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From Alarmed to Disengaged: Profiles of Climate-Related Psychosocial Orientations and Climate Literacy Among Adolescents

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Abstract

Climate change education (CCE) addresses a conceptually complex, emotionally charged, and politically contested issue. To design effective instruction, it is important to understand the prerequisites with which students engage in climate-related learning. These prerequisites extend beyond prior knowledge to include climate-related psychosocial orientations. However, previous profiling studies have typically considered only a limited set of such orientations and have rarely examined their relation to cognitive climate literacy as a central educational outcome. This study examined whether meaningful profiles of adolescents' climate-related psychosocial orientations can be identified and how these profiles differ in cognitive climate literacy, climate-related behavior, and policy support. Questionnaire and test data from 632 ninth-grade students in Baden-Württemberg, Germany were analyzed using latent profile analysis. Indicators included climate change beliefs, worry, personal and external responsibility attributions, individual and collective efficacy beliefs, and trust in society and politics. Five profiles were identified: Alarmed (11%), Pragmatic (25%), Distanced (29%), Ambivalent (21%), and Disengaged (14%). The profiles differed systematically not only in their psychosocial orientations but also in all outcome measures. The findings reveal substantial heterogeneity in adolescents' climate-learning prerequisites. They suggest that CCE may benefit from adaptive, profile-sensitive approaches that address not only cognitive starting points but also varying constellations in students' appraisals of the climate problem, their agency, and their trust in others to contribute to climate action.

Keywords: adolescents; climate change attitudes; climate change behavior; climate change education; climate literacy; education for sustainable development; heterogeneity; latent profile analysis



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1. Introduction

Public negotiations over how to respond to the climate crisis are especially in western industrialized countries marked by substantial disagreements ([Hornsey et al., 2025](#); [McCright et al., 2016](#)), which extend into the everyday lives of young people ([Andersen, 2024](#)). Against this backdrop, climate change education (CCE) is inherently political and normatively charged. Young people enter classrooms with diverse beliefs, emotions, values, and prior experiences ([Ray, 2020](#)). Therefore, CCE cannot be reduced to the transmission of

scientific knowledge; it must acknowledge these individual starting points in order to empower students to participate in societal decision-making about climate futures (Karsgaard & Davidson, 2023).

In educational research, CCE is commonly associated with the goal of promoting climate literacy, that is enabling learners to engage in informed ways with climate-related issues (Leve et al., 2023; Mochizuki & Bryan, 2015). Climate literacy includes knowledge about the climate system, the causes and consequences of climate change, and options for mitigation and adaptation (USGCRP, 2024). Beyond content knowledge, climate literacy includes an understanding of how knowledge claims in climate science are generated and warranted, as well as the ability to locate, critically evaluate, and communicate climate-related information, and to reflect on normative questions and conflicts relating to climate change (Azevedo & Marques, 2017). The overarching educational aim is to enable young people to develop well-informed positions and to participate responsibly in individual, collective, and political responses to climate change (González-Gaudiano & Meira-Cardia, 2019; Kranz et al., 2022; OECD, 2025).

Societal transformation towards sustainability is also shaped by affective- motivational orientations, values, and behavioral intentions, as widely discussed in the environmental education literature (e.g., Krasny, 2020). Accordingly, many climate literacy frameworks incorporate socio-emotional and action-oriented dimensions (e.g., MECCE & NAAEE, 2022). However, prescribing values (e.g., sufficiency), attitudes (e.g., climate concern), or behaviors (e.g., sustainable consumption) as educational outcomes raises normative and pedagogical questions (Barth & Michelsen, 2013; Shephard, 2016; Wiek et al., 2011). For instance: Can schools promote climate activism without risking indoctrination? Since these questions have not yet been sufficiently addressed, the present study focuses on the cognitive dimensions of climate literacy as learning objectives. Action-related outcomes are instead understood as indicators of how young people engage with climate change beyond the classroom.

Although fostering climate literacy is widely endorsed as an educational goal (Westphal et al., 2025), there is still limited systematic evidence on which instructional approaches are effective for which learners and under which conditions (Aeschbach et al., 2025; Anderson, 2012; Bhattacharya et al., 2021). This gap is particularly consequential because of the topic's interdisciplinary nature and high complexity (Jorgenson et al., 2019; Stevenson et al., 2017). Understanding climate change requires systems thinking (Bhattacharya et al., 2021; García-Vinuesa et al., 2024) and dealing with substantial ambiguities and uncertainties, for instance regarding scientific projections, societal risks, and possible policy pathways (Eggert et al., 2017; IPCC, 2023).

Yet, knowledge and competencies do not automatically lead to involvement in climate issues (e.g., information seeking, reflection, or activism; DeWaters & Powers, 2011; Kollmuss & Agyeman, 2002). Research suggests that the ways in which individuals attend to, interpret, and use information about climate change is also shaped by psychosocial orientations, including beliefs (Hornsey et al., 2016), emotions (Chapman & Peters, 2024), responsibility attributions (Bolsen et al., 2014; Kalch et al., 2021), efficacy expectations (Busch et al., 2019; Morton et al., 2011), and trust in societal and political actors (Diehl et al., 2021; Sarathchandra & Haltinner, 2023). These orientations may therefore represent important learner characteristics to be considered when designing CCE. The present study adopts a person-centered latent profile approach to identify distinct profiles of students' climate-related psychosocial orientations and to examine how these profiles predict climate literacy as well as climate-related behavior and policy support.

1.1. Climate-Related Psychosocial Orientations as Learner Characteristics Relevant to Climate Literacy

Building on the preceding discussion, we conceptualize climate literacy primarily as a cognitive educational outcome. It comprises students' knowledge about climate change and their ability to understand, critically evaluate, communicate, and reflect on climate-related information, evidence, and issues (Martin et al., 2025). Such cognitive resources provide an important, albeit not sufficient, foundation for developing informed positions and participating in societal responses to climate change (OECD, 2025).

Climate-related psychosocial orientations, by contrast, refer to subjective appraisals of the personal and societal significance of climate change and possible responses to it. They do not concern students' ability to assess the accuracy or quality of climate-related evidence, but rather how students make sense of the issue, including its implications for responsibility, perceive possibilities for agency, and evaluate the context in which climate-related action takes place. The distinction is analytical: Climate literacy and psychosocial orientations may influence one another (e.g., Bedford, 2016; Boucher et al., 2026), but they capture different aspects of adolescents' engagement with climate change.

We regard climate-related psychosocial orientations as learner characteristics that may shape students' engagement with climate-related learning opportunities and, consequently, the development of cognitive climate literacy. Self-determination theory (SDT; Ryan & Deci, 2000) provides a framework for this assumption by proposing that engagement is more likely when the basic psychological needs for autonomy, competence, and relatedness are satisfied. In CCE, these needs are not fulfilled by climate-related content per se, but through the interaction between students' individual orientations and the learning environment. For example, students may differ in the extent to which they experience climate-related tasks as personally meaningful, manageable, and embedded in a supportive environment, thereby influencing the likelihood of intrinsic motivation and, ultimately, cognitive learning outcomes.

Control-value theory of achievement emotions (Pekrun, 2006) specifies one possible mechanism through which these processes may affect learning. According to the theory, students' appraisals of control and value shape achievement-related emotions, which in turn influence motivation, attention, learning strategies, and achievement. Applied to CCE, students' pre-existing appraisals of climate change, possible responses, and the wider social context may affect whether climate-related learning is perceived as valuable and manageable. These appraisals may thereby shape learning-related emotions and students' willingness to attend to, elaborate on, and persist in climate-related tasks. This relationship is likely reciprocal: learning experiences and gains in climate literacy may also influence psychosocial orientations.

We operationalize climate-related psychosocial orientations through three domains: problem appraisals, agency appraisals, and social-context appraisals. These domains capture how adolescents perceive climate change, possibilities for responding to it, and the social and institutional context of climate-related action.

Problem appraisals encompass adolescents' perceptions of the reality, causes, consequences, and emotional significance, and responsibility implications of climate change. In this study, they are represented by climate change beliefs, climate change worry, and personal and external responsibility attributions. Climate change beliefs refer to subjective assumptions, which may or may not accurately reflect reality and can be differentiated into beliefs about the reality of climate change, its predominantly anthropogenic causes, and its consequences (Milfont et al., 2015; Poortinga et al., 2019). Climate change worry denotes a future-oriented, emotionally charged concern about potential threats to oneself, close others, societies, non-human nature, or future generations (Wullenkord & Ojala, 2023).

Unlike risk perception, which primarily relates to likelihood and severity, worry captures a more personally experienced emotional response (Bouman et al., 2020). Responsibility attributions refer to adolescents' perceptions of who should assume responsibility for addressing climate change. Following Boerschig and de Young (1993), personal responsibility reflects an individual's sense of obligation to contribute to climate change mitigation, whereas external responsibility involves attributing such duties to other actors, such as politicians, managers, or—in case of adolescents—adults.

Agency appraisals capture adolescents' perceived capacity to contribute to climate change mitigation and their expectations regarding the effectiveness of individual and collective action. They include individual response efficacy, collective outcome expectancy, and self-efficacy expectations. Individual response efficacy refers to the extent to which one's own actions are expected to contribute to mitigation; collective outcome expectancy describes the anticipated effectiveness of coordinated action by many people; and self-efficacy refers to the extent to which individuals believe they can successfully perform certain relevant actions themselves (Bandura, 1997; Hamann et al., 2023).

Social-context appraisals address adolescents' expectations of whether societal and political actors will respond adequately to climate change. They are represented by trust in society and trust in politics—that is, positive expectations that other people will contribute to mitigation and that political actors will take adequate action (Cologna & Siegrist, 2020; Kitt et al., 2021; Smith & Mayer, 2018).

The selection is not intended to be exhaustive. Rather, it captures psychosocial orientations that may shape students' emotional and motivational engagement with climate-related learning and, consequently, their opportunities to develop cognitive climate literacy.

