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ORIGINAL ARTICLE

The impact of teenagers' emotions on their complexity thinking competence related to climate change and its consequences on their future: looking at complex interconnections and implications in climate change education

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Abstract
This study seeks to address critical gaps in climate change education research with regard to (1) emotions triggered in teenage students learning about climate change, (2) the students' complexity thinking competence in the context of climate change consequences, and (3) the interconnections between different types of emotions and the levels of complexity thinking competence in teenagers' explanations of climate change. The study drew on quantitative and qualitative data from 315 (2013–2015) and 246 (2021) teenage secondary school students from a pre-/post-intervention survey from Austria's year-long *k.i.d.Z.21—Competent into the Future* program, in which almost 3,500 students aged between 13 and 19 have participated up to now. Climate change triggered expected types of emotions in students. Following exploratory factor analyses, these were clustered into two groups. Multilevel modeling revealed that the *k.i.d.Z.21*-modules had no influence on teenage students' levels of complexity thinking competence in their explanations of climate change for themselves and humanity in general. The first group of emotions (i.e., *angry, sad, helpless, insecure, worried and inspired to act*) was associated with higher levels of complexity thinking competence in participants' answers to questions about climate change and, therefore, designated "stimulation". The opposite was true for the second group (i.e., *apathetic, annoyed, and hopeful*), which diminished the level of complexity thinking competence in responses and, therefore, designated "attenuation". Future studies are encouraged to draw on the emotion measures developed for this study to replicate and advance this study's findings. Educationists are urged to pay greater attention to emotions in climate change education.

Keywords Climate change · Climate change education · Teenagers' emotions · Complexity thinking · Complex interconnections

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Introduction

Climate change and its associated consequences are some of the most important grand challenges of the twenty-first century (IPCC 2014, 2018, 2021) and is also one of the central Planetary Boundaries to be tackled by humanity (Stockholm Resilience Centre 2021). Humankind is already experiencing the impacts of anthropogenic climate change and will continue to do so for some considerable time (UN 2020; WBGU 2011), creating a compelling need for urgent, collective action in the form of mitigation, adaptation, and transformation (UNEP 2021; IPCC 2014). Political agreements and technological advances alone will not be sufficient to counter these needs and to achieve the ambitious goals set by the United Nations Climate Conference COP21 in December 2015 in Paris (United Nations Framework Convention on Climate Change 2016; Barnosky et al. 2016). Therefore, fundamental societal transformations will be required to meet the global Sustainable Development Goals (SDGs). To this end, climate change education (CCE) will be essential (UNESCO 2021; WBGU 2011; Feola 2015; Rieckmann 2018).

Within the context of Education for Sustainable Development (ESD), the main aims of CCE are to empower young people to understand and address the impacts of climate change, to alter their attitudes, foster climate-friendly behaviors, and to help adapt to a changing climate (Schrot et al. 2021, 2019; UNESCO 2019). CCE must equip today's young people to become sustainable and climate-friendly decision-makers and actors with a more uncertain future. In this context, it has to be stressed that simply passing on knowledge about climate change alone is inadequate. In addition to this, the functional chains, e.g., between knowledge and action, are fuzzy and partly inexplicable—even though much research in various fields (economics, psychology, education, environmental research etc.) has been performed in an effort to explain (and influence) human actions (Tasquier and Pongiglione 2017; Carmi et al. 2015; Shi et al. 2016; Corner et al. 2015; Kuckartz and Haan 1996; Mandl and Gerstmaier 2000; O'brien 2012; Kollmuss and Agyeman 2002; Oats and McDonald 2014; Ranney and Clark 2016; Leichenko et al. 2021).

Recent studies point to the importance of addressing affective and behavioral aspects to achieve CCE goals (Izadpanahi et al. 2017; Carmi et al. 2015; Markowitz and Guckian 2018). The role of emotions in CCE is receiving increasing attention, which will be discussed later. Nevertheless, the full potential of the role of emotions in supporting learning about climate change has been understudied in CCE (Ojala 2015, 2013; Wang et al. 2018). Therefore, the first research gap addressed within this paper is the role of emotions in learning about climate change, in particular trying to learn more about the types of emotions triggered by learning about climate change.

As previously mentioned, the traditional additive approach of increasing young people's knowledge through providing information according to information deficit models is insufficient (Burgess et al. 1998; Kollmuss and Agyeman 2002; Ockwell et al. 2009; Wibeck 2014). Climate change is multifaceted and interacts in incalculable ways (APCC 2014). CCE, therefore, needs to advance students' competence to deal with complex, even unpredictable issues. How to foster and evaluate this competence within students in CCE is underrepresented within literature (Molderez and Ceulemans 2018; Grohs et al. 2018; Cabrera et al. 2021). This is the second research gap this paper sets out to address. The authors refer to this competence as "complexity thinking competence" as described within the chapter *Complexity thinking competence in CCE*. This study sets out to measure participants' complexity thinking competence with regard to climate change consequences on their own lives and humanity in general.

Young people's emotions as well as their complexity thinking competence may be key in choosing climate-friendly behaviors and the pursuit of other transformations. Few relevant studies exist on the importance of emotions for CCE and climate-friendly behavior: Kleres and Wettergren (2017) found fear, hope, anger, and guilt to predict climate activism and action. Tasquier and Pongiglione (2017) identified fear and negative emotions as barriers to behavioral change, and Ojala (2016, 2017) dealt with the role of fear, hope and anticipation in CCE. None of these authors, however, have explored the relationship between emotions and complexity thinking competence (Muis et al. 2018; Chevrier et al. 2019). This study, therefore, seeks to verify different types of emotions triggered by learning about climate change, and to explore their effects on young people's complexity thinking competence about it and the consequences for their own lives as well as humanity in general. This is the third research gap this study wants to address.

A literature review on emotions in education in general, and in CCE in particular, is provided next, along with complexity thinking competence in CCE. This is followed by the description of study methods and results. The main findings of this study are discussed in terms of how they advance CCE.

Emotions in education and CCE

The role of young people's emotions[1] in education has been investigated in a number of studies. Although examining different aspects, these clearly have in common that emotions have concrete effects on learning processes and outcomes. Some research, for example, focuses on the need to connect young people's social, emotional, and cognitive development with behavior to influence the development of competencies critical to beneficial school and life outcomes (Jones et al. 2019). Therefore, studies suggest supporting students in managing their emotions through pedagogic partnerships (Hill et al. 2019; Reicher and Matischek-Jauk 2018; Valtl 2019) to enhance students' perception of emotions and their regulation, resulting in enhanced cognitive

[1] In this study, the authors use an understanding of emotions according to Pekrun (2006) who describes them "as multi-component, coordinated processes of psychological subsystems including affective, cognitive, motivational, expressive and peripheral physiological processes".

Table 1 Classification of emotions

Valence	Positive: pride, pleasure		Negative: fear, shame	
Object focus	Activity: pleasure, boredom		Outcome: pride, disappointment	
Temporal dimension	Present: (learning) pleasure, boredom, frustration	Prospective: hope, fear		Retrospective: gratitude, relief, disappointment
Degree of activation	Activating: hope, pride, gratitude, pleasure, frustration, fear		Deactivating: boredom, disappointment, relief	

This table shows examples for the classification of emotions based on Frenzel and Stephens (2017), Pekrun (2006) and Pekrun et al. (2007)

development, skills to build and maintain relationships, self-efficacy and self-regulation (Hill et al. 2019; Zimmerman 2000; Zimmerman 2002; Zembylas 2005; Kural and Kocakülah 2016; Sinatra 2005; Bada 2015). Other studies focus on the relationship between emotions and personal epistemology, referring to individuals' thinking and beliefs about knowledge and knowing, self-regulated learning and studying, and so-called epistemic emotions to either facilitate or constrain learning processes (Muis et al. 2018). Other researchers have acknowledged the malleable relationship between positive/negative affect and cognition (Muis et al. 2018; Panayiotou et al. 2019; Postareff et al. 2017; Ray and Huntsinger 2017).

