



# Head in the clouds, feet on the ground: how transdisciplinary learning can foster transformative change—insights from a summer school

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## Abstract

There is a pressing need for transformative change, with a vision of long-term human well-being within planetary boundaries. The lack of progress—despite increasing awareness and action—illustrates how challenging it is to foster change in our complex global society. Education and learning are needed to enable change. Transdisciplinary learning, which meaningfully integrates diverse knowledge and perspectives, contributes to developing an integrative understanding—a necessity for tackling complex challenges. We explore how transdisciplinary learning for early-career researchers can foster transformative change and lead to increased biodiversity conservation. This paper focuses on a case study of the authors' shared experiences during the 2021 Alternet Summer School, which focused on transformative change for biodiversity conservation and human well-being. In this introspective research, we gained insights through an online survey for participants and organizers of the summer school ( $n=27$ ). Using qualitative content analysis, we identify seven crucial elements of transdisciplinary learning which can lead to transformative change on (a) a personal level, as the learning process shifts values and helps researchers identify their roles; (b) a research level, by rethinking science and providing tools for transdisciplinary approaches, and (c) a societal level, by moving from the individual to the collective and constructing a shared vision for a sustainable future. Participants highlighted how changes on all these levels could benefit biodiversity conservation. These insights point to the benefit of transdisciplinary learning opportunities that empower young researchers to take up their part in fostering transformative change.

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## Introduction

Biodiversity is essential for human existence and well-being (Brauman et al. 2020). Humans depend on ecological processes to sustain life on earth, but we also represent a relentless, dominant force that tests the earth's resilience (Folke et al. 2016). Prevailing agricultural practices and overexploitation of wild species have caused unprecedented biodiversity loss and ecosystem deterioration worldwide (Maxwell et al. 2016; IPBES 2019). To account for intertwined relations within social-ecological systems, humans must be considered an integral part of the biosphere (Folke et al. 2016; Rockström et al. 2021). Such an understanding recognizes the necessity of the biosphere for human life and well-being but also calls for improved stewardship of human actions. Given the need for rapid and comprehensive action, transformative change is understood as necessary for achieving human well-being within planetary boundaries, including safeguarding biodiversity (IPBES 2019).

Transformative change encompasses comprehensive, system-wide reorganization across technology, economics, and society, as well as paradigms, goals, and values (IPBES 2018). In the context of sustainability, transformations are revolutionary systemic shifts of human-nature interactions that involve multiple elements of agency, behavior, institutions, values, incentives, and practices on multiple scales (Olsson et al. 2014). Transformative change requires us to imagine and implement complex, diverse, and comprehensive solutions. This also demands a radical transformation of societal value systems towards more inclusivity and pluralism (IPBES 2022). Identifying what local to global leverage elements can be mobilized is highly relevant to bring humanity back to a sustainable path and effectively tackling the biodiversity crisis (Chan et al. 2020). Levers may address direct drivers, such as actions on consumption habits or land use, and indirect drivers, such as the values we share (e.g., how we relate to nature). Influencing indirect drivers, which constitute the underlying foundation of our behavior (de Groot and Steg 2008), may happen through education and research on learning processes. Education and learning were identified as key leverage points for pathways to sustainability (Chan et al. 2020). Alongside impacts on attitudes and behavior, it can be understood as a preparation for system change that ensures windows of opportunity for change may be seized (Olsson et al. 2014). According to Chan et al. (2020), education can also serve as a “*precursor to well-functioning societies*”, especially if a “*whole person approach*” is embraced in education.

Transdisciplinary education has evolved as a response to this urgent need for systemic change. According to Luckerhoff et al. (2020), it not only represents a “*collaborative approach to the development of knowledge*”, but one that can help us to “*better understand and act on the complex issues that are present in our societies*”. Nicolescu (1997) defines “[*Transdisciplinary education*] [*a*]s a way of self-transformation oriented towards knowledge of the self, the unity of knowledge, and the creation of a new art of living in the society. [...] The emergence of a new culture capable of contributing to the elimination of the tensions menacing life on our planet, will be impossible without a new type of education

## Box 1: Definition of important terms

While the basic principle across the approaches defined below is similar (i.e., focusing on integrated complex problem-solving by crossing disciplinary boundaries), there are differences between the terms that do not make them interchangeable (Stock and Burton 2011)

**Multidisciplinarity** involves studying a research topic in not just one discipline but in several at the same time. The incorporation of the perspectives of several disciplines will ultimately enrich any topic. The multidisciplinary approach overflows disciplinary boundaries, but its goal remains limited to the framework of disciplinary research (Nicolescu 2014)

**Interdisciplinarity** concerns the transfer of methods from one discipline to another. Like multidisciplinary, interdisciplinarity overflows disciplines, but its goal remains within the disciplinary research framework (Nicolescu 2014)

**Transdisciplinarity - Nicolescuan approach** (also referred to as “mode 1” transdisciplinarity): Here, transdisciplinarity is seen at once between the disciplines, across the different disciplines, and beyond all disciplines. Its goal is the understanding of the present world, of which one of the imperatives is the unity of knowledge (Nicolescu 2014). The Nicolescuan approach provides a comprehensive theoretical framework and stronger links to education. However, besides its theoretical strength, it can be interpreted as a proposition for a “*way of being*”, encompassing more than just the scientific, but also the personal domain (Rigolot 2020)

**Transdisciplinarity - Zurich approach** (also referred to as “mode 2” transdisciplinarity): Here, transdisciplinarity is framed as a practical approach characterized by the inclusion of stakeholders in participatory problem-solving approaches that are applied to tangible, real-world problems (Scholz and Steiner 2015). According to Rigolot (2020), this school of transdisciplinarity, with its proposition of a new way of doing research, can be considered a discipline of “*integration and implementation sciences*”

*which takes into account all the dimensions of the human being.*” In the following, we refer to the Nicolescuan approach of transdisciplinarity (see Box 1), especially his understanding of transdisciplinary learning,<sup>1</sup> unless stated differently.

The importance of integrating transdisciplinary learning into higher education has been advocated to offer those moving through the contemporary education system a learning culture not constrained by disciplinary silos (Flogie et al. 2015). In pursuit of such a culture, Nicolescu (1997) turns his attention to the four pillars of a new model of education. These include (1) *learning to know*, or leading students to the “*very heart*” of scientific reasoning while maintaining the capability of bridging disciplines and relating to their personal capacities, (2) *learning to do* or the acquisition of both a skilled (specialized) craft or profession and the creativity that enables flourishing and productivity far beyond the confines of any particular specialization; (3) *learning to live together* with, or the learned adoption of a “*transcultural, transreligious, transpolitic and transnational*” attitude which transcends tolerance to embrace unity and plurality in both the active norms of the collective and the internally validated experience of the individual; and (4) *learning to be*, or that self-discovery attained through the never-ending questioning of our convictions and conditioning—practiced both through internal reflection and ongoing transpersonal exchange, learning from and with others.

Research on transdisciplinary learning has increased in recent decades, with a strong focus on higher education (Dedeurwaerdere 2013; Gillis et al. 2017; Mokhele and Pinfold

<sup>1</sup> In particular we understand transdisciplinary learning as defined by (Nicolescu 1997) through the four pillars of transdisciplinary education. We therefore refer to transdisciplinary learning as a concept that overlaps with – but is distinct from – transdisciplinary research (Hadorn et al. 2008).

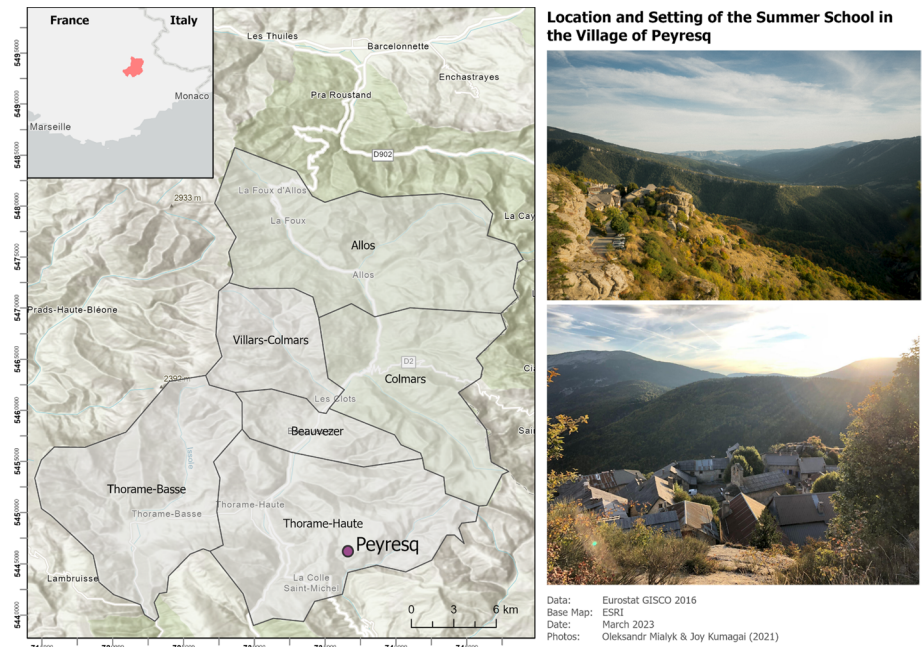
2021). Here, different conceptualizations of transdisciplinary learning have been used. Following the Zurich approach (see Box 1), efforts have been made to immerse students in transdisciplinary research practices (Stauffacher et al. 2006; Manring 2014; Pearce et al. 2018). Through hands-on experience in collaborative, participatory research, students learn to apply and advance knowledge—for example, in the field of sustainability science, e.g., assessing social-ecological systems (Manring 2014). To allow students to develop those critical skills necessary to make sense and, ultimately, solutions to complex and uncertain issues, training opportunities for higher learning institution staff are a key prerequisite (Barth and Rieckmann 2012). This body of literature highlights the added value of transdisciplinary learning in higher education. However, research on transdisciplinary learning opportunities as part of lifelong learning has been underrepresented (Derry and Fischer 2005; Wals and Benavot 2017).

For early-career researchers, transdisciplinary learning is also of particular importance as they are at a formative stage of career development and more frequently (explicitly) confronted with normative ideas on how science should be conducted (Felt et al. 2013). Thus, broadening their horizons and supporting their personal development holds the potential for transformative impacts (Derry and Fischer 2005; Dedeurwaerdere 2013). This potential link to transformative change has also been made for “*action-oriented knowledge for sustainability*” (taking a Zurich school viewpoint) by Caniglia et al. (2021). As Andrade et al. (2014) emphasize in the context of interdisciplinary higher education, safe spaces are needed for students and researchers to step out of their “disciplinary comfort zone”. Summer schools are, in that sense, a well-suited platform to initiate researchers in transdisciplinary learning. Defined as “*a course of lectures held during school and university summer vacations, taken as part of an academic course or as an independent course of study for professional or personal purposes*” (Oxford Languages 2023), summer school programs offer time for group processes and interactions and forums (both formal and informal) for the sharing of expertise and perspectives. Their nature as detached from—and, indeed, disruptive toward—the work and social habits of everyday life is likewise vital.

Analyses of perspectives and reflections of participants in such training events outside of formal education are valuable. They can contribute to understanding the elements perceived as important for personal development, redirecting future research endeavors, and wider societal impacts. These insights can inspire future transdisciplinary learning endeavors. Therefore, there is a need for studies assessing the perceived value and impacts of transdisciplinary learning opportunities in the context of lifelong learning, especially regarding their potential to support transformative change.

The authors attended a summer school on biodiversity and ecosystem services. Most authors were participants in the summer school and are early-career researchers. Based on our experiences, we reflected on whether and how transdisciplinary learning by early-career researchers can contribute to transformative change and, in particular, support biodiversity conservation. Based on a self-reflection questionnaire of participants and organizers of the 15th Alnet Summer School in 2021, we strive to answer the following two research questions:

- (1) What elements made the summer school a transdisciplinary learning experience?
- (2) Did transdisciplinary learning (during the summer school) contribute to transformative change, especially for biodiversity conservation?



