*inspire their parents towards higher levels of climate concern and in turn, collective action*' and '*may be a promising pathway to overcoming socio-ideological barriers to climate concern*' (Lawson et al. 2019).

This paper attempts to determine the opinion signals of this age group in central urban centres and how those opinion signals relate to one another. Additionally, we explore the influence of other factors such as the effect of country of residence and gender on those opinions. The relatedness of the opinion signals to one another is important in terms of predicting attitudes in adolescence

and developing communication strategies, education materials or support networks that respond to adolescent needs and concerns. We explore the suitability of this age group for science communication interventions toward improving their understanding and preparedness for the future. For example, if we know that worry about climate change is strongly associated with the belief that climate change is caused by humans and is happening now, we can develop curricula that addresses the concern (i.e. anxiety) associated with this opinion that includes other emotion-laden opinions (i.e. guilt associated with anthropogenic emissions or the imminent threat associated with it happening now). We also endeavour to determine how worried early adolescents are with the issue of climate change and how well their opinions align with their respective adult populations. Adolescence is quite daunting and anxiety-ridden, even without the pressure and uncertainty of climate change (Piaget 1972). Assessing 12 to 13-year-olds on their opinions related to climate change, therefore, becomes quite meaningful in broader social terms as one indicator of their overall emotional and mental well-being.

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Objectives and hypotheses

The overarching objective of this study is to determine the current opinion state of 12 to 13-year-olds with regard to whether climate change (a) is something to worry about ('concern'), (b) predominantly has anthropogenic causes ('anthropogenic') and (c) is happening now ('imminence'). Specific interests are how opinions on these three dimensions relate to each other (H1) and differ across country, and gender (H2).

- H1: Opinions on the three dimensions ('concern', 'anthropogenic' and 'imminence') are related with each other (*H0: There is no correlation of the respective opinions with each other.*)
- H2: The opinions of early adolescents on climate change differ based on demographic factors, such as country and gender. (*H0: There is no difference in the opinions of early adolescents based on demographic factors.*)

We also discuss the alignment of early adolescent climate change opinions with their respective adult and older adolescent populations' opinions to assess their suitability for science communication interventions. Finally, we discuss the influence of demographic factors in context with risk perception in early adolescence and how these compare to risk perception in adults and older adolescents.

MATERIAL AND METHODS

To test the hypotheses, an opinion survey was created based on a previous survey by the primary researcher (Harker-Schuch and Bugge-Henriksen 2013) and administered to first-year secondary students at six inner-urban high schools in Austria (in February–March, 2017) and Australia (June–August, 2017). The opinion survey was part of a larger research project examining the role of serious-gaming interventions to improve climate science literacy in the 12 to 13-year-age group. The survey was administered within the scheduled science class time (45–50 min) and was approved by the relevant education departments and the ethics committee at the Australian National University (ANU ethics protocol number: 2015/583). All protocols were followed in accordance with the requirements: ethical approval, anonymisation of the data, certifications for working with children/vulnerable people and permissions. All obtained permissions were stringently vetted: removing any participants where permission was not obtained.

Schools and students

The research catchment criteria for this study were secondary public schools in an inner-urban setting < 10 km from the central business district. The selection of the school depended, as per requirement, on whether the school director and head of science would be willing to participate in this research. According to the requirements and procedures, 6 schools agreed to participate in this study (2 in Vienna, Austria—Coded as VHS1 and VHS2—and 4 in Australia: 2 in Sydney—coded as SHS1 and SHS2—and 2 in Canberra—coded as CHS1 and CHS2). All schools taught in the 'mother tongue' of their respective nationalities (i.e. German in the Austrian schools and English in the Australian schools) and followed the state-regulated curriculum of their respective education departments. The survey was administered in the 'mother tongue' for each nation.

The students were 12–13 years old and all first-year secondary students. A total of 901 students took part in the survey with a final 459 (208 (45.3%) 'female', 245 (53.4%) 'male', and 6 (1.3%) 'other') respondents in the dataset. Due to the small sample size, 'other' were removed, leaving 453 respondents eligible for inclusion and final analysis. Of these, 78 Austrian and 375 Australian students took part (see Table 1, see "Results"). Eligibility depended on approval from the respective department of Education and the school, as well as parental and student approval, participation in the study and valid responses to the survey.

Very little previous research has been done on the opinions and concerns of this age group about climate change (Lee et al. 2020). The difficulties obtaining

permission to work with students of this age necessitated identification of a small target group of schools. Ethical considerations further limited our focus to urban/suburban schools as students at those schools were considered to have the easiest access to quality mental health support services should the survey cause distress. Therefore, in order to access early adolescents in the educational setting for participation in this research project, we engaged directly with educational institutions in Australia and Austria. By including two schools in each of three cities (Vienna, Sydney, Canberra) across the two countries, we have sought to access a cross-section of adolescents that allow us insight into comparisons across countries and within countries. In order to conduct the research within the classroom setting (as a part of a larger research project that also involved a knowledge intervention and assessment; see Harker-Schuch and Watson 2019; Harker-Schuch et al. 2020), we gained access to classes of early adolescents in the six schools. The population of our research is an approximation of the early adolescent population in the two countries, though we note that our sampling technique cannot be considered adequate to represent the country-level population. As such, we consider our population to be early adolescents in Vienna, Canberra, and Sydney, and view our present research as an insight into trends that would be ideally supported by a broader and randomised sampling of early adolescents across both countries (and others) in future research. However, due to the research ethics limitations of working with children, accessing early adolescents via the educational system, as we did, will necessarily lead to participation on a school-by-school (and/or class-by-class) basis.