The emotions associated with achievement have been studied extensively in education. Hope, joy, and anxiety, which are tied to achievement activities, like enjoyment or anger have been focal points alongside achievement outcomes, like pride or sadness (Pekrun 2006). Typically criteria like valence, object focus, temporal dimension or degree of activation are used to classify these emotions (Frenzel and Stephens 2017; Pekrun 2006; Pekrun et al. 2007), as depicted in Table 1. According to Pekrun (2006, 2007), valence and degree of activation are the most important criteria to describe the performance effects of emotions that influence students' cognitive resources, interests and motivations, strategies for learning and problem solving, uses of self-regulation or external regulation of learning and problem-solving, as well as learners' academic achievement.

Although Pekrun's theory originally suggests that achievement emotions exclusively relate to school contexts, this particular theory also helps to explain emotions triggered in the context of CCE and more specifically learning about climate change. As CCE takes place in formal school settings, the connection between achievement emotions and CCE is evident. Connecting achievement emotions to climate change, however, is not straightforward. When defining climate change as a global challenge that society as well as individuals have to master, coverage of the topic and decisions to engage in climate-friendly actions can be seen as achievement activities and enactment of climate-actions become the achievement outcome.

Critical engagement with climate change has been found to trigger emotions in individuals (Chapman et al. 2017), and thus can be expected to do so in students. With the exception of *hope*, the emotions most commonly associated with climate change are negative ones such as *anxiety*, *despair*, *stress*, *fear*, *worry*, *guilt*, *anger*, *sadness*, *helplessness*, *apathy and frustration* (Corner et al. 2015; Strife 2012; Hofman-Bergholm 2018; Tasquier and Pongiglione 2017; Kleres and Wettergren 2017; Ojala 2012, 2016). Emotions can also be considered to be a significant factor influencing students' critical skills acquired via twenty-first century education (Di Fabio and Saklofske 2019; Ojala 2013; Martiskainen and Sovacool 2021; Di Fabio et al. 2018; Graesser 2020; Marouli 2021). Among these are collaboration, communication, critical thinking, creativity, and collaborative problem solving (Camacho-Morles et al. 2019), all of which are similar to the key competencies of ESD (Rieckmann 2017). It is important to note that not only do young people experience emotions differently from adults (Camacho-Morles et al. 2019; Theurel and Gentaz 2018; Zeman et al. 2006; Vierhaus et al. 2016), they are also less well equipped to regulate them (Camacho-Morles et al. 2019; Theurel and Gentaz 2018; Zeman et al. 2006; Vierhaus et al. 2016). It is therefore particularly important to consider the role of emotions in CCE (Chapman et al. 2017).

Within the context of CCE, few have studied young people's emotions until recently. Most of this research has focused on emotions as a personal factor influencing climate-friendly behaviors (Chiari et al. 2016; Lindenberg and Steg 2007; Loewenstein et al. 2001; Kollmuss and Agyeman 2002; Grob 1995), and on the mediating role of emotions between knowledge and intentions to engage in climate actions (Kleres and Wettergren 2017; Strife 2012; Hofman-Bergholm 2018; Tasquier and Pongiglione 2017; Ojala and Lakew 2017; Ojala 2016, 2012; Carmi et al. 2015; Frisk and Larson 2011). Another related and important area of research concentrates on critical emotional awareness, which refers to the competences of being able to identify, explain, and discern one's own and other's emotions as well as disrupting unsustainable emotion regulation. The latter, in turn, refers to the competences and processes unsuitable for changing emotional experiences and responses (van Beveren et al. 2019; Gross 1999) that limit transformative action toward a climate-friendly society (Ojala 2012, 2013, 2016, 2017).

One study by Lehtonen et al. (2018) dealt with the challenges of sustainability education from a perspective of modern dichotomies (e.g., individual—social, local—global, nature—culture, emotion—reason). They conclude that there is a need for a pedagogy of interconnectedness, including the opposites of reason and emotion, and the need for students to become aware of how emotions interfere in knowing and how they guide personal values. To support students in successfully addressing sustainability topics, a number of authors call for enriching rationality, analytic and mechanistic ways of thinking with creative ways of thinking, and emotional and ethical intelligence (Lehtonen et al. 2018; Estrada et al. 2021; Förster et al. 2019; Grund and Brock 2020; Ojala 2013).

Complexity thinking competence in CCE

As already suggested in the introduction, the multifaceted, dynamic and unpredictable quality of climate change (APCC 2014) requires learners to develop a respective competence of complexity thinking in order to grasp this issue. In this study, the definition of complexity thinking competence is seen as a consequence of the definition of competences of ESD as given in Brundiers et al. (2021). Here competences are described as a set of specific and interrelated dispositions, including, e.g., knowledge, skills, motives, attitudes, etc., facilitating self-organized action, which itself is seen as pre-requisite of successful performance and positive outcome in complex situations. As such, complexity thinking competence is a concept not yet fully described in the literature, yet fundamental in the field of CCE.

The concept of complexity thinking is derived from complexity theory and draws on qualities of complex systems to describe learning systems such as organic, non-linear, relational and holistic features (Forsman et al. 2014; Davis and Sumara 2008). Some authors (Jennstål 2019; Suedfeld 2010) use the term "complexity of thinking" to identify individuals' capacities to deal with ambiguous, uncertain information, or with competing perspectives. Their usage of the term also includes the recognition of links between various perspectives, which opposes dogmatism, extremism, stereotypical, prejudicial thinking and simplified forms of reasoning. Complexity thinking therefore refers to a manner of thinking in terms of structure of perceptions or operations of thinking (Podschuweit et al. 2016; Crochran-Smith et al. 2014; Davis and Sumara 2008; Jennstål 2019). Such a form of high-order thinking is essential for understanding grand challenges like climate change and to make mature decisions concerning one's own actions (Taber and Taylor 2009; Moser 2010). This is why complexity thinking has also been identified as an important sustainability competence (Guia 2020; Wiek et al. 2011; Brundiers et al. 2021). Within the field of ESD it is usually referred to as 'systems thinking competency', and defines the skill to recognize and understand relationships, to analyze complex systems within different domains and scales, and to deal with uncertainty, which is fundamentally in line with the aforementioned concept of complexity thinking (Rieckmann 2017). As this study unites the two approaches to a capacity to recognize, understand and deal with uncertain information and competing perspectives within complex systems on various scales, the authors subsequently use the term complexity thinking competence, a competence CCE should ideally enhance.

For many decades, scholars in education and psychology have studied complexity thinking processes, exploring the structures of perceptions and the operations of thinking, attitudes or motives (Podschuweit et al. 2016; Mandl and Huber 1978), which are based "on a cognitive theory of individuals' (verbalized) information processing, reasoning skills and decision-making" (Jennstål 2019). In order to initiate learners to express such verbalized pieces of information, Bloom's Taxonomy is frequently used to create appropriate assignments in an educational context. This taxonomy defines six levels of thinking, with each level more complex than the previous one (i.e., knowledge/remembering, comprehension/understanding, applying, analyzing, evaluating, and synthesizing) (Golding 2019; Adams 2015; Bloom 1956). Applying the idea of complexity thinking competence, each of Bloom's levels requires a higher level of complexity thinking competence than the previous one. In order to evaluate these levels of complexity thinking competence, various competence models of standards for science education have been developed over the past decades (Kauertz and Fischer 2006; Kauertz et al. 2010; Rechtsinformationssystem des Bundes 2021; Bundesministerium für Bildung und Frauen 2012; Baker-Brown et al. 2009), which include thinking processes and different levels of abstraction. Thinking processes are described as thinking styles that may influence the level of complexity thinking competence (Vorholzer and Aufschnaiter 2020; Kauertz et al. 2010) and the ability of transferring skills from known contexts to novel ones (Vorholzer and Aufschnaiter 2020).