**Fig. 1** The communities of the Upper Vendon area and the village of Peyresq (the location of the summer school) from a distance

Based on our results, we aim to advise future learning endeavors (like the Alternet Summer School) to strengthen their transdisciplinary nature and highlight links to transformative change.

## Materials and methods

This paper is based on the shared experience of the authors during the 2021 summer school. It is, thus—by definition—a reflexive analysis, which can be described as introspection (Finlay 2002). As Haraway (1988) states, knowledge is always situated and hence partial. Like Harding (1986), we believe that by looking at things from the point of view of the people involved (i.e., in this case, participants and organizers of the summer school), we provide a deeper understanding of the subject. Notably, because people’s experience is a condition for looking more critically at the conditions “outside” the subject under study that have an important impact on the subject.

## The 2021 Alternet Summer School

The international non-profit organization Alternet (<https://www.alterneteurope.eu>) has organized summer schools annually since 2006, intending to address the challenges of biodiversity conservation following transdisciplinary and systemic approaches (Van Dijk et al. 2012). The 2021 summer school took place from October 6–16, 2021, in the village

of Peyresq (Fig. 1), situated in the Upper Verdon region of the Alpes-de-Haute-Provence (France). Nine conveners and tutors with differing levels of responsibility (henceforth, the "organizers") coordinated the on-site activities of the summer school. Five of them have already occupied these roles for more than ten years. Nineteen speakers gave talks throughout the 10-day event. Three speakers gave their presentations online. The remaining 16 participated in person for several days, creating opportunities for the participants to exchange further on their topics of expertise. The Alternet Summer School organizers intentionally invited speakers with diverse disciplinary backgrounds and expertise. Speakers and organizers likewise represented different disciplines (including interdisciplinary and transdisciplinary approaches) and sectors (academia, NGO). The topics of the talks included biodiversity monitoring; biodiversity conservation; ethology; environmental management; environmental governance; ecological economics; biodiversity policy; science-policy interface; political science; environmental conflicts; socio-ecological systems and system thinking; human behavior ecology; environmental psychology; ecosystem services; sustainable agriculture and food systems; indigenous environmental knowledge; ecosystem conservation, restoration, and sustainable use; ammonia and the nitrogen cycle; and green-blue infrastructure. The 23 participants of more than 15 nationalities were mostly early-career researchers, and the majority ( $n=21$ ) were PhD students. The mean age of participants in the summer school was 30 years old. All organizers were in a later career stage relative to the participants. For participants, the gender distribution was 57.0% female and 43.0% male, while the organizers' gender distribution was 62.5% female and 37.5% male. Their disciplinary backgrounds spanned from geography to ecology, social sciences, marine biology, law, communication, and landscape architecture. Basic relevant demographic information and a more detailed background of the participants (derived from their application registration forms) is displayed in the Appendix, Table 2. Fifteen participants (including one organizing administrator) and two organizers are co-authors of this paper.

The summer school's theme was "*Biodiversity and ecosystem services: Science and its impact on policy and society*". As one major component of the program, a collective project centered around identifying transformative pathways to foster biodiversity conservation and human well-being in the Upper Verdon region. The participants developed this project in a self-organizing manner throughout the summer school. It included scientific and outreach activities and was guided by the five tutors, who facilitated the self-organization and supported the work when necessary. This collective work integrated information from the lectures, field trips, interviews with local stakeholders, and the participants' backgrounds. Contributions from and interactions with diverse local actors—including shepherds, local politicians, national park and NGO workers, tourism industry representatives, and more—were included alongside those of natural and social scientists. The combination of knowledge types and formats aimed at assembling a holistic understanding of transformation pathways of social-ecological systems.

The isolated character of Peyresq was paired with an utterly communal social structure that kept participants, organizers, staff, and speakers in close proximity. This meant that all attendees commonly shared all experiences (learning, work, meals, recreation, and play). Conversations and exchanges of skills, knowledge, and expertise could easily spill over from the classroom into informal settings. Furthermore, Peyresq's situation in the landscapes and nature of Upper Verdon meant that students were surrounded by and confronted with the subject matter of their studies each time they exited the classroom. Peyresq was intentionally chosen by organizers due to its remote setting. The natural isolation and full program (ten days without a break) prevented opportunities for life's obligations

(work, social, or otherwise) outside of the summer school to interrupt the summer school experience.

### **Data collection: self-survey following the summer school**

We conducted an online survey from December 2021 to January 2022 with two open survey questions (further referred as SQ1 and SQ2.1) sent to the participants and organizers. The first survey question addressed the first research question, namely, what transdisciplinary elements could be identified during the summer school. The second survey question addressed the second research question, namely, how the summer school could contribute to transformative change. A second survey, conducted in May 2022, included an additional question (SQ2.2), based on SQ2.1, but focusing on biodiversity conservation. The exact wording of each survey question is provided in the Appendix.

The respondents were asked in the first question (SQ1) to cite elements of the summer school that supported the Nicolescu (1997) and Luckerhoff et al. (2020) definitions of *transdisciplinary education*. Those definitions were chosen (particularly Nicolescu's) because the general setup of the summer school (see above) aligned well with the idea of experiencing a “*way of being*” (Rigolot 2020; see Box 1). However, the interaction with non-scientific stakeholders and being immersed in transdisciplinary research (which stronger relates to the Zurich school, see Box 1) were also important elements of the summer school. In addition, respondents were asked to report on any *transformative changes* (Olsson et al. 2014) that they experienced after the summer school at a personal, research, and societal level (SQ2.1). In the second survey round, respondents reflected on the specific links to biodiversity conservation (SQ2.2).

The questionnaire was designed to capture the enabling elements of the summer school and the mental models of the respondents that highlighted the positive facilitating links and processes between the elements of the summer school and the possibility of transformative change. Nonetheless, respondents could answer with “no” or mention negative or counterproductive tendencies, which are also highlighted in the results and discussion. We gathered 27 answers in the first survey round, including seven responses from organizers and 20 from participants. The second survey round also yielded 27 answers, eight from organizers and 19 from participants.

### **Data analysis: qualitative content analysis**

We performed a qualitative content analysis (Ritchie et al. 2014) by coding statements from the survey questions using NVivo 11 (QSR International Pty Ltd 2020). We analyzed the answers to SQ1, SQ2.1, and SQ2.2 separately. Moreover, we treated answers from participants and organizers as two different subsets. The purpose was to distinguish participants with a single summer school experience from the organizers, who participated in numerous summer schools and might have a more comprehensive view.

We resorted to slightly different coding approaches for each question. For SQ1, we started with a deductive approach with the four pillars of transdisciplinary learning (Nicolescu 1997): *learning to be*, *learning to know*, *learning to do*, and *learning to live together*. We then continued coding inductively, sentence by sentence (Timmermans and Tavory 2012; Tavory and Timmermans 2014). We chose this abductive approach to combine the advantages of inductive (finding new cases of existing theories) and deductive

methods (testing existing theories). This creative inferential process aims at producing new hypotheses and theories best suited to analyze data containing unexpected observations that do not fit existing theories (Timmermans and Tavory 2012). For SQ2.1, we likewise used an abductive approach. We began by first coding deductively the answers into three categories (personal level, research level, and societal level), followed by inductive coding for in-depth understanding. SQ2.2 was coded only inductively. We coded statements multiple times if their content related to more than one code. It should be noted that we proofread quotes displayed in the results for clarity.

The coding dynamic followed a 5-step system performed in groups. Two groups of three co-authors started coding, as detailed in the previous paragraph (step 1). The groups met to merge their selection and identification of the codes (step 2). Next, each group cross-checked the codes of the other group for consistency purposes (step 3). To ensure a common understanding of codes by all co-authors, representative quotes for each code were selected during a working group session involving most authors (see supplementary material) (step 4). Another group (including coders involved in steps 1 to 3) used the codes to extract key messages about how transdisciplinary learning provided by a summer school can foster transformative change (step 5). Collaborative live-coding allowed the coder teams to challenge, debate, and contribute ideas to the process of generating a codebook (Naganathan et al. 2022).

## Results

The survey results are presented separately for participants and organizers and per survey question. Figures also indicate shared codes with the other respondent group. Organizers' answers to the survey questions were generally more extensive than those of participants.

### What elements made the summer school a transdisciplinary learning experience?

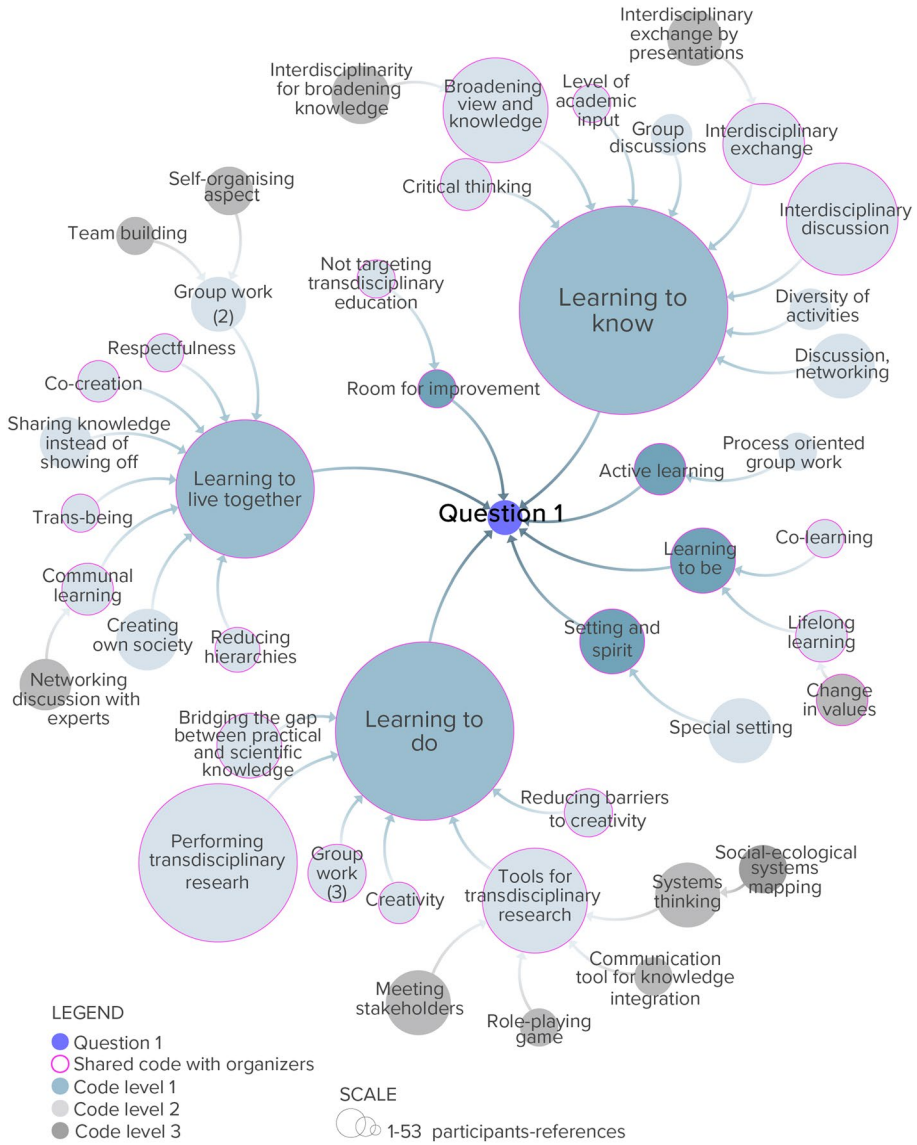
#### Participants

Participant's answers (SQ1) could be attributed to all four pillars of education elaborated by Nicolescu (1997), but especially *learning to do*, *learning to know*, and *learning to live together* (see Fig. 2). Additionally, two new themes emerged through the inductive coding: active learning and setting and spirit.