Beyond their educational relevance, climate-related psychosocial orientations may also be relevant to the mobilization of climate literacy in individual and collective forms of societal participation. The Theory of Planned Behavior (TPB) links behavior to intentions, shaped by attitudes, subjective norms, and perceived behavioral control (Ajzen, 1991). The Value-Belief-Norm Theory (VBN) emphasizes values and environmental worldviews as antecedents of awareness of consequences, ascribed responsibility, personal norms, and pro-environmental behavior (Stern, 2000). Together, these frameworks suggest that climate-related action depends not on factual knowledge alone, but also on psychosocial appraisals of the problem and possibilities for action.

Existing research is broadly consistent with this assumption. Perceived personal responsibility has been associated with climate-related behavior and policy support (Bouman et al., 2020; Syropoulos & Markowitz, 2022), whereas the implications of external responsibility depend on whether this attribution is understood as appropriate delegation or institutional failure (Bolsen et al., 2014; Buchanan & Russo, 2015). Efficacy beliefs—including individual response efficacy, self-efficacy, and collective outcome expectancy—have also been linked to climate-related behavior and policy support (Bolsen et al., 2014; Bostrom et al., 2019; Busch et al., 2019; Hohenhaus et al., 2023; Thaker et al., 2019; Tobler et al., 2012). Trust in societal and political actors has likewise been associated with support for climate policies and collective climate action (Cologna & Siegrist, 2020; Davidovic & Haring, 2020; Kitt et al., 2021; Thaker et al., 2019).

These indicators should not be understood as a single, uniformly positive or negative orientation toward climate change. Rather, they may occur in various combinations within individuals. For example, adolescents may perceive climate change as real, serious, and emotionally concerning while simultaneously doubting their own ability to contribute to mitigation (Thomas et al., 2022) or distrusting the willingness of societal and political actors to respond adequately (Smith & Mayer, 2018). Research also indicates that relationships between climate-related orientations, knowledge, and action are not necessarily linear.

Climate change beliefs and worry were found to be associated with higher levels of climate-related knowledge (Bergquist et al., 2022; Hornsey et al., 2016; Pennycook et al., 2023; Ranney & Clark, 2016) and engagement (Bostrom et al., 2019; Prendergast et al., 2021; Sibley & Kurz, 2013). However, among youth, greater certainty that climate change is real has also been associated with lower individual pro-environmental behavior (Busch et al., 2019). Similarly, moderate levels of climate anxiety may motivate information seeking, whereas higher levels may foster avoidance; behavioral intentions may be strongest at moderate rather than very low or very high levels of anxiety (Chapman & Peters, 2024).

These findings suggest that climate-related orientations cannot be adequately understood by considering single indicators in isolation. Instead, their implications for cognitive and action-related outcomes may depend on how different appraisals co-occur within individuals. A person-centered perspective is therefore well suited to examine configurations of climate-related orientations among adolescents. Rather than focusing on associations between isolated variables, it identifies groups of students with similar psychosocial profiles. This makes it possible to examine how such profiles are associated with cognitive climate literacy and action-oriented forms of societal participation.

1.2. Previous Typology Approaches

Person-centered approaches have been utilized to identify distinct groups of people who differ systematically in their climate-related beliefs, affective responses, and action tendencies. In previous studies, authors have used different labels such as “segments”, “groups”, or “profiles” to describe the resulting typologies. In the following, we use the umbrella term “profiles” while retaining the original labels when referring to specific studies.

The “Global Warming’s Six Americas” framework (Leiserowitz et al., 2009) is a notable example of the person-centered approach in climate communication research, distinguishing between six distinct adult segments ranging from the highly engaged “Alarmed” to the actively opposed “Dismissive”. These segments differ not only in their climate change beliefs and perceived risks but also in their policy preferences and self-reported behaviors (Leiserowitz et al., 2009). Subsequent studies have demonstrated that such segments exhibit varied responses to message framing and communication strategies (e.g., Myers et al., 2012), emphasizing the practical relevance of identifying distinct climate-related profiles. However, this body of work has paid limited attention to cognitive dimensions such as climate-related knowledge or competencies.

A smaller number of studies have begun to apply person-centered approaches specifically to adolescents and to derive implications for CCE. Gossen et al. (2018), for instance, conducted a German youth study in which they clustered adolescents according to their value orientations, environmental concerns, climate-relevant consumption patterns, and beliefs about efficacy and politics. The researchers identified three distinct segments that differed not only in their attitudes and behaviors related to climate change, but also in their political views and perceived efficacy. The first segment, designated as the “Idealistic”, demonstrated elevated levels of climate awareness and a critical stance towards politics. The “Distanced” segment also expressed disapproval of politics and furthermore, reported feelings of social marginalization and a low sense of individual efficacy regarding climate change. The third segment, the “Pragmatic”, acknowledged climate change as a problem but placed greater trust in technological and economic solutions and therefore attributed less responsibility to themselves. Veijonaho et al. (2024) identified four profiles based on climate-related distress and denial, demonstrating that distress and denial can co-occur, and that membership in these profiles is relatively unstable over time.

Kuthe et al. (2019) discovered four groups of adolescents based on their level of awareness regarding climate change, distinguishing between cognitive, affective, and volitional

components. Their description of the “Paralyzed”, who combine high concern with low behavioral engagement, provides additional evidence for the complex interrelationships between affective-motivational facets and behavioral intentions. By including a cognitive component in their profiling approach, they go one step further and reveal a counterintuitive relationship between knowledge and engagement in their results: The group with the highest level of engagement, designated “Concerned Activists”, demonstrated only average knowledge about climate change, whereas the group with the most knowledge, termed “Charitables”, exhibited relatively low concern despite their superior understanding of the causes and consequences of climate change. However, the knowledge component in this study is measured only in a rudimentary way and treated as one additional profile indicator among others.

1.3. The Present Study

When considered as a whole, this collection of studies indicates that person-centered methods may offer valuable insights into the heterogeneity of climate-related orientations. Nevertheless, several gaps persist from the perspective of CCE. First, previous typology studies each focus on a relatively limited subset of psychosocial factors, thereby providing only a partial picture of the diverse climate-related psychosocial orientations exhibited by young people. Second, most existing profiling studies do not include cognitive dimensions such as climate-related knowledge or competencies at all, and the few studies that do consider knowledge typically capture it only in a rudimentary way and use it as one additional profile indicator. However, in CCE, knowledge and competencies are central cognitive outcomes. Thus, we lack an integrated perspective that relates broad profiles of psychosocial orientations to cognitive climate literacy. At the same time, most previous typology studies have related identified profiles primarily to behavioral engagement or policy-related orientations. Examining climate change behavior and policy support in the present study therefore permits comparison with this earlier work. Given these considerations, the present study poses the following research questions (RQs):

1. Which latent profiles of adolescents can be identified based on a comprehensive set of climate-related psychosocial orientations?
2. How do the identified latent profiles differ with respect to cognitive climate literacy, climate change behavior and support for climate policies?

Against the backdrop of these research questions, the following hypotheses (Hs) are derived from the existing typology studies: First, building on the consistent findings across adult and adolescent typologies, we expect the existence of at least one profile that is more convinced of and more worried about climate change than others (H1a). In accordance with the findings of Gossen et al. (2018), we further expect this highly concerned profile to hold comparatively critical views of politics (H1b). Second, we assume to find additional profiles that, similar to those identified in previous adolescent studies, are characterized by lower levels of climate change worry but divergent constellations of climate-related beliefs, responsibility attributions, and trust in society and politics (H2). Third, consistent with the findings of Kuthe et al. (2019) and Veijonaho et al. (2024), we expect a comparatively small profile in which elevated climate-related worry co-occurs with rejecting or denialist beliefs, indicating a state of ambivalence in climate-related orientations (H3).

With respect to the associations between the identified profiles and cognitive climate literacy, prior findings are mixed: While Kuthe et al. (2019) found that the most engaged group did not exhibit the highest levels of factual knowledge, Bedford (2016) reported in his study with undergraduate students that the most engaged segments scored highest on climate knowledge. Moreover, his results point to a small denialist segment that showed at

least average levels of knowledge despite rejecting climate change, further underscoring the complexity of these relationships.

To address the research questions and test the hypotheses, latent profile analysis (LPA) is used to derive distinct profiles of adolescents based on a broad set of psychosocial indicators. LPA is a person-centered mixture modeling approach that groups individuals into unobserved subgroups with similar response patterns across observed variables (Pastor et al., 2007; Vermunt & Magidson, 2009). Examining cognitive climate literacy, climate change behavior, and policy support serves two related purposes in the present study. First, cognitive climate literacy represents the central educational outcome, whereas climate change behavior and policy support indicate action-oriented forms of societal participation. Second, because they are not used to derive the latent profiles, differences between profiles on these outcomes provide an opportunity to examine whether the identified typology is meaningfully related to further central climate-related characteristics of adolescents.

1.4. Theoretical Contribution and Originality

This study contributes to CCE research by conceptualizing climate-related psychosocial orientations as heterogeneous learner characteristics that may shape how adolescents engage with climate-related learning opportunities. Existing research has predominantly examined single psychosocial variables and their associations with pro-environmental engagement. A person-centered perspective complements this work by examining how multiple orientations co-occur within individuals. Identifying recurring profiles can make this complexity more tangible and offers a potentially useful basis for understanding heterogeneous learner prerequisites in CCE. In this sense, the approach follows the broader idea of “knowing one’s audience”: rather than assuming that all students respond similarly to climate-related learning opportunities, it distinguishes groups with different psychosocial constellations that may require different forms of educational support.

The study makes two main contributions. First, it extends previous typology research by considering a comparatively broad set of climate-related psychosocial orientations among adolescents. Second, it relates the resulting profiles to cognitive climate literacy as a central educational outcome, rather than treating knowledge as merely one additional profiling indicator. This provides an integrated perspective on how psychosocial learner characteristics are associated with adolescents’ cognitive engagement with climate change. The psychosocial orientations under consideration have been studied within a long tradition of environmental psychology, primarily with regard to the extent to which they are linked to climate-related environmental behavior. Their relationship to cognitive climate literacy has received little empirical attention to date. Against this background, examining differences in cognitive climate literacy across distinct psychosocial profiles addresses an understudied aspect of CCE research.

