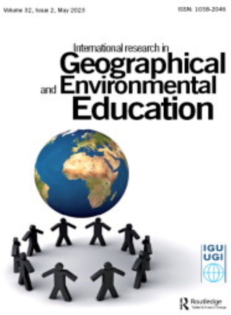

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Identifying gaps in climate change education - a case study in Austrian schools

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ABSTRACT

In a case study among Austrian school students, we checked the school students' knowledge and awareness of climate change on different levels of complexity. We aimed to find out whether school students are able to understand more complex, reciprocal relations between human activities and consequences for the climate. Furthermore, we tested whether a more active and longer engagement with the topic achieved a better understanding and raised climate-friendly behavior more effectively than a short learning phase. Our online survey results revealed that the students had high fact knowledge of climate change (effects) but lacked deeper understanding of more intricate relationships and long-term interactions of climate change effects on people and ecosystems. The vast majority of students believed that every single person can contribute significantly to tackle climate change, however, personal and deliberate climate-friendly actions were limited. The differences between the two levels of engagement were small. We suggest that modern educational concepts should foster system-understanding and support young people's positive attitude towards climate protection by pointing out concrete, climate-friendly ways of behavior to bridge the gap between knowledge and action.

KEYWORDS

Climate change education; climate literacy; scientific literacy; system understanding; value-action gap

Introduction

The relationship between humans and nature is extremely complex due to multiple interactions between the abiotic and biotic environment and the social, economic, and ecological activities of humans occurring across all scientific disciplines and spheres of life (Glaser, Krause, Ratter, et al., 2012). Humans often see themselves as standing outside, if not above, the natural system (Williams, 2010), constituting a formative power for ecosystems' structures, processes, and linkages. However, humans are an integral component of nature and are thus reciprocally affected by

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ecosystems' changes and transformations (Comberti, Thornton, Wyllie de Echeverria, & Patterson, 2015; Hofstra & Huisingh, 2014). Human actions, their impacts on the climate, and the induced feedback loops are typically non-linear and often disconnected in time and space (Vörösmarty, Meybeck, & Pastore, 2015; IPCC, 2021).The increase of greenhouse gas emissions, for example, does not immediately affect the earth's climate system but with a notable time delay. Vice versa, emerging changes in the climate system, including the biosphere and cryosphere, will continue long into the future even if we take strong and immediate reductions in greenhouse gas emissions right now (IPCC, 2021; Steffen et al., 2018). The spatial and temporal disconnection of causes and effects was identified as one major reason for the gap between the individual's perceived or assumed effects and the actual or scientifically proven effects of human actions on the natural system (Deffner & Haase, 2018; Myers, Maibach, Roser-Renouf, Akerlof, & Leiserowitz, 2013; Trebitz & Wulfhorst, 2021). Moreover, this time delay may result in personal frustration as the individual's climate- friendly actions have no instantly visible impacts (IPCC, 2021), resulting in lack of motivation for climate-friendly behavior (Gifford, 2013).

Science can contribute to environmental and climate literacy by unravelling the complex causes for and impacts of climate change and can, therefore, play an important role in raising pro-environmental behavior of our society (Nkoana, 2020; Weber, 2010). However, studies in climate change communication show that basic scientific knowledge as well as latest scientific insights do often not reach the broader public and, more important, do often not convince people (Smol, 2018). Despite strong consensus in the scientific community that the current climate development is a sign of human-driven changes to the global environment (IPCC, 2014, 2021; Powell, 2017; Steffen, Broadgate, Deutsch, Gaffney, & Ludwig, 2015), climate change skepticisms and denial theories persist (Cutter-Mackenzie & Rousell, 2020). Science faces the challenge to provide information transfer into the public in a more effective way in order to correct misconceptions people have about the global climate situation and the way science functions (Moser, 2016; Weber, 2010) and to sustainably raise climate and scientific literacy (Smol, 2018).