In summary, there is a solid body of educational research on complexity thinking competence and how to measure it. Within the scope of this study, complexity thinking competence strongly resembles key sustainability competencies such as systems and critical thinking (Rieckmann 2017). Therefore, it is important to learn more about complexity thinking competence within the context of CCE.

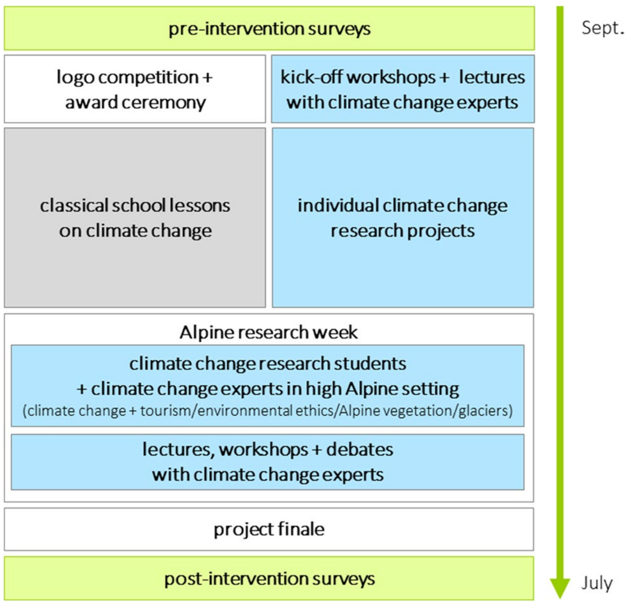

Fig. 1 The k.i.d.Z.21-modules. This overview of the k.i.d.Z.21-modules only roughly reflects the amount of time invested in the various modules. Gray = traditional teaching styles, blue = constructivist and/or transdisciplinary approaches in authentic learning settings

Materials and methods

Study design

This study was carried out as part of the CCE project *k.i.d.Z.21—kompetent in die Zukunft* (in English: competent into the future), a long-term collaboration between the University of Innsbruck's (Austria) Department of Geography and regional secondary schools. The program's goals are to increase young people's awareness of climate change on the environmental, economic and social grand challenges of the twenty-first century (Keller et al. 2019; Stötter et al. 2016; k.i.d.Z.21). Previous descriptions of complexity thinking competence indicate that in order to meet these goals complexity thinking competence is necessary. Which means, that although not explicitly addressed within the project's overall goals it is considered an important underlying concept. As depicted in Fig. 1, *k.i.d.Z.21* engages students with the topic of climate change over an entire school year both within and outside the school settings (Keller et al. 2019).

Since the 2012/13 school year, when the collaboration between the University of Innsbruck's Department of Geography and a Southern German school was established, the number of participating schools and students has continuously grown. Almost 3,500 students aged 13 to 19 from Austria, Southern Germany and Italy have participated in the program's full school-year CCE project.

Pedagogical approach

First of all, the central approach to learning is constructivist, strongly reflecting the theories of conceptual change (Basten et al. 2015). Students construct their own learning from their prior knowledge, their experiences and preconcepts, and develop these preconcepts in an individual, constructive, social, self-regulated and situated process (Duffy et al. 1993) in the cause of the project.

The Alpine research week is one of the highlights of the project year where students come into contact with experts in the fields of tourism, environmental ethics, alpine vegetation, and glaciology. Within these fields, students do their own research on climate change consequences. In accordance with an inquiry-based learning process, students develop their own research questions, find adequate methods for data collection and collect, analyze, and interpret the data. During the whole process they are supported by the aforementioned experts (Kubisch et al. 2021). Therefore, *k.i.d.Z.21* is transdisciplinary (Scholz and Steiner 2015) in that it fosters dialogue and learning between students and (scientific) experts. The constructivist and transdisciplinary approach to learning is intended to foster students' complexity thinking competence.

From the beginning of the project, emotions have been considered to be an important factor in the effectiveness of the project, as research already demonstrated subjective elements of change, for example beliefs, values, identities or emotions that influence perceptions or actions (O'brien 2012). This is reflected in some of the *k.i.d.Z.21* modules, which explicitly address students' emotions. For example, students map their emotions as part of the unit on environmental ethics and climate change, to increase their awareness of how they feel in the surroundings of a high mountain area (e.g., almost natural vs. strongly influenced by humans). These maps are used as a base for discussions about environmental ethics with the expert supporting them.

Continuous, research-based evaluation

The modules of the long-term research-education co-operation have been accompanied by continuous scientific evaluative research from the beginning. Insights gained from resulting findings have been used to constantly improve *k.i.d.Z.21*-modules and to expand its content and activities. As also depicted in Fig. 1, participants complete the pre-survey at the beginning of the school year and the post-survey at the end of the school year. Results have been used to assess students' learning outcomes such as their awareness of climate change, their impressions about when exactly during the school year they learned the most about climate change and why and, especially relevant for the current study, their complexity thinking about climate change and their emotions while learning about this topic in particular.

Survey instrument

The pre- and post-intervention surveys were administered online and in German. For the purpose of this article, the questions and responses have been translated into English.

One set of closed questions asked students which emotions they feel when thinking about climate change. Nine emotions were assessed (i.e., apathetic, annoyed, angry, sad, helpless, insecure, worried, inspired to act, and hopeful) with six response options ranging from *1 = I strongly feel this emotion when thinking about climate change* to *6 = I do not feel this emotion at all when thinking about climate change*. These particular emotions were selected because an Austrian youth study, carried out by Allianz (2012) asked a similar question (i.e., Which emotion do you feel when thinking about climate change?) using the same emotions. The question stem and response options were slightly adjusted to match the other questions in the pre- and post-questionnaires.

The question about students' emotions was removed from the questionnaire after the first three years of the study, due to changes to the overall questionnaire. Based on the increasing amount of research on emotions in connection to climate change awareness, the same question was re-introduced in the project year 2020/21 especially for the current study. This explains why data from the years between were omitted. The reintroduction of the question led to the adjustment of the emotion scale to use adjectives rather than nouns consistent with Searle and Gow (2010).