Finally, the study lays groundwork for research on adaptive CCE. Whereas adaptive teaching has primarily focused on cognitive prerequisites such as prior knowledge or misconceptions (Corno, 2008; Hardy et al., 2019; Hardy et al., 2022; S. A. Parsons et al., 2018), climate-related psychosocial orientations may be particularly relevant in this emotionally and politically charged domain (Bhattacharya et al., 2021). By identifying meaningful learner subgroups with distinct psychosocial configurations, the profiles may provide a basis for differentiated and adaptive CCE. They may therefore inform future research on whether, for whom, and under which conditions different instructional approaches and targeted educational interventions are effective.

2. Materials and Methods

2.1. Sample and Data Collection

We collected data from $N = 825$ students attending the 9th grade at 17 secondary schools in Baden-Württemberg, Germany. Data collection took place at the end of the 2022/2023 school year. In Germany, secondary education is generally divided into three types of secondary school tracks—academic or high track, intermediate track, low track—that typically differ in their demographic profiles. Over half of the students in the sample attended academic-track schools, which means that this group of students tends to be overrepresented in the sample. The average age of the students was 15.60 years ($SD = 0.98$). The gender distribution was approximately balanced (46.9% female). The proportion of students who do not primarily speak German at home is markedly lower in the upper track subsample; this reflects the observable pattern that academic-track schools in Germany generally have fewer students with a migration background than lower-track schools, so the distribution does not constitute a methodological bias but rather mirrors the actual composition of the German school system. Table 1 provides an overview of the sample characteristics.

Table 1. Overview of the student sample divided by school track.

	Academic Track	Intermediate Track	Low Track	Full Sample
<i>N</i> students	487	235	103	825
Age mean (<i>SD</i>)	15.51 (0.81)	15.76 (1.18)	15.90 (1.16)	15.63 (0.98)
Gender				
Female	257	82	48	387
Male	195	115	47	357
Other	20	19	5	44
Not indicated	15	19	3	37
Main language spoken at home				
German	413	155	66	634
Other	59	60	35	154
Not indicated	15	20	2	37

Both students and their parents were informed of the study's objectives, and parents were required to complete a consent form. Participation in the survey was exclusively permitted for students who provided written parental consent. The participants did not receive any form of compensation. However, to engage the schools, they received individualized feedback reports based on the data of their students. The data collection was formally approved by the responsible Ministry of Education and Cultural Affairs of the federal state in which the study was conducted. The administration of the questionnaire occurred at the schools.

After removing $n = 84$ cases that had over 50% of missing answers and excluding students who showed indications of too low willingness, data from $N = 711$ students (354 female, 301 male, 33 diverse) were available.

2.2. Measures

In the following, we first describe the climate-related psychosocial variables used as profile indicators and then the measures of climate literacy outcomes; an overview of all constructs and example items is provided in Table 2.

Table 2. Overview of constructs, example items, and reliability of the scales.

Construct	Items	Example	Response Format	Reliability	Adapted from
Profile indicators					
Climate change beliefs	5	In your opinion, how positive or negative do you think the effects of climate change will be on people around the world?	4- to 7-point rating scale	0.70 ^a	Poortinga et al. (2018)
Climate change worry	4	How worried are you about climate change?	5-point rating scale	0.74 ^a	Poortinga et al. (2018)
Personal responsibility	2	To what extent do you feel personally responsible for taking action against climate change?	7-point rating scale	0.80 ^b	Poortinga et al. (2018)
External responsibility	3	To what extent are politicians responsible for taking action against climate change?	7-point rating scale	0.81 ^a	
Individual response efficacy	3	What impact would it have on climate change if you reduced your energy consumption (e.g., electricity, heating, hot water) by 20 percent?	5-point rating scale	0.84 ^a	Bostrom et al. (2019)
Collective outcome expectancy	1	Now imagine if a large number of people were to reduce their energy consumption. How likely is it that this would help mitigate climate change?	7-point rating scale		Poortinga et al. (2018)
Self-efficacy	4	How easy or difficult would it be for you to reduce your energy consumption (e.g., electricity, heating, hot water) by 20 percent?	7-point rating scale	0.50 ^a	Bostrom et al. (2019)
Trust in society	1	How likely do you think it is that a large number of people will actually reduce their energy consumption to combat climate change?	7-point rating scale		Poortinga et al. (2018)
Trust in politics	1	And how likely do you think it is that governments in many countries will take measures to curb climate change?	7-point rating scale		Poortinga et al. (2018)
Distal outcomes					
Cognitive climate competencies	155	Which fuel produces the least amount of CO ₂ ?	multiple/single choice, open-ended text responses	0.90 ^c	Martin et al. (2025)
Climate change behavior	40	For shorter trips (10 to 15 min), I walk or ride my bike.	5-point and dichotomous rating scales	0.82 ^c	Kaiser et al. (2007)
Policy support	3	To what extent are you in favor of or opposed to raising taxes on fossil fuels such as oil, gas, and coal?	5-point rating scale	0.62 ^a	Poortinga et al. (2018)

^a Cronbach's alpha; ^b Spearman–Brown; ^c EAP-Reliability.

2.2.1. Profile Indicators

We measured nine distinct constructs as profile indicators. Item selection was guided by existing survey instruments and prior empirical studies. In particular, several items were adapted from the European Social Survey (ESS) Round 8 (Poortinga et al., 2018),

which assessed public climate change attitudes across 23 countries and has been used successfully in secondary analyses addressing a range of climate-related questions (e.g., Bouman et al., 2020; Davidovic & Harring, 2020; Syropoulos & Markowitz, 2022). Items were linguistically adapted to enhance their comprehensibility and age-appropriateness for adolescents. Where existing measures did not sufficiently capture the intended construct, additional items were developed. Prior to the main study, adapted and newly developed items were piloted and examined regarding response patterns, distributions, internal consistency where applicable, and correlations with related and theoretically distinct measures. Given the broad range of climate-related psychosocial orientations included in the present study, measurement had to be parsimonious. Data collection took place during regular school lessons and was embedded in a broader assessment of climate literacy, which included a comprehensive competence test. To limit participant burden and fit the available assessment time, some constructs were therefore assessed using single items. These items were selected to capture relatively specific and concrete appraisals; nevertheless, they should be understood as proxies of the respective constructs rather than as comprehensive measures. All items of the profile indicators were answered on Likert-type rating scales.

Climate change beliefs: Climate change beliefs were assessed with five items capturing beliefs about the reality, causes, and consequences of climate change. Three items were adapted from Poortinga et al. (2018), and two additional items were developed to tap beliefs about consequences of climate change in different regions of the world.

Climate change worry: Climate change worry was measured with four items. One item assessed general worry about climate change (Poortinga et al., 2018), and three newly developed items captured worry about specific future consequences (extreme weather, shortages of food supply, biodiversity loss), drawing on previous conceptualizations of climate-related worry (e.g., Bouman et al., 2020; Wullenkord & Ojala, 2023).

Personal responsibility: Two items measured personal responsibility for mitigating climate change, capturing adolescents' perceived obligation to reduce climate change (adapted from Poortinga et al., 2018) and their views on how responsible adolescents in general should feel.

External responsibility: Previous research suggests that support for climate policy may depend not only on individuals' own sense of responsibility but also on the extent to which responsibility is attributed to other societal actors (Bouman et al., 2020), with qualitative research among adolescents likewise pointing to the potential relevance of such external responsibility attributions (Reuter & Frick, 2024). Building on the distinction between individual and societal responsibility attribution (Kalch et al., 2021), three newly developed items assessed external responsibility. They asked to what extent respondents attributed responsibility for addressing climate change to actors beyond their own peer group, such as politicians, managers, or adults in general.

Individual response efficacy: Individual response efficacy was assessed using three items adapted from Bostrom et al. (2019) that evaluated the perceived effectiveness of various behaviors in mitigating climate change.

Collective outcome expectancy: Collective outcome expectancy was assessed with one item adapted from Poortinga et al. (2018) asking to what extent collective action (many people reducing their energy consumption) was perceived as effective in mitigating climate change. This item has also been used in previous studies examining climate-related efficacy beliefs and policy support (Choi & Hart, 2021; Gregersen et al., 2021).

Self-efficacy: Self-efficacy expectations in the climate domain were measured using four items adapted from Bostrom et al. (2019). These items asked respondents how easy or difficult they thought it was to perform specific climate-related behaviors in their everyday lives. The behaviors referred to different domains of everyday life, including mobility, diet,

energy use, and communication. Although all behaviors were related to climate change mitigation, the items were thus intended to capture a broader picture of the extent to which individuals believe they can successfully carry out climate-related actions on their own.

Trust in society: Trust in society was measured by one item asking respondents how likely they thought it was that people around the world would reduce their energy consumption enough to combat climate change (adapted from [Poortinga et al., 2018](#)).

Trust in politics: Trust in politics was assessed by one item asking respondents how likely they thought it was that governments around the world were to take adequate measures to mitigate climate change (adapted from [Poortinga et al., 2018](#)). Although trust is commonly understood as a multidimensional construct (e.g., encompassing perceived competence and integrity; [Kitt et al., 2021](#)), single-item measures have been successfully employed in prior research to capture general expectations regarding climate-relevant actors (e.g., [Sarathchandra & Haltinner, 2023](#)).

2.2.2. Distal Outcomes: Cognitive Climate Literacy, Climate Change Behavior, and Policy Support

To examine whether the identified psychosocial profiles were associated with educationally relevant outcomes, we assessed cognitive climate competencies as well as two self-reported action-oriented outcomes: climate change behavior, and support for climate mitigation policies. Cognitive climate literacy represents the central educational outcome of the present study. Climate-friendly behavior and policy support, in contrast, were included as distal indicators of how adolescents engage with climate change beyond the classroom. Cognitive climate literacy may provide an important resource for informed individual and political participation; however, it does not automatically translate into climate-related engagement. The two action-oriented outcomes should therefore not be understood as direct educational learning outcomes, but as indicators of adolescents' reported participation in societal responses to climate change.

