





ARTICLE



<https://doi.org/10.1057/s41599-023-02541-w>

OPEN

Transdisciplinary learning trajectories: developing action and attitude in interplay

Annemarie Horn ^{1✉}, Marijke W. Visser², Carina A. C. M. Pittens², Eduardo Urias ²,
Marjolein B. M. Zweekhorst² & Gerda M. van Dijk³

Addressing complex societal challenges requires professionals capable of integrating multiple perspectives on problems and possible solutions. This requires crossing disciplinary boundaries and boundaries between science and society. Transdisciplinary approaches respond to this demand by deliberately integrating knowledge of different disciplinary specialists and societal actors for a joint framing and co-creation of new options for addressing societal challenges. There is, however, limited understanding of which assets transdisciplinary work requires and how students can be trained in these. We studied transdisciplinary learning in the context of a novel course in which students engaged in multi-actor agenda-setting and facilitated multi-actor dialog sessions at a community event. We found that with the support of teachers and a detailed script, and by acquiring knowledge and skills through theoretical learning and exercises, students were able to facilitate safe and structured multi-stakeholder dialog sessions. Shifts towards a more transdisciplinary attitude were sparked by eye-opening experiences in transdisciplinary encounters if students processed these critically and openly. Based on our findings we propose “Transdisciplinary Learning Trajectories” which conceptualizes transdisciplinary learning as developing the ability to engage in transdisciplinary action and developing towards a transdisciplinary attitude. Based on our findings, we argue for a combination of experiential and instruction approaches that support learning in both dimensions, simultaneously and in interplay.

¹ Liberal Arts and Sciences, Utrecht University, Janskerkhof 13, 2512 BL Utrecht, the Netherlands. ² Athena Institute, Vrije Universiteit Amsterdam, De Boelelaan 1087, 1081 HV Amsterdam, the Netherlands. ³ Zijlstra Centre for Public Control, Governance and Leadership, Vrije Universiteit Amsterdam, De Boelelaan 1105, 1081 HV Amsterdam, the Netherlands. ✉email: a.horn@uu.nl

Introduction

Contemporary society faces complex challenges, such as climate change and inequality in health and wealth, that pose a threat for a sustainable future (Brown et al., 2010; IPCC, 2022). Addressing those complex societal issues requires nuanced understanding of the different views and stakes that are involved and dealing with inherently conflicting perspectives of different actors; they require a transdisciplinary approach (Regeer and Bunders-Aelen, 2009). This means that approaches transcend the boundaries of scientific disciplines and integrate practice-based, tacit and lay knowledge from different societal actors (Bunders et al., 2010; Jahn et al., 2012; Klein, 2004; Lang et al., 2012; van Loon and van Dijk, 2015; Rysler et al., 2009; Steger et al., 2021). Transdisciplinarity is founded on the notion that societal actors (such as policy-makers, practitioners, or citizens) hold legitimate and indispensable knowledge that is developed through experiences in work or daily life (experiential knowledge) which is necessary for developing responsive (new) knowledge (Polk, 2014). As such, transdisciplinarity aims to provide tailor-made solutions that can increase the use and (re)integration of a plurality of knowledge into future research and practice (Lang et al., 2012; Jacobi et al., 2022). Adopting transdisciplinary approaches thus marks a substantial departure from more traditional science that is conducted in a more disciplinary fashion and with a clear demarcation between science and non-science (Gieryn, 1983; Kurtulmuş, 2021).

Given that transdisciplinary approaches to research and education are fundamentally different from more traditional disciplinary approaches, they also place different demands on actors engaging in transdisciplinarity (Guimarães et al., 2019; McGregor, 2017; Klein, 2017). The challenge of engaging in transdisciplinarity is widely acknowledged, and collaborators are reported to require a diverse set of assets (Augsburg, 2014; Guimarães et al., 2019; Nash et al., 2003; Nurius and Kemp, 2019). However, which assets engaging in transdisciplinary approaches exactly require is the subject of ongoing debate, and conceptualizations are as numerous as they are diverse. For instance, Augsburg (2014) speaks of transdisciplinary individuals, Guimarães et al. (2019) of transdisciplinary personality, Misra et al. (2015) of transdisciplinary orientation, and Nash et al. (2003) and Nurius and Kemp (2019) of transdisciplinary competencies. These conceptualizations include different combinations of the assets: motivations, attitudes, beliefs, values, habits of mind, skills, knowledge, and behaviors. What all these conceptualizations have in common, despite their diversity, is that they approach transdisciplinarity as a complex process that requires a multiplicity of diverse and interrelated assets of the individual as a whole.

