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Willingness to mitigate climate change: the role of knowledge, trust, and engagement

Antonia Larrain[a], Paulina Freire[b], Hernán Cofré[c], Ana Andaur[b], Sakari Tolppanen[d], Jingoo Kang[d], Joaquín Grez[a], Marisol Gómez[a], Claudia Vergara[e], María Teresa Rojas[e] and Andoni Arenas[f]

[a]Faculty of Psychology, Universidad Alberto Hurtado, Santiago, Chile; [b]School of Psychology, Pontificia Universidad Católica de Chile, Santiago, Chile; [c]Institute of Biology, Pontificia Universidad Católica de Valparaíso, Valparaíso, Chile; [d]School of Applied Educational Science and Teacher Education, University of Eastern Finland, Joensuu, Finland; [e]Faculty of Education, Universidad Alberto Hurtado, Santiago, Chile; [f]Institute of Geography, Pontificia Universidad Católica de Valparaíso, Valparaíso, Chile

ABSTRACT

The recent IPCC report (IPCC, 2023) highlighted the need to increase the perception of risk and prompt climate action through education. The question is what contribution science and environmental education can make—if any—to this challenge. Psychological research has suggested that knowledge (topical and epistemological) and beliefs about self-efficacy are relevant starting points, but the evidence is scarce and inconsistent. We conducted a transversal correlational study to test the direct and indirect effects of system knowledge of climate change, personal engagement with science, and trust in climate science on the willingness to mitigate the effects of climate change. The participants were 386 students attending high schools in Chile. The results reveal that there is no direct effect of climate change system knowledge on the willingness to act. We did find indirect effects of system knowledge on the willingness to act, mediated by personal engagement with science and trust in climate science knowledge. The results also demonstrate a direct effect of personal engagement with science, and an indirect effect mediated by trust in science. The implications for science education are discussed.

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Introduction

The recent IPCC report (IPCC, 2023) on climate change warns about the diminishing window of opportunity to secure a livable and sustainable future for all, calling for urgent climate action and climate-resilient development integrating adaptation and mitigation. The report also highlights the need to increase education, through formal and informal channels, to increase the perception of risk and prompt climate action. The question that has been asked for years (Sharma 2012), which needs to be urgently addressed within the scientific and science education community, is as follows: *What contribution can science and environmental education make—if any—in this?* In the field of environmental education research, different models have been

CONTACT Antonia Larrain alarrain@uahurtado.cl
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proposed to foster pro-environmental behavior (Kollmuss and Agyeman 2022; Li et al. 2019), including psychological variables such as behavior, attitudes, knowledge, identity, and reflection or awareness (Hungerford and Volk 1990), among others. Therefore, environmental psychological research is extremely relevant to the discussion on the role of science and environmental education within the context of the climate crisis.

Given the urgency of the climate crisis, and the evidence demonstrating skepticism among young people about the usefulness of mitigation actions (Lehnert et al. 2020), and a low sense of self-efficacy (Baldwin, Pickering, and Dale 2022), it is tempting to think that the role of science and environmental education should be to directly foster attitudinal and dispositional aspects, at both an individual (individual mitigation actions) and a collective (consensus-seeking and democratic habits) level. In fact, it seems that it is possible to directly impact attitudes and dispositions: a recent meta-analysis suggested that interventions based on emotions, psychological distance, and religion have been shown to impact climate change attitudes (Rode et al. 2021). However, critical voices have emerged doubting the possibility to hold and sustain environmental action without a deeper appropriation of the issue (Hungerford and Volk 1990); in other words, without relevant knowledge. The challenge is not just to promote dogmatic activism, because adaptation and mitigation require careful consideration of different perspectives and experiences to achieve a local consensus. Critical evidence-based action that is able to take situated nuances into account is also needed. Considering the limited system knowledge of climate science and global warming among the world population (Abasto et al. 2023; Elsharkawy, Elsheikh, and Refaat 2023; García-Vinuesa et al. 2021; Ranney and Clark 2016; Tolppanen et al. 2021), this is a key question to address. According to Frick, Kaiser, and Wilson (2004), system knowledge of climate change is a type of declarative knowledge involving a mechanistic understanding of climatic systems and the drivers and impacts of climate change. It can be differentiated from action knowledge, or knowledge about mitigation actions, and effectiveness knowledge, or knowledge of the effectiveness of mitigation actions.