Cognitive climate literacy: We refer to cognitive climate literacy as students' foundational knowledge about the climate, as well as their ability to understand, evaluate, and use climate-related information in a scientifically informed way. It was assessed using a 155-item test developed and validated by the authors in previous research ([Martin et al., 2025](#)). The test is based on an interdisciplinary competency model that integrates perspectives from nine school subjects across the natural sciences, social sciences, technology, and the humanities. Its development involved cognitive pretesting, two pilot studies, a teacher survey, and a validation study. Evidence from these studies supports the intended interpretation of the test scores as indicators of cognitive climate literacy in secondary education, including the theoretically derived four-dimensional structure and meaningful relations with external variables.

The test assessed cognitive climate literacy in four competence facets: dealing with content knowledge (85 items), knowledge generation and evaluation (14 items), information and communication (27 items), and normative evaluation (29 items). It covers content areas in terms of scientific fundamentals, causes, and consequences, as well as options for action and barriers regarding climate change. The items consist of multiple-choice, single-choice, and open-ended questions. Data collection was conducted using a booklet design ([Frey et al., 2009](#)), in which each student completed 73 to 78 items within 70 min. Rasch scaling yielded an EAP reliability of 0.90 and item infit values ranging from 0.84 to 1.20. For further analysis, we used weighted likelihood estimates (WLEs) as person scores for cognitive climate literacy. For further details, see [Martin et al. \(2025\)](#).

Climate change behavior: Participants completed an adapted 40-item scale of climate change mitigation behaviors ([Kaiser et al., 2007](#)), covering mainly private-sphere and some public-sphere behaviors. Thirty-four items were rated on a five-point frequency scale

("never" to "very often"), and six items had yes/no response options; all responses were dichotomized prior to analysis. A Rasch model was estimated (EAP-Reliability = 0.82), and WLEs served as person scores for climate change behavior.

Policy support: Policy support was assessed with three items from [Poortinga et al. \(2018\)](#) that asked respondents to indicate the extent to which they favored or opposed selected policy measures for mitigating global warming, including comparatively restrictive measures such as taxes on emissions. The measure therefore captures support for a specific set of regulatory mitigation policies.

2.3. Data Analysis

All analyses were conducted in R (version 4.5.2). Data preparation and visualization were carried out using the tidyverse ([Wickham et al., 2019](#)). Confirmatory factor analyses were estimated with lavaan ([Rosseel et al., 2025](#)). Latent profile models were fitted with tidyLPA ([Rosenberg et al., 2018](#)) and evaluated using bootstrapped likelihood ratio tests implemented in mclust ([Scrucca et al., 2023](#)). We employed AI-assistance from Claude (Anthropic, Sonnet 4.6) to generate and iteratively refine the R scripts for our statistical analyses to improve efficiency and reduce errors. All code was reviewed, tested, and validated by the first author. The AI-model received only metadata and a short description of the analysis; no raw or identifiable data were transmitted.

2.3.1. Preliminary Analysis

After z-standardizing all the profile indicator variables to place measures with different response-scale ranges on a common metric, we conducted a confirmatory factor analysis (CFA) to examine the factorial validity of the multi-item scales. The hypothesized model specified six correlated latent factors representing climate change beliefs (5 items), climate change worry (5 items), individual response efficacy (3 items), personal responsibility (2 items), external responsibility (3 items), and self-efficacy (4 items). CFA models were estimated using maximum likelihood estimation in the R-package lavaan ([Rosseel et al., 2025](#)). The model showed adequate, although not optimal, fit to the data (robust CFI = 0.91, robust TLI = 0.89, RMSEA = 0.06, SRMR = 0.05).

All retained items demonstrated acceptable to strong standardized factor loadings, with the majority ranging between 0.46 and 0.88. One item from the climate change worry scale was excluded due to a low loading (<0.40). For the self-efficacy scale, two items showed weaker loadings (0.31 and 0.40). However, excluding the weakly loading item (0.31) did not substantially improve model fit or composite reliability (see Table A1). A sensitivity analysis confirmed that the reduced indicator set yielded the same profile solution and overall pattern of distal outcome differences, with only minor variations in pairwise significance. Given the scale's intent to capture perceived capability across diverse climate-related actions, high item homogeneity was not a primary expectation ([McCrae et al., 2011](#)). All other items across the remaining scales met the loading threshold of ≥ 0.40 .

To derive meaningfully interpretable profiles rather than merely grouping random combinations of indicators in an LPA, the profile indicators must demonstrate inter-correlation ([Bauer, 2022](#)). As illustrated in Table 3, the correlations are, for the most part, statistically significant, with most of them ranging in strength from weak to moderate. Two strong correlations were identified between climate change worry and personal responsibility ($r = 0.59$), and between personal and external responsibility ($r = 0.56$).

Prior to LPA, we examined the missing data mechanism for the profile indicators at the item level. Little's MCAR test indicated that the missing values were not distributed completely at random, $\chi^2(3471) = 4165$, $p < 0.001$, ruling out a missing-completely-at-random (MCAR) mechanism. Substantively, inspection of the subsample with missing

values showed consistently lower scores on the psychosocial variables, suggesting that nonresponse predominantly occurred among adolescents with relatively low interest in climate change and thus pointing to a missing-not-at-random (MNAR) mechanism. Under MNAR, neither full-information maximum likelihood (FIML) nor multiple imputation (MI) can be expected to yield unbiased estimates without correctly modeling the missingness process (Enders, 2025; Pepinsky, 2018). In addition, the indicators with the highest proportions of missing data showed only small or negligible correlations with most of the other profile indicators, implying limited potential for auxiliary variables to recover the missing information. For these reasons, we adopted a conservative approach and conducted the main LPA on complete cases for the profile indicators, resulting in a preliminary sample of $N = 639$. Subsequently, we screened multivariate outliers by computing Mahalanobis distances across all profile indicator variables and comparing them to a chi-square cutoff with $p < 0.001$ (Cousineau & Chartier, 2010); cases exceeding this cutoff were excluded from further analysis, yielding a final sample of $N = 632$.

Table 3. Means, standard deviations, and correlations (with confidence intervals) of profile indicators.

Variable	<i>M</i>	<i>SD</i>	1	2	3	4	5	6	7	8
1. Climate change beliefs	−0.02	0.69								
2. Climate change worry	−0.00	0.75	0.38 ** [0.31, 0.44]							
3. Personal responsibility	−0.00	0.92	0.40 ** [0.33, 0.46]	0.59 ** [0.54, 0.64]						
4. External responsibility	−0.01	0.85	0.43 ** [0.37, 0.49]	0.44 ** [0.38, 0.50]	0.56 ** [0.51, 0.61]					
5. Individual response efficacy	−0.00	0.87	0.34 ** [0.27, 0.40]	0.16 ** [0.08, 0.23]	0.23 ** [0.15, 0.30]	0.28 ** [0.21, 0.35]				
6. Collective outcome expectancy	−0.00	1.00	0.22 ** [0.14, 0.29]	0.28 ** [0.21, 0.35]	0.41 ** [0.34, 0.47]	0.32 ** [0.25, 0.39]	0.26 ** [0.19, 0.33]			
7. Self-efficacy	−0.00	0.64	0.29 ** [0.22, 0.35]	0.32 ** [0.25, 0.38]	0.41 ** [0.35, 0.47]	0.28 ** [0.21, 0.35]	0.16 ** [0.08, 0.23]	0.19 ** [0.12, 0.26]		
8. Trust in society	−0.00	1.00	−0.00 [−0.08, 0.07]	0.11 ** [0.03, 0.18]	0.23 ** [0.16, 0.30]	0.07 [−0.00, 0.15]	−0.00 [−0.08, 0.08]	0.23 ** [0.15, 0.30]	0.01 [−0.07, 0.08]	
9. Trust in politics	−0.00	1.00	0.07 [−0.00, 0.15]	0.13 ** [0.05, 0.20]	0.18 ** [0.11, 0.25]	0.08 * [0.00, 0.15]	0.02 [−0.05, 0.10]	0.16 ** [0.09, 0.24]	0.02 [−0.06, 0.09]	0.41 ** [0.35, 0.47]

Note. *M* and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. * indicates $p < 0.05$. ** indicates $p < 0.01$.

2.3.2. Latent Profile Analysis

Identification of the best profile solution: To determine the optimal number of latent profiles, we conducted a model comparison using the tidyLPA package in R (Rosenberg et al., 2018). We estimated models with one to eight profiles under three different parametrizations (EEI, VVI, VVV) and compared solutions based on fit indices (Bayesian Information Criterion, BIC). To further evaluate the solutions, we performed Bootstrapped Likelihood Ratio Tests (BLRT) with the mclust package in R (Scrucca et al., 2023). For each pair of consecutive models (e.g., two vs. three profiles) and each parametrization, BLRTs were computed with 99 bootstrap samples to assess whether adding an additional profile significantly improved model fit. Model selection was guided by statistical fit indices, parsimony, and substantive interpretability.

Classification accuracy: We evaluated the classification accuracy of the profile solution using discriminant analysis with leave-one-out cross validation, deriving a confusion matrix and profile-specific average posterior probabilities. We additionally examined the robustness of the selected solution in a split-half analysis by estimating the profile model separately in two random subsamples and comparing the resulting profile configurations.

To further examine profile separation, we conducted a multivariate analysis of variance (MANOVA) with profile membership as the independent variable and the nine profile indicators as dependent variables, testing multivariate group differences using Wilks' Λ and reporting partial η^2 as an effect size. Significant multivariate effects were followed up with univariate ANOVAs for each indicator.

2.3.3. Analysis of Distal Outcomes

To examine the external relevance of the latent profiles, we analyzed whether they differed on three distal outcomes: cognitive climate literacy, climate change behavior, and policy support. Because these variables were not included as profile indicators, systematic between-profile differences on these outcomes can be interpreted as supporting evidence for construct validity of the latent profiles.