*Learning to do* relates mostly to learning to perform transdisciplinary research by doing. The group work was considered a light version of transdisciplinary research as it was an interdisciplinary effort to find pathways to foster biodiversity conservation in a complex system. These pathways were grounded, to a certain extent, in the experience of people living in the research area, as well as the experiences of the researchers—ourselves temporarily part of the study are—and aided by organizers who had spent months in the landscape after many summer schools. It was noted by one of the respondents that the research done in the group work was not fully transdisciplinary:

*“It should be noted, however, that the product of the joint analysis was achieved through contact with researchers only. And if they were based on actors whose*





**Fig. 2** Visualization of the coding structure for SQ1 by the participants with the size of code proportional to the number of times mentioned, the color representing code (sub) level, and border indicating codes shared with organizers

*knowledge is more practical or traditional, the latter did not deeply integrate the process of co-construction of the result of the analysis.”*

Rather than pursuing research outputs, the work of the summer school had an educational purpose. Its methods aimed to give participants a first taste of transdisciplinary research and apply insights gained through expert presentations. Mentioned examples include the

systems thinking approach and transdisciplinary research tools, such as causal loop diagrams. This was illustrated by a participant as follows:

*“Every element of the program could be directly mobilized by individuals and by the group to progress on the group project resolution, thereby providing an opportunity to immediately test and implement the abstract knowledge acquired during the morning and evening seminars.”*

The most cited elements relating to *learning to know* were “*interdisciplinary discussion*” and “*broadening views and knowledge*”. As noted by many participants, the summer school brought together people from a diverse range of disciplines within natural and social sciences. They came “*with an intention of learning, sharing, exchanging and co-constructing*” which ultimately resulted in “*cross-fertilization of knowledge*” and enabled a more holistic approach to problem-solving, as illustrated by the following quote:

*“Due to the close cooperation with people from different professional fields on a problem with different thematic focuses, it became clear that a one-sided view of the problem and thus a one-sided approach to solving it cannot be goal-oriented.”*

Concerning learning to live together, participants underscored the benefits of living communally in an isolated setting and the possibility of informal interactions, which can be understood as important group processes. For example, one respondent found talks outside the classroom to be “*the most inspiring and transforming*”. Many participants also emphasized the importance of extracurricular activities (e.g., dancing, talent show, and sports), which allowed more personal connections to be built and reduced hierarchical relationships, thereby creating a basis for honest exchanges:

*“The creation of a new art of living came to me through the horizontal and self-organizing society that we created up in Peyresq. I guess the isolation we lived in and the beauty of the surroundings contributed to it and made the experience more intense, but I am more inclined to think that the summer school was a blank canvas that we painted together through co-creation.”*

Within this quote there is also a clear reference to the setting and spirit that was deemed an important part of the process. Participants also noted shifts and changes in their values and worldviews. For example, one expressed that the school “*changed [my] perspective a bit on organic food and certified products*” and another mentioned that “*humans are just a part of nature and not gods*”. Participants also emphasized the usefulness of stepping outside scientific realms to meet with local stakeholders, such as farmers, municipalities, and environmental NGOs. Understanding their problems, values, and desires allowed participants to see the complexity of conflicts and synergies in social-ecological systems. As a result, there was a common perception that biodiversity conservation can only be addressed by combining different types of knowledge: disciplinary, practical, and traditional.

## Organizers

The organizers also reported elements of transdisciplinary learning relating to all four pillars of Nicolescu (1997), as well as the two other themes of *active learning* and *setting and spirit* (see appendix, Fig. 6). In addition, the organizers mentioned room for improvement

to adhere better to the definition of transdisciplinary learning. From all coded elements, four main themes emerged (the first three being the same as those of the participants): *learning to do*, *learning to know*, *learning to live together*, and *setting and spirit*.

As was the case for the participants, *learning to do* focused mainly on learning by doing transdisciplinary research. The group work aimed to show the “*legitimate knowledge insights from people out of academia*” that need to be used for addressing “*a concrete problem out of the “messy real world which in itself forces to think beyond disciplinary and ideally even scientific boundaries*”.

In *learning to know*, organizers cited interdisciplinary discussion and critical thinking. They pointed out that the unique structure of the summer school made it possible “*to set bridges across disciplines for a better understanding of the topic*” while enabling open dialogue among organizers and participants. This facilitated critical analysis of the presented information and provided space for co-learning. Organizers also emphasized the importance of practical work as illustrated in the following quote:

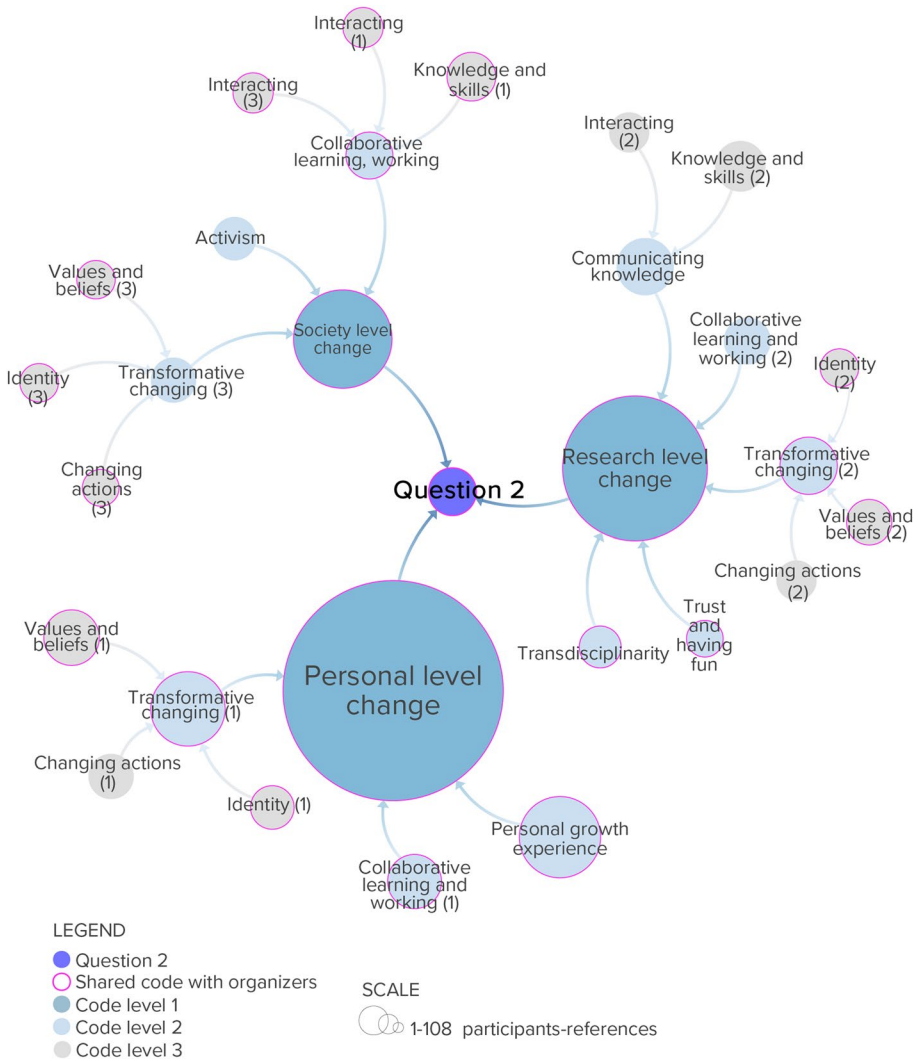
“*Other activities [practical ones] are also designed in order for the participants to adopt an active posture (Luckerhoff et al. 2020), such as a hike to meet and discuss with a local shepherd and a day of field trip during which participants have the opportunity to interact with local stakeholders all facing issues that are key topics of the summer school such as climate change and biodiversity loss. This matches with the idea that ‘intelligence assimilates knowledge much better and much more rapidly when this knowledge is also understood with the body and feeling’ (Nicolescu 2005).*”

In *learning to live together*, organizers highlighted the usefulness of communal learning, transculturality, and social interactions. For almost two weeks, both organizers and participants lived together in a small isolated village. In this setting, “*the relations between people are on such a respectful level that it is very motivating and stimulating*”. Furthermore, all present persons “[*came*] *from a broad set of cultural horizons and are adopting a transcultural attitude to work and be together*”. Social interaction was facilitated by various informal activities like “no-talent” shows, games, or sports. Such activities reduce hierarchical distances between organizers and participants which are important group processes to enhance trust: “*an ingredient that is essential for transdisciplinary cooperation.*”

Organizers also focused on their role in group work. They contributed to the design and implementation of students’ projects, which promoted co-creation and co-learning. For example, one wrote that he/she “[*did*] *not only come to ‘give a talk’ but really to interact and blend in with the wider group for a few days*”.

The *setting and spirit* were given prominence by the organizers as crucial for the success of the summer school. The setting was described as the “*small isolated village of Peyresq that is almost entirely for us*” and the spirit as “*an atmosphere where people dare to open up and give their best*” and a “*safe bubble*”. The importance of this combination was mentioned as follows:

“*We learn while being fully situated within and mindful of the beauty, light, heat, cold, wind of the space and the dynamics of the other beings around us. We can stand out on the deck and see our ‘case study’ location. We get happy, tired, frustrated, elated, sick, healthy. We are inspired, confused and have epiphanies. We fall in and out of love with ourselves, the ideas and the people around us. And none of these sensations can be partitioned from the learning experience.*”



**Fig. 3** Visualization of the coding structure for SQ2.1 by the participants with the size of code proportional to the number of times mentioned, the color representing code (sub) level, and border indicating codes shared with organizers

One of the organizers went so far as to ponder “*whether these elements [of transdisciplinary education] [are] formally planned or that just happened because the context allowed for them to happen*”.

## How can transdisciplinary learning contribute to transformative change?

### Participants

On the subject of transformation (SQ2.1), participants primarily spoke of transformation at the personal and research level. Transformation at a societal level only featured to a limited extent (Fig. 3). At the personal level, participants cited accelerated personal growth and transformations in held values, beliefs, behaviors, and, to a lesser extent, identity. The shift in personal values and beliefs was sometimes accompanied by stated behavior changes, including choosing more sustainable diets and modes of transportation. Illustrating these personal changes, one participant noted:

*“The question of ‘who do you want to be/what place do you want to take in this world’ (that’s how one of the talks ended) is still present in my mind and I feel a little braver (it is a shame, in my case I feel I am losing braveness with age) to act on it, instead of being afraid of the implications/feeling of needing security in life.”*

Furthermore, many participants reported a shift toward more collaborative learning and working at personal and research levels. Specifically, participants recognized the value of collaborating and sharing perspectives in research and daily life. At the research level, this collaboration was often associated with the mention of skills and knowledge, as expressed in the two following quotes:

*“I experienced a new form of working together and with that, I have incorporated the perspectives and methodological approaches of other disciplines into my toolbox.”*

*“The conviction that knowledge is not to be found in the individual, but that the reality of the world lies somewhere at the intersection of everyone’s knowledge, and that research processes/methods should to some extent adjust to this (new?) representation of knowledge.”*

Embracing activism and learning to live as a collective instead of as individuals were also mentioned as helpful for transforming society for the better. Participants expressed encouragement following the summer school to embrace activism and be bolder, no longer inclined to separate activism from professional activities. This inspired a general re-examination of their role in society as scientists:

*“I also felt very inspired to stop being passive and become an active activist (if that is possible). Sometimes we tend to think that as scientists we need to be neutral all the time, and we were shown that our research does not need to be compromised by our activism.”*

Two participants stressed that the way science is conducted impacts our societies. They expressed that early-career researchers who experience transdisciplinary learning will have the tools and courage needed to take more collaborative and participatory approaches in research. By considering their work’s societal relevance, these early-career researchers could spark a shift in how research is conducted through a general rethinking of science:

*“Since the scientific revolution, it must be acknowledged that science occupies a significant place in the development patterns of our societies. If science is thought, approached, and concretized in a fundamentally different way than it has been today,*

*I think that yes, such a transformation could not leave the development of society indifferent ...”*