Two open-ended questions were included to obtain information about participants' perception and awareness of climate change. The first asked students to share their thoughts about which climate change consequences could affect their personal lives in the future, and the second, which could affect humanity in general. These questions were deliberately chosen for this study's analysis, as they offer adequate scope for learners to show their complexity thinking competence, and the IPCC and APCC provide a framework for qualitative analysis in terms of validity. The questions are based on Spence et al. (2012) whose research focused on the psychological distance of climate change, finding that lower psychological distance is associated with higher levels of concern, as well as perceived climate change consequences on developing countries and how it relates to preparedness to act on climate change. Their focus of qualitative analysis was completely different, nevertheless students' verbal contributions to these questions allow an analysis of students' complexity thinking competence, as they can choose freely to write about what they know about climate change consequences, connect pieces of knowledge and relate their own attitudes and motives with these answers. Therefore, analysis of students' answers according to integrative complexity (IC) is feasible, which is a validated measure used to assess the structure of spoken as well as written communication. IC analyzes the structure of information processing, detached from content (Békés and Suedfeld 2019; Jennstål 2019; Conway et al. 2011). IC distinguishes *differentiation*, referring to the amount of different pieces of information, perspectives or dimensions a person mentions on a topic, and *integration*, referring to the perceived connections among these divergent elements, like trade-offs, synthesis, or belonging under a unifying schema (Békés and Suedfeld 2019). Low IC is associated with rigid, black-and-white thinking, intolerance for ambiguity and uncertainty, a desire for rapid closure, and not recognizing the validity of other viewpoints. In contrast, high IC incorporates flexible, broad thinking, which leads to the consideration of multiple aspects and possible interpretations as well as connections and tensions between perspectives (Békés and Suedfeld 2019; Suedfeld 1985). This can also be transferred to an educational context where some authors describe a progression of students' statements in terms of their skills to link different contextual information to construct arguments and make elaborate decisions (Podschuweit et al. 2016; Bravo-Torija and Jiménez-Aleixandre 2012; Jiménez-Aleixandre and Reigosa 2006). Another possibility for analyzing students' complexity thinking competence is to determine the links between pieces of information that refer to more complex conceptual understanding. Similarly, the German national standards for natural sciences education propose a complexity model with six levels: individual facts, several unconnected facts, one relation, several unconnected relations, several interconnected relations, and generic concept/basic concept (Kauertz and Fischer 2006; Podschuweit et al. 2016; Kauertz et al. 2010). This model of complexity has been applied to developing assessment tests by creating tasks corresponding to the different levels of complexity (Kauertz and Fischer 2006).

A final question asked students about their sociodemographic information including age and gender (i.e., female or male). The original questions and according scales can be found within the appendix.

Study participants

One data set for this study was collected from three cohorts (2012/13–2014/15) of 315 students in the same grade aged 13 to 15 years ($M_{age} = 13.8$, SD = 0.7, 51.1% girls) from a single school in Southern Germany (Gymnasium Eggenfelden). Another data set comes from 246 students aged 10 to 19 years ($M = 14.4$, SD = 1.9, 61.7% girls) who participated in *k.i.d.Z.21*-modules during the most recent project year (2020/21) (cf. Table 1). Of the 561 students, 463 completed the pre-test and post-test and 98 completed either

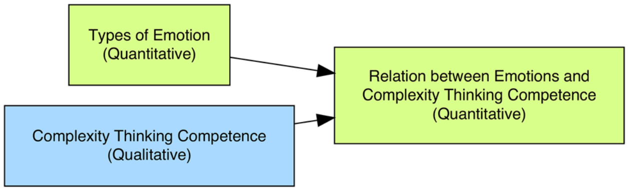

Fig. 2 Design of data analysis

the pre-test only or the post-test only. Table 2 depicts more details of all participating students, including type of school, school year, and pre-/post-intervention survey.

Before participating in k.i.d.Z.21, students as well as their parents gave their written informed consent. At any stage of the survey, they could refuse further participation without giving any reason. In case of problems or questions, the participants or parents could contact the teachers and project team. The quantitative surveys were conducted including pseudonymization via self-generated identification codes (SGIC). The ethics committee of the University of Innsbruck approved the ethical guidelines of the study.

Data analysis

To answer the study's research questions and test the respective hypotheses, a series of quantitative and qualitative analyses were conducted (Fig. 2). First, students' quantitative responses describing their emotions were analyzed, including through exploratory factor analyses, as were their qualitative levels of complexity thinking competence about the climate change consequences on their own lives and on humanity in general. Next, the relationships between students' emotions and levels of complexity thinking competence were tested, including through multilevel modeling.

Analysis of types of emotions

To find the latent dimensions behind the nine measured emotions, an exploratory factor analysis (EFA) was used. The EFA was conducted as a principal component analysis followed by Kaiser varimax rotation. To determine the number of dimensions, the results of a Horn parallel analysis, the visible scree and the factor matrix were assessed while maintaining a minimum number of three items per latent dimension (Watkins 2018). The goodness-of-fit of EFA in general was assessed using the Kaiser–Meyer–Olkin measure of sampling adequacy (KMO-MSA) (Kaiser and Rice 1974).

Analysis of complexity thinking competence

Students' qualitative responses to the open-ended questions were coded consistent with content analysis (Kuckartz 2018; Mayring 2007), with support from the MAXQDA Plus 2020 Network software. Based on Kuckartz (2019) a mixture of inductive, data-driven and deductive, concept-driven categories of complexity thinking were developed for this study. As such, we built on prior research focused on assessing levels of complexity (Kauertz and Fischer 2006) and integrative complexity (Békés and Suedfeld 2019; Baker-Brown et al. 2009), on the Austrian grading system (Rechtsinformationssystem des Bundes 2021) and the competence oriented A-level exams of geography (Bundesministerium für Bildung und Frauen 2012), in order to compile concept-driven categories.

These categories were underpinned by inductive, data driven analysis of the actual data. The category scheme for analyzing these questions followed the main categories: "1—concept", "2—integration clearly evident", "3—distinction and connection of 2", "4—simple, one-dimensional" and "5—not connected", which are defined in Table 3. This category scheme allowed not only mapping individuals' explanations of climate change consequences, but also a

Table 2 Participants during the school year

School	Pre-intervention survey n	Post-intervention survey n	Emotion item type
School year 2012/13			
Gymnasium Eggenfelden	88	91	Noun
School year 2013/14			
Gymnasium Eggenfelden	100	99	Noun
School year 2014/15			
Gymnasium Eggenfelden	99	100	Noun
School year 2020/21			
Five general secondary schools	108	107	Adjective
Three vocational secondary schools	116	116	Adjective

n = number of cases coming from the same school in the same school year. Total number of cases is $2 \times 463 + 98 = 1024$

Table 3 Coding scheme for analyzing levels of complexity

Scale used for the present study	References	**Authentic anchor examples** Translated into English by the authors for better understanding
1—concept » Multiple perspectives—relationship/connectedness/interaction » Part of some overarching view » Far beyond the expectable Significant autonomy	(Kauertz and Fischer 2006; Kauertz et al. 2010; Rechtsinformationssystem des Bundes 2021; Bundesministerium für Bildung und Frauen 2012; Baker-Brown et al. 2009)	"Maybe I will be a farmer someday, therefore climate change, especially changed vegetation will have a huge impact on my harvest yield in one year." - 4 connected elements - Various perspectives: agriculture, climate, vegetation, economy
2—integration clearly evident » Explicit expression of integration = clearly evident (interrelation) » Beyond the expectable Noticeable autonomy		"There will be more floods. Or summers will be so hot and winters so cold that there will be less food and prices will rise." *Although more perspectives are mentioned, only 3 of them can be read to be connected (temperature* ǀ *food production* ǀ *economy)*
3—distinction and connection of 2 » Clear distinction and connection of 2 elements » Specification of conditions » Task fully complied Shortcomings balanced with noticeable autonomy		"It will be warmer therefore sports are going to be more strenuous." *Temperature + relation to humanity*
4—simple, one-dimensional » No sign of conceptual differentiation or integration » Simple, one-dimensional » No links Task mainly complied		"The weather changes."
5—not connected requirements not met	(Rechtsinformationssystem des Bundes 2021)	"I don't know"

This table describes the different levels of complexity used for analyzing the data material and gives authentic anchor examples for each level. Further details about the respective sources consulted as well as more anchor examples can be found in the appendix

categorization of participants' verbal information according to complex thinking processes and IC (Mandl and Huber 1978; Podschuweit et al. 2016; Jennstål 2019; Békés and Suedfeld 2019).