We therefore conducted a one-way MANOVA with profile membership as a between-subjects factor and the three distal outcomes as jointly modeled dependent variables. In case of a significant multivariate test, we examined the univariate ANOVAs for each outcome and conducted post hoc pairwise comparisons between profiles based on estimated marginal means with Bonferroni-adjusted p-values. Effect sizes are reported as partial η^2 for the univariate omnibus effects.

Before running the MANOVA and follow-up ANOVAs, we examined the assumptions of normality and homogeneity of variances. Normality of residuals was assessed via visual inspection of Q-Q plots and Shapiro–Wilk tests, and homogeneity of variances was evaluated using Levene's test.

3. Results

In this section, we first present the results of the LPA, including model selection, classification accuracy, and the configuration of the five-profile solution. We then examine how the profiles differ on three distal outcomes: cognitive climate literacy, climate change behavior, and policy support.

3.1. Identification of Latent Profiles (RQ1)

A two-profile and a five-profile solution showed the best fit according to the BIC, with the lowest values observed for these two models (see also Table A2). From a substantive perspective, however, the two-profile solution would have provided only a very coarse distinction between adolescents with broadly lower versus higher levels of the included psychosocial orientations. Such a solution would not adequately reflect the heterogeneous and potentially complex configurations of climate-related beliefs, worry, responsibility attributions, efficacy beliefs, and trust that are theoretically relevant in CCE. Moreover, it would offer only limited value as a basis for future research on profile-sensitive and adaptive approaches to CCE, which require a more differentiated understanding of students' psychosocial learning prerequisites. In contrast, the solution involving five profiles is, in terms of theoretical interpretability, much more plausible, realistic, and nuanced. We therefore retained the five-profile solution as our final model.

The BLRT further supported this decision: assuming a VVI parametrization (i.e., models with variable class-specific variances and diagonal covariance matrices), adding profiles significantly improved model fit up to five profiles, whereas a sixth profile did not yield a significant improvement. Entropy for the five-profile model was 0.74, indicating acceptable classification accuracy. Profile sizes were also adequate, with the largest profile comprising 29% and the smallest 11% of the sample. Taken together, these results suggest that the five-profile model provides a reasonable balance between statistical fit (see Table A2), parsimony, and substantive interpretability.

3.2. Classification Quality and Robustness of the Profile Solution (RQ1)

To evaluate the internal separation of the five-profile solution, we conducted a linear discriminant analysis with leave-one-out cross-validation, using profile membership as the grouping variable and the LPA indicators as predictors. Overall, 84.34% of participants were reassigned to their estimated profile based on their indicator pattern. Classification rates were high for profiles 2 (88.12%), 3 (90.66%), and 5 (88.51%), whereas classification was lower for profiles 1 (69.57%) and 4 (76.12%). The most notable overlaps occurred for profile 1, which was misclassified as profile 2 in 24.64% of cases, and for profile 4, which was misclassified as profile 3 in 13.43% of cases (Table 4). Thus, the profiles were generally distinguishable, although the separation was weaker for some adjacent profile configurations.

Table 4. Confusion matrix of assigned versus predicted profiles.

Assigned Profile	Predicted Profile				
	1	2	3	4	5
1	69.57	24.64	2.90	2.90	0.00
2	4.38	88.12	7.50	0.00	0.00
3	0.55	6.04	90.66	2.75	0.00
4	0.75	8.96	13.43	76.12	0.75
5	0.00	0.00	8.05	3.45	88.51

Note. Entries represent row-percentages, indicating the proportion of cases from each assigned profile (rows) classified into each predicted profile (columns). Diagonal entries reflect correct classification rates per profile.

Mean posterior probabilities for the assigned profile ranged from 0.79 to 0.91 across profiles, indicating moderate to high certainty in profile assignment. Furthermore, a MANOVA showed that the profiles differed significantly on the nine profile indicators, Wilks' $\Lambda = 0.09$, $F(36, 2321.4) = 57.71$; $p < 0.001$. Follow-up ANOVAs revealed that the five profiles differed on all profile indicators with large effects (all partial $\eta^2 > 0.16$).

As an additional sensitivity analysis, we estimated the selected five-profile solution with VVI parametrization separately in two random halves of the sample. To account for arbitrary differences in profile numbering across model estimations, profiles were matched using the optimal one-to-one assignment based on correlations between their indicator means. The matched profile patterns showed high correspondence for profiles 1 ($r = 0.99$), 3 ($r = 0.88$), 4 ($r = 0.78$), and 5 ($r = 0.79$), while correspondence was not quite as high for profile 2 ($r = 0.60$). Thus, the central profile configurations were broadly reproduced across the two subsamples, although the results also suggest that profile 2 is less robustly differentiated than the other profiles.

Taken together, the internal classification indices, marked multivariate profile differences, and split-sample analysis support the use of the five-profile solution as a substantively meaningful representation of heterogeneity in climate-related psychosocial orientations. However, because the robustness of the profiles was not uniform, the solution should not be interpreted as establishing five fully discrete and invariant population types. Rather, it provides an empirically supported, but preliminary typology whose replication should be examined in independent samples.

3.3. Description of the Five-Profile Solution (RQ1)

For each profile, we obtained profile sizes (n) as well as means and standard deviations of the profile indicator variables, using individuals' posterior classification probabilities as weights. In this way, the characteristic patterns within each profile appropriately reflect the uncertainty in profile assignment. In addition to the z -standardized scores shown in Figure 1, Table 5 reports the profile-specific means of all psychosocial indicators on their

Profiles

- Alarmed
- Pragmatic
- Distanced
- Ambivalent
- Disengaged

Appraisal Category	Appraisal Item	Alarmed	Pragmatic	Distanced	Ambivalent	Disengaged
Problem appraisals	Climate change beliefs	0.65	0.35	0.15	-0.35	-0.55
	Climate change worry	0.85	0.30	-0.05	0.00	-0.95
Agency appraisals	Personal responsibility	1.10	0.65	-0.15	0.05	-1.35
	External responsibility	0.95	0.50	0.05	-0.25	-1.05
	Individual response efficacy	0.30	0.55	0.30	-0.55	-0.45
	Collective outcome expectancy	0.20	0.60	-0.05	0.05	-1.10
Social-context appraisals	Self-efficacy	0.45	0.30	0.00	-0.10	-0.45
	Trust in society	-0.30	0.55	-0.55	0.55	-0.55
	Trust in politics	-0.15	0.40	-0.30	0.45	-0.55

Table 5. Profile-specific means and standard deviations of climate-related psychosocial orientations on the original response scales.

		Climate Change Beliefs																					
		<i>n</i>	R (1–4)		Cau (1–5)		Con (1–7)		CCW (1–5)		PR (1–7)		ER (1–7)		IRE (1–5)		COE (1–7)		SE (1–7)		TS (1–7)		TP (1–7)
Alarmed	69	3.97	(0.24)	4.19	(0.49)	6.35	(0.38)	4.01	(0.42)	5.85	(0.65)	6.49	(0.43)	4.07	(0.90)	5.23	(1.29)	5.08	(0.90)	2.66	(0.64)	3.50	(1.35)
Pragmatic	160	3.89	(0.33)	3.98	(0.45)	5.97	(0.58)	3.49	(0.52)	5.13	(0.74)	5.80	(0.65)	4.34	(0.43)	5.79	(0.92)	4.73	(0.82)	3.79	(1.26)	4.26	(1.37)
Distanced	182	3.77	(0.43)	3.85	(0.59)	5.75	(0.64)	3.17	(0.56)	3.90	(0.92)	5.13	(0.96)	4.11	(0.51)	4.90	(1.41)	4.26	(1.04)	2.35	(0.84)	3.31	(1.41)
Ambivalent	134	3.53	(0.55)	3.54	(0.69)	5.11	(0.95)	3.24	(0.58)	4.21	(0.98)	4.67	(0.96)	3.23	(0.98)	5.05	(0.91)	4.04	(1.03)	3.83	(1.33)	4.36	(1.27)
Disengaged	87	3.33	(0.63)	3.28	(0.88)	5.08	(0.90)	2.30	(0.60)	2.09	(0.87)	3.53	(1.29)	3.36	(0.69)	3.36	(1.57)	3.40	(1.25)	2.40	(1.26)	2.94	(1.30)
Total	632	3.70	(0.50)	3.77	(0.69)	5.63	(0.86)	3.23	(0.71)	4.22	(1.38)	5.10	(1.24)	3.85	(0.84)	4.97	(1.42)	4.29	(1.12)	3.08	(1.32)	3.75	(1.46)

The first and smallest profile ($n = 69$, 11%) is labeled the *Alarmed*. Regarding problem appraisals, these adolescents show the strongest overall recognition of climate change as a real, predominantly human-caused, and serious problem, report by far the highest levels of worry, and express high levels of both personal and external responsibility. Their agency appraisals are also positive: they endorse the effectiveness of individual and collective action and report relatively high self-efficacy expectations. However, these beliefs are less pronounced than their problem appraisals. In terms of social-context appraisals, the Alarmed stand out through comparatively low trust in society and below-average trust in politics. Thus, this profile combines a strong sense of climate-related problem urgency and responsibility with less confidence that societal and political actors will respond adequately.

The second profile ($n = 160$, 25%), labeled the *Pragmatic*, also exhibits above-average but internally more consistent psychosocial orientations than within the Alarmed. Their problem appraisals indicate a clear recognition of climate change and above-average worry, although both are less pronounced than among the Alarmed. They also report positive personal and external responsibility attributions. In contrast to the Alarmed, the Pragmatic show particularly positive agency appraisals, including strong beliefs in the effectiveness of individual and collective action as well as high self-efficacy expectations. Their social-context appraisals are likewise positive, with above-average trust in society and politics. However, the latter vary considerably within this profile. Overall, the Pragmatic are characterized by a comparatively coherent pattern in which concern about climate change is accompanied by confidence in individual, collective, societal, and political capacities to address it.