The question is therefore whether focusing on system knowledge and the understanding of climate science would, in turn, impact climate action. This is important given the focus on knowledge reported in several national curricula (Dawson et al. 2022). Studies on this question have produced mixed results. There is psychological evidence suggesting a correlation between science knowledge and acceptance of global warming among the North American population (Drummond and Fischhoff 2017; Ratinen and Uusiautti 2020). In addition, acceptance of global warming has been shown to correlate with a willingness to make sacrifices for the greater good (Ranney & Clark, 2016). Moreover, there is evidence connecting system knowledge and pro-environmental action among Egyptian adults (Elsharkawy, Elsheikh, and Refaat 2023); system knowledge and climate action among Finnish elementary and secondary students (Ratinen and Uusiautti 2020); and system knowledge and a belief in the efficacy of climate change mitigation among Czech school students (Jurek et al. 2020). There is also evidence showing how delivering brief explanations of global warming promotes acceptance (Ratinen & Clark, 2016), and how interventions based on communicating scientific consensus on climate change have a significant effect on climate change attitudes (Rode et al. 2021).

However, consistent with the work of Kollmuss and Agyeman (2002) on pro-environmental behavior, studies have also failed to find a direct relationship between system knowledge and the willingness to act among Czech secondary students (Kolenatý, Kroufek, and Činčera 2022), Finnish pre-service teachers (Tolppanen et al. 2021), and university students (Tolppanen, Kang, and Riuttanen 2022). Relevant mediators between the two variables have been proposed, including personal variables such as self-efficacy (Geiger, Swim, and Fraser 2017; Hurst Kolenatý, Kroufek, and Činčera 2022; Loo et al. 2023; Loy, Hamann, and Reese 2020) and epistemological variables such as trust in science (Cologna and Siegrist 2020; Drummond and Fischhoff 2017).

Regarding self-efficacy beliefs, defined by Bandura (1977) as 'the conviction that one can successfully execute the behavior required to produce the outcomes' (p. 177), evidence shows

that climate change self-efficacy among German adults predicts exposure to climate-change-related information, climate change system and action knowledge, reported climate-protected behavior, and knowledge about protected behavior (Loy, Hamann, and Reese 2020). However, the opposite relationship between self-efficacy and knowledge has also been reported, with a study of North American adults showing that system-knowledge-based interventions predict climate change self-efficacy beliefs, in turn promoting engagement in climate change discussions (Geiger, Swim, and Fraser 2017).

More than thirty years ago, Hardwig (1991) argued about the importance of trust in knowledge as a building block of scientific research, declaring it to be even more fundamental than data: 'In most disciplines, those who do not trust cannot know; those who do not trust cannot have the best evidence for their beliefs' (pp. 693–94). His arguments apply especially to climate science, where different disciplines, scientific approaches, and methods concur: as science is progressively collegiate, scientists must trust one another to conduct scientific research, counting on their different specializations and disciplines. No one scientist has all of the answers, having to rely on the expertise of colleagues to construct a unified argument. If this is the case with scientists who produce knowledge, the public needs to trust and value scientific knowledge to make their knowledge meaningful and transform it into action. Meta-analytical evidence shows how trust in scientists and environmental groups matters when it comes to climate change behavior (Cologna and Siegrist 2020), but less is known about trust in climate scientific knowledge.

Based on the available literature, in our study we investigate the direct and indirect effects of climate change knowledge, personal engagement with science, and trust in climate change knowledge on the willingness of secondary students to take action. Our aim is to add to the available knowledge in order to inform scientists and the science and environmental education community about aligning science and environmental education with the urgent demands of the climate crisis. We assess knowledge of the causes and effects of climate change through a questionnaire containing different dimensions: anthropogenic and natural factors causing CO_2 variations in different time frames and global warming; the effects of global warming on floating ice and on changes in oceans' absorption of CO_2; the definition of greenhouse gases and effects; and the role of plants in CO_2 absorption. We assess the willingness to mitigate the effects of climate change through exploring the propensity to act individually (recycling, electrical and clothing consumption, a change in dietary habits) and the willingness to take action (changes in lifestyle, learning about and discussing climate change, joining environmental groups, taking political action, local and national participation, joining strikes, and vocational and professional choices). Trust in scientific knowledge was assessed through items addressing the value of scientific knowledge to orient collective and individual climate action. Finally, personal engagement with science was assessed, including the value of science items based on expectancy value theory (Willie et al. 2020), exploring the intrinsic, attainment, and utility value of science and scientific self-efficacy (beliefs about scientific competence).