In a first run, two coders independently analyzed 10% of the material to test the applicability of the category scheme (according to Kuckartz (2016), 10% of the data can be sufficient for this initial test). According to the results, the code memos were discussed and refined and the main coding process was carried out (see Appendix for final Code Memos). The lead author analyzed the whole data material and for calculating inter-coder reliability another coder analyzed 40% of the data. The intercoder agreement as a calculation of the relative proportion of matching coding shows a very high degree of agreement at 97%. In line with consensual coding (Kuckartz 2016), cases of different coding were discussed, agreement reached, and corresponding adjustments in the analysis of the entire material were made.

Analysis of the connection between emotions and complexity thinking competence

A mixed model panel regression analysis was conducted to determine the relationship between emotions and complexity thinking competence. Complexity thinking competence was defined as an outcome, in line with the descriptions in the chapter *Emotions in Education and CCE* within this paper. The sociodemographic variable gender, the emotion types found by the EFA, and the time of measurement (pre-/post-intervention survey) were included as predictors. Age could not be included because age was missing from the post-intervention survey in school year 2014/15. Since most students had participated in the survey twice, a random intercept was included for each participant (to account for and present individually different values). The students' pre- and post-intervention questionnaires were merged using the SGIC. The SGIC consisted of five parts (first letter of mother's name, first letter of father's name, month day of birth, gender, year of birth). First, pretest and posttest questionnaires of students from the same school with the same

SGIC (Levenshtein distance zero) were merged. Then, the Levenshtein distance was increased by one. This was done up to Levenshtein distance two. Due to missing values in the outcomes and predictors, individual cases were subsequently deleted. Therefore, the numbers of survey cases sometimes differ within a school. The different schools were also assumed to be a random effect. Multilevel modeling was conducted using R version 4.1.1 and the lmerTest package. Standardized regression coefficients (β) for each predictor were calculated for each outcome by multiplying the unstandardized regression coefficient by the standard deviation of the predictor and dividing by the standard deviation of the outcome. β corresponds to the effect size (Lorah 2018) of a predictor on the outcome. The intraclass correlation coefficient (ICC) was calculated for each random effect and is the ratio of between-cluster variance to total variance. If the ICC is close to zero, it would not be necessary to treat this set of clusters as a random effect. Marginal and conditional R2 are reported as summary for multilevel model fit (Nakagawa and Schielzeth 2013). Difference between full model and baseline is converted to effect size Pearson *r*. Effect sizes (β, *r*, ICC) ≥ 0.1 were considered small, ≥ 0.3 medium, ≥ 0.5 large. *P* values $\leq 5\%$ were considered significant (two-sided NHST).

Results

Two latent emotions underpin the range of emotions triggered by climate change

A principal component analysis with the nine emotions that occur when thinking about climate change resulted in a single-factor or four-factor structure according to the visible scree. KMO-MSA was 0.73, which is middling. The five highest eigenvalues were 2.91, 1.53, 1.18, 0.92 and 0.61. A parallel analysis according to Horn with the upper eigenvalue limit in the 95. percentile (Glorfeld 1995) suggested a three-factorial structure with the five highest threshold values of 1.18, 1.13, 1.09, 1.05 and 1.02. By trying different numbers of factors, followed by a Kaiser-Varimax rotation, two factors resulted in the solution with the largest number of latent dimensions, taking into account that there should be at least three items per dimension. As the focus of this survey was not only to prove that certain types of emotions occur while learning about climate change, but also to find out more about the latent emotions these emotions pertain to and their effect on participants' explanations, the authors decided to choose telling names for the two latent constructs. Therefore, these are called stimulation (*worried, sad, insecure, angry, helpless, inspired to act*) and attenuation (*apathetic, annoyed, hopeful*) in the following, due to their relation to complexity thinking competence as described later in this chapter. The factor matrix is shown in Table 4.

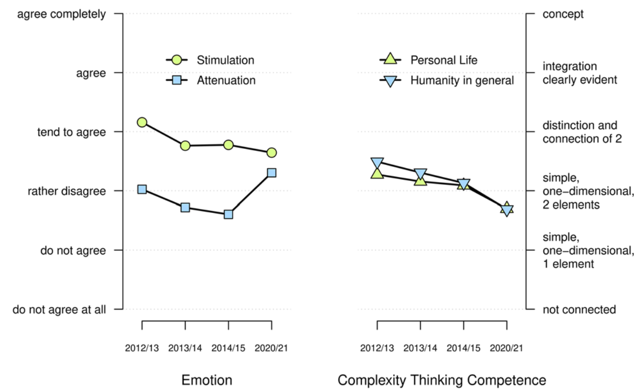

Fig. 3 Descriptive analysis of emotions and complexity thinking competence. Note: Likert scale for emotions in school year 2020/21 is shown. In previous school years, only the two extremes of the Likert scale were labeled (This feeling comes up a lot with this topic/This feeling does not come up at all with this topic). The error bars are not visible because they are only as large as the points, or even smaller

Table 4 Results from an exploratory factor analysis of the Emotions Scale

	Factor loading			
	F1	F2	*M*	SD
Factor 1: Stimulation				
Worried	**0.78**	−0.06	0.53	0.30
Sad	**0.75**	−0.11	0.50	0.31
Insecure	**0.69**	0.18	0.51	0.29
Angry	**0.67**	0.12	0.50	0.31
Helpless	**0.65**	0.21	0.45	0.30
Inspired to act	**0.54**	−0.23	0.65	0.26
Factor 2: Attenuation				
Apathetic	−0.03	**0.83**	0.33	0.31
Annoyed	−0.01	**0.81**	0.39	0.31
Hopeful	0.17	0.30	0.52	0.27

F1 = stimulation. F2 = attenuation. Principal component analysis with Kaiser-varimax rotation. Factor loadings above 0.4 are in bold. *N = 1024*. *M* = mean, possible mean of emotion is scaled and ranges from 0 (do not agree at all) to 1 (agree completely)

SD standard deviation

Although the emotion hopeful cannot unambiguously be classified one of the two found latent factors, the authors decided to assign this emotion to factor attenuation, as Ojala (2017) admits that this emotion leads to denial or de-emphasizing of a serious problem, if not addressed and developed in terms of critical emotional awareness. The mean scores of the two latent dimensions of emotion and the mean scores of complexity thinking competence can be seen separately by school year in Fig. 3.

Relation between emotions and complexity thinking competence

Multilevel Modeling revealed that complexity thinking competence is more pronounced in girls ($\beta = -0.08$, $p = 0.017$). It increases with the feeling of stimulation ($\beta = 0.11$, $p < 0.001$), whereas it decreases with the feeling of attenuation ($\beta = -0.13$, $p < 0.001$). Complexity thinking competence did not change as a result of the *k.i.d.Z.21*-interventions ($\beta = -0.04$, $p = 0.208$). The joint effect of stimulation and attenuation together on complexity thinking competence is small ($r = 0.21$, $p < 0.001$).

Referring to climate change consequences for humanity in general, complexity thinking competence rises with the feeling of stimulation ($\beta = 0.08$, $p < 0.012$) and falls with the feeling of attenuation ($\beta = -0.11$, $p < 0.001$). Here, neither gender ($\beta = -0.06$, $p = 0.071$) nor the *k.i.d.Z.21*-interventions ($\beta = -0.02$, $p = 0.458$) have an influence. The joint influence of emotions on complexity thinking competence is small ($r = 0.17$, $p < 0.001$).

Detailed regression coefficients and model statistics can be seen in Table 5.

To facilitate the interpretation of the effect of the types of emotions, the authors illustrated these within a wheel of emotions inspired by that of Plutchik (2001), based on the results of multilevel modeling (Fig. 4). It is an attempt to arrange the emotions measured as part of this study according to their valence from positive (hopeful) to negative (annoyance and apathy). The green color indicates the factor stimulation, whereas the blue color indicates the factor attenuation, which interestingly do not coincide with emotions' valence.