The summer school, by design, provided a unique opportunity to learn how to live in a connected community and recalibrate one’s focus from individualism toward the collective. This idea was embedded in the responses of many participants. For example, participants mentioned that knowledge is a shared product, noted how “*different backgrounds and points of view came and worked together*”, and described “*the concrete experience of building a unified vision from multiple perspectives.*” This experience of moving from individualism to collectivism was understood to hold transformative potential if applied to larger segments of our societies. One participant wrote:

*“In western societies, we are taught to work so hard on our egos that we dismiss how to live in a community or a group. This makes us feel welcome and wanted. If we are able to transport this to our lives outside the summer school it would be a great step.”*

## Organizers

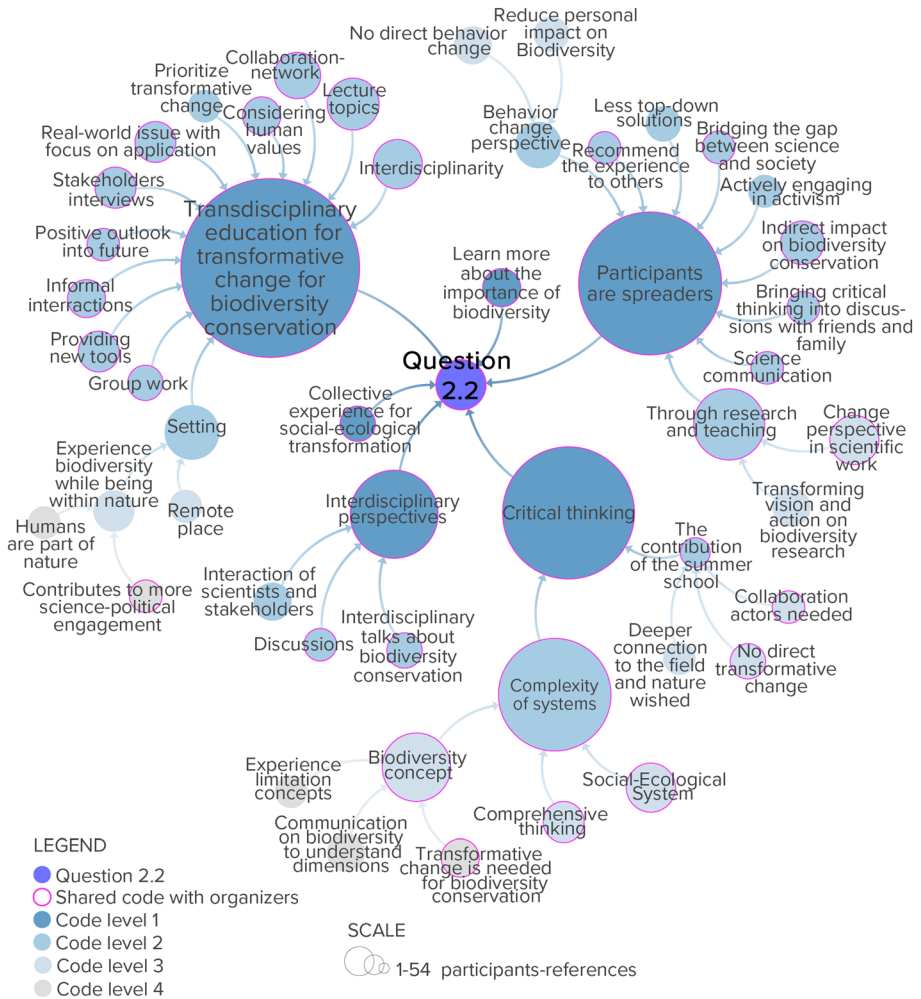
In response to SQ2.1 on how transdisciplinary learning can contribute to transformative change, organizers focused on changes at the personal level more than the research level in their answers and wrote extensively on how these changes can contribute to the transformation of societies (see appendix, Fig. 7). At the personal level, a focus was set on community and the importance of the summer school setting. As the quote below reflects, this was understood by one respondent as a progressive shift in values, beliefs, and actions:

*“The transformative ‘change of self’ happened to me personally through a progressive shift in values, beliefs, and actions that gradually occurred during my last 15 years (i.e. since I first participated in the summer school). Of course, it would be impossible to specify just how much of this change can be attributed to the summer school, but there is no doubt that it played a significant role.”*

There were fewer and more varied reflections on the research level for organizers. Increased transdisciplinarity in science and critical self-reflection were mentioned several times. Answers that mentioned self-reflection encompassed teaching students to ask questions, encouraging their critical self-reflection, and the independent exploration of disruptive ideas encountered in the summer school. These disruptive ideas may be interpreted as a counter to current hegemonic beliefs (for example, humans being part of biodiversity).

Organizers responded that the changes experienced at the summer school can indeed contribute to transforming societies. This is supported by constructing a network of people willing to question how we live within the world, engaging in critical thinking, and integrating more transdisciplinarity into science education. Consistent with participants, the role of community was highlighted as key for learning how to enact change within society. One organizer mentioned:

*“I believe that bringing together people from diverse cultures/countries/backgrounds and offering a safe space for developing care towards each other and the world, for*



**Fig. 4** Visualization of the coding structure for SQ2.2 by the participants with the size of code proportional to the number of times mentioned, the color representing code (sub) level, and border indicating codes shared with organizers

*questioning our ways to live with and in the world is one of the many ways that [we] contribute to transforming society.”*

## How can transdisciplinary learning contribute to transformative change for biodiversity conservation?

### Participants

When asked how the summer school would lead to transformative change for biodiversity conservation (SQ2.2), the participants reiterated that the summer school did indeed have

transdisciplinary elements and related these elements to biodiversity conservation (see Fig. 4). They reported that the setting was not only an exceptional learning environment, but also that being close to nature (and, thus, biodiversity) reinforced the content of the talks:

*“Besides intellectual understanding, the summer school provided space to experience biodiversity. This is important, as it prevented the reproduction of the dangerous idea that nature is something separate being observed by scientists.”*

The lectures provided a multidisciplinary perspective on biodiversity conservation and sometimes questioned the concept’s very meaning. This sparked many formal and informal conversations leading to new and more nuanced insights:

*“Personally, it provided me with a more complete understanding of what biodiversity conservation means and how we can achieve it, thanks to the lectures and discussions (in and out of class) between researchers from multiple disciplines (from economics, conservation, and sustainable livelihoods).”*

These new insights can help biodiversity conservation both directly (stated by three participants) and indirectly (stated by 17 participants). The indirect impact of the summer school on biodiversity conservation was mentioned to take place through different pathways. The first is through research on biodiversity conservation, where new insights may be incorporated and the construction of a shared vision of what biodiversity conservation could or should look like:

*“I am convinced that the Alternet Summer School contributes to transforming the way we, as researchers, envision and handle biodiversity conservation challenges, hence, this has a strong, although indirect, positive impact on biodiversity conservation”.*

Creating a network of researchers with diverse backgrounds and trajectories but common goals could likewise aid in future collaborations for research on biodiversity conservation. Such a network could *“lend support when making changes at the research level to push for research and activities with more input from practitioners and stakeholders [...] which can have a real impact on the environmental sector and possibly foster transformational change for biodiversity.”* Another indirect pathway mentioned was increased topical communication with the non-scientific community in and through personal networks, popular science, and environmental activism.

Two other often mentioned effects of the summer school that support indirect pathways were (a) the stimulation of critical thinking and (b) the fostering of interdisciplinary perspectives—both with an emphasis on systems thinking, as illustrated by the following quote:

*“In the summer school, we learned to reflect on existing approaches, definitions, and methods critically. It started with the definition and delimitation of biodiversity. In this talk and in the further project work we have learned to look at the whole system and to include social and economic aspects when talking about biodiversity and ecosystems.”*

A direct pathway involves the participants’ individual actions, changing their own behavior or lifestyle in a way that directly aids biodiversity conservation. Such changes were only reported by two participants. Three participants, however, stated that the summer school experience further reinforced behavioral practices which they had already adopted.



As opposed to direct impacts, the indirect impact seemed to be more widely accepted and embraced. One participant summarized their thoughts on the matter as such:

*“I guess I am using a decaffeinated version of ‘transformative change’ here since a ‘fundamental, system-wide reorganizationfundamental, system-wide reorganization’ did not take place, and has not taken place since the AltSS [Alternet Summer School]. But what matters for me is the trend, the path that has been open, the ideas that are germinating in us and that will acquire a form if we water them enough.”*

## Organizers

The organizers’ answers to the question of how the transdisciplinary learning of the summer school leads to transformative change for biodiversity conservation were similar to participants’ views (see appendix, Fig. 8). Three of the eight responding organizers questioned if the summer school itself directly leads to transformative change for biodiversity conservation. One of the organizers mentioned the small scale and specific target group of the summer school as a limiting factor to achieving transformative change at the societal scale. However, all organizers agreed that the experience can indeed lead to positive change for biodiversity conservation indirectly. The main identified pathway was through creating ripe conditions for transformative change among the organizers, participants, and speakers on a personal level, and in their research. This would then benefit biodiversity conservation in the long run. The conditions for transformative change were identified as follows by one of the conveners:

*“Those conditions include developing empathy and patience in understanding others’ worldviews, exposure, and curiosity towards disciplines that are not your own, and creating a safe environment for taking risks and testing new ideas. I’d argue that these conditions are foundational for transformative change.”*

Another organizer described the transformative character of the summer school as a holistic learning environment that presents an opportunity for breaking out of “*silo thinking*”. According to another organizer, this can stimulate challenges to common assumptions on nature-society relationships, the lenses through which we see these relationships, and even the concept of biodiversity conservation itself. These inter- and transdisciplinary insights could lead to a better understanding of the root causes of biodiversity loss, the complexity of decision-making around biodiversity conservation, and the governance systems behind these decisions.

The participants, organizers, and speakers take these experiences and insights with them and apply them both in their personal and professional lives, acting as agents of transformation. As the summer school, branded as a “network for life” also facilitates the creation of a network, attendants have the opportunity to maintain their connections and work jointly on transdisciplinary projects long after the program’s conclusion. One of the organizers expressed the hope that this would lead to a new and improved science-policy interface:

*“Transdisciplinary education will help future scientists and policymakers to work more closely together and form the Science-policy interface 2.0 needed to lead transformative change for biodiversity conservation. [...] It will hopefully help to build trustworthy relationships between science, policy, and society and regain trust in sci-*

*ence. Transdisciplinary education will help scholars understand early on the complexity of decisions and bring more perspective and more values (plural values)."*

This expression of hope that the summer school could be a part of transformative change for biodiversity conservation was likewise seen in the answers of most organizers, in such phrases as: *"It's our hope as conveners"*, *"I sure hope that it does"* and *"[the summer school] might favor new ways of thinking"*. One organizer reinforced this hope with observed experience, noting that *"basically every single person I have met who is doing really interesting, courageous and highly visible things within the biodiversity, ecosystem services kind of space within (European, for sure, but also broader) academic and science-policy interface work has attended or in some other way been part of the summer school"*. Such statements indicate that those involved in the summer school *"do go on to make and/or advocate for transformative change for biodiversity conservation"*.