The direct effects are investigated to advance the evidence regarding the relevance of the different variables for climate action, allowing curricular and pedagogically informed decisions to be taken. Regarding indirect effects, given the inconclusive evidence of the direct effects of knowledge on action, we mainly test one mediational model with two mediators. The first mediation examines the relationship between climate change knowledge and personal engagement with science—and its effects on the willingness to act. The evidence strongly suggests that system knowledge impacts domain-specific self-efficacy (Geiger, Swim, and Fraser 2017), which in turn impacts the willingness to mitigate; we therefore test the mediational role of personal engagement in the relationship between knowledge and the willingness to act. The second mediational path examines how these two variables (knowledge and engagement) predict the willingness to act through trust in science. We investigate these relations in two

independent samples of secondary students attending their last years of schooling, with the second sample used in a confirmatory way.

Materials and methods

This research was approved by the Ethical Committee of Universidad Alberto Hurtado. The code used for this analysis is available from the second author.

Procedure and participants

A total of 386 high-school students (172 female, 5 non-binary) from the 9th to the 12th grade (14–18 years old) at 12 different schools in 4 different regions of Chile. In Chile only 5% of the national curriculum's learning science goals are related to climate change education. In 2019 climate change was incorporated into the curriculum in the context of a new subject ('Science for citizenship'), which is learned by students in the last 2 years of high-school education. Although since 2022 a national law on climate change has promoted informal education in local settings, few educational spaces outside school settings are operating in the country. However, globalized practices of informal education through YouTube and other social media outlets have also been shown to predict climate change awareness in the countries of the region (Gómez-Casillas and Gómez Márquez 2023). All of the students gave their own and their parents' permission to participate in the study. We contacted school principals, who consented to invite students from relevant classes to participate. Schools were recruited through different media: social media advertising; and personal contacts.

The questionnaire, which had different scales, was administered by science teachers in regular science lessons at schools in 2 consecutive pedagogical hours (90 min). Data were administered in 2021 (237 students, 135 female, and 3 non-binary; $M = 16.4$ years of age, $S.D = 1.05$) and 2022 (149 students, 34 female, and 2 non-binary; $M = 16.7$ years of age, $S.D = 0.86$). Analyses are reported separately for each sample. To evaluate the model fit, we selected widely regarded indices following the guidelines of Hooper, Coughlan, and Mullen (2008). These indices ensure a robust evaluation of the proposed model, providing a balanced view of different aspects. A non-significant chi-square at the 0.05 threshold indicates a good fit (Barrett 2007), but chi-square is sensitive to sample size. Therefore, we also used the comparative fit index (CFI), standardized root mean square residual (SRMR), and root mean square error of approximation (RMSEA). A CFI above 0.90 indicates an acceptable fit, while above 0.95 is a good fit (Bentler 1990). For SRMR and RMSEA, values below 0.08 are acceptable, and values under 0.05 indicate a good fit (Hu and Bentler 1999).

Measures

Climate change knowledge

We adapted the climate change knowledge scale developed by Aksit et al. (2018) and validated by Libarkin et al. (2018). The scale was translated, and 13 items were selected. We developed two additional items to better capture common misconceptions about radiative forcing. Sample items are: 'Which of the following is the best definition of a greenhouse gas?'; and 'Which of the following will occur if the amount of ice floating in the ocean decreases?' Six cognitive interviews were held with students, all aged 16, to examine clarity and validate students' interpretations of the items. Confirmatory factor analysis (CFA) with the data of the 2021 sample showed three items with small loadings; as we were exploring items to confirm the one-dimensionality of the scale, these were excluded. CFA showed a good fit. The chi-squared

fit index was non-significant (χ2 (35) = 40.819, $p = 0.239$). Other indexes showed a good and acceptable fit (CFI = 0.98; SRMR = 0.07; RMSEA = 0.03).