Discussion

The three main goals of this study were (1) to learn about the types of emotions triggered by climate change in young people and (2) their complexity thinking competence with regard to climate change consequences on their own lives and humanity in general, and (3) to what extent their emotions are associated with enhanced or diminished levels of complexity thinking competence. The results are discussed below.

Emotions and complexity thinking competence

Results show that participants confirm experiencing the queried types of emotions when dealing with climate change. Concerning participants' level of complexity thinking competence, the results also prove varying levels of complexity. Correlating these two central elements via multilevel modeling points to the fact that within the scope of this study, a certain effect of emotions on the complexity thinking competence of participants about climate change could be demonstrated. Apart from a frequently occurring finding in this field of research, namely the negative association between situational or dispositional anxiety and school outcomes like test performance or test grades (Valiente et al. 2012), research has also been carried out on a more general level, highlighting the importance of emotions in education. Social, emotional and cognitive development are deemed to be connected and as having an influence on school performance (Jones et al. 2019; Panayiotou et al. 2019; Schultheiss and Köllner 2014; Pekrun and Perry 2014; Postareff et al. 2017; Gumora and Arsenio 2002), which is in line with the results of this study, since the classification of the types of emotions into factor stimulation and factor attenuation reflects their relevance for complexity thinking competence and, therefore, also for education.

Types of emotions and learning outcomes

Analyzing the effect of emotions on learning outcomes, or in the case of this study, on students' complexity thinking competence, research models commonly classify these into types of emotions having a stimulating or attenuating impact on learning outcomes (Pekrun et al. 2007; Meinhardt and Pekrun 2003; Mitchell and Phillips 2007). The most outstanding result of this study is that both latent constructs of emotion contain positive and negative emotions. The factor attenuation comprising, for example, feeling *hopeful*, as well as *annoyed*, appear to be detrimental for young people's complexity thinking competence in the context of climate change. Similarly, the factor stimulation includes positive as well as negative emotions, like feeling *sad* or *inspired to act,* and correlates with a higher level of complexity thinking competence. By contrast, authors like Ray and Huntsinger (2017) or Mitchell and Phillips (2007) found that positive or negative feelings influence learners' processing styles. Positive moods lead to more creative thinking, and flexible solutions for divergent, heuristic tasks, whereas negative moods are connected to convergent, analytic thinking and focusing on details (Ray and Huntsinger 2017; Mitchell and Phillips 2007). This current study, however, contradicts these assertions, which means that the connection between emotions and learning outcome is not straightforward and may vary between individuals as well as learning situations. This is why critical awareness of emotions and how to manage these in each educational context is vital.

Emotions in climate change communication and ESD

Going beyond the scope of this study, relating the results to the context of climate change communication as well as ESD seems worthwhile. Several studies claim that learners

Table 5 Multilevel Modeling to predict participants' levels of complexity thinking competence based on emotions triggered by climate change

	Personal life				Humanity in general			
	Baseline		Full model		Baseline		Full model	
	B	SE	B	SE	B	SE	B	SE
Regression coefficients for predictors (fixed effects)								
Intercept	2.25*	0.15	2.11*	0.19	2.29*	0.19	2.22*	0.21
Sex	−0.34*	0.09	−0.23*	0.09	−0.23*	0.09	−0.16	0.09
Pretest/posttest	−0.11	0.08	0.10	0.08	0.06	0.07	−0.05	0.07
Stimulation	0.80*		0.23		0.55*		0.21	
Attenuation	−0.96*		0.23		−0.74*		0.22	
Variance components (random effects)								
Students ICC	0.18		0.18		0.18		0.17	
Schoolyear ICC	0.04		0.02		0.08		0.06	
Model statistics								
$R^2_{GLMM(m)}$	0.02		0.04		0.01		0.02	
$R^2_{GLMM(c)}$	0.22		0.22		0.24		0.23	
Comparison of full model with baseline								
Chi square	$X^2(1) = 25.13$, $p < 0.001$*				$X^2(1) = 15.28$, $p < 0.001$*			
r (effect size of emotion)	0.21				0.17			

*$p \leq 0.05$. No significance level correction. Sex: 0 = female, 1 = male. Test: 0 = pretest, 1 = posttest. ICC = intraclass correlation coefficient. $R^2_{GLMM(m)}$ = marginalR^2. $R^2_{GLMM(c)}$ = conditionalR^2. Number of students $N = 561$. $n_1 = 463$ students did pre- and posttest. $n_2 = 98$ students did only pretest or posttest

Fig. 4 Authors' model of correlation between types of emotions and complexity thinking competence. The study's measured emotions are arranged in a "wheel of emotions" inspired by Plutchik's (2001) model. The color indicates the factors stimulation and attenuation

process positive/negative/neutral framed learning materials more efficiently when they themselves are in the respective mood (Frenzel and Stephens 2017; Bower 1981; Kensinger and Schacter 2016). Relevant literature often recommends positive or so-called 'gain' framing of messages describing the benefits of climate-friendly actions rather than the negative consequences of not acting, which in turn leads to more positive attitudes and increased willingness to act (Corner et al. 2015; Rabinovich et al. 2011; Maibach et al. 2010). Although such recommendations usually occur in connection with climate action, the line of argument is similar to the one of this study: a specific emotional state influences learners' processing of information. The results of this study indicate that exclusively positive or negative emotions do not stimulate deep processing of information or complexity thinking competence. Rather a specific mix of emotions comprising the factor stimulation (*angry, sad, helpless, insecure, worried, inspired to act*) is favorable. As one essential part of the research-education-cooperation k.i.d.Z.21 is to constantly improve the learning settings, applying the findings of this study to the settings appear to be self-evident. Therefore, one suggestion to support participants to develop complexity thinking competence is to give them time and the necessary support to handle their emotions already within the according learning settings, for example via explicitly addressing these in research diaries or introducing pedagogical partnerships or a peer system.

Limitations

Although there is a large body of literature on the importance of (key) competences within ESD, the practice of assessing learners' sustainability competences is still in its infancy. This is also a structural limitation of this study, as the assessment of performance observation can be subjective and participants might not fully understand competences. Limitations concerning the scaled self-assessment of emotions are, for example, the unknowable way in which participants interpret the items and that participants might not be able to rate their own feelings subjectively (Redman et al. 2021).

A content-related limitation of this study is that it does not consider the development of the different types of emotions in one particular participant, because these were not assessed continuously during all learning activities. Doing so would open up the opportunity to analyze the possible effect of different types of emotions on one participant's complexity thinking competence and how well he or she is equipped to regulate these types of emotions. Nevertheless, future research on the creation of learning settings considering certain types of emotions, and, for example, their regulation seems to be crucial to gain a sophisticated picture of how the correlation of different types of emotions and complexity thinking competence can be efficiently integrated into CCE.

Conclusion

By investigating the different emotions triggered by climate change and participants' complexity thinking competence about climate change, alongside examining differentiation in their abilities to recognize different pieces of information, perspectives or dimensions, and perceiving connections between these aspects and integrating them (Békés and Suedfeld 2019), this study analyzes how these elements are connected. The results clearly support the hypothesis that there are different groups of emotions either stimulating or attenuating participants' complexity thinking competence about climate change.

This study shows that climate change triggers positive and negative types of emotions. Within the scope of this study, emotions comprising the factor stimulation (*angry, sad, helpless, insecure, worried, inspired to act*) stimulate participants' complexity thinking competence.

In its second line of analysis, this study deals with the differing levels of participants' complexity thinking competence about climate change. The conduction of multilevel modeling revealed that participating in the intervention did not influence participants' complexity thinking competence. Nevertheless, one aim of CCE should be fostering young people's complexity thinking competence.

