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Is it possible to build adolescents' cognitive adaptive capacity through climate change education? Insights into a two-year long educational programme in North Tyrol (Austria) and South Tyrol (Italy)

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ABSTRACT

Adapting to anthropogenic climate change requires informed citizens capable of managing personal and societal risks. This study explores the contribution of climate change education (CCE) to build adolescents' cognitive adaptive capacity. As defined by Grothmann and Patt's (2005) *Model of Private Proactive Adaptation to Climate Change* (*MPPACC*), cognitive dimensions of adaptive capacity correspond to *climate change risk perception* and *adaptation appraisal* as preconditions for individual adaptation actions. Their model has been operationalised to examine adolescents' cognitive adaptive capacity in a pre-test–post-test design, and the educational programme *Generation F^3–Fit for Future* is presented as a quasi-experiment linking this concept with CCE. Because cognitive adaptive capacity is a complex and multifaceted concept, this contribution also studies the influence of CCE on *knowledge* and *thinking skills*, which are important dimensions as well. Overall, 173 upper-secondary school students aged between 16 and 18 years actively collaborated with 57 scientific and practical experts on climate change adaptation (CCA) in North and South Tyrol. Additionally, the programme included control groups. Over two school years, *Generation F^3–Fit for Future* encouraged students to follow constructivist inquiry-based CCE, and they carried out their own research-oriented CCA projects. A mixed methods approach compared data from a multivariate multilevel mixed model collected by web-based questionnaires (N = 231) and qualitative data from problem-centred interviews (N = 47), which were analysed by documentary method. The results suggest a mismatch between quantitative and qualitative data. Quantitative data do not show any change in adolescents' *risk perception* and *adaptation appraisal*, but qualitative data reveal that intervention group students demonstrated increased levels of *adaptation knowledge* and elaborated *critical* as well as *forward thinking skills*. Control group students did not show such capacities after standard curriculum education. It is concluded that CCE holds potential to build several dimensions of adolescents' cognitive adaptive capacity. Upcoming

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research should further explore mixed research approaches and advance adaptive capacity theory to better understand this concept.

1. Introduction

For decades, the scientific community has been providing unequivocal evidence of dangerous human interference with Earth's climatic system. From the beginning of the industrial age to the period 2006–2015, global mean land surface temperature has increased by +1.53 °C, triggering abnormally hot weather, droughts, heavy precipitation events and sea level rise (IPCC, 2019). Societies across the globe are affected in manifold ways by these and other more indirect climate impacts and unmitigated warming makes them increasingly vulnerable (Carleton and Hsiang, 2016). In short, some consequences like health issues or damage to infrastructure are unavoidable, and most national mitigation policies remain insufficient to meet the 2015 Paris Agreement (Rogelj et al., 2016). Thus, preventive and preparatory efforts must be taken to enhance peoples' adaptive capacity (i.e., the ability to moderate, or avoid harm from climate change consequences and to seize opportunities) (Thomas et al., 2018; UNFCCC, 2015).

The literature also suggests that current young people are and will be more intensively challenged by observed and projected impacts of anthropogenic climate change than any other generation before (Corner et al., 2015, Hansen et al., 2017). Particularly, if business-as-usual warming continues over the coming decades, they could suffer from more intense heatwaves in cities, new spreading infectious diseases and unexpected social disruptions (Watts et al., 2018). Some impacts, however, cannot be completely avoided even if current global mitigation efforts turn out to be fully successful and for most of today's adaptation decisions, children and adolescents rely on adults (UNICEF, 2015). To minimise their specific vulnerability to climate-related risks, current and future young generations depend upon prompt mitigation as well as adaptation actions alike by all global leaders, who, have, however, been failing for decades to act on climate scientists' warnings appropriately (Lawson et al., 2019).

1.1. Climate change adaptation and the role of education

In the face of an accelerating global climate crisis, it is vital to ask this question: What is the role of education in enhancing adaptation? According to a literature review from Lee et al. (2020), the trust in science that climate change is happening among youth is high and similar to adults. However, there appears to be some disconnection between perceived effectiveness of individual climate actions and willingness to act. Moreover, the understanding of mitigation or adaptation solutions among different members of youth is often reported to be superficial and includes misconceptions. To overcome this situation, climate change education (CCE) and learning could serve as promising strategies for reducing adolescents' future vulnerability to climate-related risks and can shape their capacity for taking adaptive actions (Kagawa and Selby, 2012). Beyond education that provides basic and numerical skills (Muttarak and Lutz, 2014), CCE, which is often more specific, provides understanding of the causes, effects and consequences of anthropogenic climate change and helps to develop competencies to eventually act climate-friendly (Anderson, 2012). CCE directly contributes to capacity-building (Lutz et al., 2014), for example by developing young learners' systemic and holistic thinking skills and preparing them to better understand adaptation actions as well as their consequences for solving the global climate crisis. Fazey et al. (2007) similarly recognise this, arguing that knowing about impacts of current behaviour, knowing about appropriate direction of change and knowing about how to achieve change can strengthen individual adaptive capacity.

More generally, the practice of CCE directly contributes to realising synergies among the United Nations' *Sustainable Development Goals (SDGs)*, especially between *SDG 4 'Quality Education'* and *SDG 13 'Climate Action'* (UNESCO, 2017). In this context, CCE may be treated as a direct investment in peoples' abilities to understand climate-related risks with which they are likely to be confronted with, and potential adaptation measures they could undertake (Striessnig et al., 2013). Furthermore, following a whole institution approach, school infrastructure itself could be made more resilient and safe against site-specific climatic impacts and reduce its carbon footprints through better insulation and the use of renewable heating technologies (UNESCO, 2016).

This paper draws from various disciplines, such as climate science, education and social psychology to argue that by providing situated and creative learning environments to adolescents (Whitney et al., 2017), CCE does far more than simply create knowledge about causes of global warming (Mochizuki and Bryan, 2015). In addition to promoting deeper understanding of causes and climate response, CCE can foster cognitive competences that are useful for both future mitigation and adaptation actions, such as forward-looking or the ability to recognise personal opportunities as well as barriers for a climate-resilient living (Ledley et al., 2017). According to Tschakert and Dietrich (2010), the competences of uncovering underlying factors of vulnerability, creating visions for alternative futures, and avoiding maladaptation from an early stage, are strengthened by forward thinking. Furthermore, Anderson (2012) argues that adaptation to an uncertain future requires educational approaches that strengthen cognitive dimensions of adaptive capacity among individuals, such as the development of critical thinking and the ability to deal with unexpected climate-related risks.

Against this background, this contribution focuses on cognitive factors of adaptive capacity and the importance of learning in shaping them (van Valkengoed and Steg, 2019). It examines the influence of a two-year CCE programme on upper-secondary school students' cognitive adaptive capacity and thereby addresses several cognitive determinants including thinking skills. Thereby, the educational interventions provided by the educational programme and quasi-experiment *Generation F^3–Fit for Future* are evaluated (see Background). As most adaptation research overlooks cognitive phenomena at the individual level (Oakes et al., 2016), this experimental study compares selected dimensions of cognitive adaptive capacity and competences of upper-secondary school students participating in the educational programme with control group students receiving standard curriculum education only.