The schools were 'state suburb' zoned (5 schools of 6) for their district or suburb (with one school allowing exceptional students to enrol alongside those in the district) (*2016 Census QuickStats* 2016). We are prevented from disclosing precise demographic information (census data) due to privacy laws as this is likely to make identification of the participating schools possible. It is, however, useful to provide some background information (*2016 Census QuickStats* 2016; *Statistisches Jahrbuch der Stadt Wien 2017* 2017) and to note a few aspects of the demographics that may assist in interpreting the findings without compromising the privacy laws. The Austrian catchment had a higher proportion of adults with non-mandatory secondary levels of attainment (approx. 18 years) compared to the zoning for the other schools. CHS1 and SHS2 both had fewer citizens in the selected age group (12–13 years). The catchments for CHS1, CHS2, and SHS1 all had significantly higher tertiary levels of attainment (Bachelor and above). Canberra residents have far higher 'country of birth' percentages than Sydney or Vienna and the catchments for CHS1 and CHS2 have significantly lower net immigration at present than the other schools. The catchment for CHS1 had the lowest level of unemployment. The selection of schools excluded from consideration opinions in rural regions in both countries. However, in terms of population, the urban population in Austria as of 2016 is 59.0% of the total (World Bank 2018) and urbanisation is increasing. The urban/suburban population in Australia as of 2017 is 89.6% of the total (World Bank 2018) and is also increasing. While urban population is higher in Australia than in Austria, population density is higher in Vienna (176/ha) than in Sydney (27.6/ha) or Canberra (15.9/ha) and Austria is also significantly smaller than Australia (1:92, respectively) which allows for a higher rate of idea transmission and socio-cultural interaction between urban and rural communities. Thus, the study population is likely to be reasonably representative of a large majority of the young adolescents in each country. Vienna, Austria and Sydney and Canberra, Australia, were chosen as sites for initial study because (a) European and Australian adults show significant differences in their opinions, (b), polarisation of political ideologies is evident in Australia but is low or absent in Austria (see below), (c) the lead researcher had access to Vienna high schools based on prior research with them (Harker-Schuch and Bugge-Henriksen 2013), (d) the Australian government funded the study and (e) the Sydney and Canberra high schools had established relations with the ANU.

Climate change in Australia and Austria

In Australia, climate policy remains a socially and politically contentious issue, with emissions reductions efforts that are broadly considered to be inadequate (den Elzen et al. 2019), and social divisions over climate change aligned closely with political preferences (Hornsey et al. 2018). Recently, public acceptance of the reality of climate change has grown (Kassam 2019), but political divisions remain (Merzian et al. 2019). Australia is a high per capita emitter of greenhouse gases yet has comparatively low vulnerability to the impacts of climate change (Althor et al. 2016).

In Austria, '*environmental preservation is a concept deeply rooted in the Austrian public conscience*' (Keinert-Kisin 2015, p. 138) and there are few discernible social or political divisions over climate change. Denialism is low and not polarised along political lines, as it is in the USA and Australia (Rhomberg 2016) which is evidenced by the recent formation of the national Conservative and Green coalition (Murphy 2020; Schütze and Bennhold 2020). Emission reduction endeavours, in alignment with EU directives, are well established (reduction of 13 million tonnes CO_2 equivalent since 2005) and ambitious (Federal Ministry Republic of Austria Sustainability and Tourism

and Federal Ministry Republic of Austria Transport Innovation and Technology 2018). Austria has moderate to high per capita emissions of greenhouse gases yet has comparatively low vulnerability to the impacts of climate change (Althor et al. 2016).

Survey

Our research instrument was three questions that were administered to early adolescents as a measure of their opinion on climate change. We developed this survey to reflect common approaches to assessing climate opinion and to deliver the survey in a way that was compatible with the educational classroom setting. We drew on the extensive research in adult opinions and we synthesised those questions (see Tables S1 and S2) and then adapted them for early adolescents. We explicitly state that the questions were related to opinion (i.e. *'In your opinion, do you think climate change…'*) in consideration of socio-cognition theory. We consider the role of emotions and proximity (O'Neill and Nicholson-Cole 2009a; Lombardi and Sinatra 2013; Brügger et al. 2015) by altering previous questions that implied explicit personal concern i.e. '…are you personally worried about climate change?', to a question which would allow respondents to feel a collective socio-cultural proximity, i.e. 'is something we all should worry about') We ensured age-appropriate readability before finally testing the prospective survey with four 12-year-olds.

As our climate opinion questions were deployed as part of a larger project that also included assessment of climate science knowledge (Harker-Schuch 2020), it was our view that the research burden on participants would be too great if we were to include multiple measures of climate opinion across the three dimensions. In an ideal setting, our research instrument would have included multiple questions on each aspect of climate opinion.

In the first three survey items, the students were asked to put in an anonymous tracking code and gender. Following this, the next three items were Likert-style questions pertaining to their personal opinion with regard to their concern (In your opinion, do you think Climate Change is something we all should worry about?), their belief that it is anthropogenic (In your opinion, do you think humans cause Climate Change?), and its imminence (In your opinion, do you think the climate is changing now?). The Likert scale ranged along a five-point scale:

No—Probably not—Maybe—Probably yes—Yes

For analyses, the Likert scale was converted to a numerical scale with No = 1, Probably not = 2, Maybe = 3, Probably yes = 4, and Yes = 5.