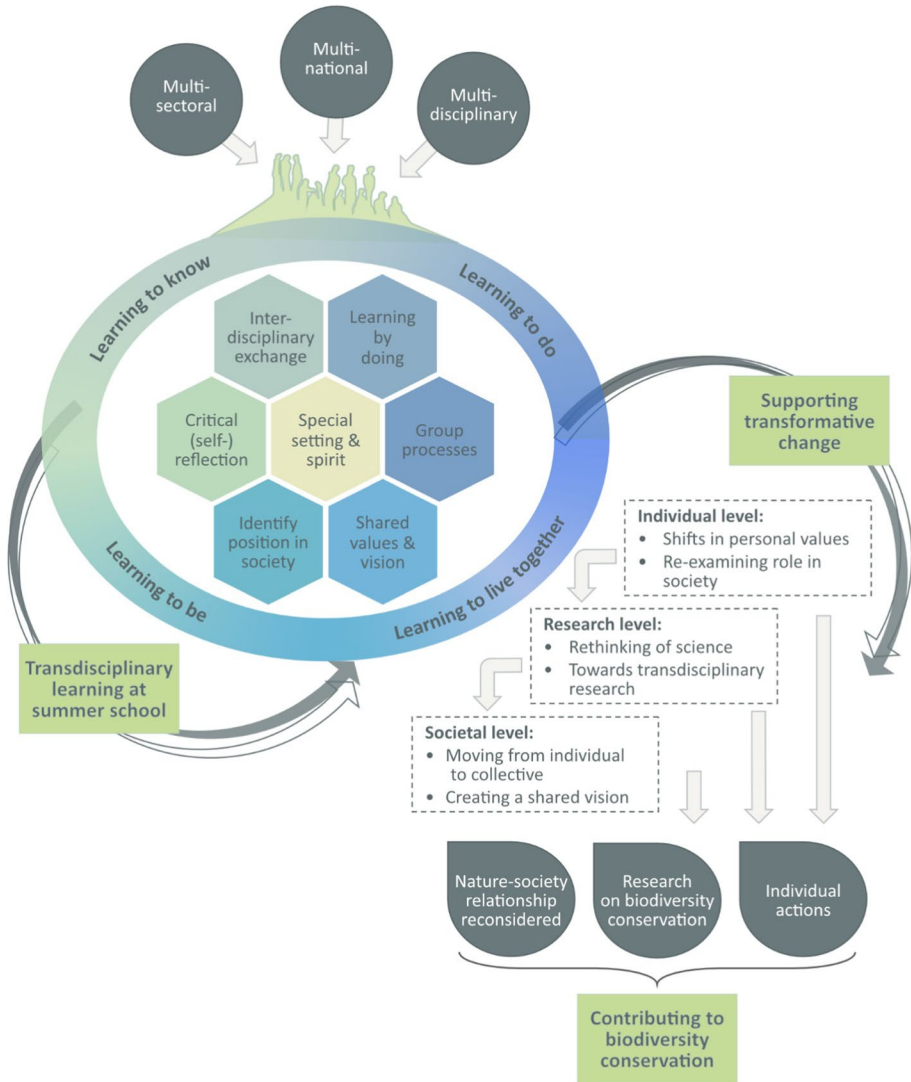
It is, of course, important to acknowledge the difficulty of untangling the effect of the summer school from other effects in such observations. The organizers generally recognized that it is hard to specify or quantify the real impact of the summer school, as expressed in the following quote:

*"The answer to your question needs to stay vague because, in my opinion, it is never clear how and how much education leads to a change. My hope is that the Alternet Summer School contributes to a bigger transformation that is already taking part in different parts of Europe."*

## Discussion

The results show that transdisciplinary learning can change attendees' perceptions of and approaches to complex social-ecological problems (Wei et al. 2020). Interpreting these results, we assume that the effect of the summer school emerged from an interplay of many variables highlighted in the existing literature on education for sustainability (Manring 2014; Kioupi and Voulvoulis 2019) and transformative change (Leichenko et al. 2022).

Guiding our discussion is exploring the transformative pathway of transdisciplinary learning leading to biodiversity conservation. We want to highlight potential links based on our experience during the summer school (Fig. 5). This pathway is broken down into its different components and discussed in the following sections. The pathway starts with the people that are part of it (upper left), with their different disciplinary, cultural, and professional backgrounds. These feed into the transdisciplinary learning experience based on the four pillars of transdisciplinary learning (outer circle) and underpinned by seven key ingredients (hexagons) that fostered the transdisciplinary learning process, identified from the survey. Six of these hexagons are clearly linked to the pillars, whereas the "setting and spirit" as the middle hexagon was identified as an extra enabling element for the six other processes. The transdisciplinary experience may lead to transformative change on three different levels: personal research and society, which can trickle down into each other and contribute to biodiversity conservation. We hope this pathway can inspire other transdisciplinary learning endeavors attempting to increase their impact.



**Fig. 5** Conceptual graphic of the transformative pathway of transdisciplinary learning at a summer school, contributing to transformative change that can benefit biodiversity conservation. A similar pathway could be followed to help design future transdisciplinary learning endeavors

**Methodological considerations**

This study sheds light on attendees’ self-reports, including their ideas of how the summer school format impacts transformative change for biodiversity conservation. Thereby, it does not measure if this change actually took place. It only provides insight into organizers’ and participants’ perspectives and mental models. Moreover, the study does not examine long- or mid-term effects on the participants. Data collection took place two and seven months after the summer school. When participants reported a change of behavioral intentions, values,

or attitude shifts, this report only gives insights into the short-term effects. Research on attitude change has provided ample evidence and theory on persistence and “snapping back” of attitudes in longer time spans (Cialdini et al. 1981). To consider this effect, the first survey focused on the more broad possible impacts of the summer school, capturing the positive energy and inspiration it provided. The second survey was distributed seven months after the summer school, when the experience could already be better placed into perspective, and asked for a more specific possible impact of the summer school. The organizers provide more insights into long- and mid-term effects as they attended the summer school already for multiple years. Nonetheless, future surveys should be conducted to gain insights into actual and persistent change. Adding to this uncertainty is the difficulty of disentangling the effects of ongoing personal and societal shifts from the impact of the summer school alone.

Another consideration is that we could not make statements within our analysis on factors’ effects and dependencies regarding each other. For example, interdisciplinary discussion (*learning to know*) could be without any effect if not accompanied by learning of transdisciplinary tools (*learning to do*). Future research should examine the effect of different factors in isolation and possible relations between factors.

A limitation of the summer school itself concerns the privileged character of this experience. This affects the generalization of the results and our conclusions about the suitability of the format to support transformative change. Participation required social and financial capital through institutional affiliation and support. These two criteria (at the very least) limit opportunities for many students to participate. Making these transdisciplinary learning opportunities widely accessible would increase their transformative potential.

### **Was the summer school transdisciplinary or just learning?**

*“Learning to be is also a permanent apprenticeship in which teachers inform the students as much as students inform the teachers.”* (Nicolescu 1997).

*“A modern-day School of Aristotle, where lecturers learn as much as students—if not more.”*—Martin Sharman (former European Commission policy officer), on the Alternet Summer School <http://alterneteurope.eu/summerschool>.

By analyzing the answers of both the participants and the conveners, we can conclude that the summer school had transdisciplinary learning elements. These were not all planned for as such but developed over the years. All four pillars of a new way of learning were acknowledged by participants and organizers (Nicolescu 1997). There was room for both traditional and practical knowledge in group work and general activities, confronting participants with different types of knowledge (Luckerhoff et al. 2020). Nonetheless, possible adaptations for increased transdisciplinarity were still identified. This should not come as a major surprise as transdisciplinarity is known to be a process that takes time to establish (Klein 2008), and the summer school is on this trajectory.

### **Lessons learned: How to create an impactful transdisciplinary learning experience in four statements**

From our results, we identified seven key ingredients for transdisciplinary learning. Multiple frameworks already exist which highlight vital elements, competencies, or pillars of transdisciplinary or sustainability education. See, for example, the pillars of Nicolescu

(1997) or the competencies of Brundiens et al. (2021). We relate to this work and expand on it to fit the results of our own experience. Our seven key ingredients operate together and influence each other. They can be summarized into four statements or guiding principles which could serve as guidelines for constructing or adapting a transdisciplinary learning experience to foster its transformative potential.

### You learn best when learning actively together

**Learning by doing** was reported as one of the most important elements, giving the participants the tools to integrate these concepts into their research. The active learning was (in this particular summer school) embodied by the group work on transformative pathways for the social-ecological system of the region where the summer school was held. The benefits of using a case study to activate the learning process (Manring 2014) were confirmed by our results and are in line with the Zurich approach of transdisciplinary learning. This approach also aligns with three of the key competencies in sustainability science (integrated problem-solving, implementation, and systems thinking) defined by Brundiens et al. (2021). The learning experience was also enhanced by being actively together, enabling **group processes**. The lively interdisciplinary discussions during formal and informal moments, including dancing together, were seen as an integral part of the learning process. Indeed, the informal learning moments can be interpreted as second-order learning, deemed necessary for transformative climate science by Tåbara et al. (2019) and as the development of interpersonal competencies highlighted by Brundiens et al. (2021). This informal second-order learning was only possible because hierarchies were deliberately broken. This was achieved within the group of participants by allowing them to organize themselves for group work while asking them to take up roles that they normally would not and by making them aware of group dynamics through role-playing. It was also achieved within the whole group of attending persons by inviting speakers to stay multiple days, attend other talks, and share meals, coffee, and recreation with the participants and other speakers. A final important benefit of learning actively together in a horizontal manner is the true **interdisciplinary exchange** it creates as no person or discipline fully dominates the conversation, and all topical knowledge is regarded (Brundiens et al. 2021).

### Changing from individualism to collectivism through activating shared values creates a safe space for constructing shared visions

The summer school activated communal and **shared values** and understanding interpreted within the survey as a switch from individualism to collectivism, as participants reported shifts in personal values and the importance of learning to live as a collective. This is understood as an important part of social learning within transdisciplinary and sustainability research (Herrero et al. 2019; Brundiens et al. 2021). It had three noted effects on the learning experience and motivation: First, the collaborative learning environment and methods that the organizers used activated shared values such as tolerance, compromise, recognition, and collective problem-solving. These shared values lowered the possibility of individual negative experiences. They created a safe space for open discussion and learning, which is stressed as necessary for researchers to step outside of their “disciplinary comfort zone” (Andrade et al. 2014). The emotional intelligence that is accordingly fostered was also identified by Lambrechts et al. (2013) as an integral part of learning for sustainability. Second, this activation contributed to a possible adjustment of participants’

vision on sustainability towards a more collective vision that relied on the exchange of perspectives and the transgression of knowledge types (Herrero et al. 2019; Schneider et al. 2019). Third, the two points mentioned above contribute to the possible concretion of a **shared vision** of sustainability and, by extension, transformative change (Jacobs et al. 2022; Brundiers et al. 2021).

### Knowing where you are, gets you half the way

Learning who you are, what you stand for, and where you **position yourself in society** were some of the experiences participants reported after the summer school. This “*knowledge of the self*” is described by Nicolescu (1997) as fundamental to transdisciplinary education. One of the main topics was linked to discussing dividing lines between “sciences” and “activism”. Many discussions referred to contestation about what it means to be a researcher trying to be an active part of societal transformations presently characterized by slow political processes. Participants experienced the already documented “*urge to make a difference*” (Leichenko et al. 2022). They reported feeling encouraged following the summer school to embrace activism and be bolder instead of separating activism from professional activities. This is a clear re-examination of their role in society as scientists. Thereby the summer school went beyond a teaching system of knowledge (state of biodiversity), orientation knowledge (vision on sustainability), and transformational knowledge (transdisciplinary methods) towards mentoring (Lyll and Meagher 2012).

**Critical self-reflection** is recognized as a cornerstone of transdisciplinarity (Jahn et al. 2012; Schneider et al. 2019). This was mentioned by the organizers (to be encouraged) and by participants (to have taken place). The self-reflectivity included in the summer school concerned a re-examination of roles in society, how to perform research, and how society relates to nature. It has, therefore, a link to all four types of reflective science identified by Popa et al. (2015). There was a clear “*reflexivity on normative commitments and ideological orientations*” through the talks and following exchanges. The group work, grounded in tangible reality and informed by the various talks, contained elements of both “*deliberation on the socially relevant framing of research problems*” and “*reflexivity on values and understandings in concrete problem-solving*”. Only for the fourth element could it be argued that the focus was on the epistemic orientation of research rather than on questioning the normative orientation. The latter could be explained by already largely similar values and norms shared by the participants because of similar backgrounds and professions, which might therefore be less frequently or strongly questioned.