Factor loadings were reasonably homogenous, although two item loadings were moderately low. Reliability was estimated using separation reliability as one of the internal consistency estimations, as suggested by Wilson (2005). This considers the reliability of the factor scores of the latent model. We had low reliability coefficients for individual inferences, because the test was difficult for this population, and most of the information was obtained from the higher levels of the latent variable (separation reliability, $r = 0.47$; Alpha = 0.63). Considering these results, two items were changed in order to decrease the level of complexity. The final scale included 10 items (8 of which were the same for the 2 samples). CFA with the data of the 2022 sample showed a good fit. The chi-squared fit index was non-significant (χ2 (35) = 47.217, $p < 0.08$). Other indexes showed a good and acceptable fit, with the exception of SRMR (CFI = 0.96; SRMR = 0.10; RMSEA = 0.05). Factor loadings were homogenous, and we had acceptable reliability coefficients (separation reliability, $r = 0.63$; Alpha = 0.72).

Willingness to act

We adapted one scale developed by Tolppanen, Kang, and Riuttanen (2022). Overall, the scale included Likert-scale-type items (four levels: 1 = not willing, 4 = very willing) and measured the willingness to act in seven areas of life (e.g. reducing long-distance flights and eating a plant-based diet). The scale was translated and adapted, and eight items were included. An additional 12 items from Tolppanen, Kang, and Tirri (2023) were included examining the willingness to act individually and collectively to reduce the carbon footprint and participate in decision-making with a Likert-type scale of 5 levels (1 = not willing, 5 = very willing). Six cognitive interviews were held with students, all aged 16, to examine clarity and validate students' interpretation of the items. Sample items were: 'Even if it would require more planning and may be more inconvenient, would you be willing to do the following for environmental reasons: recycle all household paper, cardboard, metal and glass?'; and 'I want to challenge politicians and businesses to do more to mitigate climate change'.

Confirmatory factor analysis (CFA) with the data of the 2021 sample showed five items with small loadings, which were excluded. The final scale included 15 items, and CFA showed a good fit. The chi-squared fit index was significant (χ2 (90) = 242.124, $p < 0.001$). However, other indexes showed a good and acceptable fit (CFI = 0.98; SRMR = 0.05; RMSEA = 0.08). Factor loadings were reasonably homogenous. We had good reliability coefficients (separation reliability, $r = 0.93$; Alpha = 0.93). The same items were used in the 2022 sample, and CFA with the data of the 2022 sample showed an acceptable fit. The chi-squared fit index was significant (χ2 (90) = 251.638, $p < 0.000$), but other indexes showed an acceptable (CFI = 0.94; SRMR = 0.07) and poor fit (RMSEA = 0.11). Factor loadings were homogenous, and we had good reliability coefficients (separation reliability, $r = 0.92$; Alpha = 0.90).

Trust in climate science knowledge

We used a scale developed by Tolppanen and Kang for what we called trust in climate science knowledge. The scale is based on PISA items on the value of science and outcome expectations. It comprises four Likert-scale-type items, with a Likert-type scale of four levels (1 = completely disagree, 4 = completely agree). The scale was translated and adapted. Six cognitive interviews were held with students, all aged 16, to examine clarity and validate their interpretation of the items. Items were: 'I need scientific knowledge in tackling climate issues'; 'Climate actions should be based on scientific knowledge'; 'Scientific knowledge will help me participate in climate action'; and 'Scientific knowledge I studied at school will help me understand climate issues'.

Confirmatory factor analysis (CFA) with the data of the 2021 sample showed a good fit. The chi-squared fit index was significant (χ2 (2) = 7.602, $p = 0.022$). However, other indexes showed

an excellent (CFI = 0.99; SRMR = 0.01) and poor fit (RMSEA = 0.11). Factor loadings were homogenous, and we had good reliability coefficients (separation reliability, $r = 0.80$; Alpha = 0.84). The same items were used in the 2022 sample; CFA with the data of the 2022 sample showed an acceptable fit. The chi-squared fit index was significant ($\chi 2$ (2) = 14.348, $p < 0.001$). Other indexes showed an excellent fit, with the exception of RMSEA (CFI = 0.98; SRMR = 0.02; RMSEA = 0.21). Factor loadings were homogenous, and we had acceptable reliability coefficients (separation reliability, $r = 0.77$; Alpha = 0.79).