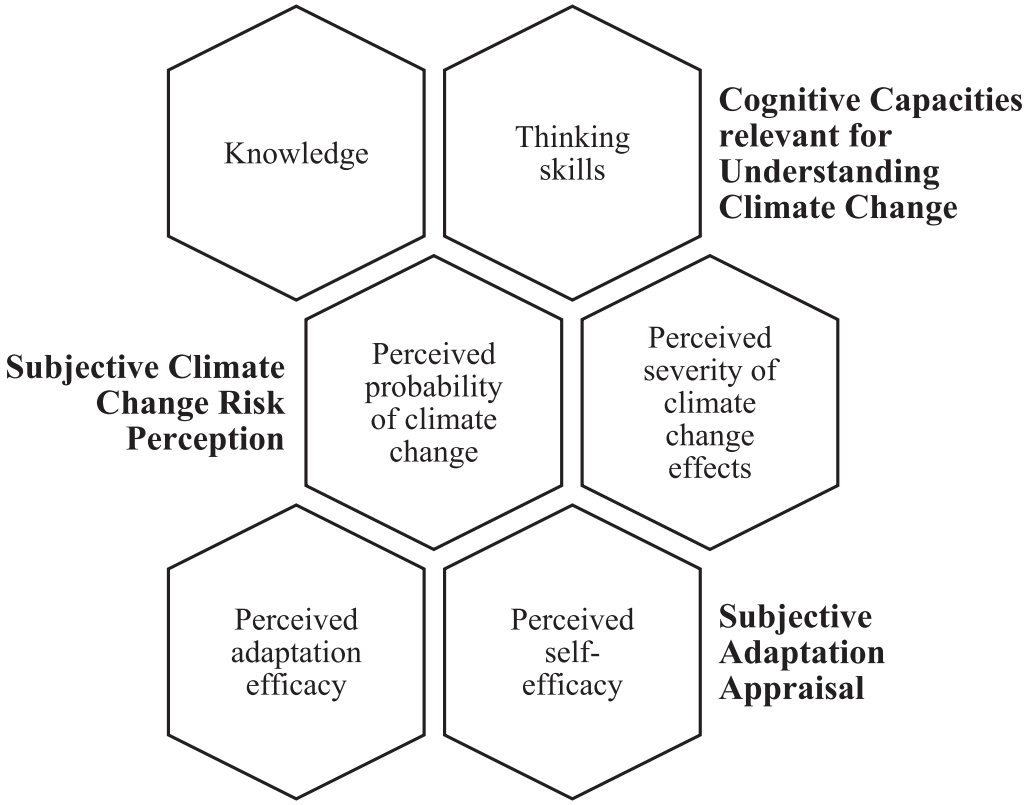

Fig. 1. Individual cognitive adaptive capacity is a complex and multifaceted construct. This study is an attempt to assess the effectiveness of climate change education to strengthen six selected dimensions building cognitive adaptive capacity based on Grothmann and Patt (2005), Muttarak & Lutz (2014), Stevenson et al. (2017) and Fazey et al. (2007).

1.2. Adaptive capacity, cognition and climate change education

Realised adaptations are understood as real-life manifestations of peoples' or systems' adaptive capacities and adaptive capacity refers to human abilities to adjust to potential negative consequences and to seek opportunities in anthropogenic climate change (Smit and Wandel, 2006). At the individual level, adaptive capacity is shaped by more than technological, financial and social resources. These 'objective' factors however do not entirely explain to what degree cognitive factors, such as knowledge, thinking skills, climate risk perception and problem-solving competences determine individual adaptive capacity and how they mediate adaptation behaviour (van Valkengoed & Steg, 2019). To understand why some people perform better in adaptation than others, Mortreux and Barnett (2017) studied additional psycho-social factors such as personal experience with adaptation, trust in authorities and belief in the effectiveness of adaptation measures. Furthermore, Adger et al. (2009) emphasise human cognition as a leverage point for solving adaption problems relevant to society. They argue that the ways in which individuals perceive their vulnerabilities and whether they belief in adaptation strategies (or not), have the potential to constrain collective adaptation efforts significantly.

This study builds on a framework from Grothmann and Patt (2005) that provides an elaborated understanding of how human cognition shapes individual adaptive capacity. Drawing in turn from *Protection Motivation Theory* (*PMZT*) (Rogers, 1983), their *Model of Private Proactive Adaptation to Climate Change* (*MPPACC*) includes two main cognitive dimensions that mediate private and proactive adaption, namely (1) *climate change risk perception* and (2) *adaptation appraisal*. The first dimension, *climate change risk perception,* explains how individuals perceive the likelihood of being exposed to climatic effects (so-called *perceived probability*) and how they judge consequences of climate change (so-called *perceived severity*). For instance, individuals examine their exposure to a heatwave and judge the degree they could suffer from it. According to Slovic (1987), both kinds of perceptions are preconditions for adequate risk response at the individual level. The second dimension, *adaptation appraisal,* explains the degree to which adolescents believe in the effectiveness of adaptation measures in protecting them or others (so-called *perceived adaptation efficacy*) as well as their ability to implement adaptation measures by themselves (so-called *perceived self-efficacy*). For instance, individuals appraise the relief that results from cooling behaviours during a heatwave and evaluate their ability to carry them out. Together, *climate change risk perception* and *adaptation appraisal* can enhance or constrain human adaptive capacity (Grothmann and Patt, 2005).

Previous research also reveals that basic understanding of climate change and *knowledge* for climate-response shape an individual's cognitive adaptive capacity. Understanding the ways in which humans are interfering with Earth's climatic system (cause-knowledge), comprehending direct and indirect consequences on human and natural systems (impact-knowledge) and understanding incremental

and transformative adaptation translate to higher *risk perception*, as well as stronger *adaptation appraisal* (van der Linden, 2015). There is also ample empirical evidence of *knowledge* and *thinking skills* shaping adaptation understanding and behaviour. Williams et al. (2015) show that *knowledge* of long-term climate change effects encourages people to take proactive approaches, and Oakes et al. (2016) reveal that knowing local environmental changes makes a difference in what adaptations are carried out by forest managers in order to anticipate climate-induced forest dieback in Alaska. Furthermore, findings from Esham and Garforth (2013) suggest cognition to be equally important as socio-economic factors in taking of adaptation measures in a farming community in Sri Lanka.

Both relevant theory and corresponding empirical works clearly indicate the importance of cognitive competencies for building adaptive capacity and demonstrate the potential role of CCE for preparing individuals for carrying out adaptation actions. This study links climate, educational and psychological research by hypothesizing that CCE directly contributes to building adolescents' cognitive adaptive capacity. It is believed that through learning adolescents cultivate their *climate change risk perceptions*, *adaptation appraisals*, *knowledge levels* and *thinking skills*, all of which are important for better understanding of climate change and the development of individual adaptive capacities (see Fig. 1).

1.3. Research questions and hypotheses

In examining adaptive capacity at the individual level, exceptionally different approaches can be taken Lockwood et al. (2015) and Engle (2011) encourages experimenting with novel methods to further investigate this complex concept. This study combines quantitative and qualitative methodologies to investigate several dimensions of upper-secondary school students' cognitive adaptive capacity developed through innovative CCE, as compared to control group students in standard curriculum education. Because it remains open to debate in the context of education how to assess adaptive capacity at the individual level in a holistic and meaningful way, this study focuses only on the dimensions of *knowledge*, *thinking skills*, *climate change risk perception* and *adaptation appraisal*, and thereby ignores other dimensions like past experience with climate risks, reliance on public adaptation or fatalism. The decision to focus on these particular six dimensions was motivated by the educational design of *Generation F^3–Fit for Future*, which is very well in line with state-of-the-art CCE teaching strategies according to Monroe et al. (2017), but did not address past experiences, reliance on public adaptation or fatalism systematically. Mixed research is further argued to be suitable for describing complex phenomena, such as cognitive adaptive capacity, and offsets the weaknesses of each approach used by itself (Johnson and Onwuegbuzie, 2004). In education and other fields such research designs are chosen for investigating challenging (and often fuzzy) questions that cannot be answered by one research paradigm alone (Leech and Onwuegbuzie, 2009). Against this background, this paper focuses on the superordinate research question: *Can CCE contribute to building upper-secondary school students' cognitive adaptive capacity?*

Attempting to provide comprehensive answers, the inquiry process of this study takes two directions. Quantitative analysis examines the potential effects of CCE on upper-secondary school students' cognitive adaptive capacity at intervention and control group levels in terms of *climate change risk perception* and *adaptation appraisal*. No control group effects are expected. The four research hypotheses are as follows:

- H1: CCE provided by *Generation F^3–Fit for Future* will influence upper-secondary school students to increase their *perceived probability of climate change*.
- H2: CCE provided by *Generation F^3–Fit for Future* will influence upper-secondary school students to increase their *perceived severity of climate change effects*.
- H3: CCE provided by *Generation F^3–Fit for Future* will influence upper-secondary school students to increase their *perceived adaptation efficacy*.
- H4: CCE provided by *Generation F^3–Fit for Future* will influence upper-secondary school students to increase their *perceived self-efficacy*.