It has been shown that academically trained professionals are not self-evidently capable of engaging in transdisciplinarity, and cannot be assumed to possess the above described complex and diverse set of assets (Augsburg, 2014; Guimarães et al., 2019; Klein, 2017). They are often trained as disciplinary specialists and tend to have been socialized to favor disciplinary rigor over process-oriented transdisciplinary learning (Gillis et al., 2017; McGregor, 2017). As such, being prepared to engage in transdisciplinarity requires training that specifically targets transdisciplinary learning (Di Giulio and Defila, 2017). This places the university in a critical position to prepare future professionals, as they are responsible of training a substantial part of our workforce, who may engage in transdisciplinarity, either as a researcher or as a professional outside the university context. Acknowledging the need for more transdisciplinary approaches thus calls for rethinking the dominant disciplinary approach to higher education (McGregor, 2017; Mossman, 2018).

This raises the question how we can prepare university students for transdisciplinary work as professionals. Although

several transdisciplinary educational programs have been reported, much of the literature remains limited to descriptions of those programs, and the experiences of challenges and opportunities of such approaches (Horn, Scheffelaar et al., 2022). The literature thus provides limited insight into *how* transdisciplinary learning by students takes place, which is further accentuated by the lack of understanding of which assets are to be trained. A deeper understanding of transdisciplinary learning mechanisms is necessary to inform educational design and implementation to prepare graduates to address societal grand challenges.

In this study we sought to gain insight into how university students with little or no experience with transdisciplinarity can be prepared for transdisciplinary approaches to address complex societal challenges. We developed and implemented a master's course in which students engaged in transdisciplinary agenda-setting by facilitating multi-actor dialog sessions and were provided with learning materials about transdisciplinarity. We aimed to understand the assets required for students to engage in transdisciplinarity, through which learning mechanisms students develop towards gaining those assets, and the specific teaching strategies that supported their development.

Methods

We studied a transdisciplinary agenda-setting course through a multi-perspective, multi-actor, qualitative approach to understand the students' transdisciplinary learning. We identified students' development towards being more prepared for transdisciplinary approaches through a combination of changes in orientation that we observed at different points during the course (e.g., students demonstrating a different attitude towards transdisciplinarity in their reflections at the beginning of the course compared to at the end), and student self-reports of their subjectively experienced changes. From data on the experiences and reflections of the multiple actors involved in the course (students, teachers, participants of the event), we acquired insight into the students' prior experience, development throughout the course, and learning experiences. Through this multi-perspective qualitative approach, we gained a rich understanding of the students' transdisciplinary learning process and overcame self-reporting bias through triangulation.

The setting: a transdisciplinary agenda-setting course

Overall design of the course. We collected the data for this study in the context of the master's course "Interdisciplinary Community Service Learning 1: Defining Challenges in a Multi-Stakeholder Context" (iCSL1) offered at the Vrije Universiteit (VU) Amsterdam, in the Netherlands. This course is one step in a cyclical transdisciplinary collaboration between the university and several, expanding networks of trusted community partners. In this process the agenda-setting in which students engage in iCSL1 is just one step and is followed up by subsequent stages of transdisciplinary co-production of knowledge (Mauser et al., 2013). For more detailed information about the course, cyclical transdisciplinary process of which it is part, and the organizational context in which it is embedded, see Tijsma et al. (2022). Taking a participatory research approach, as researchers we were involved in the design and delivery of the course as well as the research. Collecting insights at different instances throughout the course and through different methods allowed us to develop a detailed understanding into the learning and gave us the opportunity to link learning processes to course design and implementation choices (Dosemagen and Schwalbach, 2019). We collected data in 2019 during the first year in which we offered the course, which functioned as a pilot of the newly designed course. The course is

an eight-week part-time course (84 study hours) which is open to students from all master's programs across the VU, in most cases as an extracurricular course (for more details about the curricular embedding, see Tijmsa et al., 2022).

The learning objectives of the course were for students to: 1) become familiar with transdisciplinary research; 2) acquire insight into complex problems and the corresponding multi-actor systems; 3) gain (basic) experience with qualitative community-based participatory research methods; and 4) learn in a real-life situation how transdisciplinary research can contribute to tackling current societal challenges. It thus aimed to function as an introductory course about transdisciplinarity and transdisciplinary agenda-setting for students with little or no prior experience with these topics. Rather than training full transdisciplinary competence, it focused on providing a first experience with transdisciplinary agenda-setting as to familiarize and sensitize students to such approaches, and potentially spark a shift in their views about transdisciplinarity and the relationship between science and society. Such a shift in perspective could be described as transformative learning in the broad sense, as described and distinguished by Hoggan (2016).

In order to meet the learning goals, we designed the course with an experiential learning (Kolb, 2014) design, in which we combined experience, theory, and reflection. The experiences comprised transdisciplinary encounters (see below) and were complemented by learning materials (lectures, knowledge clips, readings) about the theoretical underpinnings of transdisciplinarity, interactive in-class exercises, and weekly self-reflection exercises to bring home some of the lessons learned from the experiences.