Personal engagement with science

We adapted the scale based on the expectancy value theory of what we called personal engagement using science from Wille et al. (2020), and we confirmed the one-dimensionality of the scale, including 17 Likert-scale-type items, with a Likert-type scale of 4 levels (1 = completely disagree, 4 = completely agree). Four of them were associated with science identity ('Science is important to me personally'), six with scientific self-efficacy ('I am good at science'), and seven with the attitude to science ('I enjoy puzzling over science problems'). The scale was translated and adjusted. Six cognitive interviews were held with students, all aged 16, to examine clarity and validate their interpretation of items. CFA with the data of the 2021 sample showed six items with small loadings, which were excluded. The final scale included 11 items, and CFA showed a good fit. The chi-squared fit index was significant ($\chi 2$ (44) = 191.174, $p < 0.000$). However, other indexes showed a good and poor fit (CFI = 0.98; SRMR = 0.04; RMSEA = 0.12).

Factor loadings were homogenous, and we had good reliability coefficients (separation reliability, $r = 0.92$; Alpha = 0.92). The same items were used in the 2022 sample; CFA with the data of the 2022 sample showed a good fit. The chi-squared fit index was significant ($\chi 2$ (44) = 121.84, $p < 0.001$). Other indexes showed a good (CFI = 0.97; SRMR = 0.04) and poor fit (RMSEA = 0.11). Factor loadings were also homogenous, and we had good reliability coefficients (separation reliability, $r = 93$; Alpha = 0.92).

Analyses

Data were analyzed using Mplus 8.8 (Muthén & Múthen, 1998–2017) and estimated using the WLSMV estimator for ordinal variables given the use of Likert scales (see methods and Stevens 1946, for a discussion about different scales). The descriptive results by gender and grade, and the correlation between latent variables, are presented in supplementary materials Tables 4, 5, and 6, respectively. For the inferential analyses, we tested two models in the 2021 sample using structural equation modeling.

Results

The model (Model 1a, Figure 1) includes climate change knowledge (hereafter 'knowledge') and personal engagement with science (hereafter 'personal engagement') as predictors of trust in climate change knowledge (hereafter "trust") and the willingness to act, and knowledge as a predictor of personal engagement with science. We included two indirect effects of knowledge on the willingness to act: one mediated by personal engagement; and one mediated by trust. Gender, again, was included as a control observed variable. The indirect effects were tested given that previous models showed significant direct effects of both variables on the willingness to mitigate when no other variables were introduced (see Tables 1, 2, and 3 in Supplementary materials). We observed the results (see Figure 1) that all of the direct effects modeled were significant, except for the direct effect of knowledge on the willingness to act. The willingness to act was predicted by personal engagement ($b = 0.19$, $p < 0.001$) and trust ($b = 0.50$, $p < 0.001$),