Statistical methods

Due to the lower numbers of respondents who selected 'no', 'probably not' and 'maybe', the response data were aggregated ('yes' with 'probably yes' and 'no' with 'probably not') and the responses 'maybe' was used as a neutral reference point. Chi-square tests were conducted to examine whether there was a relationship (i.e. dependent structure) between concern/anthropogenic, concern/imminence and anthropogenic/imminence. Since Chi-square tests only provide information if there is dependent structure between the variables and do not provide information on the effects (both magnitude and direction of the effects), further analysis was required as the Chi-square test showed a relationship. Ordinal logistic regression (OLR) (IBM SPSS statistics 23.0) was selected due to its suitability to ordinal data from the Likert scale. OLR allowed further analysis of respondents' opinions about climate change and to assess whether country and gender may affect opinion responses, i.e. to control for demographic factors while investigating the connections amongst the opinions. For the OLR, the 3 variables examined in the Chi-square analysis, 'concern', 'anthropogenic' and 'imminence' were considered as the response variables (5-point Likert scale aggregated as described above) as well the main effects of country and gender.

In summary, the analysis approach consisted of the following stages:

1. Aggregate response data ('yes' with 'probably yes' and 'no' with 'probably not'), using 'maybe' as the neutral reference point.
2. Descriptive statistics on trends in overall opinion of early adolescents.
3. Chi-square test to determine dependent structure between concern/anthropogenic, concern/imminence and anthropogenic/imminence.
4. Ordinal logistic regression to determine the relationship between the responses and the predictors.

RESULTS

Descriptive data

In total, 401 students, corresponding to 88.5% of the students (total $n = 453$), were of the opinion that climate change is something to worry about (regarding variable "concern") (yes = 299 students, 66%; probably yes = 102 students, 22.5%) (Table 1a). The remaining responses (maybe= 3.1%, probably not/no= 8.4%) totalled 52 students, or 11.5%.

In total, 374 students, corresponding to 82.5% of the students, were of the opinion that climate change is anthropogenic in nature (regarding variable "anthropogenic") (yes = 252 students, 55.6%; probably yes = 122 students, 26.9%) (Table 1b). The remaining responses ('maybe' = 10.6%, 'probably not'/'no' = 6.9%) totalled 81 students, or 17.5%.

In total, 386 students, corresponding to 85.2% of the students, were of the opinion that climate change is happening now (regarding variable "imminence") (yes = 264 students, 58.3%; probably yes = 122 students, 26.9%) (Table 1c). The remaining responses (maybe = 11.7%, probably not/no = 3.1%) totalled 67 students, or 14.8%.

Statistical analysis

Relationship between climate opinions regarding worry, imminence and human causation

Analysis shows high Chi-square test statistic results, with high significance ($p < .001$) in all pairs of variables between the three opinion items (Table 2). Due to the low number of observations for 'no'/'probably not'/'maybe', Fisher's exact test (which is suitable for analysis with fewer observations (Kim 2017)) was also run. This test also found that the opinions regarding concern, anthropogenic and imminence are significantly related ($p < .001$). Therefore, we can reject the null hypothesis that the effect between the opinions concern/anthropogenic, concern/imminence and anthropogenic/imminence are independent of each other. As discussed above, the results of the Chi-square tests do not provide further insights such as the nature of the dependent structure amongst the variables, or whether this dependent structure differs amongst demographic factors.

Table 1 Frequencies of responses for concern, anthropogenic and imminence opinions and for country and gender. Aggregated values group negative and positive responses together ('yes' with 'probably yes' and 'no' with 'probably not') with 'maybe' kept as a neutral reference point

	Response	Frequency (*n*)	Frequency (%)	Aggregated (%)
(a) Concern	No	4	0.9	3.1
	Probably not	10	2.2	
	Maybe	38	8.4	8.4
	Probably yes	102	22.5	88.5
	Yes	299	66.0	
	Total	453	100.0	
(b) Anthropogenic	No	17	3.8	6.9
	Probably not	14	3.1	
	Maybe	48	10.6	10.6
	Probably yes	122	26.9	82.5
	Yes	252	55.6	
	Total	453	100.0	
(c) Imminence	No	9	2.0	3.1
	Probably not	5	1.1	
	Maybe	53	11.7	11.7
	Probably yes	122	26.9	85.2
	Yes	264	58.3	
	Total	453	100.0	
Country				
Austria		78	17.2	
Australia		375	82.8	
Gender				
Female		208	45.9	
Male		245	54.1	

Effect of opinions, country and gender on opinions about climate change

Here, we present the results of ordinal logistic regression (OLR) to examine the relationship between outcome variables, i.e. opinion on climate change, and predictor variables, i.e. country and gender. We report the coefficient estimates, its standard error and 95% confidence interval, as well as the Wald test statistic, testing the null hypothesis that the regression coefficient equals 0 and noting its *p*-value. Since we are mainly interested in the effects of the independent variables (gender and country) on the response variables (concern, imminence, anthropogenic), we will focus on the direction and magnitude of the coefficient estimates and statistical significance for these. In the upper section of the regression table, we report the threshold coefficient estimates of the dependent variable as they represent the intercepts, i.e. the level of the latent *y* variable where an observation is predicted to fall in the higher categories of the *y* variable, when all independent variables equal zero. These values predict the cumulative logits and could be transformed for obtaining category probabilities, i.e. the probability that an observation falls into one specific category of our *y* variable, setting all *x* variables to zero. Since this is not of much interest for our analysis, we