### Aim for the full experience, engaging head, hands, and hearts

For enabling sustainability competencies, engaging the trinity of head, hands, and hearts is deemed imperative (Kioupi and Voulvoulis 2019). As was previously shown, the head and the hands were perpetually engaged throughout the summer school. The heart certainly was, too – especially in the **setting and spirit** of the summer school. The setting encompassed the isolation of the social situation from influences linked to urban areas and participants’ everyday life, the experience of nature, and the traditional surroundings. It produced an aesthetic experience reported by the attendees, directly impacting the emotional,

sensitive, and affective dimensions. This made the participants experience their work with the whole body, being physically and mentally submerged in their case study. The former underlines the situated, place-bound element and unique atmosphere of the summer school – one of beauty, immensity, and isolation. This led to the creation of a spirit of intense community. The setting and spirit of Peyresq are inextricably linked as a space for knowledge communication but also “*a place for co-living and aesthetic, cultural and psychological appreciation.*”

### **How our transdisciplinary learning experience can support transformative change and biodiversity conservation**

It is widely accepted that transformative change is needed for a sustainable future (IPBES 2019). Nonetheless, the concept of transformative change in itself does not imply a direction (Jacobs et al. 2022). The summer school provided a clear and shared vision of a sustainable future and, thereby, a direction for transformative change. Biodiversity conservation is explicitly anchored within this vision of a sustainable future. This is shown by the aim of Alternet to foster the European science-policy interface on biodiversity and ecosystem services and by the focus of the group work on transformative pathways for biodiversity and human well-being. Therefore, we argue that if transformative change is reached in the direction that the summer school presents and intends, biodiversity conservation will be a key component of the resulting sustainable future. Keeping this in mind, the summer school will support biodiversity conservation if a) transformative change is fostered in the intended direction; or b) if the participants are incentivized to perform actions that lead (in) directly to biodiversity conservation.

### **Change on a personal level happened and could lead to transformative change and support biodiversity conservation**

Most attendees related the effect of the summer school to a **shift in or increased clarity of personal values** and beliefs. Real change therein is however questionable due to a bias towards an audience who presumably already share similar values and beliefs. Shifting to sustainability-aligned values is nevertheless key to biodiversity conservation (IPBES 2022). Additionally, results show that the summer school successfully advocates the importance of shared understanding, which is perceived as a vital contribution to sustainability science (Kioupi and Voulvoulis 2019) and transformative change (Schneider et al. 2019). Moreover, understanding transformation and its achievability, the sense of agency, and **re-examining which role one can play in society and transformative change** are three fundamental aspects of teaching transformative change (Leichenko et al. 2022), which were explicitly reported by the participants in Sect. “**Participants**”. The summer school also provided knowledge through presentations of multiple experts from various scientific fields on the state of the planet, the way we influence it, and possible ways towards sustainable development. This knowledge is critical for constructing pathways to sustainability (Kioupi and Voulvoulis 2019) and, according to the behavior change wheel (Michie et al. 2011), is one foundation for behavior change. The personal transformations towards increased awareness and behavior change are ways that transdisciplinary learning, like that featured in the summer school, can directly influence

participants' daily decisions in the areas that affect biodiversity conservation, such as consumption patterns and connection to nature (Miller 2005). They also have the potential to create ripple effects in attendees' social circles as they share these newfound beliefs and behaviors with other peers and mentors if maintained (Centola et al. 2018). Different methods are needed to assess whether and when the reported change translates into actual behavior.

We can conclude that this (new) knowledge, values, and re-examinations could be one component towards **personal and, indirectly, research and societal transformative change** which can support biodiversity conservation. They could also support **individual actions that contribute to biodiversity conservation**.

### Changing the way we perform research could lead to biodiversity conservation

What effectively took place during the summer school can be interpreted as **rethinking of science**. Firstly, how it should relate to and be embedded in society, and secondly, how research is performed. Regarding the position of science in society, (new) science-society-policy interfaces and the use of transdisciplinary research to integrate and confront different knowledge types were highlighted by the participants and organizers. This corresponds to Turnhout and Lahsen's (2022) call for a new science-society contract and Maas et al.'s (2022) plea for a new science-policy interface. The importance of confronting different knowledge systems was also highlighted as key to transdisciplinary research (Schneider et al. 2019), sustainability science (Caniglia et al. 2021), and transformative change (IPBES 2022). As a summer school primarily intended for early-career researchers, one of its primary goals is to teach good research practices. We argue that through transdisciplinary learning (in the sense of the Zurich school), participants receive the necessary tools for performing transdisciplinary research themselves, as supported by Baumber (2022). This can be seen as successful, with many participants reporting increased knowledge of tools and strategies to perform research in a transdisciplinary manner or at least convincing them of the importance of it. Systems thinking is a tool and competency that was cited multiple times by the respondents and supported in the literature to be important (Kioupi and Voulvoulis 2019; Armitage et al. 2019). The participants referenced the confrontations of different types of knowledge. Some indicated the intention of integrating these more strongly into their current and future research, suggesting a shift **towards more transdisciplinary research**.

In conclusion, the learning experience convinced the participants of the merits of transdisciplinary research. The role of transdisciplinary research in transformative change is already widely accepted (Young et al. 2014). Thus, the summer school could act as a lever to achieve **transformative change through teaching transdisciplinary research**. The increased collaboration and rethinking of science could result in **research on biodiversity conservation** of the participants becoming more relevant and widely supported and thus effective.



## Change in the way we are part of and function in society could lead to biodiversity conservation

As the recent IPBES values assessment mentioned, transformative change is more likely to be catalyzed through actions targeting specific values-based leverage points, like creating spaces to deliberate and shift societal goals and norms (IPBES 2022). A goal that was reflected on extensively during the summer school was that of achieving a sustainable society. Creating **a shared vision** of what this society could look like was initiated at the summer school. This shared imagination is reported as an important process in instigating transformative change (Pereira et al. 2019). One of the elements highlighted by both participants and organizers as being important to reach transformative change is **moving from a society focused on the individual to a society focused on the collective**. This would encompass moving from the neo-liberal paradigm of the individual as the building block of society towards a society that is organized around and for the collective. This discourse is supported widely in ecofeminist (see for example the work of Vandana Shiva) as well as commons-based literature (see for example the work of Elinor Ostrom). Organizers who have been involved in the summer school for several years and could thus reflect more deeply on this experience tended to emphasize the transformative potential with more conviction. They argued and hoped that newly built networks and communities of researchers engaged in critical thinking could help transform societies. In particular, the (indirect but perceived) transformative potential of the summer school's encouragement to **reconsider the nature-society relationship** and the plea for plural valuation were highlighted. Again, this aligns with conclusions from the IPBES values assessment (IPBES 2022) and would directly contribute to biodiversity conservation.

In conclusion, the experience provided during the summer school has the potential to transform society by **creating a community with a shared vision** on what a sustainable society could look like. Also, the plea for a **less individualistic society** could be regarded as a transformative change that the summer school supports. Specifically for biodiversity conservation, **reconsidering the nature-society relationship** is a meaningful societal change.

## Conclusions

In this paper, we identified transdisciplinary elements of the Alternet Summer School. They developed over the course of many years and will keep on evolving. The seven most important elements of transdisciplinary learning were identified as (1) learning by doing, (2) fostering group processes, and (3) interdisciplinary exchanges, all of which were cultivated by the group work. Together with thought-provoking talks, this led to (4) activation of shared values and the construction of a shared vision of a sustainable future, guiding the way forward to transformative change. The key role in these processes was (5) critical self-reflection, fostered and nurtured in the safe environment of the summer school. It helped participants to (6) identify the position they want to take in society and the role they want to play in transformative change. All of this was possible through and supported by (7) the setting and spirit of the summer school, an isolated village grounded in nature and culture.

Nonetheless, there are still elements that can be improved to increase the summer school's transdisciplinarity – for example, rooting the group work even more deeply into practice with co-creation of the research together with the local stakeholders.

We determined several impact pathways of the summer school, identified by participants and organizers. These pathways could support transformative change on personal, research, and societal level, potentially supporting biodiversity conservation. The summer school stimulated change on a personal level by enabling a shift in values and questioning how the participants position themselves in society. On a research level, it questioned the position of science in society and stimulated transdisciplinary research. The summer school also advocated a move towards a less individualistic society and stimulated the creation of a shared vision for a sustainable future, which can foster transformative change. Moreover, the summer school could also affect biodiversity conservation in a more direct manner. Individual actions through shifting values can immediately support biodiversity conservation. More effective research can contribute to biodiversity conservation. A reconstruction of the nature-society relationship could also directly lead to biodiversity conservation. What the specific contribution of this transdisciplinary learning experience may be in the broader context of societal change cannot be distinguished with our present data. What's certain is this: if more such endeavors follow, the impact will be greater. The promising impact of transdisciplinary learning calls for more lifelong learning opportunities, open and accessible for diverse audiences. With the seven ingredients we presented for a successful and transformative transdisciplinary learning experience, we hope to inspire similar educational endeavors that foster personal, research, and societal change.

## Appendix

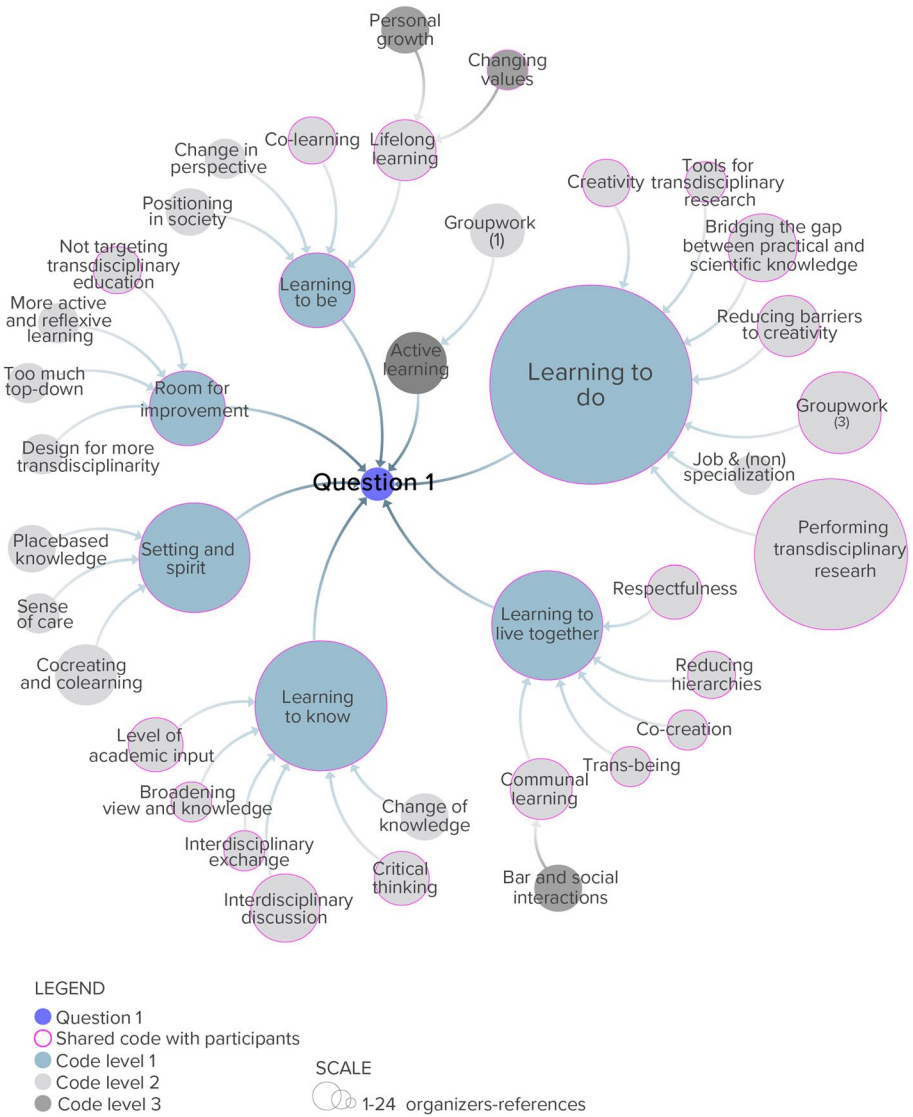
### Survey questions

The questions (SQ) included in the online surveys were:

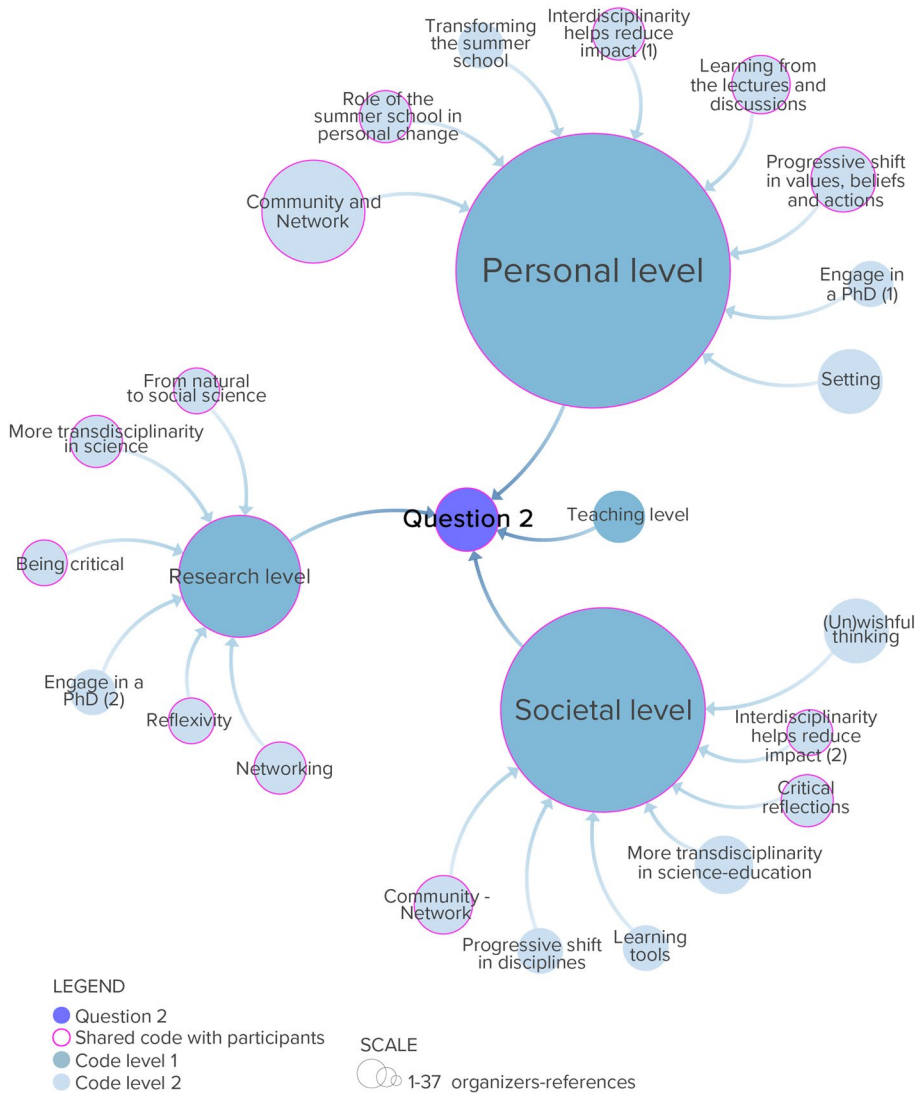
- 
- SQ1 We chose to use the term **transdisciplinary education** as defined by Nicolescu (1997) (1) as “a way of self-transformation oriented towards knowledge of the self, the unity of knowledge, and the creation of a new art of living in the society.” and (Luckerhoff et al. 2020) (2) “[confronting] scientific knowledge from established disciplines, their practical knowledge from intervention environments and their traditional knowledge that has stood the test of time.” Could you cite elements of your summer school experience that support this definition?
- SQ2.1 How did **transformative change** happen for you at a personal level and research level after the summer school? How (and why?) do you think it could contribute to transforming societies? (Transformation: radical system change (shifts in values and beliefs, patterns of social behavior, and multilevel governance and management regimes)—(Olsson et al. 2014)
- SQ2.2 Please answer the following question using your own words: How does transdisciplinary education, as provided by the Alternet Summer School, lead to transformative change for biodiversity conservation?
- 

### Coding structures of the organizers

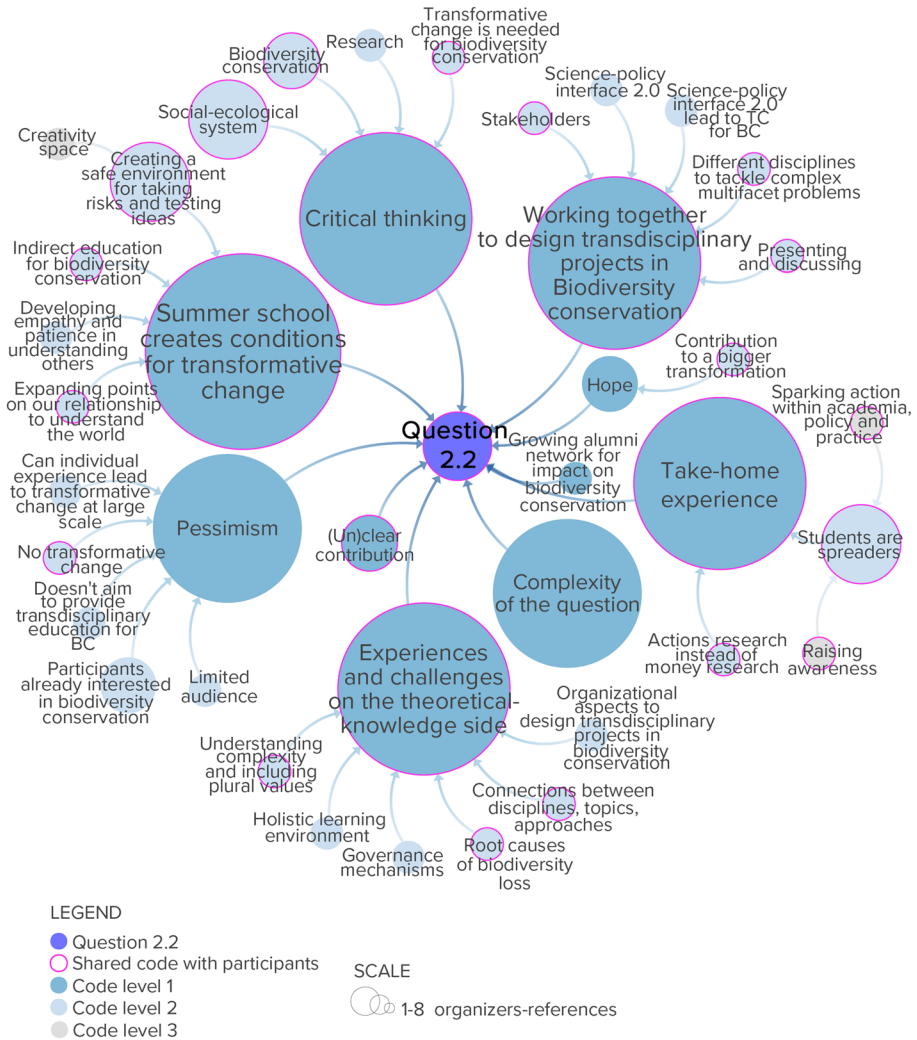
See Figs. 6, 7, 8.



**Fig. 6** Visualization of the coding structure for SQ1 by the organizers with the size of code proportional to the number of times mentioned, the color representing code (sub)level, and border indicating codes shared with participants



**Fig. 7** Visualization of the coding structure for SQ2.1 by the organizers with the size of code proportional to the number of times mentioned, the color representing code (sub)level, and border indicating codes shared with participants



**Fig. 8** Visualization of the coding structure for SQ.2.2 by the organizers with the size of code proportional to the number of times mentioned, the color representing code (sub)level, and border indicating codes shared with participants

## Student demographic information

**Table 2** Demographic information of the 2021 Alternet Summer School students derived from the application/registration form. Two registered students whose demographic info is featured above did not participate in the survey

Country of Nationality	Type of institution	Institution Location	Research Field/Topic
Spain	Research institute; university	Trondheim, Norway	DNA and eDNA metabarcoding for monitoring the ecological condition of Norwegian lakes
Italy	University	Castagnole delle Lanze, Italy	Transfer of Development Rights (TDR) to enhance urban ecosystem services
Belgium	University	Namur, Belgium	Science didactics
Italy	Research institute	Bolzano, Italy	Ecosystem services; viticulture, global change
Belgium	University	Namur, Belgium	Human geography: sociological approach of food system transition at the territorial scale
Belgium	Research institute	Brussels, Belgium	Ecosystem service supply and demand in a changing climate and landscape; the impact of second generation biofuels on landscape, ecosystem services and biodiversity, including economic valuation and spatially explicit (GIS) analysis; environmental justice
Peru	University	Malmö, Sweden	Sustainability science: role of power and subjectivities in climate change adaptation policy in marine and coastal ecosystems
Germany	Research institute	Frankfurt am Main, Germany	Conflict studies; biodiversity conflicts
Norway	Research Institute	Tromsø, Norway	Vegetation-climate interactions in Arctic, alpine and boreal ecosystems
Belgium	University	Louvain-la-Neuve, Belgium	International environmental law: agrobiodiversity law and governance
Germany	University	Bayreuth, Germany	Agri-environmental policy; ecosystem services
Germany	University	Hannover, Germany	Ecosystem services and modeling (pollinator habitat suitability)
Poland;	University	Krakow, Poland	Social aspects of a circular economy of single-use plastics; sustainable transition; science communication and popularization; citizen science; participative knowledge co-creation and brokerage; mindful consumption; zero-waste
Germany	University		

Table 2 (continued)

Country of Nationality	Type of Institution	Institution Location	Research Field/Topic
United States	Intergovernmental organization; research institution	Frankfurt am Main, Germany	Marine ecology and conservation
Ukraine	University	Enschede, Netherlands	Water and land footprints (sustainable water and land management)
Mexico	University	Wageningen, Netherlands	Tropical forest resilience
Germany	Research institute	Leeds, United Kingdom	Urban ecology
North Macedonia	University	Tartu, Estonia	Cultural ecosystem services; human well-being; urban-wilderness gradient
Sweden	Research institute; university	Stockholm, Sweden	Sustainable development; biodiversity and climate feedbacks
Brazil	University	Giessen, Germany	Socio-metabolic analysis of agroecological systems in Brazil
Tibet	Research institute	Ceske Budejovice, Czech Republic	Fish behavior
Germany	Research institute	Hamburg, Germany	Flood regulation ecosystem services in urban areas under climate change

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## Declarations

**Conflict of interest** Three organizers of the summer school (that serves as a case study) are co-authors of the paper. Two of these co-authors are part of the Alternet management. Nine co-authors are employed at Alternet member institutes. The remaining authors declare no competing interests.