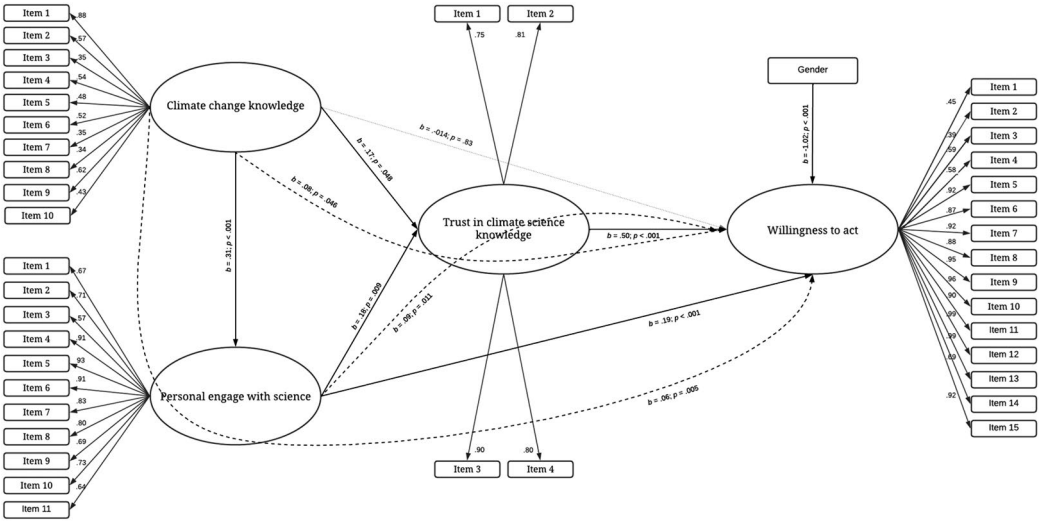

Figure 1. *Model 1a*. Continuous black lines represent significant direct effects. Discontinuous black lines represent significant indirect effects. Continuous grey lines represent non-significant direct effects. CFI =0.96, RMSEA =0.05, SRMR =.09. 90% CI [0.04, 0.051], $p < 0.05 = 0.892$. The sum of the indirect effects of knowledge on the willingness to act: $b = 0.15$, $p = 0.004$.

and trust was predicted by knowledge ($b = 0.17$, $p = 0.048$) and personal engagement ($b = 0.18$, $p = 0.009$). Personal engagement was predicted by knowledge ($b = 0.31$, $p < 0.001$).

The two mediational paths included were significant: knowledge had an indirect effect on the willingness to act through trust ($b = 0.09$, $p < 0.046$) and through personal engagement with science ($b = 06$, $p < 0.005$), as predicted. Personal engagement also had an indirect effect on the willingness to act through trust ($b = 0.09$, $p = 0.011$). The model accounted for 57.8% of the variance in the willingness to mitigate and had a statistically significant chi-squared (χ2 (773) = 1159.583, $p = < 0.001$) but good fit indexes (Hu and Bentler 1999),[1] except for the SRMR (see Figure 1). This value, while higher than the conventional threshold, suggests a discrepancy between the observed and the predicted covariance, but this might be due to the complexity of the model or the nature of the data. Our model, however, demonstrates a robust fit across other indices, with a CFI and an RMSEA indicating a good overall fit (Bentler 1990; Hu and Bentler 1999). Furthermore, the use of a two-index strategy, as recommended by Hu and Bentler (1999), supports our model's adequacy. The good fit indicated by CFI and RMSEA, coupled with the theoretical justification, reinforces that the model, despite its high SRMR, remains a robust and meaningful representation of the underlying constructs.

Given that the evidence suggests that climate change self-efficacy could affect climate change knowledge (Loy et al. 2022) we cannot discard the path through which personal engagement with science, as a more general variable, predicts topic knowledge, and ultimately climate action. Therefore, we tested the same model with the inverse path, including personal engagement as a predictor of knowledge (considering that knowledge was specific to climate change but personal engagement was generally referred to as 'science'). Personal engagement predicted knowledge ($b = 0.32$, $p < 0.001$), accounting for only 10.2% of the variance, but the indirect effect on the willingness to act through knowledge was non-significant.

We tested Model 1 in the 2022 sample (Figure 2, Model 1b) as confirmatory analysis. The model behaved exactly like Model 1a, confirming the non-existence of the direct effect of knowledge on the willingness to act ($b = -0.04$, $p = 0.727$). However, while knowledge predicted the willingness to act mediated by personal engagement ($b = 0.08$, $p = 0.010$), the effect was mediated by trust ($b = 0.23$, $p < 0.001$). The willingness to act was also directly predicted by trust ($b = 0.44$, $p < 0.001$) and personal engagement ($b = 0.25$, $p < 0.001$), which in turn was directly