The third and largest profile ($n = 182$, 29%), is labeled the *Distanced*. In terms of problem appraisals, these adolescents closely reflect the overall sample average: their mean levels of climate change beliefs, worry, and personal and external responsibility attributions are broadly average. Their agency appraisals likewise represent a comparatively average pattern, although their self-efficacy expectations are significantly less positive than those of the Alarmed and the Pragmatic. Social-context appraisals of the Distanced are clearly below average, as indicated by low trust in both society and politics. Thus, the Distanced do not reject climate change as a problem, nor do they display uniformly lower agency beliefs than the average; rather, they are distinguished primarily by their limited trust in social and political actors.

The fourth profile ($n = 134$, 21%) is labeled the *Ambivalent*. Their problem appraisals are mixed: compared with the other profiles, they are less convinced that climate change is real, predominantly human-caused, and associated with serious consequences, while their level of worry remains close to the sample average. Their responsibility attributions are also broadly moderate. Agency appraisals reveal a further inconsistency. The Ambivalent report the lowest perceived effectiveness of individual action of all profiles, whereas their expectations regarding the effectiveness of collective action are comparatively average and positive. Their self-efficacy expectations are lower than those of the Alarmed and Pragmatic and comparable to those of the Distanced. In sharp contrast to the Distanced and the Alarmed, the Ambivalent express clearly above-average trust in society and politics. Overall, this profile combines ambivalent problem beliefs with mixed agency appraisals, and high social and institutional trust.

The fifth profile ($n = 87$, 14%) is labeled the *Disengaged*. This profile occupies the lower end of the observed spectrum of climate-related psychosocial orientations across all three domains. Its problem appraisals are characterized above all by exceptionally low worry, which is clearly separated from all other profiles. At the same time, climate change beliefs are not entirely absent: inspection of the original response-scale means suggests that these adolescents still show some endorsement of the reality and negative consequences of climate change, although they are comparatively less convinced of its predominantly human causes and seriousness. Responsibility attributions are low both for themselves and for other societal groups. Their agency appraisals are also generally low but display a pattern opposite to that of the other profiles: perceived individual effectiveness is somewhat more pronounced than perceived collective effectiveness. Self-efficacy expectations are significantly lower than in the other profiles. Finally, the Disengaged report low trust in both society and politics. Thus, rather than representing a complete absence of climate change beliefs, this profile is characterized by very low worry and a broadly disengaged orientation marked by low responsibility, limited efficacy beliefs, and low social-context appraisals.

A cross-profile view of the indicators shows that, despite statistically significant and educationally meaningful differences between profiles, the adolescents in our sample generally recognize climate change as a real phenomenon with rather negative future consequences and tend to attribute somewhat more responsibility for mitigation to other societal groups than to themselves, as can also be seen in Table 5. Perceived effectiveness of individual and collective action, as well as self-efficacy expectations, is on average located in the positive range of the response scales, although not at very high levels. In contrast, trust in society and, to a lesser extent, in politics is generally low. Overall, the most pronounced attitudinal gaps emerge between the Disengaged and the remainder of the sample.

3.4. Profile Differences in Cognitive Climate Literacy, Climate Change Behavior, and Policy Support (RQ2)

To examine whether the latent profiles differed with respect to cognitive climate literacy and action-oriented indicators of societal participation, we conducted a one-way MANOVA with profile membership as a between-subjects factor. Cognitive climate literacy, self-reported climate change behavior, and support for climate mitigation policies were included as dependent variables. Shapiro–Wilk tests and Q–Q plots indicated no severe deviations from normality, and Levene’s tests suggested no violations of homogeneity of variances. The MANOVA revealed a significant multivariate effect of profile membership, Wilks’ $\Lambda = 0.56$, $F(12, 1579.80) = 32.60$, $p < 0.001$, indicating that the profiles differed reliably in their overall pattern of outcomes. Follow-up univariate tests showed significant between-subjects effects for each dependent variable, as reported below.

Cognitive climate literacy: For cognitive climate literacy, a robust effect of profile membership was shown, $F(4, 599) = 43.33$; $p < 0.001$; $\eta^2 = 0.22$. Post hoc tests with Bonferroni adjustment indicated that the Alarmed achieved significantly higher scores in cognitive climate literacy ($M_{WLE} = 0.79$, $SD = 0.85$) than all other profiles (all $p < 0.01$; Cohen’s $d = 0.48$ – 1.62). The Pragmatic and the Distanced showed slightly above-average levels of cognitive climate literacy ($M_{WLE} = 0.41$, $SD = 0.77$ and $M_{WLE} = 0.19$, $SD = 0.77$, respectively) and did not differ significantly from each other ($p = 0.11$). Below-average scores were observed for the Ambivalent and the Disengaged ($M_{WLE} = -0.37$, $SD = 0.81$ and $M_{WLE} = -0.49$, $SD = 0.80$, respectively), again with no significant difference between these profiles ($p = 1.00$). As depicted in Figure 2 and Table 6, profiles characterized by more positive climate-related psychosocial orientations tended to show higher levels of climate-related knowledge and cognitive competencies.

Table 6. Profile-specific means and standard deviations of cognitive climate literacy, self-reported climate change behavior, and support for mitigation policies.

	<i>n</i>	Cognitive Climate Literacy		Climate Change Behavior		Policy Support	
Alarmed	69	0.79	(0.85)	0.97	(0.76)	3.86	(0.62)
Pragmatic	160	0.41	(0.77)	0.48	(0.82)	3.43	(0.66)
Distanced	182	0.19	(0.77)	−0.12	(0.71)	3.01	(0.77)
Ambivalent	134	−0.37	(0.81)	−0.29	(0.85)	2.93	(0.71)
Disengaged	87	−0.49	(0.80)	−0.86	(0.83)	2.35	(0.88)
Total	632	0.10	(0.89)	0.02	(0.95)	3.10	(0.85)

Note. Values represent means of cognitive climate literacy (WLE scores), self-reported climate change behavior (WLE scores), and self-reported support for mitigation policies (mean scores on a 5-point Likert-scale) as well as standard deviations in parentheses.

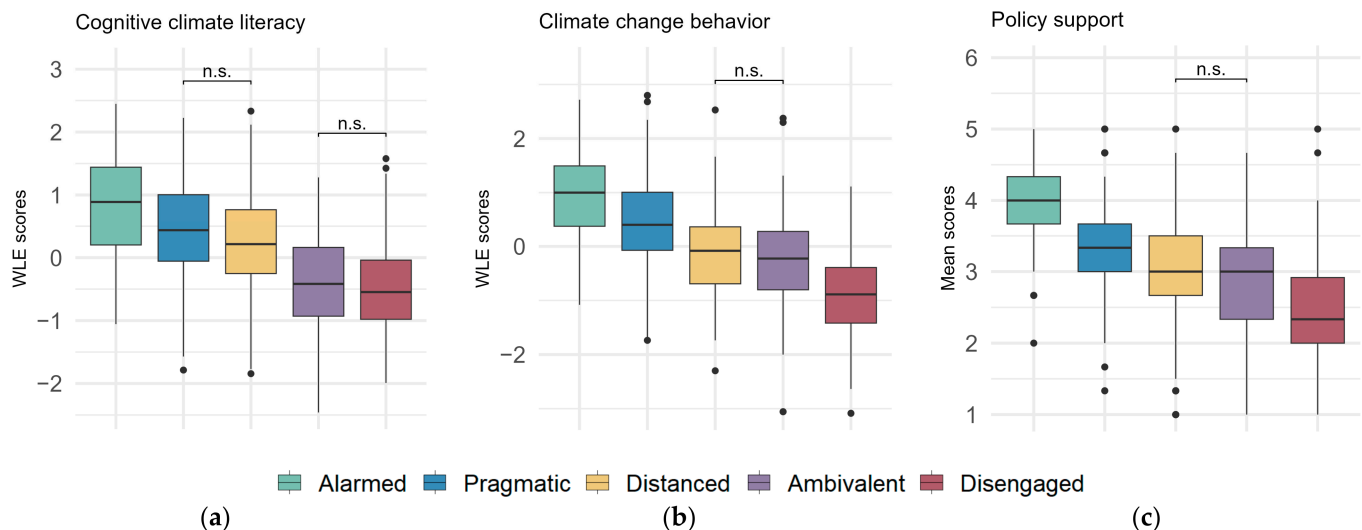


Figure 2. Boxplots displaying the distribution of (a) cognitive climate literacy (WLE scores), (b) self-reported climate change behavior (WLE scores), and (c) support for climate mitigation policies across the five latent profiles, with higher values indicating higher levels of the corresponding constructs. Boxes represent the interquartile range with the median as the central line; whiskers extend to 1.5 times the interquartile range, and points beyond the whiskers indicate outliers; n.s. = not significant.

Climate change behavior: For self-reported climate change behavior, the univariate ANOVA also yielded a sizeable effect of profile membership, $F(4, 599) = 69.39$; $p < 0.001$; $\eta^2 = 0.32$. Bonferroni-corrected post hoc comparisons showed that the Alarmed reported the highest levels of mitigative climate change behavior ($M_{WLE} = 0.97$, $SD = 0.76$), whereas the Disengaged reported the lowest levels ($M_{WLE} = -0.86$, $SD = 0.83$; all pairwise comparisons with these two profiles: $p < 0.001$; Cohen's $d = 0.63$ – 2.33). The Pragmatic also reported clearly above-average levels of climate-friendly behavior ($M_{WLE} = 0.48$, $SD = 0.82$) and differed significantly from the Distanced, the Ambivalent, and the Disengaged (all $p < 0.001$; Cohen's $d = 0.76$ – 1.70). The Distanced and the Ambivalent did not differ significantly from each other ($p = 0.73$), and both were in the mid-range across profiles ($M_{WLE} = -0.12$, $SD = 0.71$ and $M_{WLE} = -0.29$, $SD = 0.85$, respectively). Overall, profiles characterized by more positive climate-related psychosocial orientations reported more frequent climate-friendly behavior (Figure 2, Table 6).