To complement hypothesis testing, a qualitative method is followed to investigate the degree to which upper-secondary school students show *knowledge* and *thinking skills* after CCE, which are important dimensions of cognitive adaptive capacity on their own (Fazey et al., 2007, Stevenson et al., 2017) and partly feed into Grothmann and Patt's (2005) *climate change risk perception* and *adaptation appraisal*. Intervention group students' *knowledge* of CCA and *thinking skills* after CCE are investigated through problem-centred interviews and compared to the results from control group students in standard curriculum education. The research question used in the documentary analysis of transcripts from problem-based interviews is as follows: *What differences in adaptation knowledge and thinking skills can be observed between upper-secondary school students after CCE (intervention group) and upper-secondary school students after standard curriculum education (control group)?* In a final step, quantitative and qualitative findings are comparatively discussed to find robust answers to the superordinate research question. It is important to note that this research question is novel, and cognitive adaptive capacity is to our understanding still unexplored in CCE research.

2. Background: The research–education cooperation *Generation F^3–Fit for Future* as a means of active and participatory CCE in North Tyrol (Austria) and South Tyrol (Italy)

According to Gobiet et al. (2014), projected 21st-century climate change in the European Alps will lead to manifold impacts which are expected to challenge adaptive capabilities of Alpine communities. Against this background, from 2017 to 2019, the research–education cooperation *Generation F^3–Fit for Future* initiated a science–society collaboration on adaptation problems in North Tyrol (Austria) and South Tyrol (Italy) between 173 upper-secondary students (between 16 and 18 years old, grades levels 5–7 in the

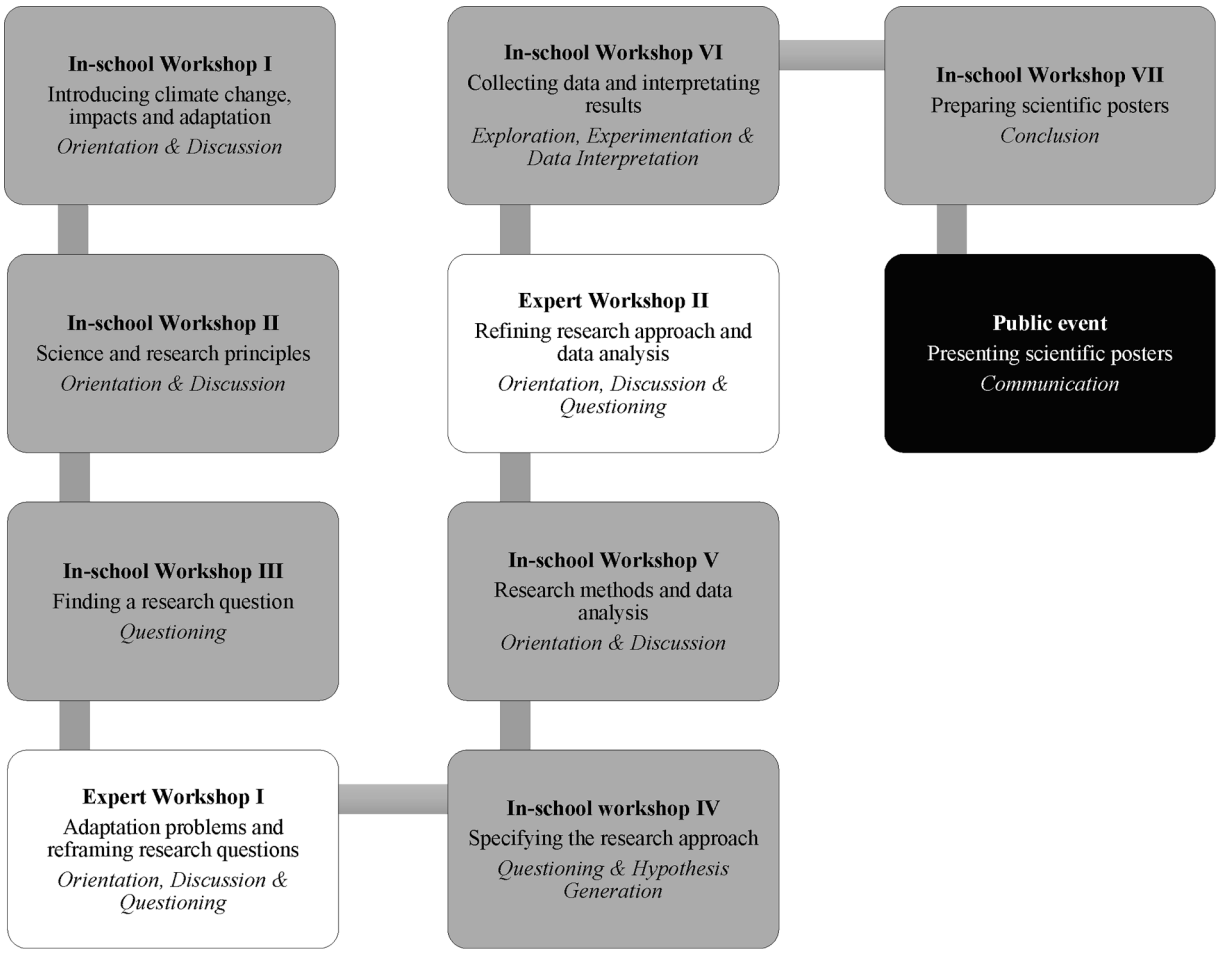

Fig. 2. Milestones and workflow of the educational programme *Generation F³–Fit for Future* and the connection of in-school workshops (grey), expert workshops (white) and the final event (black) with the inquiry cycle described by Pedaste et al. (2015). Each single box describes the content that was mainly addressed in the expert workshops or in-school workshops.

secondary level II of the Austrian education system), 57 adaptation experts from within and outside of academia and five upper-secondary school teachers. All teachers taking over responsibility in the project and helping to organise the educational interventions were also involved in the development of the project proposal. Intervention and control group classes participated in the educational project voluntarily. A *'community of learners'* between teachers, students and adaptation experts (Rogoff, 1994) was developed and implemented at four different secondary schools for two consecutive school years (2017/18 and 2018/19) with two separate cohorts of intervention group students. The research–education cooperation followed a moderate-constructivist approach, which means that learning processes have started with students' individual conceptions of CCA (Keller et al., 2019) and real-life adaptation problems were an essential part of the education design. Applying inquiry-based learning (see final paragraph of this section), upper-secondary school students discovered climate-specific vulnerabilities and adaptation behaviours in different societal sectors in their home regions, such as the economy, health sector, agriculture, forestry, tourism and infrastructure. The students developed their own research questions and were supported by experts and teachers in investigating adaptation among different societal groups, such as farmers, tourism managers, and private households. Participating in CCE, intervention group students co-produced original and place-specific knowledge for adaptation in North and South Tyrol (Cutter-Mackenzie and Roussel, 2019). All in all, *Generation F³–Fit for Future* is expected to have supported intervention group students building both their *climate change risk perceptions* and *adaptation appraisal*, alongside with their *knowledge* for adaptation and *thinking competences* relevant for understanding adaptation actions. Control group students received standard curriculum education and did not actively participate in the CCE intervention.

Generation F³–Fit for Future is treated as a pilot experiment testing a CCE approach tailored to the topic of adaptation (see Fig. 2). Throughout both study years, the quality of the educational intervention has been steadily improved by applying a hermeneutic circle (Kezar, 2000). In the first year, the authors developed an understanding of the effectiveness of their education to build adolescents' cognitive adaptive capacity by engaging with intervention group students. In the second year, in order to increase its effectiveness, the educational programme was adapted and refined according to an external evaluation and the first empirical analysis of intervention

Fig. 3. Intervention group students presenting their original research on adaptation in a public event in Bolzano, South Tyrol (Italy) (Source: Eurac Research).

group students' learning outcomes (see Schrot et al., 2019).

Overall, the educational programme featured seven in-school workshops (each 100 min long) while two additional expert workshops (full day) offered space for extensive collaboration between students and adaptation experts (Moser, 2014). The interventions started at the beginning of each school year and were evenly spread over all months until the end of the school year to establish a routine for the students. In-school workshops strictly followed the inquiry learning cycle as described by Pedaste et al. (2015), and members of the project team and experts accompanied the students' learning processes. There were continues meetings between the project team and the teachers and they were assisted in redesigning their own lessons. At first, the intervention aimed at creating curiosity about CCA among the participating students (*Orientation*) and starting to develop their own research questions relevant to their home-regions (*Conceptualization*). During the next step, experts supported students in finalising their research concepts (content and method), and the students started collecting empirical data in their communities (*Investigation*). Students then analysed their data, answered their research questions (*Conclusions*). In a final event and in follow-up meetings they presented and discussed their research outcomes publicly (*Discussion*) with high-profile regional stakeholders (Roland Psenner, the president of Eurac Research Bolzano; Arnold Kompatscher, the head of the province of South Tyrol; and Markus Reiterer, the secretary general of the Alpine Convention) (see Fig. 3).