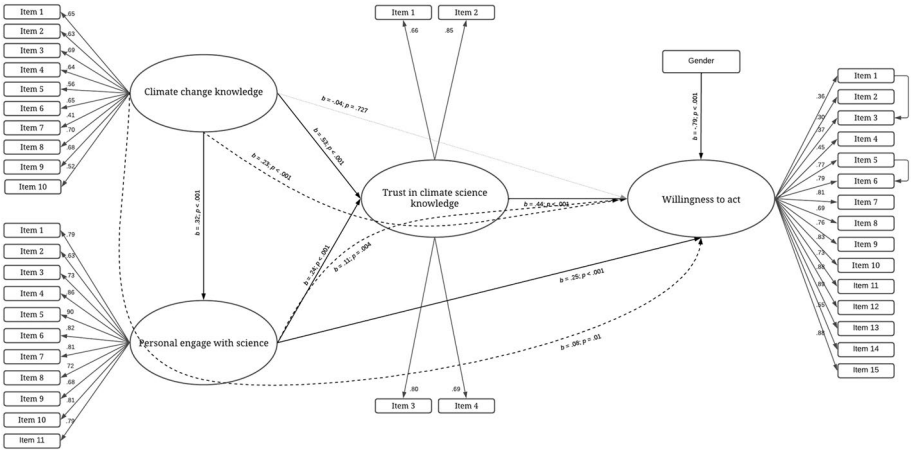

Figure 2. *Model 1b*. Continuous black lines represent significant direct effects. Discontinuous black lines represent significant indirect effects. CFI =0.95, RMSEA =0.04, SRMR =.10. The sum of the indirect effects of knowledge on the willingness to act: $b = 0.31$, $p < .001$. 90% CI [0.037, 0.053].

predicted by knowledge ($b = 0.32$, $p < 0.001$). The direct and indirect effects on the willingness to act explained 44% of the variance. The model had a statistically significant chi-squared ($\chi 2$ (771) = 1002.984, $p = < 0.001$) but good fit indexes, with the exception of the SRMR (CFI = 0.95, RMSEA = 0.04, SRMR = 0.10).

Discussion

The role of science and environmental education in promoting climate action should be debated as a matter of urgency. Prior research has been inconclusive about the role of system knowledge in the causes and effects of climate change. Some studies have revealed associations with acceptance and the willingness to act (Ranney and Clark 2016) and engage (Rode et al. 2021), while others have failed to find direct associations (Kolenatý, Kroufek, and Činčera 2022; Tolppanen et al. 2021; Tolppanen, Kang, and Riuttanen 2022). Considering that research has often focused on knowledge in some national curricula (Dawson et al. 2022), this knowledge gap needs to be addressed. We examined the relationship between climate change system knowledge and the willingness to act, exploring both direct and mediated relations going beyond bilateral associations but testing whole models.

We found that the effect of system knowledge on the willingness to act is not direct but mediated by other variables, in line with prior research (Kolenatý, Kroufek, and Činčera 2022; Tolppanen et al. 2021). This suggests that promoting system knowledge is not sufficient when it comes to educating concerned young citizens and collectives willing to participate and adapt their behavior to ensure a sustainable future. However, this does not mean that knowledge about the causes and effects of climate change is not important: while in our samples it does not directly account for the willingness to act, it clearly contributes to it when other factors are considered. Therefore, this study re-evaluates the idea that system knowledge contributes little to pro-environmental behavior (Kempton et al. 1995): the fact that it does not have a direct effect does not mean its contribution is negligible. If indirect effects are not tested, we can be led to partial conclusions.

Our models consider two additional factors: trust in climate science knowledge; and personal engagement with science. Both factors directly predict the willingness to act. They also interact with each other and with the knowledge needed to account for it. This means that climate action is dependent on not only information but also experience of science and climate science

more generally. The latent variable of personal engagement with science includes aspects of the value of science (Vincent-Ruz and Schunn 2018) and beliefs about competence. We tested the one-dimensionality of the variable, with our data showing good results. As such, personal engagement with science depends on past experiences with science in formal and informal settings, and experiences of failure or success, as assessed by concrete achievements and interpreting relevant others. It is worth noting that not only is this general variable associated with climate science system knowledge—being predicted by it—it also mediates the effect of climate change knowledge on the willingness to act. This shows the relevance of life-long science education, and the citizen experience of science in broader social activities, on climate action. It also demonstrates that knowing about the causes and effects of climate change can influence this general variable and, through it, climate action, having personal and cognitive impacts. The crucial point is that it is possible that personal engagement is not only, or mostly, relevant because of its effects on system knowledge—–as suggested by Loy, Hamann, and Reese (2020)—because the indirect effect of personal engagement on the willingness to act was non-significant. The sense of engagement and competence in science also seems to be important for climate action. This requires further causal exploration.