The education system is an ideal place for impactful scientific outreach and educational concepts can be powerful tools in effective climate protection and climate change adaptation (Chang, 2015; Feinstein & Mach, 2020; Reid, Dillon, Ardoin, & Ferreira, 2021). Innovative and attractive teaching concepts can reach young people by delivering scientific knowledge tailored to the specific target group. Furthermore, effective school education can correct young people's misconceptions widely spread through social and mass media (Monroe, Plate, Oxarart, Bowers, & Chaves, 2019; Roussel & Cutter-Mackenzie-Knowles, 2020). The education system is also an ideal starting point to raise awareness for and knowledge about the complexity of ecosystem functioning and human-nature interactions (Reid et al., 2021). This would require an interdisciplinary approach in school curricula, yet sectoral teaching often still prevails (McCright, O'Shea, Sweeder, Urquhart, & Zeleke, 2013; Scheuch & Sippl, 2019). Whereas the underlying educational concepts try to live up to the complexity of the human-nature linkages (Austrian Federal Chancellery, 2020; UN General Assembly, 2015; UNESCO, 2015) curricula do often not succeed in conveying the multidimensionality and intricacy of human-nature relationships (Cox, Elen, & Steegen, 2019; Weigelhofer & Feldbacher, 2020). Finding answers to current crises such as climate change, biodiversity loss, infectious diseases, and inequitable access to resources are, however, big challenges for our society and our educational system (already Berry, 1988; Lidstone & Stoltman, 2008; Steffen et al., 2018; Reid et al., 2021) and require the application of complex system thinking competences based on sound scientific results.

We initiated a small case study among Austrian school students aged 13 to 17 with the aim to check the school students' knowledge about climate change on different levels of complexity. Primarily, we wanted to find out whether school students were able to detect and understand complex, reciprocal, time-delayed, or spatially distant relations between human activities and consequences for the climate. Furthermore, we tested whether a more active and longer engagement with the climate crisis achieved an enhanced understanding of complex interactions and raised climate-friendly behavior more effectively than a short learning phase. Here, both the short and the longer engagement of the students were led by their teachers in the classrooms without the involvement of scientists to minimize influences from outside on the learning process. Finally, we gathered information on the school students' pro-environmental behavior and attitude towards climate activism.

Method

We performed a small research-education-cooperation project with 7 Austrian school classes and school students aged 13 to 17 coming from mixed-gender middle and high school classes from both urban and rural locations. During an introductory workshop at the schools, scientists gave an overview of the effects of climate change in general and on water bodies in particular, focusing on the situation in Austria and on water bodies in the immediate vicinity of the students. After that, the students had to collect and prepare information on climate change impacts as well as suggestions for climate-friendly behavior for peer students. The students were free to choose the teaching format they liked best and developed offline or online learning activities (e.g. online quizzes, videos, and (board-) games). These "developer" groups (Figure 1) were actively involved in the topic over several weeks as part of

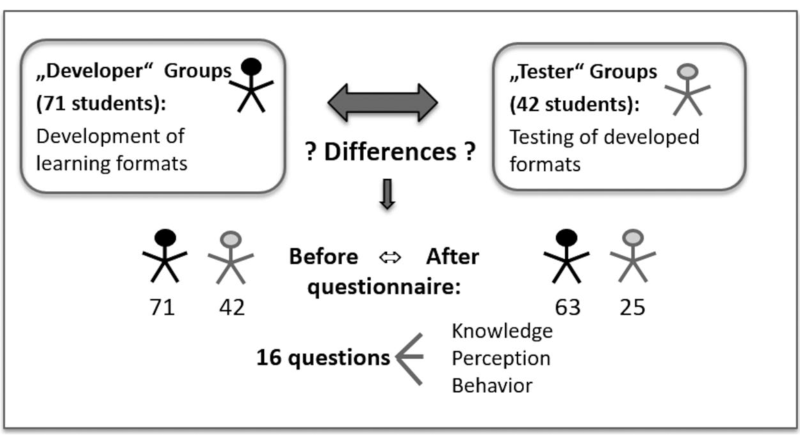

Figure 1. Methodological approach.

school project lessons. In a later stage of the project, the developed learning formats were tested by other students of the same school, whom we called "tester" groups, as part of peer learning events (Figure 1). For the "tester" groups, no additional workshop was held by scientists.

All involved school students from both "developers" and "testers" groups answered an online survey asking climate-relevant questions of the categories knowledge, perception, and behavior (according to Kuthe et al., 2019a, 2019b) directly before and after the respective project activities (Figure 1). Thus, the interval between the two surveys was several weeks for the "developers" and several days for the "testers". For both surveys, we used the same questions to reveal changes in one or more of these categories due to the project activities. The correct answers were not revealed by the involved scientists or the teachers. The survey included sixteen questions covering general knowledge of climate and climate change frequently reported in the media, regional impacts of climate change in Europe and Austria, specific effects on rivers in Austria (water scarcity and desiccation) as well as individual experiences, perceptions and behavior. All questions were multiple choice and had four possible answers (with one to four correct or climate—friendly answers each). Fifteen questions were rated (1 point per correct answer). The final not-rated question was asking for the personal opinion about Friday for Future activism. In total, 113 school students were involved in the activities and 113 pre- and 88 post- questionnaires (201 in total) were available for analysis (Figure 1).