Table 2 Chi-square and Fisher's exact tests for concern/anthropogenic, concern/imminence and imminence/anthropogenic, for all data aggregated across schools ($n = 453$)

Variables	Chi-square test statistic	*p*-value	Fisher's exact test	*p*-value
Concern and Anthropogenic	111.835	< .001	99.275	< .001
Concern and Imminence	94.398	< .001	65.641	< .001
Anthropogenic and Imminence	78.775	< .001	54.697	< .001

focus on the lower section of our regression table which presents the regression coefficients on the independent variables. Since all independent variables are modelled as factor variables, the regression coefficient on any x variable tells us how much the logarithm odds of y change, when we switch from the baseline group to another group of the reported variable holding all other variables constant. This means that, when significant, responses are affected by an order of one category, e.g. positive estimates raise the likelihood (i.e. from 'probably yes' to 'yes') and negative estimates lower the likelihood (i.e. from 'yes' to probably yes'). In other words, we can use the OLR (Table 3) to assess whether an independent variable can predict a type of response in the dependent variable, and this can take account of the direction between the ordered responses of the dependent variable.

In the first model, we regress the concern variable (Table 3a) on anthropogenic, imminence, country and gender and find significant effects on the Anthropogenic (yes/probably yes, $\beta = 1.674$, $p < .001$) and imminence variables (yes/probably yes, $\beta = 0.751$, $p = .010$). This finding aligns with the outcome of the Chi-square tests, by showing the three dimensions of opinion are correlated. However, it also identifies that the candidate predictor variables, i.e. country and gender, do not have a significant effect on the opinion variables. Therefore, regardless of students' country and gender, those who respond yes/probably yes for the anthropogenic and imminence variables are more likely to respond similarly for concern. As per the coefficient estimate, the effect is greater in the anthropogenic variable than in the imminence variable, i.e. the association between concern and anthropogenic is stronger than the association between concern and imminence, though both are significant.

For the second model, we regress the anthropogenic variable (Table 3b) on concern, imminence, country and gender and find significant effects on the concern (yes/probably yes, $\beta = 1.325$, $p < .001$) and imminence (yes/probably yes, $\beta = 1.070$, $p < .001$) variables. Again, this reiterates the strong correlation amongst concern, anthropogenic and imminence found from the Chi-square analysis (and the first model). For the gender variable, we find a significant negative coefficient estimate with female students ($\beta = -.431$, $p = .021$) less likely to have the opinion that climate change is anthropogenic than male students.

For the third model, we regress the Imminence variable (Table 3c) on concern, anthropogenic, country and gender and find less, but still significant, effects on the concern ('yes'/'probably yes', $\beta = .586$, $p = .071$), and anthropogenic ('yes'/'probably yes', $\beta = .739.$, $p = .011$) variables. Once again, this supports the findings of the Chi-square analysis and the two previous models. For the Ccuntry variable, we find a significant negative coefficient estimate with Austrian students ($\beta = -.668$, $p = .005$) less likely than Australian students to have the opinion that climate change is happening now.

DISCUSSION

Opinions of early adolescents on climate change are related with each other

The study explored the opinions, and determinants, of 12 to 13-year-olds in relation to climate change, across the three opinion arenas of worry (concern), human causation (anthropogenic) and imminence. In the light of the findings that each of the opinions (concern, anthropogenic and imminence) increases the likelihood that 'yes' or 'probably yes' is selected in the other opinions, we reject the H1's null hypothesis that there is no influence on the opinions for one another. The responses for this age group in these areas indicate that the vast majority shares the concern that climate change is something to worry about, is caused by humans and is happening now—and these relate positively to one another insofar that when a respondent selects 'yes' or 'probably yes' for any one of the opinions, they are highly likely to select 'yes' or 'probably yes' for the other opinions. The relation of the opinions to one another is an important finding as it may allow us to extrapolate the same relationship to studies that have looked at only one aspect of these opinions. Our results also are important as they suggest that worry regulation and emotional support would be worthy interventions in this age group—particularly those that foster hope and concern (Crayne 2015; Stevenson and Peterson 2016) as these are associated with stronger climate change beliefs, increased engagement and life satisfaction (Ojala 2012b). Finally, our results strongly reinforce previous research on emotional reasoning and associated changes in early adolescence which indicate that this age group are beginning to use 'objective', abstract-reasoning information to perceive threat (Rosso et al. 2004; Harker-Schuch 2020).

From an educational perspective, it is also worth considering how we may be adding to students' worry in the classroom and in their daily lives. While many researchers highlight the need to increase knowledge about the consequences and impacts of climate change (Shi et al. 2016; Meehan et al. 2018), they also show that this increases concern (Milfont 2012). We propose that positioning climate change as a concern, i.e. teaching the consequences, *before* providing context on how the climate system works, i.e. teaching the causes, is likely to increase concern and decrease rational responses to climate change. This is largely due to the fact that the consequences and impacts of climate change are inherently uncertain and fear-inducing.