To build upper-secondary school students' cognitive adaptive capacity, the educational interventions aimed at raising awareness about existing and expected consequences of anthropogenic climate change in North and South Tyrol. Interventions included scientific key note presentations and discussions, adaptation role-plays and, in particular, dealt with questions how to do research and present scientific results using scientific posters (see Fig. 2). *Climate change risk perception* has been addressed, linking climate-related risks with human vulnerabilities in communities and different economic sectors. *Adaptation appraisal* has been targeted by discussing temporal aspects of adaptation strategies and the effectiveness of different adaptation behaviours. During the two expert workshops, students were given the opportunity to identify and discuss climate change impacts in their home regions as well as adaptation solutions, which has addressed *climate change risk perception* and *adaptation appraisal*. While doing their own research on CCA, the adolescents needed to think systematically and dealt with the most common state-of-the-art knowledge on climate change risks and had to reflect upon incremental and transformational adaptation options.

3. Methodology

3.1. Research design and sampling

The study employed a quasi-experimental design (Horn et al., 2009), and taking a psychometric approach for the quantitative part of the investigation was particularly motivated by Lockwood et al. (2015). Data were collected before and after CCE and standard curriculum intervention. After the removal of outliners and missing data due to absences at the day of pre- and/or post-tests, the final sample for the quantitative analysis comprised 133 upper-secondary school students participating in CCE over one school year each

(intervention group) and 98 upper-secondary school students following standard curriculum education (control group) over one school year each. The students (56 percent female) came from two secondary schools in North Tyrol (Austria) and two secondary schools in South Tyrol (Italy). All were German-speaking. Students were not randomised because real-life class situations had to be maintained. Qualitative analysis used a much smaller sample. The interviews were conducted with intervention group students ($N = 25$) and control group students ($N = 22$) from both study years. The interview sample, however, was randomized to avoid that only students with high motivation or interest in climate change were interviewed.

3.2. Quantitative analysis and data collection

A web-based survey was developed to study intervention and control group students' cognitive adaptive capacity (Alessi and Martin, 2010). Items were operationalised according to Grothmann and Patt's (2005) *MPPAAC* and addressed the dimensions of cognitive adaptive capacity dealing with *climate change risk perception* and *adaptation appraisal*, each dimension having two sub-dimensions, namely (a) *perceived probability*, (b) *perceived severity*, (c) *perceived adaptation efficacy* and (d) *perceived self-efficacy*. The wording of the items did not come from another study because there is no comparable study on the nexus between adaptation and CCE using more standardised items. Confirmatory factor analysis was then applied to determine if the measured variables represent the four selected dimensions (see Table 2, Annex). For each dimension of cognitive adaptive capacity, the internal consistency with Cronbach's alpha was calculated. Cronbach's alpha for the three *perceived probability* items was 0.72, and for the three *perceived severity* items 0.55. Moreover, Cronbach's alpha for the four *perceived adaptation efficacy* items was 0.59, and for the four *perceived self-efficacy* items 0.78. A multilevel regression model was designed and combined all treatment and control classes for each year. Time (pre-test & post-post) and the group (intervention & control) were treated as fixed effects in the model, whereas the schools were treated as a random effect. In a final step, the pre-post differences within treatment and control groups and pre-post differences between intervention and control groups were measured using a statistical *t*-test. Significance level was $p \leq 0.05$. The intervention is expected to result in an increase in the individual outcome variables from the pre-test to the post-test in the intervention group, but not in the control group. Therefore, a baseline was defined, which represents the overall model of an outcome variable without the interaction term intervention $\times$ post-test. For each outcome variable, the overall model was compared with this baseline.

3.3. Qualitative analysis and data collection

According to Engle (2011), adaptive capacity is a latent construct, which means it must be mobilised prior to measurement. To complement the web-based survey, problem-centred interviews (Witzel, 2000) were designed to make upper-secondary school students' *knowledge* of CCA and *thinking skills* visible. It is important to note that the interviews were also constructed to provide more background information on students' *risk perception* and *adaptation appraisal*. The interviews were semi-structured and encouraged students to report about and reflect upon real-life adaptation issues in their home regions. Students could choose from the topics as far apart as tourism, agriculture, health and natural hazards, each presenting typical climate-related risks for North and South Tyrol. By questioning and re-questioning, students were asked to identify societal vulnerabilities as well as climate change impacts and were asked to discuss adaptation behaviours associated with the chase chosen (see Table 3, Annex). In the interviews, scientific graphs and photos of such adaptation behaviours were used to make their understanding of the adaptation process more explicit (Richard and Lahman, 2015). After the interviews were transcribed verbatim, the intervention and control group findings were analysed and contrasted using documentary method. Interview data were collected and codes were developed as well as analysed by two authors. Before analysis, the transcripts and codes were given to other authors of the study to perform an inter-coder reliability check.

Documentary method is a frequently used method in qualitative social research to reconstruct meaning from interview transcriptions (Nohl, 2017) and employed three analytical phases. The *formulating interpretation* summarized content and asked, *'What is the text about?'*. Then, the *reflecting interpretation* asked, *'How is the problem dealt with?'* and clarified descriptions as well as argumentations demonstrated by the interviewees. In a final step, all findings from intervention and control group students were compared and more generalized types of students' cognitive adaptive capacity were identified (Nohl, 2010). Interview codes were the same for the intervention and control group, and were developed according to the selected dimensions of cognitive adaptive capacity. For example, if a respondent talked about the plausibility of climate change impacts in their surroundings, and how people could be affected by them, his or her answer was coded as to *perceived probability* and *perceived severity*. If this person was then able to name potential adaptation actions and could differentiate between their relative effectiveness, the answer was coded as to *knowledge* and *perceived adaptation efficacy*. And, if he or she was critical or naïve about different adaptation techniques or behaviours, this was coded as to *thinking skills*. Martens and Asbrand (2009) argued for documentary method as a valid tool to evaluate a person's cognitive performance, and in this study the method was used to reconstruct upper-secondary school students' cognitive abilities for adaptation after CCE intervention or standard curriculum education. It is important to note that the qualitative analysis is more than a focus on straightforward knowledge or high-order thinking skills assessment. Next to so-called objective codes (i.e. the researchers' constructions of common themes after comparative analysis), it also emphasizes the climate change understanding of the interviewees. For example, the reflective analysis examined, if respondents were able to outline meaningful connections between their own lives or the lives of family members with current adaptation challenges in North or South Tyrol as well as their personal feelings he or she had had during the educational project.

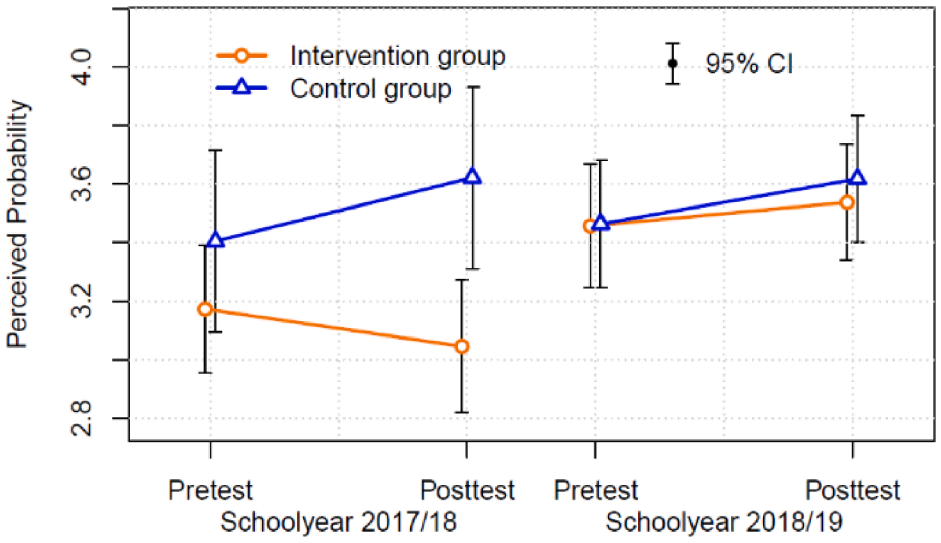

Fig. 4. Mean plot of the dimension *perceived probability* for the school years 2017/18 and 2018/19.