We used IBM® SPSS Statistics (version 26.0) to carry out statistical analyses and conducted a paired-samples t-test (dependent-samples t-test) to check the differences between pre- and post-survey results. We tested the assumption of normality using Kolmogorov-Smirnov analytical tests and graphical methods (histograms, normal Q-Q plots). The percentage of correct questionnaire answers (means per question and involved school class) was compared between the pre- and the post- survey in total and spilt up in the three questions categories. The significance level was set at $p < 0.05$ for significant differences. We also tested for differences between "developer" and "tester" groups and for differences between middle school (age group 13–15, 2 classes) and high school (age group 16–17, 5 classes) students. Furthermore, we calculated a regression to see if higher scores in the categories knowledge and awareness had an influence on climate-friendly behavior. The analyses of the complexity of the questions was purely descriptive and based on a coarse classification of the questions into low complexity (frequently reported facts, immediate and direct effects), and high complexity (indirect, delayed effects, feedback loops, etc.).

Results

The before - after comparisons of the survey results within the "developer" and "tester" groups showed only a small increase of correct answers for both groups without being statistically significant (developers +2.0%, testers +2.5%; t-tests: developers $n = 75$, testers $n = 30$, $p > 0.05$). Likewise, there were no statistically significant differences between these two groups after the activities (t-test, $n = 105$, $p > 0.05$).

The differences between middle and high school students' scores were also not statistically significant, independent of whether questions were considered in total or split up into the three question categories (t-tests, $n = 6$ to 30, $p > 0.05$).

As differences between "developer" and "tester" as well as between middle and high school groups were only small and statistically not significant, we performed all further analyses for all groups together. The comparison of the percentage of correct answers between pre- and post- survey in total showed a small not significant increase (+2.1%;t-test, $n = 105$, $p = 0.1$). Looking at the three question categories separately, all scores increased slightly (knowledge category: +3.0%, perception category: +2.0%, behavior category: +0.4%) but differences were again statistically not significant (t-test, $n = 21$, 42, $p > 0.05$; Figure 2).

The mean percentage of correct answers per involved school type and category ranged from 48.2% to 62.6%, the percentage of correct answers per involved class and question ranged from 0% to 100%.

The results of the regression showed no statistically relevant influence of knowledge ($r2 = 0.111$; $p = 0.25$) or perception ($r2 = 0.038$; $p = 0.50$) on climate-friendly behavior.

In addition to the general development of the students, the questionnaire results revealed special thematic aspects of climate change that were causing problems of understanding and were showing a lack of awareness. Many school students, for example, were not aware that Austria is particularly affected by climate change (APCC, 2014). Only 23% stated that climate change is more distinct in Austria than in other European countries, 12% believed that scientists are discordant whether Austria is affected, and 6% did not believe in climate change effects at all.

Regarding more complex climate change impacts on aquatic ecosystems, it was difficult for students to correctly assess causes and effects of water scarcity and desiccation. For example, less than 50% of the students believed that the sealing of the soil surfaces and deforestation can be reasons for water scarcity, and only around 60% of the students were aware that water scarcity can affect water temperature and water quality. It was also difficult for most of the school students to correctly estimate virtual water consumption (Figure 3a). While many students knew that the production

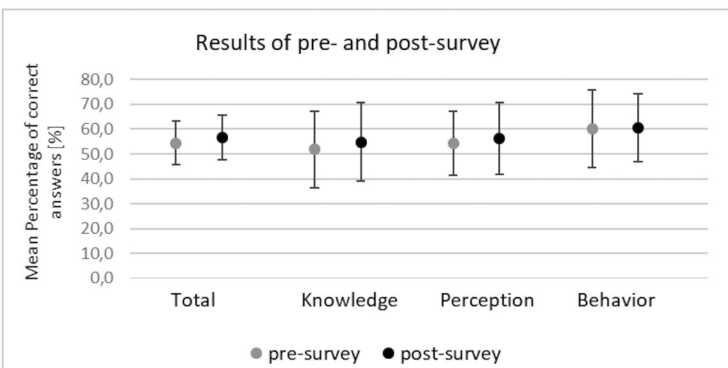

Figure 2. Comparison of before – after survey results in total and by question category (n: total = 105, knowledge and perception = 42, behavior = 21; means with 95% confidence interval).