Table 3 Parameter estimates (β) for the ordinal logistic regression analysis for (a) concern, (b) anthropogenic and (c) Imminence opinions. Data are aggregated when the opinions are treated as independent variables, i.e. aggregated values group negative and positive responses together ('yes' with 'probably yes' and 'no' with 'probably not') with 'maybe' kept as a neutral reference point. Threshold represents the response variable, e.g. for a), *y*-axis: concern that is assessed against independent variable data (*x*-axis: anthropogenic (aggregated), imminence (aggregated), country and gender)

(a) Concern		β	Std. error	Wald	df	Sig.	95% confidence interval	
							Lower bound	Upper bound
Threshold, i.e. response variable	Concern = 'no'	− 3.213	0.619	26.937	1	< .001***	− 4.426	− 2
	Concern = 'probably not'	− 1.884	0.446	17.812	1	< .001***	− 2.759	− 1.009
	Concern = 'maybe'	− 0.358	0.39	0.842	1	0.359	− 1.123	0.407
	Concern = 'probably yes'	1.224	0.395	9.628	1	0.002	0.451	1.997
Independent variables, i.e. predictor variables	Anthropogenic (aggregated) = 'no/probably not'	− 0.027	0.426	0.004	1	0.949	− 0.863	0.808
	Anthropogenic (aggregated) = 'yes/probably yes'	1.674	0.297	31.861	1	< .001***	1.093	2.255
	Anthropogenic ='maybe'	0[a]	–	–	0	–	–	–
	Imminence (aggregated) = 'no/probably not'	− 0.612	0.561	1.192	1	0.275	− 1.711	0.487
	Imminence (aggregated) = 'yes/probably yes'	0.751	0.294	6.55	1	0.01**	0.176	1.327
	Imminence ='maybe'	0[a]	–	–	0	–	–	–
	Austria	− 0.076	0.269	0.079	1	0.779	− 0.602	0.451
	Australia	0[a]	–	–	0	–	–	–
	Females	− 0.078	0.206	0.144	1	0.704	− 0.481	0.325
	Males	0[a]	–	–	0	–	–	–
(b) Anthropogenic		β	Std. error	Wald	df	Sig.	95% confidence interval	
							Lower bound	Upper bound
Threshold, i.e. response variable	Anthropogenic = 'no'	− 1.726	0.437	15.573	1	< .001***	− 2.583	− 0.869
	Anthropogenic = 'probably not'	− 1.038	0.408	6.471	1	0.011*	− 1.838	− 0.238
	Anthropogenic = 'maybe'	0.118	0.394	0.09	1	0.764	− 0.655	0.891
	Anthropogenic = 'probably yes'	1.593	0.404	15.556	1	< .001***	0.802	2.385
Independent variables, i.e. predictor variables	Concern (aggregated) = 'no/probably not'	− 0.548	0.585	0.879	1	0.348	− 1.694	0.597
	Concern (aggregated) = 'yes/probably yes'	1.325	0.315	17.651	1	< .001***	0.707	1.943
	Concern (aggregated) = 'maybe'	0[a]	–	–	0	–	–	–
	Imminence (aggregated) = 'no/probably not'	− 0.098	0.564	0.03	1	0.863	− 1.204	1.009
	Imminence (aggregated) = 'yes/probably yes'	1.07	0.276	14.986	1	< .001***	0.528	1.612
	Imminence (aggregated) = 'maybe'	0[a]	–	–	0	–	–	–
	Austria	− 0.319	0.244	1.714	1	0.19	− 0.796	0.158
	Australia	0[a]			0			
	Females	− 0.431	0.187	5.291	1	0.021*	− 0.799	− 0.064
	Males	0[a]	–	–	0	–	–	–

Table 3 continued

(c) Imminence		β	Std. error	Wald	df	Sig.	95% confidence interval	
							Lower bound	Upper bound
Threshold, i.e. response variable	Imminence = 'no'	− 3.16	0.512	38.07	1	< .001***	− 4.164	− 2.156
	Imminence = 'probably not'	− 2.693	0.472	32.559	1	< .001***	− 3.618	− 1.768
	Imminence = 'maybe'	− 0.939	0.413	5.169	1	0.023	− 1.749	− 0.13
	Imminence = 'probably yes'	0.556	0.411	1.83	1	0.176	− 0.25	1.361
Independent variables, i.e. predictor variables	Concern (aggregated) = 'no/probably not'	− 0.389	0.584	0.443	1	0.506	− 1.534	0.756
	Concern (aggregated) = 'yes/probably yes'	0.586	0.324	3.259	1	0.071	− 0.05	1.222
	Concern (aggregated) = 'maybe'	0[a]	–	–	0	–	–	–
	Anthropogenic (aggregated) = 'no/probably not'	− 0.122	0.432	0.079	1	0.778	− 0.968	0.724
	Anthropogenic (aggregated) = 'yes/probably yes'	0.739	0.292	6.406	1	0.011*	0.167	1.311
	Anthropogenic (aggregated) = 'maybe'	0[a]	–	–	0	–	–	–
	Austria	− 0.668	0.241	7.718	1	0.005**	− 1.14	− 0.197
	Australia	0[a]			0			
	Females	− 0.225	0.189	1.410	1	0.235	− 0.596	0.146
	Males	0[a]	–	–	0	–	–	–

***$p < .001$, **$p < .01$, *$p < 0.05$

[a]This parameter is set to zero because it is redundant as it is the neutral reference point against which the other variables are analysed

As O'Neill and Nicholson-Cole (2009b) argue, 'although such representations [i.e. fear] have much potential for attracting people's attention to climate change, fear is generally an ineffective tool for motivating genuine personal engagement'.