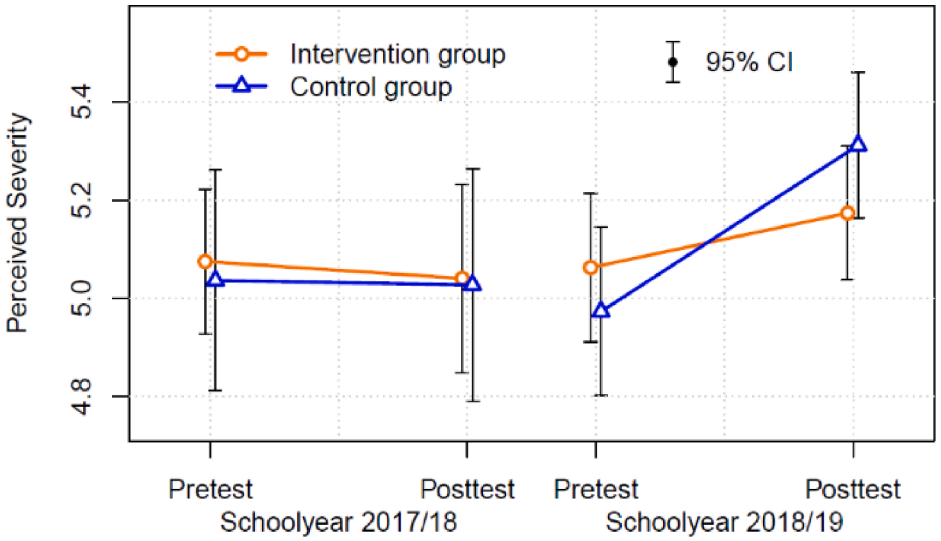

Fig. 5. Mean plot of the dimension *perceived severity* for the school years 2017/18 and 2018/19.

3.4. Triangulating survey and interview findings

A triangulation of survey and interview findings in the discussion section should avoid misinterpretations between group effects and individual effects (Kemper, 2008). Moreover, it provides a cross-check of findings (Bryman, 2006), as the measurement of adaptive capacity involves uncertainty *per se* (Adger and Vincent, 2005).

4. Results

4.1. Upper-secondary school students' cognitive adaptive capacity after climate change education versus standard curriculum education in the first year and second year based on the quantitative data analysis

In both study years, statistical analysis showed no significant pre-post differences in *perceived probability* among intervention group students (see Fig. 4). Therefore, H1 is rejected. There were also no significant pre-post differences in *perceived severity* among intervention group students in both study years (see Fig. 5). Therefore, H2 is rejected. There were also no significant pre-post differences in *adaptation efficacy* among intervention group students in both years (see Fig. 6). Therefore, H3 is rejected. And, there were no significant pre-post differences in *perceived self-efficacy* among intervention group students in both years (see Fig. 7). Therefore, H4 is

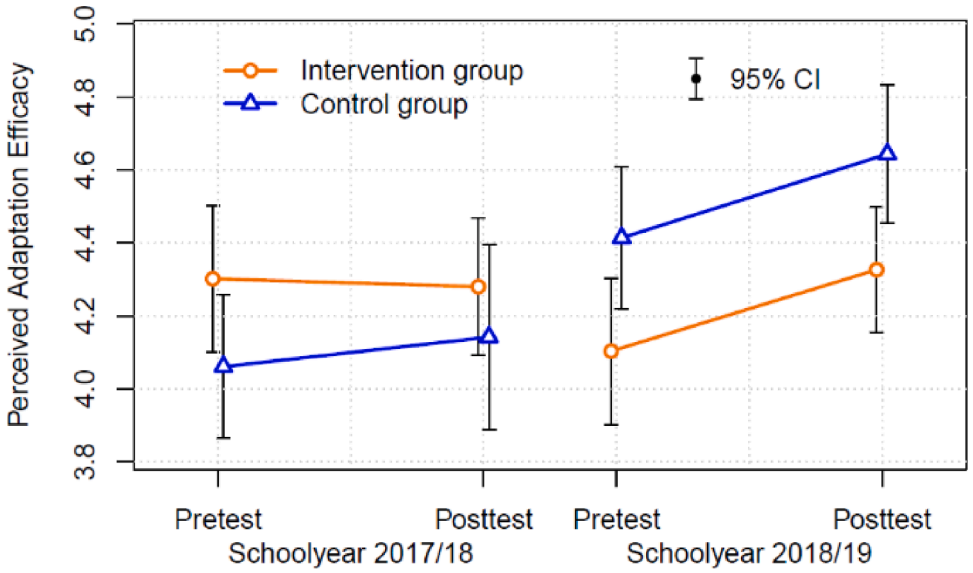

Fig. 6. Mean plot of the dimension *perceived adaptation efficacy* for the school years 2017/18 and 2018/19.

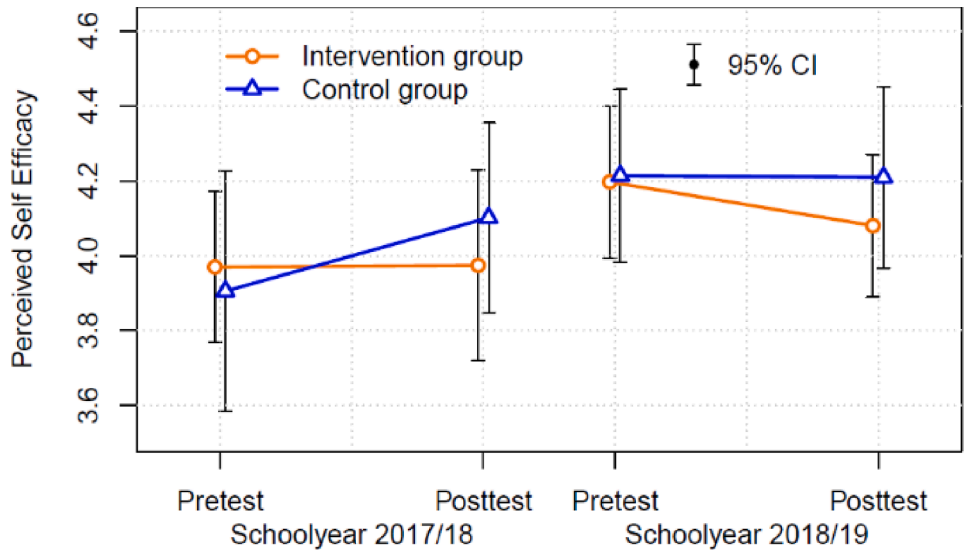

Fig. 7. Mean plot of the dimension of *perceived self-efficacy* for the school years 2017/18 and 2018/19.

rejected. As expected, there were also no significant pre–post differences among control group students in both years. Overall, the quantitative results suggest that the educational interventions provided by *Generation F^3–Fit for Future* did not result in higher *climate change risk perceptions* and *adaptation appraisal* among students. In other words, these two dimensions of cognitive adaptive capacity remained stable, and no difference was found between the overall model and the baseline for any outcome variable. The random effects suggest variance between the students but no variance between schools (see Table 1).

4.2. Intervention group students' cognitive adaptive capacity after climate change education based on the qualitative data analysis

The interview results showed that CCE has strengthened most intervention group students' *knowledge* about climate change risks and understanding about adaptation options. Within the intervention group sample, 21 out of 25 students recognised that climate change poses major risks and they knew about different climatic impacts already occurring in or expected for their home regions. They also showed profound levels of action *knowledge* for effective adaptation strategies. It was also found that many intervention group students were able to link climate-related vulnerabilities with adaptation measures, and they could reflect upon their outcomes. Two corresponding representative interview sequences are as follows:

Table 1
Multilevel modelling of outcome variables; *Note:* * = p ≤ 0.05. Significance level correction to obtain a family wise error rate (FWER) of 5% across all regression coefficients, variance components and baseline model comparisons in this table (20 + 8 + 4 = 32 NHST comparisons). Intervention: 0 = control group, 1 = intervention group. Post-test: 0 = pre-test, 1 = post-test. School year: 0 = 2017/18, 1 = 2018/19. ICC = interclass correlation coefficient.