Policy support: Finally, profile membership was significantly associated with support for climate mitigation policies, $F(4, 599) = 51.48$; $p < 0.001$; $\eta^2 = 0.25$. Bonferroni-adjusted post hoc tests indicated that the Alarmed showed the strongest support for the selected mitigation policies ($M = 3.86$, $SD = 0.62$), whereas the Disengaged expressed the lowest support ($M = 2.35$, $SD = 0.88$; all pairwise comparisons with these profiles: $p < 0.001$; Cohen's $d = 0.59$ – 2.06). The Pragmatic also reported comparatively high levels of policy support ($M = 3.43$, $SD = 0.66$) and differed significantly from the Distanced and the Ambivalent (both $p < 0.001$; Cohen's $d = 0.57$ – 0.68). The Distanced and the Ambivalent did not differ significantly from each other ($p = 1.00$) and were in the mid-range ($M = 3.01$, $SD = 0.77$ and $M = 2.93$, $SD = 0.71$, respectively). The ordering of profile means for policy support thus closely mirrors the pattern observed for climate change behavior (Figure 2, Table 6).

Taken together, the profiles differed consistently not only in cognitive climate literacy as the central educational outcome, but also in self-reported climate change behavior and support for mitigation policies as action-oriented indicators of societal participation. As these outcomes were not used to derive the profiles, this pattern provides initial evidence

that the identified typology captures meaningful heterogeneity in adolescents' climate-related orientations.

4. Discussion

Because climate change is conceptually complex, emotionally charged, and politically contested, CCE needs to account for the heterogeneous psychosocial learner characteristics that may shape how students engage with climate-related learning opportunities. The present study therefore examined latent profiles of adolescents based on their climate-related problem appraisals, perceived agency, and evaluations of the social and political context of climate action. Using LPA, we identified five profiles that differed systematically in climate change beliefs and worry, responsibility attributions, their efficacy beliefs, and trust in society and politics. The profiles were meaningfully associated with cognitive climate literacy as the central educational outcome, as well as with action-oriented indicators of societal participation. Taken together, these findings could serve as a useful informational basis for developing adaptive approaches for different groups of learners in CCE.

4.1. Interpretation of the Five Profiles of Climate-Related Psychosocial Orientations (RQ1)

Adopting a person-centered perspective complements, rather than competes with, the extensive variable-centered research on affective-motivational factors, climate-related knowledge, and behavioral tendencies. Whereas variable-centered approaches focus on relations between isolated constructs, person-centered analyses examine how different personal features or characteristics (e.g., beliefs, emotions, and other psychosocial orientations) co-occur within individuals as an organized whole (Marsh et al., 2009). This makes complex constellations of climate-related orientations more tangible and can support the identification of learner groups who may require different pedagogical approaches in CCE. In line with previous typology studies among adults and adolescents, our analysis revealed both a highly concerned profile and several additional profiles with lower levels of worry as well as divergent constellations of problem, agency, and social-context appraisals. At the same time, the present study extends earlier work by incorporating a broader range of psychosocial indicators and by relating the resulting profiles to a comprehensive measure of cognitive climate literacy (see also Table 7).

Table 7. Comparison of previous person-centered studies on climate-related orientations and the present study.

Study	Sample	Profile Indicators	Number/Examples of Profiles	Role of Cognitive Climate Literacy	Behavior/Policy-Related Variables	Key Distinction from Present Study
Leiserowitz et al. (2009)	Adults, USA	Beliefs (including efficacy), issue involvement (including worry), policy preferences, behavior	Six Americas, e.g., Alarmed, Dismissive	Not central	Self-reported behavior, policy preferences	Adult communication typology; no cognitive outcome
Gossen et al. (2018)	Adolescents, Germany	Values, ecological concern, consumption behavior, trust in politics, technology, science, and economic growth	Idealistic, Distanced, Pragmatic	Not included	Consumption patterns; trust in different societal actors	Narrower psychosocial indicator set; no cognitive outcome

Table 7. Cont.

Study	Sample	Profile Indicators	Number/Examples of Profiles	Role of Cognitive Climate Literacy	Behavior/Policy-Related Variables	Key Distinction from Present Study
Kuthe et al. (2019)	Adolescents, Austria and Germany	Attitudes (including responsibility, efficacy beliefs), personal concern, knowledge, behavior	Four groups, e.g., Concerned Activists, Paralyzed	Rudimentary knowledge measure used as profile indicator	Self-reported individual behavior, multiplicative action	No comprehensive assessment of cognitive climate literacy; knowledge is part of profile construction rather than an independent educational outcome; no policy-related variables
Veijonaho et al. (2024)	Adolescents, Finland	Climate change distress and denial	Four profiles, e.g., Normative-carefree, Overburdened	Not included	Pro-environmental behavior as distal outcome	Focuses on a small subset of psychosocial orientations; no cognitive outcomes; no policy-related variables; examines temporal stability
Present study	Adolescents, Germany	Beliefs, worry, responsibility, efficacy, trust	Five profiles, e.g., Alarmed, Disengaged	Comprehensive cognitive climate literacy as distal educational outcome	Self-reported climate change behavior; mitigation policy support	

4.1.1. A Highly Concerned “Alarmed” Profile (H1a/H1b)

Consistent with our first hypothesis and previous typology research, we identified a comparatively small profile of adolescents who were strongly convinced of the reality and human causes of climate change and reported the highest levels of worry about its future consequences. This profile of *Alarmed* closely resembles the most concerned profiles described in earlier studies (Kuthe et al., 2019; Leiserowitz et al., 2009; Veijonaho et al., 2024). In line with Hypothesis 1b and the findings by Gossen et al. (2018), these students simultaneously expressed comparatively low levels of trust in society and politics. Taken together, this constellation suggests a profile of adolescents who perceive climate change as a highly serious and urgent problem, but who are skeptical that societal and political actors will address it adequately.

Importantly, the Alarmed are not characterized by uniformly high scores across all psychosocial indicators. Rather, their profile is marked by an asymmetry between exceptionally strong problem appraisals, on the one hand, and comparatively low trust in societal and political actors, on the other. Their efficacy beliefs are generally positive, but less pronounced than their perceptions of climate-related urgency. This configuration may help explain why the Alarmed report the highest levels of climate-friendly behavior and policy support: adolescents who perceive climate change as highly urgent while doubting that institutions will respond adequately may engage personally as a way of maintaining agency, while simultaneously endorsing stronger political action (Buchanan & Russo, 2015; M. Parsons et al., 2024). Thus, their high behavioral engagement should not be interpreted as a belief that individual action alone is sufficient, but as part of a broader orientation that combines personal engagement with demands for societal and political responsibility. As the present data are cross-sectional, this interpretation is necessarily non-causal.

4.1.2. Three Profiles with Lower Levels of Worry but Divergent Orientations (H2)

In line with Hypothesis 2 and previous typology studies, we additionally identified several profiles that were less worried about climate change than the Alarmed but differed

markedly in their broader psychosocial orientations. The *Pragmatic* profile still showed above-average levels of worry, combined with substantial beliefs regarding the reality, causes, and consequences of climate change. By contrast, worry in the *Distanced* profile was close to the sample average, even though these adolescents were almost as strongly convinced of climate change as the *Pragmatic*.

The two profiles diverged substantially in their attributions of responsibility, their efficacy beliefs, and, most notably, in their trust in society and politics. *Pragmatic* adolescents combined comparatively high levels of concern with pronounced social and institutional trust, and relatively strong efficacy beliefs, reflecting comparatively high confidence that climate change can be addressed through societal and political responses. This configuration co-occurred with above-average levels of self-reported climate-related behavior and comparatively high support for mitigation policies. In contrast, *Distanced* adolescents were more skeptical about the effectiveness of collective action and expressed low trust in society and politics. Thus, although they recognized climate change as a problem, they reported lower self-efficacy and less confidence in societal and political decision-making processes. This pattern also co-occurred with lower levels of self-reported climate-related behavior and policy support than in the *Pragmatic* profile. This contrast suggests that recognition of climate change and worry alone do not account for differences in how adolescents position themselves behaviorally and politically. Rather, efficacy beliefs and trust appear to be relevant parts of the broader psychosocial configuration associated with these positions (Behrens, 2026).

Finally, the *Disengaged* profile reported clearly below-average levels of worry and comparatively weak beliefs regarding the human causes and potential negative consequences of climate change. Together with their low responsibility attributions, efficacy beliefs, and trust, this pattern indicates that climate change may have relatively little subjective salience in these adolescents' everyday lives. Alternatively, low levels of concern may partly reflect a defensive response to perceived threat in the context of limited perceived efficacy, such as avoidance, denial, or reactance (Witte & Allen, 2000). This broadly low psychosocial configuration co-occurred with the lowest levels of climate-related behavior and policy support. Rather than pointing to a single discrete obstacle, this configuration may reflect different pathways to low engagement, including low perceived relevance and limited perceived agency.

4.1.3. An "Ambivalent" Profile (H3)

In accordance with Hypothesis 3, we identified an ambivalent profile of adolescents characterized by a mixed climate-related psychosocial configuration, which we labeled *Ambivalent*. Adolescents in this profile expressed comparatively weak climate change beliefs, while reporting average levels of worry about future consequences. At the same time, they reported relatively high trust in society and politics, alongside heterogeneous patterns of responsibility attributions and efficacy beliefs. Thus, the profile cannot be described as consistently engagement-oriented or clearly dismissive. Instead, it brings together orientations that point in different directions across the assessed psychosocial indicators. With respect to the action-oriented outcomes, the *Ambivalent* occupied a middle position across profiles. Their self-reported climate-related behavior and policy support did not differ significantly from those of the *Distanced* but were lower than those of the *Pragmatic* and higher than those of the *Disengaged*. This outcome pattern complements the profile's mixed psychosocial configuration. Notably, around one fifth of the students were assigned to this profile, indicating that such ambivalence may not be a marginal phenomenon.