Efforts to prepare children need to include their emotional well-being and their action competence, which also includes managing their anxiety and feelings of worry. In a study exploring the coping strategies of early adolescents (n = 293), Ojala (2012a) demonstrated that problem-focused (looking for solutions or searching for answers) and meaning-focused coping (finding benefits in the situation or drawing on belief systems to sustain well-being) strategies are positively related to pro-environmental behaviour and efficacy. There is a need to provide avenues for individuals to take action or improve action competence, as described by van Valkengoed and Steg (2019), who show that climate adaptation behaviour is motivated by descriptive norms (i.e. everyone else is doing it), negative effect (i.e. the desire to ameliorate bad feelings and thoughts), self-efficacy (i.e. the feeling that one can do something about a problem) and response efficacy (i.e. the sense that the actions that we take will actually work).

Opinions of early adolescents on climate change differ based on country/gender

The findings on the influence of demographic factors on opinion about climate change partially reject H2's null hypothesis and there is no difference in the opinion of early adolescents based on demographic factors, such as country and gender. This is because some demographic factors correspond with significant differences in opinion on climate change, while others do not.

Although there is no signal in the statistical analysis for country with regard to the opinion for anthropogenic (meaning that it didn't matter which country the student came from with regard to the opinion that climate change is caused by humans), it does matter, in this sample, which gender you are with regard to the opinion for whether climate change is caused by humans or not. Although research shows that late adolescent and adult females are more likely to be pro-environmental (Hine et al. 2013; Scannell and Gifford 2013; Carrier et al. 2014; Stevenson et al. 2014; Skalík 2015; Chadwick 2017; Stevenson et al. 2018a, b; Skamp et al. 2019), our study suggests that this is not necessarily the case for younger adolescents in relation to the opinion that climate change is anthropogenic, with 12–13 year-old males (84.9%), more likely to report the opinion that climate change is caused by humans than their female peers (79.8%), (see Table S3). Regardless of the differences between males and females, there is still a large majority that share the view that climate change is anthropogenic. These findings suggest that research and tailored interventions aimed at targeting gender may be useful in promoting a better understanding of climate change. For example, serious gaming with a climate science topic may provide gender-specific gameplay that responds to known gender differences—or, more usefully, are derived from game analytics that interact at the individual student level to tailor learning to the learner's needs.

The most surprising finding of this study is the stronger opinion amongst 12 to 13-year-old Australian public-school students living in central urban districts that climate change is happening now than is shared by their Austrian peers (87.5% Australian respondents vs 73.1% Austrian respondents; see Table S3). It is especially remarkable that, in the light of the amplified warming that is taking place in Austria (Nemec et al. 2013; Rhomberg 2016), that Austrian students are less likely to have the opinion that it is happening now. While the findings from the demographic factors are atypical and do differ for anthropogenic from previous findings in relation to gender the opinions of early adolescents in general tend to show a high levels of concern, a strong belief that its cause is anthropogenic and a strong belief it is happening now.

Comparison of climate change opinions with other peers, adults and older adolescents

A lack of existing data specifically from early adolescent opinions necessitated a comparison of the opinions of early adolescents to adults (see Tables S1, S2 and S3 for additional information) to obtain an idea of where the early adolescent opinions are positioned in the climate change opinion realm. The following table (Table 4) provides an overview of early adolescent opinions in comparison with their respective (or proxy) adult population.

Both student groups in Australia and Austria (Table 4a) show a strong alignment with one another, a stronger positive concern level than Australian (63.3%) and European (71.3%) adults (Table 4c) which strongly supports the scientific consensus in the concern opinions related to climate change. Regarding the anthropogenic and imminence opinions, the Australian student group demonstrates a much higher level of belief that climate change is happening now and is anthropogenic than their Austrian peers and the European and Australian adults. Overall, Australian 12 to 13-year-olds were more likely than their respective adult population to think climate is something to worry about (89.1% respondents vs 63.3% adults), is caused by humans (83.6% respondents vs 63.7% adults) and is happening now (87.5% respondents vs 77.7% adults). In comparison, although Austrian 12 to 13-year-olds show a higher level of opinion for concern to their adult population (84.6% respondents vs 71.3% adults), they are less likely to have

Table 4 Comparison of 12–13-year-old adolescents with respective older adolescents and adult population. [@]Data have been averaged from 2 or more surveys. See Tables S1, S2 and S3 for more information

	Concern (%)	Anthropogenic (%)	Imminence (%)
(a) Early adolescents (this study)			
Austria	85	76	73
Australia	89	84	88
(b) Older adolescents			
US	43	57	54
Austria	60	73	91
Denmark	82	90	94
(c) Adults			
Austria	71	87	87[@]
Australia	63[@]	64[@]	78[@]

the opinion that climate change is caused by humans (anthropogenic: 75.6% respondents vs 87.2% adults) and happening now (imminence: 73.1% vs 87.0%) compared to their respective European adult neighbours.

Although we might have anticipated a strong alignment with the respective political position on climate change in each country (i.e. strong positive adolescent and adult opinions in Austria in line with EU climate policy and weaker positive adolescent and adult opinions in Australia in line with weaker Australian climate policy), we found that Austrian students were less likely to have the opinion that climate change is happening now and is caused by humans—both in comparison with their proxy adult population and with their Australian peers. This finding challenges the anticipated influence of their adult populations—especially as the comparison shows, Australian 12 to 13-year-olds think climate change is something to worry about, is caused by humans and is happening now, more than their adult cohort. In contrast, although Austrian 12–13-year-olds are more worried than their respective adult population, they show lower opinion levels for Anthropogenic and Imminence than their proxy adult population. These findings are at least partially consistent with some previous studies (Stevenson et al. 2014; Lawson et al. 2018).