	Perceived probability		**Perceived severity**		**Perceived adaptation efficacy**		**Perceived self-efficacy**	
	b	*SE*	*b*	*SE*	*b*	*SE*	*b*	*SE*
Regression coefficients *(fixed effects)*								
Intercept	3.29*	0.11	4.95*	0.08	4.22*	0.12	4.03*	0.16
Intervention	−0.09	0.12	0.08	0.09	−0.08	0.10	0.01	0.12
Post-test	0.18	0.10	0.21	0.07	0.17	0.09	0.07	0.10
School year	0.24	0.10	0.08	0.07	0.10	0.08	0.13	0.10
Intervention × post-test	−0.19	0.14	−0.16	0.09	−0.06	0.12	−0.14	0.13
Variance components *(random effects)*								
Students ICC	0.34		0.41		0.31		0.38	
Schools ICC	0.00		0.00		0.04		0.07	
Comparison with baseline model *(baseline = overall model without intervention × post-test interaction)*								
$X^2(1)$	1.90		2.87		0.23		1.15	
p	0.168		0.090		0.630		0.283	

Interviewer: Which groups of people in Bolzano could be affected by summer heat?
A13: Probably the older population, because of health. I don't want to throw them all into the same pot, but health problems increase with age."
Interviewer: What can they do now to adapt to heat waves?
A13: A fan could cool the air, or an air conditioner. Maybe, the municipality of the city could make something like this available to the citizens. I think there are even cooled rooms in Bolzano, that are available for the older people when it gets hot.

Interviewer: What can be done to adapt Tyrolean tourism to the negative and positive consequences of climate change? Do you know of different means of adaptation?
A24: It would be generally smarter not to push so strongly for winter tourism anymore. In our region, winter tourism is essential, and if the warming continues it could collapse. So, I would focus more on other seasons, not winter, but summer, and promote cycling or hiking activities instead. This helps to deal with a warmer climate, like a summer tourism with lakes and so on and focus on that. It is important to start a slow transition when winter tourism becomes smaller. Nevertheless, snowmaking is almost necessary and people will continue doing it as long as possible. You cannot stop the winter tourism all at once.

Moreover, another interesting finding dealing with *adaptation efficacy* was that most intervention group students could differentiate between autonomous and planned adaptions as well as limitations of both strategies. In this context, some students understood that the capacity to adapt is shared unequally across different stakeholder groups, so they claimed that more holistic adaptation measures would be essential to reduce harm. A corresponding interview sequence is as follows:

Interviewer: What is your assessment of adaptation to natural hazards for people living in the mountains?
A2: Well, I think they are good in adjusting to natural hazards. For example, you can protect yourself using sandbags or by building the house on stronger ground so that is not washed away. Thinking of debris flow and roads, a private person cannot do so much. The province of Tyrol or the municipality must make sure that the slopes are protected so that there is no chance of a debris flow. So, they must think ahead and not wait to act until it is too late.

Beyond *knowledge* about adaptation, 16 out of the 25 interviewed intervention group students showed *critical thinking skills*. Compared to control group students, they also recognised dilemmas caused by adaptation more often. Specifically, they were critical about adaptation actions that are maladaptive, and they were also found to think of benefits and costs of different adaptation measures. Furthermore, many intervention group students reflected on barriers to adaptation in their home regions and the *adaptation efficacy* of certain stakeholder groups. Two representative interview sequences are as follows:

Interviewer: What can people in Bolzano do to adapt to heat stress?
A6: I suggest climate protection now, so that global warming does not get any worse. They could use air conditioning in houses or cars. Of course, this is counterproductive because then more CO_2 will be emitted again and that is against climate change.

Interviewer: What was your most important research finding?
A20: Specifically, in terms of subsidies, that the farmers are supported by the government, who now very strongly need to rethink their practices. For example, farmers in the lowlands who are switching from apple to kiwi or other exotic fruits. For the winegrowers, it's only a matter of the varieties, but for the fruit growers, they must completely change fruits. That's a greater burden for them.

Problem-solving for adaptation requires *forward-thinking skills*. Comparative analysis suggests that 11 out of the 25 interviewed intervention group students demonstrated *forward-thinking skills*, such as flexible thinking or the anticipation of long-term risks. In other words, those students could recognise differences between pro- and re-active adaptation and their outcomes for climate risk management. Two corresponding interview sequences are as follows:

Interviewer: How can we adapt to the consequences of climate change?
A18: In the event of flooding, you can build dams or a kind of retention basin. You can argue about whether it should be artificial or natural. In any case, you should make sure in advance that not so much is built in risky areas. If there are houses, then the people there probably don't want to leave. But they should no longer be allowed to build there.

Interviewer: In settlement planning you can prevent and identify risk zones where construction is not taking place, or you can create awareness for residents. What are the advantages and disadvantages here?
A23: Risk zones are very important in my opinion, because everything that can be presented should be done in any case. Because if flooding occurs, you can save a lot of money, and you don't need to reconstruct things. In any case, both measures must be combined so that residents are supported in adapting to climate change.

4.3. Control group students' cognitive adaptive capacity after standard curriculum education based on the qualitative data analysis

The following results shows significant differences to those in the intervention group. 14 out of the 22 interviewed control group students showed limited or no *knowledge* about climate-related risks or adaptation options in North or South Tyrol. Many control group students also lacked specific intellectual resources to develop nuanced responses to the challenge of managing climate-related risks in North and South Tyrol suggesting that their *climate change risk perceptions* and *adaptation appraisals* were very low compared to intervention group. Two representative interview sequences are as follows:

Interviewer: Now, we have talked about the first graph and the trend of extreme weather, and we have talked about concern. Now it's about how to react and how to adapt. What do you think farmers can do? Do they already know how to adapt?
C3: I don't know any. But I also think the two pictures with the irrigation here just show that it is getting drier.

Interviewer: What do you think these groups of people can do now to adapt to heat?
C12: Adaptation will be hard. I don't know if it is possible for farmers to do their work later in the day when it's less hot.
Interviewer: Any other measures in the adjustment that you know of or that come to mind?
C12: No. In my view, it would be better to do something against climate change. But not just the individual, also others, and then they won't have to adapt. Then things will change on their own.

10 of the 22 interviewed control group students held various misconceptions about the causes of climate change and addressed maladaptation less critically. Many control group students confused adaptation measures with environmental protection, and demonstrated an understanding of climatic effects expected for their home regions that is not in line with findings from climate research for North or South Tyrol. Two interview sequences are as follows:

Interviewer: What might this warming of the climate mean for winter and summer tourism in North Tyrol?
B2: If I am right, I think it snows a lot because of climate change. Because more water condenses, and so everything must go down again, so to speak, and then, of course, it snows a lot. And that's very good for tourism in Tyrol.

Interviewer: There are two measures for adaptation. One is to buy an air conditioner, as you said, or the other is to use the bike to go on trips to cooler places to refresh yourself. Do you think there are any advantages or disadvantages to these two measures?
C13: Yes, the main problem with air conditioning is the cost of electricity, and travelling is even more expensive. Going to the mountains in South Tyrol is not that far, but to travel to other places, that's more expensive to get into a cooler environment.

11 of the 22 interviewed control group students showed examples of *simplistic thinking*. Specifically, they appeared to be unaware of the complexities as well as risks of climate change and addressed the realities of adaptation in North and South Tyrol less critically. For instance, many control group students argued that adaptation would be purely a question of financial resources, which suggests that

their *adaptation appraisal* was not well informed and they were less aware of the urgency of adaptation in North or South Tyrol. Furthermore, some control group students showed *wishful thinking*, arguing that adaptation only takes place after a real disaster has occurred, which is a rather naïve appraisal of adaptation since adaptation also could occur in advance of climate-related impacts. Two interview sequences are as follows:

Interviewer: What do you think people in winter tourism can do to adapt to the consequences of climate change?
C15: I think they can't really do much. Of course, you can advertise the type of tourism you are doing. But if you don't have the financial means, it's hard. And people always prefer to follow the masses instead of coming up with their own ideas.

Interviewer: Do you mean that you can't do a lot to adapt tourism to climate change?
C15: Yes, I believe that if you don't have the financial means, then not really, no.
Interviewer: When you think of inhabitants of mountainous areas, and it is assumed that natural-hazards will increase because of climate change, how do you assess the ability of these people to adapt?
B3: Yes, their abilities are different. In the beginning, it will always be difficult, I guess, but after that, people will be able to adapt. Humans are always adapting. That has always been so, I think.