To foster participants' complexity thinking competence, it is vital to consider different emotions in the context of CCE. An important insight gained via this study is that emotions subsumed under *stimulation* enhance, whereas *attenuation* emotions diminish participants' complexity thinking competence about climate change. This does not mean CCE, or rather climate change educators, should focus on evocation of *stimulation*, but they should be aware of participants' emotions having an influence on their complexity thinking competence and, therefore, also on their learning outcomes.

This leads to the central recommendation resulting from this study's findings. As the affective component, in the form of young people's emotions, occupies a major role in CCE, critical emotional awareness and regulation skills addressing the different types of emotions can contribute to the creation of effective CCE learning settings. The results of this study also indicate an influence on their approaches to dealing with climate change. This leads to the authors' claim for addressing emotional awareness and regulation skills in CCE.

Authentic learning settings based on moderate constructivism (Basten et al. 2015) and transdisciplinarity (Scholz and Steiner 2015; Stauffacher et al. 2006) and encouraging active involvement of participants, like those presented in this study, offer opportunities to include the affective component in CCE. By doing so, CCE interventions may increase the quality and depth of participant's understanding of climate change, which may influence their willingness to continually re-engage with the topic during their lifetimes, and possibly influence their climate-relevant decisions and actions for a climate-friendly future. Furthermore, the mutual impact of complexity thinking competence and emotions could lead to the assumption that a high level of complexity thinking competence can also lead to feeling, for example, helpless, which might subsequently be an obstacle for action. Both aspects are possible approaches for further research.

Appendix

- Original questions used for this study

k.i.d.Z.21
kompetent in die Zukunft

0% ausgefüllt

1. Welche Folgen des Klimawandels könnten Dich zukünftig persönlich betreffen?
Erkläre uns das bitte genauer.

2. Welche Folgen des Klimawandels könnten Deiner Meinung nach die gesamte Menschheit betreffen?
Erkläre uns das bitte genauer.

3. Wie fühlst Du Dich, wenn Du über den Klimawandel nachdenkst?
Wenn ich über den Klimawandel nachdenke, fühle ich mich ...

	stimme überhaupt nicht zu	stimme nicht zu	stimme eher nicht zu	stimme eher zu	stimme zu	stimme völlig zu
ängstlich						
traurig						
hilflos						
wütend						
zuversichtlich						
gleichgültig						
unsicher						
genervt						
handlungsbereit						

4. Abschließend möchten wir Dich noch um einige Angaben zu Deiner Person bitten.

Du bist ... [Bitte auswählen]

5. In welchem Jahr bist Du geboren?

Jahr [Bitte auswählen]

- Levels of complexity

See Table 6.

Table 6 Levels of complexity

Six levels of complexity	German competence model—science education	LBVO	Austrian competency model—geography	Conceptual/integrative complexity score	Scale used for the present study
Kauertz and Fischer (2006)	Kauertz et al. (2010)	(Rechtsinformationssystem des Bundes 2021)	(Bundesministerium für Bildung und Frauen 2012)	(Baker-Brown et al. 2009)	
Generic concept/basic concept	Generic concept/basic concept	1 Far beyond expectations significant autonomy	**Interrelation and interaction clearly visible** Content + method | synthesis | multi-perspectivity | communication | action | reflection **Requirement area III:** Complex application and complex transfer—genuine problem solution	**Score of 7:** » Overarching viewpoint of relationship or connectedness between alternatives » Alternatives described in reasonable detail » Each alternative may be seen to be part of some overarching view	**1—concept** » Multiple perspectives—relationship/connectedness/interaction » Part of some overarching view » Far beyond the expectable » Significant autonomy
Several interconnected relations	Two relations	2 Beyond expectations, noticeable autonomy		**Score of 6: (transitional level)** High-level interaction indicates multiple levels **Score of 5:** Explicit expression of integration = clearly evident	**2—integration clearly evident** » Explicit expression of integration = clearly evident (interrelation) » Beyond the expectable » Noticeable autonomy
One relation	One relation	3 Tasks fully complied, shortcomings balanced with noticeable autonomy	**Requirement area II:** (difficult) reorganization of knowledge | (simple) application and transfer of knowledge	Score of 4: (transitional level) » Implicit integration of alternatives Score of 3 » Clear distinction of at least 2 distinct ways of dealing with the same information held in mind simultaneously » Specification of conditions » No evidence of conceptual integration	**3—distinction and connection of 2** » Clear distinction and connection of 2 elements Specification of conditions » Task fully complied » Shortcomings balanced with noticeable autonomy
Several unconnected relations					
Several unconnected facts	Several unconnected facts	4 Task mainly complied	**Requirement area I:** repetition | (simple) reorganization of knowledge	**Score of 2: (transitional level)** Transition level between score of 1 and score of 3	**4—simple, one-dimensional** » No sign of conceptual differentiation or integration » Simple, one-dimensional » No links » Task mainly complied
Individual fact	Individual facts			**Score of 1:** » No sign of conceptual differentiation or integration » simple, one-dimensional rule for interpreting events or making choices	
		5 Task not complied to meet category 4			**5—not connected** » requirements not met

This table describes the different levels of complexity used for analyzing the data material and the respective sources consulted

- Code memos

General rules for coding
The whole text passage is coded: One document consists of two answers, already coded with PT13 and PT14. These codes refer to the questions. – *PT13: Which CCC may affect yourself?* – *PT14: Which CCC may affect humanity in general?* Each answer gets another code for complexity thinking competence. At the end of the coding process each document includes four codes. There are two identical but separate code-schemata for each question, which makes it possible to distinguish between the two questions. Please, always use the respective code-scheme.
The highest possible code is used: As soon as there is a connection between two elements, it is not possible to use the code 4! If an answer includes one invalid element simultaneously with one valid, one-dimensional element, this answer is coded with “4 – simple, one-dimensional”.
Invalid content: Some contents are coded as “5 - not connected” (to the question). In this case the complexity of the answer is irrelevant. *Examples:* deforestation ∣ waste ∣ pollution (+ air, water, nature…) ∣ ozone layer ∣ exhaust/greenhouse gases ∣ fossile fuels ∣ greenhouse effect ∣ CO2 ∣ future aspect *Exception:* when they are connected and explained in connection with other pieces of information.
Personal relation *Attention:* if an answer doesn’t clearly show why a consequence is directly related to the participant, but is still a valid answer, this is coded as valid answer, because it is a self-assessment of the participant.
Be gracious in terms of expression. This analysis is not about wording or correct spelling, but about how much participants understand. E.g.: climate rise (original: *Klimaerhöhung)* = “4 – simple, one-dimensional”, as it may be seen as a mixture of global warming (German: Klimaerwärmung) and temperature rise.
Arrows The use of arrows, dashes can indicate connections. Line break, comma, point Line breaks, commas and points indicate NO connection. (Attention   is HTML and means line break!)
Special case: natural catastrophe vs. natural hazard Some describe floods or other natural catastrophes and combine this with the term natural hazard, which indicates a connection to humanity. – A natural catastrophe becomes a natural hazard as soon as human beings are involved.

1-concept	
Code-description before coding: **1 - concept** Multiple perspectives – relationship/ connectedness/ interaction Part of some overarching view Far beyond the expectable Significant autonomy	Decision support during coding process: Chain of information with at least three elements Non-obvious connection to another perspective indicated: we don't know exactly what participants (do not) think, therefore we are gracious! Indication that not all regions on Earth are equally affected is a valid perspective. Two great perspectives but only two elements each – no overall connection – is NO Concept!

sample:

1:

Original:

„wenn es im winter hohe Temperaturen gibt d.h zum Beispiel 15°C dann schneit es auch nicht und es müssen künstliche pisten angelegt werden und das schadet der natur"

Translation:

„If there are high temperatures in winter, e.g. 15°C there won't be snowfall and slopes need to be established artificially. This harms nature."