There may be differences in culture or lifestyle between adolescents in Austria and Australia, such as differences in population density or interactions with nature (Saltzman et al. 2011), that lead to the observed differences in opinion. However, it would be likely to see any such effect reflected in the adult populations if it is simply an effect of place. Instead, if there is no methodological or measurement error responsible for the difference, then these results indicate there is an interaction between the adolescent experience and place which shapes the attitudes. For example, curriculum content or norms around adolescents' awareness of climate change or other key policy issues. Both Australian and Austrian 12–13-year-olds show higher rates of reporting the concern opinion when compared to their respective adult populations—and with a stronger positive response than for the other opinions (imminence and anthropogenic), particularly for Australian adolescents. This concern signal is an important one as it suggests that, although Austrians in this age group are attuned to the emotional aspect of climate change as a threat, they do not possess the fundamental understanding of climate change processes to recognise the major dimensions of climate change which make it worthy of concern—the imminence of the threat (Imminence), and the fact that the observed warming and climatic changes are resulting from human activities (anthropogenic).

Opinions in older adolescents in Austria, Denmark and the USA (Table 4b) in comparison with early adolescent opinions (Table 4a) show that both Australian (89%) and Austrian (85%) early adolescents are more worried about climate change than older adolescents in Austria (60%) but they share a similar level of concern to older adolescents in Denmark (82%). Older adolescents in the USA report an even lower degree of concern (43%) about climate change than their peers in other countries and the younger adolescent group. For opinion that climate change is anthropogenic, we see that older adolescents in Denmark (90%) and early adolescents in Australia (84%) share a strong belief that climate change is caused by humans. For the same opinion, we see that older (73%) and younger (76%) Austrian adolescents also share a similar level of belief, but with a lower shared consensus. Once again, older adolescents in the USA indicate a lower shared belief that climate change is caused by humans (57%). For the opinion that climate change is happening now, we find that early adolescent Australians (88%) share a similar high level of opinion that climate change is currently occurring as the older adolescents in Austria (91%) and Denmark (94%). As reflected in the previous opinions, older adolescents in the USA show a lower shared belief (54%) that climate change is happening now than their respective peers and the early adolescent age group.

With clear differences amongst the adult, older adolescent and early adolescent age groups so apparent, more work needs to be done to determine the drivers and forces that create this disparity. Of import is the apparent disconnect between the attitudes of adults, older adolescents and younger adolescents. This disconnect may be used to assist young people in the development of attitudes and viewpoints that better reflect scientific findings and evidence. These findings reinforce work by Stevenson et al. (2014) who argue that 'while worldviews are well

entrenched amongst adult populations, during teenage years they are still forming and this 'plasticity' may explain why climate change knowledge mitigates worldview-based scepticism amongst young people' (summarised by Corner et al 2015, p. 525).

Potential limitations to this study

It is necessary to note that certain potential biases may have influenced the data and affected the findings. The first is that the selected students were from a total of six schools, and as a result cannot be considered a geographically or demographically representative sample of either country. Despite this, the results are useful, especially as data on the 12 to 13-year-old age group is scarce in the literature. It would be beneficial for future studies focused on early adolescents to adopt compatible methods to allow for aggregation of data, developing a more robust dataset.

One of the barriers to more geographically and demographically representative data from 12 to 13-year-olds is the (necessary) challenge posed by research ethics of working with young and vulnerable people. Those who maintain climate-friendly sensitivities are, therefore, more likely to participate in this research than those who do not. The level of teacher engagement was, perhaps, the most influential of all the potential biases for the teachers were the essential driver behind participation numbers in each class. The researchers observed that the teachers who were not enthusiastic had a far lower number of participants in their class than those who were favourable towards the research. This observation was apparent in anecdotal negative criticism of the project by those teachers who returned fewer participation notes from their students and, in some cases, suggesting to the researcher that climate science was not a 'settled' science. In addition, one of the schools in Vienna (VHS2) had parents that were very sceptical about their children's involvement in a research project, with all parents for students in two out of the four classes returning notes that denied permission. Many of these parents were new residents in Vienna (and very recent arrivals to Austria), so it was difficult to discern whether declining to participate was on account of their vulnerability as new residents, language barriers, anxiety over new administrative procedures or negative attitudes toward climate change. If the last, then these important perspectives were not able to be captured in the study.

Curiously, nearly all permission notes were returned by the parents in the Austrian schools (even those stating that their child could not participate) whereas just over half were returned from Australian schools (with nearly all saying their child could participate) even though the recruitment process had been the same. The researcher speculates whether the unreturned notes in Australia are in lieu of a returned note that does not allow their child to participate or a lack of procedure between the school and home that results in lost or misplaced permission notes—or a mix of both. These unavoidable challenges of working with schools and their adolescent students are useful for other researchers to note when engaging with similar samples for future research.