5. Discussion

This study examined the role of CCE and inquiry-based learning in shaping selected dimensions of adolescents' cognitive adaptive capacity. The quantitative data suggest that the educational interventions did not result in any meaningful changes in intervention group students' *climate change risk perception* or *adaptation appraisal*. Qualitative data, however, deliver a different picture. It shows that most intervention group students were able to demonstrate sophisticated *knowledge* about adaptation to climate-related risks, had developed *critical* as well as *forward thinking competences*. In contrast, control group students revealed less reflexive thinking and held various misconceptions about climate change and adaptation.

The qualitative results from this study confirm Stevenson et al. (2018), who showed that educational intervention increases climate-specific knowledge among adolescents. Results also indicate that, after CCE, most intervention group students reached several cognitive learning objectives for *SDG 13 'Climate Action'*. These students knew about major ecological, social, cultural and economic consequences of climate change locally, and about adaptation strategies at different levels and in various contexts (UNESCO, 2017). While most intervention students showed action knowledge for adaptation, and reflected upon maladaptation critically, some did not acquire such understanding or competences. This could be explained by the constructivist educational design itself, which allowed for a high degree of autonomous learning. As a consequence, some intervention students chose to work on topics rather connected to mitigation than adaptation issues. Working at eye-level throughout the intervention, educators avoided strong control on topics, but, instead, attempted to bridge mitigation and adaptation strategies in a meaningful way (Keller et al., 2019).

Interview findings from this study also suggest that CCE holds considerable potential to enhance the dimensions of adolescents' cognitive adaptive capacity that relate to higher-order thinking. In specific, intervention group students showed higher degrees of *critical* and *forward thinking* after CCE. This confirms the findings of Wamsler (2011), according to whom such cognitive skills help people to better assess public information on climate risks, and safeguard a more profound selection of risk reduction measures. Interestingly, intervention group students were more flexible in addressing different real-life adaptations, and could reflect in more detail on advantages and disadvantages of both incremental and transformative measures than control group students. Such understanding of adaptation strategies is crucial, since many adaptation practices in students' home regions, such as artificial snow-production (North Tyrol) and air-conditioning (South Tyrol) are incremental, and probably are not suitable anymore under more extreme climatic conditions the world is heading towards. Therefore, these findings underline the argument by Cinner et al. (2018) that individuals with higher cognitive flexibility are better at adapting in terms that they are less likely to adopt maladaptation. Other educational programmes on adaptation are therefore strongly advised to focus on capacity-building that synthesises mitigation and adaptation, and to include critical discussions about the status-quo of adaptation realities.

This study demonstrates mismatches between quantitative and qualitative results. Thus, there is no support for all four hypotheses among intervention group students. The missing changes in *climate change risk perception* or *adaptation appraisal* among intervention group students shown by the quantitative data may be explained by at least three factors: (a) the quality of educational design of *Generation F^3–Fit for Future*, (b) the operationalisation of the newly designed items for the questionnaire, or (c) the high complexity and latent character of the cognitive adaptive capacity concept itself. Regarding educational quality, it is highlighted that the chosen focus on constructivist inquiry-based learning as well as the learning content are very much in line with state-of-the-art CCE literature and practice. For example, the in-school and expert workshops led to active engagement of the participants, who could interact with scientists in a community-of-learners-approach. Following inquiry-based learning theory, the participants were encouraged to leave their classroom world behind, and to explore adaptation realities in their home regions actively by themselves (Monroe et al., 2017). What is also true, however, is that a lot of time had to be invested in order to create the inquiry-based learning and research situation for the students, because they had had no experience in this whatsoever (see Fig. 2). Another limitation might arise from the effect that,

although most intervention group students performed their own research about stakeholders who do real-life adaptation in North and South Tyrol, this does not necessarily mean that their personal roles or perceptions of adaptation were addressed. This explanation, however, conflicts with the qualitative finding that intervention group students were well aware about the fact that climate change is posing a major threat to North and South Tyrol (*risk perception*) and that they could autonomously assess the effectiveness of various adaptation measures presented in the problem-centred interviews (*adaptation appraisal*). The missing effectiveness of CCE to increase intervention group students' *perceived probability* could also be explained by findings from Kuthe et al. (2019). In their study, approximately 75 percent of 792 upper-secondary school students (between 13 and 16 years old) from schools in Germany and Austria already showed medium to higher levels of climate change awareness before CCE. On the other hand, the missing signal in the quantitative data could also be the result of the items wordings used in the questionnaire. As mentioned before, they had to be newly designed because there were no standardised items for measuring cognitive adaptive capacity in the context of education. This leads to the conclusion that other research is strongly recommended to assess the quality of the items presented in this experimental study and to further develop them. A third line of argumentation for the mismatch between the quantitative and qualitative data is that it could be attributed to the complex and latent nature of cognitive adaptive capacity itself, which had been reported by Oakes et al. (2016) before. In other words, researchers could be limited in measuring cognitive adaptive capacity until it is realised or mobilised within people (Engle, 2011). To overcome this limitation in adaptation science, a triangulation between quantitative and qualitative data is encouraged, and the interview data of this study are probably more direct proxies of students' dimensions of cognitive adaptive capacity than questionnaire data. In problem-based interviews, people need to express their cognitive resources through explaining, analyzing or evaluating (Siders, 2019). In the context given, qualitative data might thus reveal more reliable findings that quantitative data.

Methodologically, further limitations are acknowledged as well. As recommended by Engle (2011), four dimensions of upper-secondary school students' cognitive adaptive capacity were measured *ex-ante* and *ex-post,* whereas two dimension of the interview were measured *ex-post* only. The development of the quantitative and qualitative measurement tools had been challenging, since the operationalisation of the six dimensions of adolescents' cognitive adaptive capacity suffered from a lack of established items or standardized examples of semi-structured interviews. The authors followed Grothmann and Patt's (2005) framework and other studies like Anderson (2012) to develop their own items (see Table 2, Annex) since other field-tested items from Lockwood et al. (2015) or Koerth et al. (2013) did not fit this study's purpose. Because uncertainty is part of the concept of adaptive capacity and its assessment (Adger and Vincent, 2005), a mixed methods approach was undertaken, and it is also recommended to other researchers to address this fuzzy concept from as many different perspectives as possible, and to look at both quantitative and qualitative data.

In terms of significance, two open questions about CCE by Reid (2019) were addressed by this quasi-experimental study: *(a) In research terms, what has been overlooked, omitted, well understood, or would be generative for CCE?* (p.973) *and (b) Must CCE research be designed in ways that make a difference to those adapting to and mitigating climate change* (p.975)*?* Frameworks like the *MPPACC* from Grothmann and Patt (2005) and empirical findings from Wamsler (2011) as well as Striessnig et al. (2013) are claimed to be overlooked by contemporary CCE research. Specifically, it is argued that the above-mentioned cross-disciplinary theories and findings from associated empirical research can provide valuable hints for operationalising key concepts of climate science (like adaptive capacity) for CCE research and better characterizations of the nexus between adaptive capacity, human cognition and learning. Furthermore, the literature part of this contribution suggests that CCE should empower those who will be most affected by impacts of climate change, especially today's adolescents or children. It is the responsibility of all generations to mitigate climate change to avoid business-as-usual warming, whilst investing in people's risk perceptions, knowledge levels, thinking skills and understanding by education.

The empirical assessments provided by this contribution are of importance for societal stakeholders in Austria, Italy and beyond, who are interested in inquiry-based capacity-building for adaptation among young people. For example, regional programmes financed by the Austrian Climate and Energy Fund, such as *KEM (Klima- und Energiemodellregionen)* and *KLAR! (Klimawandelanpassungsregionen)*, in which children and adolescents learn about climate change risks and adaptation on a regular basis, can benefit from the educational design of the pilot experiment *Generation F^3-Fit for Future*, and could learn from its positive outcomes, and also its limitations.