- 4 different elements: temperature, precipitation, slopes (may indicate economy, or tourism), impact on nature
- Various perspectives
- Elements are connected

2:

Original:

„Da ich vielleicht mal Landwirt werde, hat der Klimawandel insbesondere die veränderte Vegetation, großen Einfluss darauf, wie viel Ernte man im Jahr hat"

Translation:

„Maybe I will be a farmer someday, therefore climate change, especially changed vegetation will have a huge impact on my harvest yield in one year."

- 4 connected elements
- Various perspectives: agriculture, climate, vegetation, economy

Difficult cases:

Original:

„Meerwasserspiegel steigt: Viele Inselstaaten könnten versinken, wodurch diese evakuiert werden müssen. So kann es zur Überfüllung der Festlandsländer kommen."

Translation:

„Sea level rises: Many island states could sink, and therefore must be evacuated. A possible result is that mainland is going to be overcrowded."

Such chains of information are common. Only as soon as there is the aspect of „Problems within the target region" is included, this is code das concept. Otherwise: "2-integration clearly evident".

<table>
<tr><th colspan="2">2 – integration clearly evident</th></tr>
<tr><td><u>Code-description before coding:</u>
2- integration clearly evident
Explicit expression of integration = clearly evident (interrelation)
Beyond the expectable
Noticeable autonomy</td><td><u>Decision support during coding process:</u>
3 elements must be clearly connected – not mentioned next to each other or implicit connection</td></tr>
<tr><td colspan="2"><u>sample:</u>
1:
Original:
„Wenn es immer wärmer wird und man keinen Schnee mehr auf den Gletschern zum Schifahren hat.
Land wird überflutet“
Translation:
„If it is going to be warmer, and there will be no snow on the glaciers for skiing.
 land is going to be flooded”

Although there are 3 elements only the colored ones are connected – therefore code 2 – integration clearly evident.

2:
Original:
„Das es immer mehr hochwasser gibt oder
das es so heiß wird im Sommer und so kalt im Winter, dass es weniger zum Essen gibt und die Preise bei allem steigen,
das es immer mehr arme und mehr reiche gibt, das es die wunderschöne welt nicht mehr gibt“
Translation:
„There will be more floods. Or
summers will be so hot and winters so cold that there will be less food and prices will rise,
there will be moor poor and more rich people, that our beautiful world won’t exist anymore.”

Although more perspectives are mentioned, only 3 of them can be read to be connected (temperature | food production | economy).

3:
Original:
„Der Klimawandel verschlimmert sich und nicht austragbare Hitzen tauchen auf, wodurch Waldbrennte und andere Katastrophen passieren.“
Translation:
„Climate Change gets worse and unbearable heat waves emerge, therefore forest fires and other catastrophes happen.”

– 3 perspectives
– Forest fire and other catastrophes are on the same level, because they seem to be results of heat – therefore „2 – integration clearly evident“.</td></tr>
<tr><th colspan="2">3 – distinction and connection of 2</th></tr>
<tr><td><u>Code-description before coding:</u>
3 – distinction and connection of 2
Clear distinction and connection of 2 elements</td><td><u>Decision support during coding process:</u>
One element describes the other | is a consequence of the other | depends of the other | is somehow connected to the other</td></tr>
</table>

<table>
<tr><td>Specification of conditions
Task fully complied
Shortcomings balanced with noticeable autonomy</td><td>May be more than one pair! (e.g. 3x2 that are not interconnected)</td></tr>
<tr><td colspan="2"><u>sample:</u>

1:
Original:
„Es wird wärmer und somit wird Sport anstrengender“
Translation:
„It will be warmer and therefore sports are going to be more strenuous.”

Temperature + relation to humanity

2:
Original:
„Erwärmung
Pflanzen Veränderungen, bezüglich Garten“
Translation:
„Warming
changes of plants, concerning garden”

(
 means line break in HTML)
Indication of (own) gardening => changes of vegetation may have an influence on working in the own garden.</td></tr>
<tr><td colspan="2"><u>Difficult cases:</u>

1:
Original:
„Da es weniger bewohnbare Gebiete geben würde, könnte es zu einem Krieg kommen. Ich denke Mitteleuropa wird es aber als letztes Treffen.“
Translation:
„As there will be less habitable areas, there could be war. I think Central Europe will be the last to be affected.”

The difficulty lies within the interpretation of an answer. In this case, the elements indicate more than is actually written down. => „less habitable areas“ could mean: temperatures rise, therefore polar ice melts, therefore sea level rises and coastal areas get inhabitable. BUT this is not written down – therefore NO concept but „3 – distinction and connection of 2“, because the orange part is defined as invalid content.

2:
Original:
„Man kann viele hobbies wie zum beispiel das skifahren nicht mehr betreiben und auch viele Tiere werden sterben müssen. Das Wasser wird noch knapper, das ist dann in den armen Ländern noch ein größeres Problem als zurzeit.“
Translation:
„We can’t carry out many hobbies anymore, like for example skiing, and many animals are going to die. Water is going to get even more scarce, which will be a more relevant problem in poor countries than it is today.”
=> much more is included in this answer, but onle 2 elements are really connected (water scarcity leads to a more serious problem in poor countries.</td></tr>
</table>

<table>
<tr><th colspan="2">4 – simple, one-dimensional</th></tr>
<tr><td>Code-description before coding:
4 – simple, one-dimensional
No sign of conceptual differentiation or integration
Simple, one-dimensional
No links
Task mainly complied</td><td>Decision support during coding process:
Here the difficulty lies within the assessment of valid vs. invalid answers. Single word answers make the interpretation really hard. Only answers that are completely nonsense (e.g. zombieapokalypse) or belonging to “invalid content” (see general rules for coding) do not belong to this code.</td></tr>
<tr><td colspan="2">sample:
Original: "Erderwärmung" | Translation: “global warming”:
– not really sophisticated but ok. Okay
Original: "die veränderung des Wetters" | Translation: „The weather changes“
Original: "Hitze" | Translation: "Heat“
Original: "Klimaflüchtlinge" | Translation: “Climate refugees”
Original: "kein skifahren mehr
Krankheiten" | Translation: “no more skiing
illnesses“

Original: "Erderwärmung Knappheit von Wasser Abholzung der Regenwälder"
Translation: “Global warming scarcity of water deforestation of rainforests”
– no visible connection therefore „4 – simple, one-dimensional“</td></tr>
<tr><td colspan="2">Distinction of subcodes:
4.1: 1 element => consisting of only ONE element
4.2: 2 elements => consisting of TWO or MORE UNCONNECTED elements</td></tr>
<tr><th colspan="2">5 – not connected</th></tr>
<tr><td colspan="2">Code-description before coding:
5 – not connected
requirements not met</td></tr>
<tr><td colspan="2">Distinction of subcodes:
5.1: I don’t know:
Participants indicate that they do not know the answer – also kA /idk (Abbreviation of keine Ahnung/I don’t know)
Attention: – kA/idk + valid answer belongs to the higher code, because the valid answer shows that the participant knows an answer.

5.2: empty field => dash/ point
5.3: answer not connected to the question:
– some letters
– Original: zombieapokalypse |Translation: zombie apocalpyse
see „invalid content“ general coding rule</td></tr>
<tr><td colspan="2">Note. Colors in this table indicate one element within an answer</td></tr>
</table>

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Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

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