Due to our deployment of these questions in the classroom setting, as necessitated by our engagement with specific educational institutions, they may not reflect the broader populations of early adolescents in Austria and Australia. Such a study would require replication of our research with a nationally representative, randomised sample of early adolescents in the two countries. We encourage such an undertaking in future research efforts in this topic area. Furthermore, the comparison of adult opinions to adolescent opinions in this study may not be a determinant of worldview influences, particularly for Austria as it lacks country-specific data on adult opinions related to the human cause of climate change and whether it is happening now.

Implications of this study

The attitude of these early adolescents is interesting in context with the recent rise in youth climate activism. The data for this study were collected prior to the global public appearance of the #FridaysForFuture movement which began in 2018 and made international news headlines in 2019 (Fisher 2019; The Lancet Planetary Health 2019; Thew et al. 2020) and go some way toward explaining this strong wave of support for political action on climate change from young people around the world. The stronger alignment of attitudes with the scientific consensus in this age group in comparison with those of the respective adult populations provides context for why young people, such as Greta Thunberg (TIME Magazine 2019), and many others, are so prominent in the current wave of social and political activism and resistance across the world (Holmberg and Alvinius 2020).

With adolescent activism currently at centre stage in the global political forum in relation to climate change, this study reinforces the deep concern and anxiety about climate change in early adolescents and provides context for their recent political will and activity. Efforts to address their concerns are warranted and these efforts require a strategy that responds to the emotional, psychological and physiological needs of this age group. Without any formal political agency such as voting rights or inclusion in policy development, they are extremely vulnerable to the decisions being made today about their future—and will be tasked with cleaning up a mess they opposed without recourse for restitution or reparation.

While coping strategies (Ojala 2012a) and improving action competence (Valkengoed and Steg 2019) show promise for support interventions, our results suggest that both action competence and coping strategies could be delivered via climate science literacy efforts that focus on causes and the mechanisms that describe climate change. Due to the association of worry with climate change, efforts that focus on causes (teaching the physical science basis: mechanisms, processes and basic climate science) ahead of consequences (highlighting the impacts: sea-level rise, increased temperatures, extreme weather events) may diminish negative emotions associated with threats (Shi et al. 2016), improve action competence and allow individuals to engage with the issue more optimistically and to perceive it and approach it in the future as a solvable problem. If adolescents require coping strategies in order to demonstrate pro-environmental behaviour, we propose that students are more likely to find benefits associated with a warming climate if they are given the intellectual foundation to imagine these benefits—and will be more likely to envisage solutions to reduce emissions toward climate equilibrium (Visintainer and Linn 2015). For early adolescents entering puberty, this method attempts to respect both their physiological transition as well as their need to be prepared for future climate change.

While there has been ongoing discussion about the value of knowledge deficit in the climate communication arena (Potter and Oster 2008; Moser and Dilling 2012; Pearce et al. 2015; Plutzer et al. 2016; Rohloff 2018; Whitmarsh and Lorenzoni 2010), domain-specific climate science literacy has been shown to be an effective intervention to motivate climate-friendly attitudes and behaviour (Clark et al. 2013; Guy et al. 2014; Stevenson et al. 2014; Corner et al. 2015; Shi et al. 2015, 2016). For young people in the early stages of worldview development, science-based education may help them anchor important climate-specific concepts and knowledge as a departure point for the development of pro-climate attitudes and behaviours. As highlighted by Stevenson et al. (2014, p. 302) 'Climate literacy efforts can overcome worldview-driven scepticism amongst adolescents, making them a receptive audience for building climate change concern'. Likewise, Ranney and Clark (2016) demonstrated that an increase in knowledge about climate science was associated with a higher willingness to accept financial sacrifices. In order to consider both opinions and knowledge dimensions, as recommended by Azevedo and Marques (2017), we are exploring the effectiveness of climate science literacy interventions that focus on causes and mechanisms of climate change in other work.

With worldview playing such a significant role in the behaviour and attitude of adults (Kahan et al. 2011), the high concern about climate change amongst early adolescents presents an avenue for interventions that may overcome the bias seen so frequently in adults (Harker-Schuch 2020). While interventions to improve attitudes and engagement amongst adults can polarise or paralyse an individual's opinions (Kahan et al. 2011), interventions in the early adolescent age group may be more receptive to educational or communication efforts (Stevenson et al. 2018a, b). Providing context about the causes and mechanisms of climate change in the early adolescent age group may also diminish anxiety and provide an avenue for coping and action competence; particularly when solutions and explanations about the problem are identified, investigated and resolved.

CONCLUSION

The suitability of the 12 to 13-year-old age group for science-based climate change education is clear. Not only do we have an age group whose opinions already align well with the scientific consensus, but also we have a group with the requisite intellectual knowledge and capability to begin learning climate science who would greatly benefit from well-designed science communication interventions. Additionally, early adolescents are easy to reach as they are all in school, and they are at the nascent stage of worldview construction. Improving scientific literacy in relation to climate change could have immense social and political implications, such as providing all young people with a fundamental understanding of the science of climate change, regardless of the political ideology or social identity, they will develop in the years ahead. Perhaps, if such a literacy programme was properly implemented, we would have a general public that, regardless of worldviews and belief systems, would share a good understanding of the science of climate change as the basis for public and policy deliberations on relevant courses of action. Climate science education of early adolescents offers alternative intervention routes that avoid the worldview-based polarisation on the reality of climate change which we have experienced in recent decades. Future climate science-educated adults could no more deny the phenomena of climate change than they could deny the existence of their large intestines: both are physical phenomena manifest invisibly in our everyday lives.

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