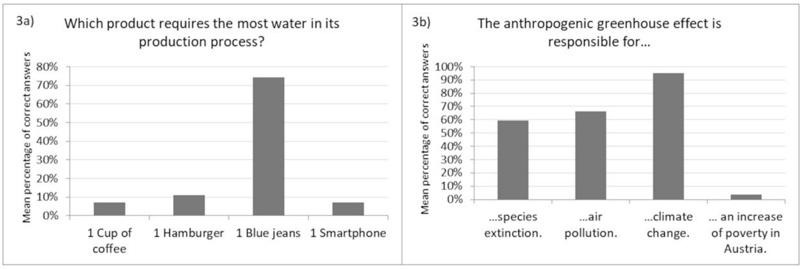

Figure 3. Students' answers on more complex, interdisciplinary questions about climate change causes and effects.

of a pair of blue jeans requires a lot of water, only 7% acknowledged that smartphones require the highest amount of water for their production among the named examples. Concerning possible climate change effects, 66% of school students mistakenly believed that the anthropogenic greenhouse effect is directly responsible for air pollution (Fig 3b). Furthermore, only 3% believed that the anthropogenic greenhouse effect can be responsible for an increased poverty in Austria. The total score of these three more complex and interdisciplinary questions was 35% before the project and could only be raised to 37% by the project activities (T-test, $n = 21$, $p > 0.05$).

However, the majority of the school students showed a positive attitude regarding climate protection and believed that everyone has to do their part in saving the climate. The proportion of students who were convinced that each individual person can make a valuable contribution to protect the climate was over 90%. The students' positive attitude was reflected in some of the responses of behavioral questions without showing statistically significant differences between pre-and post-survey. On average, 74% of the students reported that they walk as often as possible, take the bike, or use public transportation, and 81% stated that they consciously try to save and conserve energy. To protect our waters, many of the students reported that they save water in the household (60%) and mainly drink tap water (74%). Distinctly fewer students indicated that they buy regional products (47%) and only 34% answered that they also try to convince family and friends to act climate friendly. Less than 20% said that they try to buy cosmetics without microplastics or products with a low water demand in the production process, respectively.

The students' personal opinion about "Friday for Future" demonstrations showed that most students generally liked the idea of climate activism, but would not act themselves (Figure 4). This trend was even more obvious after the project (and during the first COVID-19 lock-down), where approximately 6-7% of the students switched from answer no. 3 ("I would like to take part") to answer no. 1 ("Being part is not my thing"). Differences between pre- and post- survey were small and statistically not significant (t-Test, $n = 14$, $p > 0.5$).

Discussion

Climate change is one of the most serious environmental and societal challenges we face today (IPCC, 2014, 2021). The interdisciplinary nature of climate change

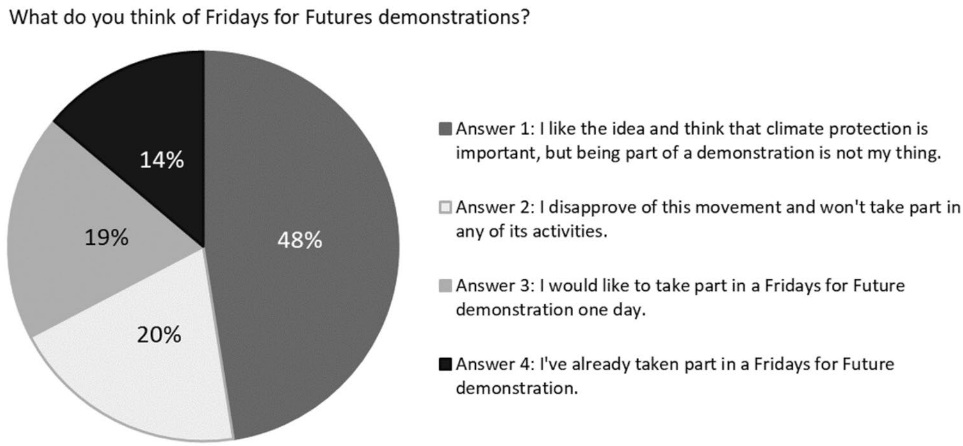

Figure 4. Students' opinion on Friday for Future demonstrations (means of pre-and post-survey answers together, $n = 14$).