4.2. Educational Implications of Profile-Specific Climate Literacy Differences (RQ2)

Profile membership was systematically associated with cognitive climate literacy, the central educational outcome of the present study. The Alarmed showed the highest levels of cognitive climate literacy, followed by the Pragmatic and Distanced, whereas the Ambivalent and the Disengaged showed below-average levels. Because cognitive climate literacy was not used to derive the profiles, these differences provide initial evidence that the profile solution is meaningfully related to an educationally relevant external outcome. However, the cross-sectional design does not allow conclusions about the direction of these associations. Psychosocial orientations may be related to how students engage with climate-related learning opportunities, but cognitive climate literacy may likewise be associated with students' orientations; both may also reflect further individual, social, or educational influences.

From an educational perspective, the findings suggest that students may approach climate-related learning from different psychosocial starting points. Adaptive CCE could therefore consider not only students' prior knowledge and misconceptions, but also differences in problem appraisals, perceived agency, and views of the social and political context of climate change. Importantly, these patterns should not be interpreted as implying that CCE should promote a particular behavioral or political position. Rather, its role is to provide knowledge, reflective capacities, and perceived agency that enable young people to form and act on their own informed judgments.

The Alarmed combine high cognitive climate literacy with strong problem appraisals, pronounced worry, and comparatively low trust in societal and political institutions. For these students, CCE might offer opportunities to work with complex evidence, uncertainty, and contested policy options, while also creating space to reflect on emotional responses to climate change. Their comparatively high level of cognitive climate literacy may enable them to engage critically with climate-related claims, including those encountered in media and public discourse. Rather than presuming that these students need additional motivation or behavioral encouragement, educational approaches could support a well-informed examination of different climate-related courses of action, including the dilemmas that may accompany them, and foster reflection on the respective roles of individual, collective, and political engagement.

The Pragmatic and the Distanced both showed above-average levels of cognitive climate literacy yet differed in their psychosocial orientations. For the Pragmatic, who combine relatively positive orientations with high trust in society and politics, CCE could place particular emphasis on systems thinking. This may support a deeper understanding of how interactions among sociocultural, political, and economic structures can complicate or delay effective responses to climate change. It could also provide opportunities to discuss conflicts of interest and goals, as well as dilemmas that may constrain climate-responsible action by individuals, groups, societies, and states. On this basis, students can be supported in developing and critically reflecting on their own positions regarding different possible courses of action and the responsibilities associated with them.

The Distanced, whose cognitive climate literacy was comparable to that of the Pragmatic but whose trust and self-efficacy were lower, may likewise benefit from learning opportunities addressing questions of fairness, collective action, and institutional effectiveness. Such approaches need not aim to foster trust in institutions or politics as a determined outcome. Rather, they can enable students to examine critically how societal and political responses to climate change are justified, contested, and evaluated. In addition, small-scale and low-threshold opportunities to explore societal and political participation may provide a context in which students can experience self-efficacy.

The Ambivalent and the Disengaged showed below-average levels of cognitive climate literacy, but their psychosocial configurations differ. For the Ambivalent, structured learning opportunities that build foundational knowledge and support the critical evaluation of climate-related information may be particularly relevant. Their mixed pattern of beliefs and worry also suggests the value of reflective spaces in which apparent contradictions, uncertainties, and emotionally challenging information can be discussed. For the Disengaged, a central educational task may be to establish the personal and societal relevance of climate change without relying on moral pressure. Connecting climate issues to adolescents' everyday experiences, future aspirations, and locally observable challenges may provide accessible entry points for developing cognitive climate literacy.

These implications should be understood as hypotheses for the design of future adaptive CCE rather than as directly validated recommendations. Whether profile-sensitive instructional approaches improve cognitive climate literacy should be examined in intervention studies.

4.3. Limitations

Several limitations of the present study need to be acknowledged. First, the data stem from a non-representative sample of 9th-grade students from one federal state in Germany. Although the participating schools cover different school tracks, caution is warranted when generalizing the identified profiles and their educational implications beyond the present context.

Second, the profiles were derived from a specific set of psychosocial indicators under the assumption of local independence. This assumption serves as an identification constraint rather than a substantive claim that the included constructs are uncorrelated within profiles. Accordingly, the five-profile solution should be understood as a parsimonious representation of major response patterns rather than an exhaustive account of all relations among the constructs. Although most profile configurations were reproduced in a split-sample analysis, the correspondence of the Pragmatic was somewhat weaker. Replication in independent and more diverse samples is therefore needed before the profiles can be regarded as stable population subgroups.

Measurement limitations also warrant caution. Several profile indicators, including personal responsibility, collective outcome expectancy, trust in society, and trust in politics, were assessed with only one or two items, limiting the precision with which profile-specific levels can be interpreted. In addition, the self-efficacy scale showed comparatively low reliability (Cronbach's $\alpha = 0.50$). Therefore, profile differences involving self-efficacy should be interpreted cautiously, as measurement error may have affected the differentiation of this indicator; however, rather low internal consistency does not necessarily mean that also validity is low (McCrae et al., 2011). Future studies should use revised or more comprehensive measures of climate-related self-efficacy and examine whether the profile solution remains robust when this construct is assessed more reliably. Sensitivity analyses excluding the weakly loading self-efficacy item supported the robustness of the overall profile structure and the general pattern of distal outcome differences. However, some individual pairwise comparisons were less stable and should therefore be interpreted with caution.

Third, the cross-sectional self-report design does not permit causal conclusions about the relations between psychosocial orientations and cognitive climate literacy, nor does it capture intraindividual developmental changes. In addition, self-reported behavior and policy support may be affected by response biases.

Finally, profile labels and interpretations are inherently somewhat subjective. Although the labels are grounded in prior research and the observed indicator patterns, other interpretations remain possible. More generally, person-centered approaches involve a

trade-off: they make recurring configurations more interpretable but are less suited than variable-centered analyses to modeling detailed relations among the original latent factors (Marsh et al., 2009).

4.4. Directions for Future Research

Future research should examine whether the identified profiles are associated with adolescents' media use and information practices. Previous research suggests that climate-related orientations may be linked to differences in the sources individuals trust and the ways they engage with climate information (e.g., Metag et al., 2017). This is also educationally relevant because critically accessing, evaluating, and communicating climate-related information are central aspects of cognitive climate literacy, while media education constitutes an important task of schooling.

Moreover, the external validity and practical utility of the profile solution require further investigation. Replication in independent and more diverse samples, longitudinal analyses of profile stability, and associations with external criteria such as media practices, classroom engagement, or information evaluation would help clarify the generalizability and substantive meaning of the profiles. Finally, intervention studies should examine whether and under which conditions the typology can inform the development and implementation of adaptive CCE.

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Appendix A

Table A1. Comparison of fit and reliability indices for the measurement model with four versus three self-efficacy items.

Self-Efficacy Specification	Ω	AVE	Robust CFI	Robust RMSEA
Four items	0.50	0.21	0.91	0.06
Three items	0.49	0.25	0.91	0.06

Note. Ω = McDonald's omega (composite reliability); AVE = average variance extracted; robust CFI = Yuan-Bentler scaled comparative fit index; robust RMSEA = Yuan-Bentler scaled root mean square error of approximation.

Table A2. Model comparison.

Model	Classes	BIC	SABIC	Entropy	prob_min	prob_max	n_min	n_max	BLRT
EEI	1	14,076.20	14,019.05	1.00	1.00	1.00	1.00	1.00	
EEI	2	13,321.46	13,232.56	0.82	0.89	0.97	0.28	0.72	
EEI	3	13,142.63	13,021.99	0.77	0.86	0.92	0.12	0.46	0.00
EEI	4	13,035.02	12,882.62	0.82	0.83	0.94	0.09	0.49	0.00
EEI	5	13,028.54	12,844.40	0.76	0.69	0.93	0.08	0.36	0.01
EEI	6	13,031.36	12,815.46	0.75	0.69	0.89	0.07	0.33	0.00
EEI	7	13,007.72	12,760.07	0.76	0.72	0.92	0.06	0.34	0.01
EEI	8	13,043.28	12,763.89	0.77	0.61	0.91	0.04	0.36	0.17
VVI	1	14,076.20	14,019.05	1.00	1.00	1.00	1.00	1.00	
VVI	2	13,257.30	13,139.83	0.78	0.93	0.94	0.49	0.51	
VVI	3	13,044.10	12,866.30	0.76	0.86	0.91	0.18	0.45	0.00
VVI	4	13,026.48	12,788.37	0.76	0.81	0.90	0.12	0.42	0.00
VVI	5	12,993.77	12,695.33	0.74	0.78	0.89	0.11	0.29	0.00
VVI	6	13,035.97	12,677.20	0.74	0.73	0.90	0.08	0.21	0.05
VVI	7	13,068.33	12,649.24	0.76	0.74	0.91	0.08	0.21	0.14
VVI	8	13,146.89	12,667.48	0.78	0.75	0.93	0.07	0.18	0.39
VVV	1	12,996.25	12,824.81	1.00	1.00	1.00	1.00	1.00	
VVV	2	12,932.87	12,586.80	0.69	0.89	0.93	0.46	0.54	
VVV	3	13,131.47	12,610.79	0.71	0.82	0.93	0.23	0.51	0.01
VVV	4	13,368.44	12,673.14	0.74	0.80	0.92	0.10	0.43	0.41
VVV	5	13,572.70	12,702.78	0.79	0.80	0.96	0.08	0.36	0.04
VVV	6	13,801.51	12,756.97	0.80	0.83	0.99	0.06	0.27	0.13
VVV	7	14,016.24	12,797.08	0.84	0.84	0.99	0.05	0.26	0.15
VVV	8	14,298.96	12,905.18	0.85	0.80	1.00	0.04	0.26	0.81

Note. BIC = Bayesian Information Criterion; SABIC = sample-size adjusted; prob_min = minimum posterior class probability; prob_max = maximum posterior class probability; n_min = smallest class size; n_max = largest class size; BLRT = bootstrap likelihood ratio test; EEI = Equal variances, Equal covariances (fixed to zero), Identity; VVI = Variable variances, Variable covariances (fixed to zero), Identity; VVV = Variable variances, Variable covariances, Variable. The three lowest values in each information criterion column are printed in bold.

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