Although prior research has studied the effect of trust in scientists, institutions, groups, and others (Cologna and Siegrist 2020), and the mechanisms that undermine trust in climate science (Oreskes and Conway 2010), the effect of trust in climate science on the willingness to mitigate the effects of climate change has been somewhat neglected. This variable emphasizes the relevance of the value and perception of climate science and climate scientists, and the relevance of the understanding of their epistemic practices and standards. Our results are unique in showing how trust in climate change knowledge is a key mediator of the effect of both climate change knowledge and personal engagement with science on the willingness to act among secondary students. Both variables help to account for the variance of trust in climate change knowledge. On the one hand, understanding the causes and effects of climate change might promote trust in, and value of, climate science knowledge, making promotion of the former an unreplaceable educational goal with both cognitive and affective outcomes that are crucial to social cohesion. On the other hand, the personal appropriation of science, and self-confidence therein, might also contribute to valuing and trusting climate science knowledge, resulting in our key study for climate action.

Unlike many previous studies on the relevant variables predicting the willingness to take climate action among adults (Elsharkawy, Elsheikh, and Refaat 2023; Hurst Loo and Walker 2023; Loy, Hamann, and Reese 2020; Ranney and Clark 2016; Rode et al. 2021; Tolppanen et al. 2021), our study focused on high-school students, contributing to the literature on the formative years (García-Vinuesa et al. 2021; Jurek et al. 2022; Kolenatý, Kroufek, and Činčera 2022; Lehnert et al. 2020; Trott and Weinberg 2020), with a comprehensive model including different variables (affective and axiological, epistemological and epistemic, and behavioral) that had not been reported among school students. Moreover, we tested the model in two independent samples, which we consider a sign of robustness of the results. However, the results are not directly generalizable to the broader adult population, which needs to be urgently addressed. In addition to this limitation, although the instruments and model are strong, the sample is limited to a group of students from one country. Considering the cultural and normative factors affecting the relation between the studied variables, this is an important condition and limitation regarding the generalizability of the conclusions. Finally, it is important to note that, in order to state causal mediational effects, longitudinal studies should be conducted.

It is worth noting that our study focused on system knowledge, but action knowledge is also said to play a relevant role in pro-environmental behavior and, hence, in the willingness to mitigate (Hungerford and Volk 1990). Moreover, studies have shown how action knowledge has a greater effect on pro-environmental behavior, even with the lack of system knowledge (Smith-Sebasto & Fortner, 1994). A lack of this type of knowledge among students has also

been reported (see Bofferding & Kloser, 2015). The next step is to include action knowledge in the model to appreciate how each type of knowledge contributes to the willingness to mitigate, with other variables considered.

In conclusion, the results show there is no direct effect of climate change system knowledge on the willingness to act. We found indirect effects of system knowledge on the willingness to act, mediated by personal engagement with science and trust in climate science knowledge. The results also demonstrate a direct effect of personal engagement with science, and an indirect effect mediated by trust in science. The implications for science education are discussed.

Overall, our results suggest that science education is very relevant and can contribute to climate action. However, instead of the focus being directly on knowledge or action, it should be on offering an articulated experience of science education in the formative years: (1) enabling students to engage with science; (2) creating confidence in understanding scientific consensus; (3) including experiences that facilitate understanding of a key consensus on climate science; (4) how this was achieved; (4) and trusting students to take climate action. We are not arguing that climate change education should be reduced to these factors. Scientific practices such as arguing and deliberating, inquiring and imagining, among others, are key for the collective life and should be central to science education. However, these practices were not the focus of this study.

Note

1. According to), a CFI value above .90 indicates acceptable fit, and a value above .95 suggests a good fit. An RMSE and SRMR value equal to or lower than 0.05 is considered good, and it is acceptable if it is below .80.

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ORCID

Paulina Freire http://orcid.org/0000-0002-7590-2231
Hernán Cofré http://orcid.org/0000-0003-2789-334X
Ana Andaur http://orcid.org/0009-0003-7625-6256
Sakari Tolppanen http://orcid.org/0000-0001-8419-9763
Jingoo Kang http://orcid.org/0000-0002-7391-3113
Claudia Vergara http://orcid.org/0000-0003-3323-1457
María Teresa Rojas http://orcid.org/0000-0001-9195-2688
Andoni Arenas http://orcid.org/0000-0002-1167-396X
Antonia Larrain http://orcid.org/0000-0002-1968-4516

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