as well as the complexity of possible impacts make teaching and learning about climate change difficult at all educational levels (Schauss & Sprenger, 2021). Climate education can be made both easier and more effective by innovative educational approaches involving participatory, interdisciplinary, creative, digital, and hands-on methods (Chang et al., 2012; Kagawa & Selby, 2012; Keller et al., 2019; Monroe et al., 2019; Rousell & Cutter-Mackenzie-Knowles, 2020) that empower both teachers and students (Chang et al., 2018; Feierabend & Eilks, 2018; France, Lee, Maclachlan, McPhee, &, 2021; Sebastián-López & de Miguel González, 2020). Active learning strategies, such as problem-based learning (e.g. Schmidt, 1995), have proven to be successful in increasing knowledge (Corner et al., 2015; Hake, 1998) and influencing attitudes (Chiari, Völler, & Mandl, 2016; Genc, 2015; Hermans & Korhonen, 2017; Oliver-Hoyo & Allen, 2005; Wu & Otsuka, 2021). However, most school curricula in Austria, and probably also in other countries, do not consider the interdisciplinary nature of climate change, including core principles of geography, biology, chemistry, physics, mathematics, and the social sciences, and often deal with climate change in disconnected subject lessons (Jackson & Pang, 2017; Scheuch & Sippl, 2019) (see Fig. 5, starting situation). As a consequence, school students are unlikely to connect important climate literacy principles in an interdisciplinary way (McCright et al., 2013). Our case study confirms that young people in Austria show knowledge of simple climate change facts and climate awareness (see similar results for Hong Kong by Jackson & Pang, 2017), but they often do not comprehend country specific impacts due to regional characteristics as these aspects are rarely part of the syllabus. In addition, complex interactions and effects on ecosystems and the society are often not covered and therefore not understood (Kuthe et al., 2019b, Hmelo-Silver & Azevedo, 2006; Vinuesa, Mucova, Azeiteiro, Cartea, & Pereira, 2022). Environmental models taught at schools are mostly simple, linear and static and do not consider complex, non-linear and dynamic human-environment-climate interactions (McCright et al., 2013). Education has to adopt a more interdisciplinary approach to enhance system

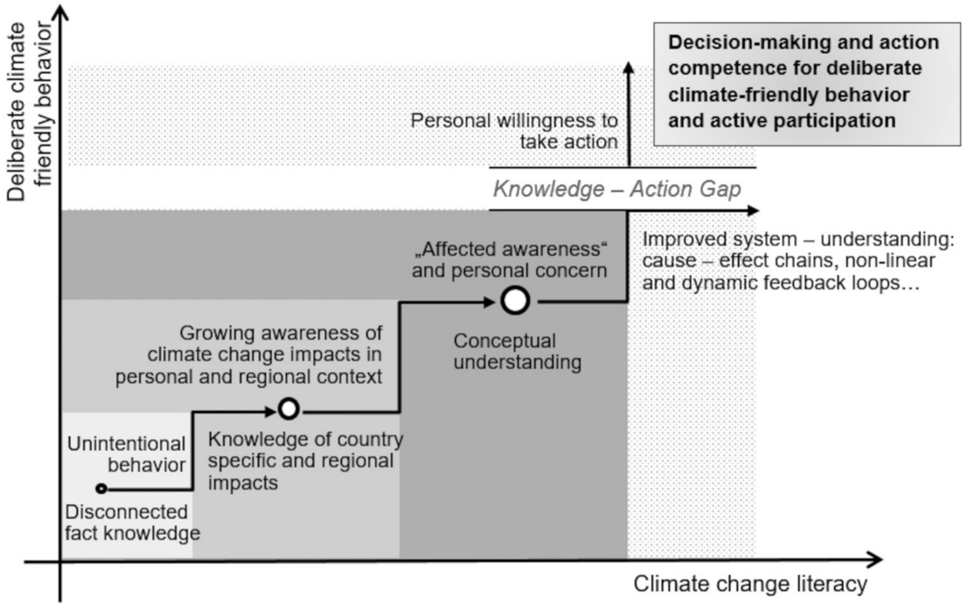

Figure 5. Scheme displaying the relationship between climate change literacy and climate friendly behavior.