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## References

- Andrade K, Corbin C, Diver S et al (2014) Finding your way in the interdisciplinary forest: notes on educating future conservation practitioners. *Biodivers Conserv* 23:3405–3423. <https://doi.org/10.1007/s10531-014-0818-z>
- Armitage D, Arends J, Barlow N et al (2019) Applying a “theory of change” process to facilitate transdisciplinary sustainability education. *Ecol Soc*. <https://doi.org/10.5751/ES-11121-240320>
- Barth M, Rieckmann M (2012) Academic staff development as a catalyst for curriculum change towards education for sustainable development: an output perspective. *J Clean Prod* 26:28–36. <https://doi.org/10.1016/j.jclepro.2011.12.011>
- Baumber A (2022) Transforming sustainability education through transdisciplinary practice. *Environ Dev Sustain* 24:7622–7639. <https://doi.org/10.1007/s10668-021-01731-3>
- Brauman KA, Garibaldi LA, Polasky S et al (2020) Global trends in nature's contributions to people. *Proc Natl Acad Sci USA* 117:32799–32805. <https://doi.org/10.1073/pnas.2010473117>
- Brundiers K, Barth M, Cebrián G et al (2021) Key competencies in sustainability in higher education—toward an agreed-upon reference framework. *Sustain Sci* 16:13–29. <https://doi.org/10.1007/s11625-020-00838-2>
- Caniglia G, Luederitz C, von Wirth T et al (2021) A pluralistic and integrated approach to action-oriented knowledge for sustainability. *Nat Sustain* 4:93–100. <https://doi.org/10.1038/s41893-020-00616-z>
- Centola D, Becker J, Brackbill D, Baronchelli A (2018) Experimental evidence for tipping points in social convention. *Science* 360:1116–1119. <https://doi.org/10.1126/science.aas8827>



- Chan KMA, Boyd DR, Gould RK et al (2020) Levers and leverage points for pathways to sustainability. *People and Nature* 2:693–717. <https://doi.org/10.1002/pan3.10124>
- Cialdini RB, Petty RE, Cacioppo JT (1981) Attitude and attitude change. *Annu Rev Psychol* 32:357–404. <https://doi.org/10.1146/annurev.ps.32.020181.002041>
- de Groot JIM, Steg L (2008) Value Orientations to explain beliefs related to environmental significant behavior: how to measure egoistic, altruistic, and biospheric value orientations. *Environ Behav* 40:330–354. <https://doi.org/10.1177/0013916506297831>
- Dedeurwaerdere T (2013) Transdisciplinary sustainability science at higher education institutions: science policy tools for incremental institutional change. *Sustainability* 5:3783–3801. <https://doi.org/10.3390/su5093783>
- Derry SJ, Fischer G (2005) Toward a Model and Theory for Transdisciplinary Graduate Education. In: 2005 AERA Annual Meeting, Symposium, “Sociotechnical Design for Lifelong Learning: A Crucial Role for Graduate Education.” Montreal, p 29
- Van Dijk J, Ulvund K, Braat L, et al (2012) ALTER-Net, a long-term biodiversity, ecosystem and awareness research network - Year 8. NINA Report 815, p 36. <http://hdl.handle.net/11250/2642959>
- Felt U, Igelsböck J, Schikowitz A, Völker T (2013) Growing into what? The (un-)disciplined socialisation of early stage researchers in transdisciplinary research. *High Educ* 65:511–524. <https://doi.org/10.1007/s10734-012-9560-1>
- Finlay L (2002) Negotiating the swamp: the opportunity and challenge of reflexivity in research practice. *Qual Res* 2:209–230. <https://doi.org/10.1177/146879410200200205>
- Flogie A, Dolenc K, Aberšek B (2015) Transdisciplinarity in education is near. In: 1st International Baltic Symposium on Science and Technology Education. pp 45–47
- Folke C, Biggs R, Norström A et al (2016) Social-ecological resilience and biosphere-based sustainability science. *Ecol Soc* 21:41. <https://doi.org/10.5751/ES-08748-210341>
- Gillis D, Nelson J, Driscoll B et al (2017) Interdisciplinary and transdisciplinary research and education in canada: a review and suggested framework. *CELT* 10:203–222. <https://doi.org/10.22329/celt.v10i0.4745>
- Hadorn GH, Hoffmann-Riem H, Biber-Klemm S et al (eds) (2008). Springer, Dordrecht
- Haraway D (1988) Situated knowledges: the science question in feminism and the privilege of partial perspective. *Fem Stud* 14:575–599. <https://doi.org/10.2307/3178066>
- Harding S (1986) *The Science Question in Feminism*. Cornell University Press, Ithaca
- Herrero P, Dedeurwaerdere T, Osinski A (2019) Design features for social learning in transformative transdisciplinary research. *Sustain Sci* 14:751–769. <https://doi.org/10.1007/s11625-018-0641-7>
- IPBES (2018) The IPBES assessment report on land degradation and restoration. Montanarella, L., Scholes, R., and Brainich, A (eds) IPBES secretariat, Bonn, Germany 744. <https://doi.org/10.5281/zenodo.3237392>
- IPBES (2019) Global assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Brondizio, E S, Settele, J, Díaz, S, and Ngo, H T (eds) IPBES secretariat, Bonn, Germany 1082. <https://doi.org/10.5281/zenodo.3831673>
- IPBES (2022) Methodological Assessment Report on the Diverse Values and Valuation of Nature of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. Balvanera, P, Pascual, U, Christie, M, Baptiste, B, and González-Jiménez, D (eds) IPBES secretariat, Bonn, Germany 784. <https://doi.org/10.5281/zenodo.6522522>
- Jacobs S, Santos-Martín F, Primmer E et al (2022) Transformative change needs direction. *Sustainability* 14:14844. <https://doi.org/10.3390/su142214844>
- Jahn T, Bergmann M, Keil F (2012) Transdisciplinarity: between mainstreaming and marginalization. *Ecol Econ* 79:1–10. <https://doi.org/10.1016/j.ecolecon.2012.04.017>
- Kioupi V, Voulvoulis N (2019) Education for sustainable development: a systemic framework for connecting the SDGs to educational outcomes. *Sustainability* 11:6104. <https://doi.org/10.3390/su11216104>
- Klein JT (2008) Evaluation of interdisciplinary and transdisciplinary research: a literature review. *Am J Prev Med* 35:S116–S123. <https://doi.org/10.1016/j.amepre.2008.05.010>
- Lambrechts W, Mulà I, Ceulemans K et al (2013) The integration of competences for sustainable development in higher education: an analysis of bachelor programs in management. *J Clean Prod* 48:65–73. <https://doi.org/10.1016/j.jclepro.2011.12.034>
- Oxford Languages (2023) Oxford English Dictionary. <https://languages.oup.com/google-dictionary-en/>
- Leichenko R, Gram-Hanssen I, O’Brien K (2022) Teaching the “how” of transformation. *Sustain Sci* 17:573–584. <https://doi.org/10.1007/s11625-021-00964-5>
- Luckerhoff J, Johnson M, Guillemette F (2020) Introduction: approches pédagogiques innovantes. *Enjeux Et Société: Approches Transdisciplinaires* 7:1–9. <https://doi.org/10.7202/1073358ar>

- Lyll C, Meagher LR (2012) A Masterclass in interdisciplinarity: research into practice in training the next generation of interdisciplinary researchers. *Futures* 44:608–617. <https://doi.org/10.1016/j.futures.2012.03.011>
- Maas TY, Pauwelussen A, Turnhout E (2022) Co-producing the science–policy interface: towards common but differentiated responsibilities. *Humanit Soc Sci Commun*. <https://doi.org/10.1057/s41599-022-01108-5>
- Manning SL (2014) The role of universities in developing interdisciplinary action research collaborations to understand and manage resilient social-ecological systems. *J Clean Prod* 64:125–135. <https://doi.org/10.1016/j.jclepro.2013.07.010>
- Maxwell SL, Fuller RA, Brooks TM, Watson JEM (2016) Biodiversity: the ravages of guns, nets and bulldozers. *Nature* 536:143–145. <https://doi.org/10.1038/536143a>
- Michie S, van Stralen MM, West R (2011) The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implement Sci* 6:42. <https://doi.org/10.1186/1748-5908-6-42>
- Miller JR (2005) Biodiversity conservation and the extinction of experience. *Trends Ecol Evol* 20:430–434. <https://doi.org/10.1016/j.tree.2005.05.013>
- Mokhele M, Pinfold N (2021) Exploring the nexus between transdisciplinarity, internationalisation and community service-learning at a university of technology in Cape Town. *Transform High Educ* 6:9. <https://doi.org/10.4102/the.v6i0.121>
- Naganathan G, Srikanthan S, Balachandran A et al (2022) Collaborative zoom coding—a novel approach to qualitative analysis. *Int J Qual Methods* 21:160940692210758. <https://doi.org/10.1177/16094069221075862>
- Nicolescu B (2005) Towards transdisciplinary education. *J Transdiscipl Res S Afr* 1:5–15. <https://doi.org/10.4102/td.v1i1.300>
- Nicolescu B (2014) Multidisciplinarity, Interdisciplinarity, Indisciplinarity, and transdisciplinarity: similarities and differences. *RCC Perspectives* 2:19–26
- Nicolescu B (1997) The Transdisciplinary Evolution of Learning. In: International Congress on What University for Tomorrow? Towards a Transdisciplinary Evolution of the University. Locarno, pp 1–11
- Olsson P, Galaz V, Boonstra WJ (2014) Sustainability transformations: a resilience perspective. *Eco Soc*. <https://doi.org/10.5751/ES-06799-190401>
- Pearce B, Adler C, Senn L et al (2018) Making the Link Between Transdisciplinary Learning and Research. In: Fam D, Neuhauser L, Gibbs P (eds) *Transdisciplinary Theory, Practice and Education: The Art of Collaborative Research and Collective Learning*. Springer International Publishing, Cham, pp 167–183
- Pereira L, Sitas N, Ravera F et al (2019) Building capacities for transformative change towards sustainability: imagination in intergovernmental science-policy scenario processes. *Elementa Science of the Anthropocene*. <https://doi.org/10.1525/elementa.374>
- Popa F, Guillermin M, Dedeurwaerdere T (2015) A pragmatist approach to transdisciplinarity in sustainability research: from complex systems theory to reflexive science. *Futures* 65:45–56. <https://doi.org/10.1016/j.futures.2014.02.002>
- QSR International Pty Ltd (2020) NVivo (released in March 2020). <https://www.qsrinternational.com/nvivo-qualitative-data-analysis-software/home>
- Rigolot C (2020) Transdisciplinarity as a discipline and a way of being: complementarities and creative tensions. *Humanit Soc Sci Commun* 7:1–5. <https://doi.org/10.1057/s41599-020-00598-5>
- Ritchie J, Lewis J, McNaughton Nicholls C, Ormston R (eds) (2014) 2nd edn. Sage, Los Angeles
- Rockström J, Beringer T, Hole D et al (2021) We need biosphere stewardship that protects carbon sinks and builds resilience. *Proc Natl Acad Sci USA* 118:e2115218118. <https://doi.org/10.1073/pnas.2115218118>
- Schneider F, Giger M, Harari N et al (2019) Transdisciplinary co-production of knowledge and sustainability transformations: three generic mechanisms of impact generation. *Environ Sci Policy* 102:26–35. <https://doi.org/10.1016/j.envsci.2019.08.017>
- Scholz RW, Steiner G (2015) The real type and ideal type of transdisciplinary processes: part II—what constraints and obstacles do we meet in practice? *Sustain Sci* 10:653–671
- Stauffacher M, Walter AI, Lang DJ et al (2006) Learning to research environmental problems from a functional socio-cultural constructivism perspective: The transdisciplinary case study approach. *Int J Sustain High Educ* 7:252–275. <https://doi.org/10.1108/14676370610677838>
- Stock P, Burton RJF (2011) Defining terms for integrated (multi-inter-trans-disciplinary) sustainability research. *Sustainability* 3:1090–1113. <https://doi.org/10.3390/su3081090>
- Täbara JD, Jäger J, Mangalagiu D, Grasso M (2019) Defining transformative climate science to address high-end climate change. *Reg Environ Change* 19:807–818. <https://doi.org/10.1007/s10113-018-1288-8>
- Tavory I, Timmermans S (2014) *Abductive analysis: Theorizing qualitative research*. University of Chicago Press, Chicago

- Timmermans S, Tavory I (2012) Theory construction in qualitative research: from grounded theory to abductive analysis. *Soc Theory* 30:167–186. <https://doi.org/10.1177/0735275112457914>
- Turnhout E, Lahsen M (2022) Transforming environmental research to avoid tragedy. *Climate Dev* 14(9):834–838. <https://doi.org/10.1080/17565529.2022.2062287>
- Wals AEJ, Benavot A (2017) Can we meet the sustainability challenges? The role of education and lifelong learning. *Eur J Educ* 52:404–413
- Wei CA, Deaton ML, Shume TJ et al (2020) A framework for teaching socio-environmental problem-solving. *J Environ Stud Sci* 10:467–477. <https://doi.org/10.1007/s13412-020-00603-y>
- Young JC, Waylen KA, Sarkki S et al (2014) Improving the science-policy dialogue to meet the challenges of biodiversity conservation: having conversations rather than talking at one-another. *Biodivers Conserv* 23:387–404. <https://doi.org/10.1007/s10531-013-0607-0>

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