6. Conclusion

This study clearly demonstrates a mismatch between quantitative and qualitative results. The quantitative data do not show any change in adolescents' *climate change risk perceptions* and *adaptation appraisal* in a pre-post-comparison before and after CCE intervention. The qualitative data, however, reveal a different picture: Upper-secondary school students participating in *Generation F^3–Fit for Future* were found to show increased levels of *adaptation knowledge* as well as elaborated *critical* and *forward thinking skills* after the educational intervention. Control group students did not show such capacities after standard curriculum education. Respecting the limitations of this study, it is concluded that CCE holds potential to build several dimensions of adolescents' cognitive adaptive capacity. However, mixed research approaches – including both quantitative and qualitative data – and the integration of further perspectives of the adaptive capacity theory should be respected by upcoming research to study this complex concept. Adopting the central ideas of this study regarding both the challenging (quantitative) and the promising (qualitative) empirical assessment, can be a

decisive step forward in linking cognitive adaptive capacity theory and CCE. At the same time, the long-term challenge of delivering solid research results instead of just giving 'anecdotal evidence' (UNESCO, 2012) on the functioning of Education for Sustainable Development and CCE, can be overcome.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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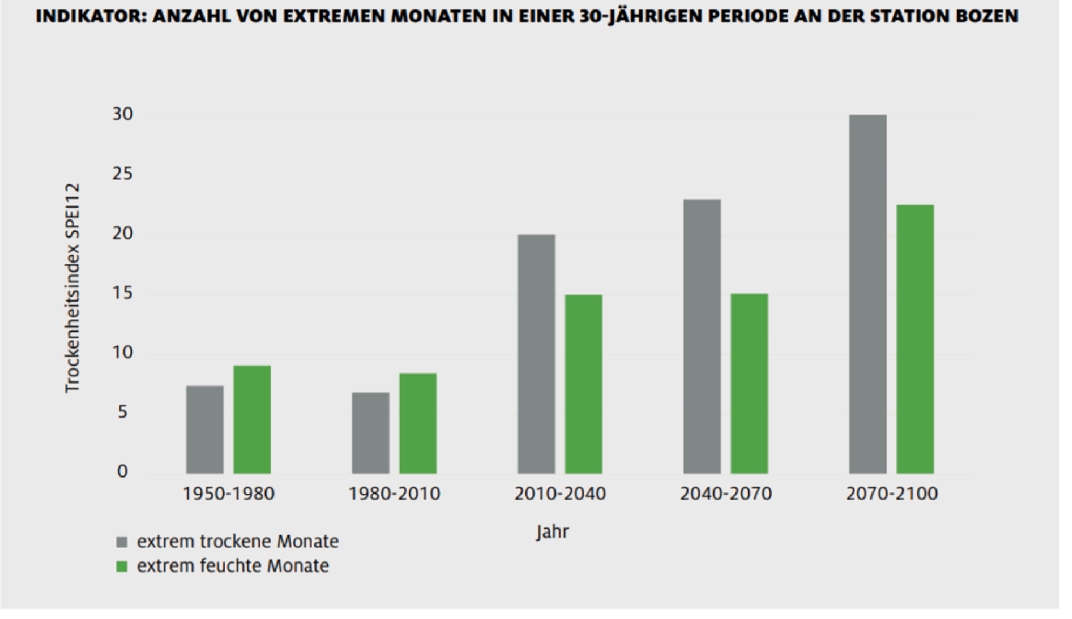
Annex.

Table 2
Survey items used to study upper-secondary school students' cognitive adaptive capacity. The table also shows results of the confirmatory factor analysis. All values are product-moment-correlations of the items with the factors. The factors were created by averaging the associated items. Correlation coefficients greater than 0.4 are in bold.

Dimension of cognitive adaptive capacity	*Sample items*	*Item scales*	*Perceived probability*	*Perceived severity*	*Perceived adaptation efficacy*	*Perceived self-efficacy*
Perceived probability	Is your personal life affected by climate change?	1-not affected at all, 6-highly affected	**0.97**	0.12	0.18	0.15
	Is the life of your family affected by climate change?	1-affected at all, 6-highly affected	**0.97**	0.11	0.18	0.13
	What is your assessment of negative climatic effects affecting your personal life?	1-very unlikely, 6-very likely	0.27	0.26	0.24	0.23
Perceived severity	Climate scientists can prove that current climate change is severe	1-do not agree at all, 6-agree entirely	0.10	**0.77**	0.11	0.17
	To what extent are natural systems changed by climate change?	1-very small changes, 6-very strong changes	0.12	**0.71**	0.24	0.20
	To what extent are human systems changed by climate change?	1-very small changes, 6-very strong changes	0.04	**0.61**	0.31	0.26
Perceived adaptation efficacy	What is the effectiveness of concrete dams to prevent flooding?	1-very inefficient, 6-very efficient	0.10	0.17	**0.61**	0.19
	What is the effectiveness of international agreements in managing climatic effects?	1-very inefficient, 6-very efficient	0.18	0.28	**0.61**	0.28
	What is the effectiveness of crop failure insurance in preparing for drought periods?	1-very inefficient, 6-very efficient	0.13	0.10	**0.74**	0.11
	What is the effectiveness of education in increasing knowledge about climate change?	1-very inefficient, 6-very efficient	0.10	0.38	**0.65**	0.37
Perceived self-efficacy	If I contribute to adaptation, I have a benefit from it	1-I cannot adapt at all, 6- I am highly capable to adapt	0.09	0.27	0.32	**0.80**
	If I contribute to adaptation, I can protect myself from harmful consequences of climate change.	1-do not agree at all, 6-agree entirely	0.15	0.20	0.26	**0.90**
	If I contribute to adaptation, I can protect others from harmful consequences of climate change.	1-do not agree at all, 6-agree entirely	0.17	0.23	0.29	**0.80**
	I feel confident adapting to climate change, if necessary.	1-do not agree at all, 6-agree entirely	0.01	0.25	0.28	**0.53**

Table 3
The semi-structured interview for the case 'adaptation to drought risk in the agriculture of South Tyrol' is shown. The other case for South Tyrol focused on 'adaptation to urban heatwaves in the city of Bolzano'. The students from North Tyrol were interviewed with two different cases showcasing climate risks and adaptation issues that are more typical to this region like 'natural hazards affecting infrastructure in North Tyrolean villages' or 'snow cover decline affecting winter tourism'. The sample questions with * only were asked to the intervention group students and dealt with their participation in the educational programme *Generation F^3–Fit for Future*. The sample questions in all semi-structured interviews targeted different dimensions of intervention and control group students' cognitive adaptive capacity.

Dimensions of cognitive adaptive capacity	*Sample questions and scientific graphs or photos used for photo elicitation method*
–	How did you feel about your participation in the Generation F^3–Fit for Future project?*
Knowledge	What did you already know about climate change adaptation before the project?*
Knowledge & Understanding	You have carried out a small research project with reference to South Tyrol. What did you find out about climate change and adaptation?*
Climate change risk perception & Knowledge	What can you see in graph 1? Please describe.



(*continued on next page*)

Table 3 (*continued*)

Dimensions of cognitive adaptive capacity	*Sample questions and scientific graphs or photos used for photo elicitation method*
	The graph 1 is from (Zebisch et al., 2018, p. 26).
Knowledge & Understanding	Do you see a connection between graph 1 and man-made climate change? If so, what is it?
Climate change risk perception & Adaptation appraisal	What can you see in graph 2? Please describe.
	
	The graph 2 is from (Zebisch et al., 2018, p. 70).
Climate change risk perception & Adaptation appraisal & Thinking skills	Look at graph 1 and 2 together. What could a drought increase at the station Bolzano mean for agriculture in Bolzano and its surrounding areas in the near-term and long-term future?
Adaptation appraisal & Understanding	What could different types of farmers do to adapt to increased periods of drought due to man-made climate change? Please discuss different adaptation measures.
Adaptation appraisal & Thinking skills	How do adaptation measures against drought that could be undertaken by the province of South Tyrol differ from adaptation measures against drought that could be undertaken by individual farmers? What advantages and disadvantages could these adaptation measures have?
Adaptation appraisal & Understanding	How do you evaluate the two following adaptation measures: (a) optimized water supply e.g. drip irrigation, or (b) switching to drought resistant varieties? What advantages and disadvantages come with the two adaptive solutions against drought risk in agriculture? Please explain.
Adaptation appraisal & Understanding	How high or low do you estimate the adaptive capacity of farmers in South Tyrol to cope with increased dry periods due to climate change? Please explain briefly.
Thinking skills	Should farmers also adapt to drought risk also if the scientific projections about future climate change impacts are characterised by uncertainty?
–	Is there anything else you want to say about climate change or adaptation?

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