thinking and raise understanding for non-linearity and dynamic feedback loops (Cox, Elen, & Steegen, 2020). Both educators and students would profit from focused teacher training programs and guidelines on how to best teach the climate crisis in an interdisciplinary way (Winter, Kranz, & Möller, 2022, Jackson & Pang, 2017). Human well-being and global sustainability can only be achieved if social, economic, and ecological systems are considered as an entity in which all components are interrelated (Liu, Fang, & Fang, 2020; UN General Assembly, 2015; Williams, 2010). This holistic (eco)system view is also a prerequisite for future problem-solving capabilities (Jonassen, 2011) and essential to sustainably raise environmental and climate literacy (Winter et al., 2022).

Various studies show that longer education leads to better knowledge about environmental and climate issues as well as a stronger sense for personal responsibility (EC, 2017, 2019). Accordingly, increased understanding of climate change may result in greater awareness and willingness to act in a climate-adapted manner (Weber, 2010). However, other findings conclude that more education does not necessarily mean increased pro-environmental behavior (Kollmuss & Agyeman, 2002). Our study confirms that higher knowledge does not directly increase pro-environmental behavior (like Fietkau & Kessel, 1981; Diekmann & Preisendoerfer, 1992; Fliegenschnee & Schelakovsky, 1998; Dijkstra & Goedhart, 2012). In addition, our findings suggest that longer engagement with climate change at school (see the "developer" group) does not automatically lead to an increased system understanding or a more adapted behavior than short engagement (see the "tester" group). The duration of the engagement is seemingly not as important as the quality of the engagement. This highlights the importance of memorable educational approaches.

For a sustainable transformation of the behavior of our society, we need to move from knowledge to real action (APCC, 2014; IPCC, 2014; Kollmuss & Agyeman, 2002). Nevertheless, only a few people show willingness to profoundly change their behavior and act more climate friendly (Barr, 2006). The discrepancy between knowledge and action (attitude - behavior gap or value - action gap, i.a. Blake, 1999; Barr, 2006; Markowitz & Shariff, 2012) is seen as an obstacle to successful adaptation to climate change (Gifford, Kormos, & McIntyre, 2011) and is particularly pronounced in the young population group (EC, 2019). Many young people believe that their possibilities are limited and their actions are not enough to achieve something ("bigger than self-dilemma", Wibeck, 2014). Moving from knowledge and system understanding towards personal climate-friendly behavior is the ultimate step in climate education, bridging the value- action gap (Figure 5). The vast majority of the school students involved in our case study was convinced that everyone has to contribute to getting the climate crisis under control already before the start of our project activities. Many students also stated that they were already implementing climate-friendly actions. Unfortunately, our questionnaire included mostly standard questions not specifically tailored to young people's personal conditions. Questions about climate-friendly mobility, for example, were positively influenced by the young age of the interviewed students (who, e.g., were not holding driver's licenses, thus relying on public transports, biking, and walking anyway). More specific questions about their buying behavior (regionally produced products, cosmetics without microplastics, water saving products) revealed a lower willingness to undertake personal actions. Likewise, when specifically asked for their opinion on climate activism, most respondents answered that they generally liked the idea but would not join such activities. Obviously, closing the gap between awareness, personal concern, and personal action remains a big challenge. Yet, it is clear that (young) people need to have sound knowledge about climate change and the human influence on the climate to be able to deliberately decide on pro-environmental actions (Chang & Pascua, 2016; Weigelhofer & Feldbacher, 2020; Figure 5). Thus, complementing young people's experience of climate change *via* hands-on experiments, field excursions, and demonstration of impacts within their direct environment can help to increase the voluntary engagement with the topic (Hermans & Korhonen, 2017; Myers et al., 2013: Lejarraga, 2010). The involvement of scientists from different disciplines dealing with complex socio-ecological systems as well as learning tools for conceptual thinking (e.g. Cmap Tools, www.cmap.ihmc.us, Cañas et al., 2005; DynaLearn, www.dynalearn.eu, Bredeweg et al., 2013) may help to increase both the awareness and the understanding of the complex humans-climate interactions. In addition, presenting strategies how to combat climate change in daily life enables young people to see the variety of possible contributions of a climate-friendly lifestyle. The more options people see for personal contributions, the more likely they are to take personal actions and live a pro-environmental lifestyle (Blake, 1999). Therefore, educational concepts should not only focus on raising (basic and complex) knowledge but also aim at highlighting the multiple possibilities of concrete climate protective actions that directly fit to the young people's reality and daily life.

Effective climate change education also provides a good opportunity to improve scientific literacy among young people (McCright et al., 2013). The science of climate change - the interdisciplinary integration of observational data, experimental results, computer modelling and so on - is a well-suited example to explain how science functions. A better understanding of the scientific process helps in correcting misconceptions about scientific findings and in accepting results with a broad scientific consensus (Moser, 2011, 2016; Weber, 2010). As ideal teaching approach for science education, Holbrook and Rannikmae (2007) suggest "education through science" rather than "science through education". Citizen science, as practical example for "education through science", offers both teachers and students the opportunity to gain insights into science and be actively involved in real and complex scientific projects (e.g. Bonney et al., 2009, Bonney, Phillips, Ballard, & Enck, 2016; Cutter-Mackenzie-Knowles & Rousell, 2020; Feldbacher, Pölz, Panzenböck, & Weigelhofer, 2018; Shah & Martinez, 2016; Weinstein, 2012). Feedback from students revealed that they appreciated the participatory engagement, especially the joint development of a scientifically correct experimental design, and that their interest in science as well as their scientific literacy increased through this process (Zoellick, Nelson, & Schauffler, 2012, Vitone et al., 2016). Involving school students can also have advantages for the science part (Thornhill, Loiselle, Lind, & Ophof, 2016) and data generated by students can have the same quality as generated by professionals regarding both absolute values and variability among replicates (Weigelhofer, Pölz, & Hein, 2019). Furthermore, personal contacts with scientists and positive experience with science can help in keeping students in STEM fields and raising their interest in a university education (Rosenzweig & Wigfield, 2016).

We are aware that our case study is small and the number of involved school students limited. Besides, survey questions could only consider selected aspects of climate change impacts and pro-climate behavior as the number of questions (and possible answers) had to stay within a reasonable extent. As numerous educational and psychological studies point out, school students' responses are always influenced by a multitude of internal and external personal factors and are also dependent on the students' condition of the particular day (concentration, motivation…). Especially the exceptional situation of the COVID-19 pandemic outbreak during the project might have influenced some of the students' answers of the behavior and perception category, as the climate crisis faded from the spotlight both in media and on personal level. Nevertheless, we believe that the results of this case study highlight significant gaps in school students' climate crisis knowledge and understanding and can, therefore, help to improve future educational initiatives in Austria as well as in other countries. From a global perspective, our study presents the attitude of young people living in a prosperous well-fare state where environmental and climate crisis are mostly seen as a "luxury problem" which does not directly concern their well-being. However, their actions contribute significantly to the current climate crisis. Furthermore, both national and cross-border cascading effects of climate change on the environment-society-economy link will also affect them or their children in the future. Thus, initiatives, which increase the understanding of complex, cascading effects of climate change at global (i.e. across countries) scale, are urgently required.

Conclusion and recommendations

Our study has shown deficits in climate education in Austria regarding the conceptual understanding of complex and reciprocal human-climate interactions, the differentiation between scientific results and non-scientific statements, and the necessary step from knowledge to climate-friendly behavior. To overcome these deficits, we suggest to transfer scientific knowledge to schools *via* revised teaching concepts that

- complement general climate change knowledge with an enhanced understanding of regional and country specific effects to reduce the spatial and temporal distance of causes and effects and to illustrate direct and indirect impacts on the daily life of school students.
- apply an interdisciplinary ecosystem and conceptual-thinking approach to increase system-understanding and awareness of dynamic, non-linear, and multidimensional interactions and feedback loops between the climate, ecosystems, and socio-economic systems.
- promote international cooperation in education to understand climate crisis effects and adaptation approaches in different countries and to learn from each other.
- use innovative and modern teaching and learning formats and tools (e.g. digital learning formats corresponding to young people's preferences and everyday life).
- foster scientific literacy by cooperation with science/scientists, for example participation in Citizen Science projects, workshops with scientists…
- build upon young people's positive attitude towards climate protection, strengthen their feeling of self-efficacy and highlight possible climate-friendly ways of action suitable for daily life.

We believe that interdisciplinary process skills and system-understanding are crucial to tackle the climate crisis and that it is vitally important for our society to have well-educated young people who are able to make deliberate decisions to meet current and future challenges by voluntary and pro-active personal participation.

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Disclosure statement

The authors report there are no competing interests to declare.

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