The course centers around a project in which the students develop a research agenda for a complex societal issue based on insights from the literature, and inputs from different actors that they collect through interviews and multi-actor dialog sessions at a community event. By the end of the course, the students hand in a group assignment in which they report their findings. In the 2019 offering of the course, we had two student teams both working on one topic: Clean City – sustainability, waste management, and public spaces; and Connected City – digitalization and digital inclusion. Both topics were the result of ongoing conversations with local communities and community actors, in which we identified broad themes that were the starting point for the student work (for more detail on this process, see Tijmsa et al., 2022).

Transdisciplinary encounters

Community interviews: In the fourth week of the course, each student conducted one semi-structured “street interview” with a resident from the area of Amsterdam on which the course and event focused. These interviews aimed to informally gauge community perspectives on the study topic as a source of information for their agenda-setting work and in preparing for the community event. In terms of learning, the interviews also served to sensitize the students to these community perspectives, and to familiarize them with the neighborhood. Students found their own respondents for an interview and followed a rough interview guide provided by the teaching staff.

Community event with dialog sessions: In week seven of the course, the students facilitated dialog sessions at a community event open to anyone to participate. The event had the purpose of collecting the input of diverse community actors on the study topics, as well as exposing students to a transdisciplinary encounter.

The dialog sessions were part of an event organized at a community location in collaboration with local community

organizations with whom we as authors and teaching team have a long-standing partnership. By meeting at the community location, we aimed to reduce the barriers for community members to participate and minimize power imbalances that are commonly reported between academic and community actors (Fritz and Meinherz, 2020; Horn, Scheffelaar et al., 2022). Participants at the event were divided into groups for the dialog sessions based on their preferred topic (following the same two broad topics that were co-defined between teachers and community partners prior to the course: Clean City and Connected City) and language¹ (Dutch/English). The sessions took approximately 90 min with a short break halfway through. In each session, between six and twelve people participated and multiple different actor groups were represented. In total, 59 people participated in the dialog sessions, who self-identified as local residents ($n = 22$), representatives of local organizations ($n = 18$), academics ($n = 11$), representatives of local government ($n = 5$), and others not otherwise specified ($n = 3$).

In order to support the collection of perspectives, we designed the dialog sessions to follow an interactive format and provided the students with a detailed script to follow. This set-up included the following subsequent steps: 1) introduction round with picture cards that served as conversation starters; 2) collection of issues related to the topic in which each participant wrote their inputs on post-its and was invited to share their insights and the insights were collectively clustered into categories; 3) prioritization of the clusters of collected issues, in which each participant got three voting stickers to indicate which clusters of issues they experienced as most pressing to discuss; and 4) further exploration of the most highly prioritized issue(s) (one or two, depending on time) through follow-up questions and gauging relationships between different issues.

We instructed the students to aim for a dialog based on guiding principles for community involvement in the context of community-based course activities (Visser et al., 2023) in which all participants had their say, were invited to respond to each other interactively, and felt comfortable. They were urged and explicitly instructed to be attentive to power relations, communication, and trust. Each student participated in one dialog session, collaborating as a duo (one facilitator and one secretary) or trio (two co-facilitators and one secretary). These roles were assigned taking into account both logistical feasibility and the students' preferred role. At each dialog session, a researcher/teacher was present to support the students and step in when necessary.

The student population. In total, 19 students completed the course. As the course was open to students from across the university, the cohort was diverse in terms of disciplinary backgrounds. The students represented 12 different master's programs representing six of the nine faculties at VU Amsterdam: science ($n = 8$), humanities ($n = 5$), business and economics ($n = 3$), medicine ($n = 1$), social sciences ($n = 1$), and religion and theology ($n = 1$). For many students this was the first time they had engaged in community involvement activities in their academic training. We collected and include data from all students who completed the course.

Data collection. In order to gain insight into the students' transdisciplinary learning, we collected multiple forms of data from multiple perspectives.

Written student reflections. Students completed weekly written reflections, which prompted their learning experiences through questions about the specific topic of that week, as well as general

questions about their learning experiences. In addition, the students wrote an additional reflection directly after the event. All reflections were completed in English.

Dialog sessions. In total, we held seven parallel dialog sessions at the community event—three about Clean City and four about Connected City. Five sessions were in Dutch, and two—one on each topic—in English. We audio recorded these sessions and transcribed them verbatim.

Post-event student focus groups. In order to gain insight into how the students experienced the event, we held four 45-min focus group discussions (FGDs) with the students one week after the event. The teaching staff of the course facilitated semi-structured conversations which followed a topic list including: composition of the groups, communication, and power dynamics during the dialog sessions at the community event. We audio recorded the FGDs and transcribed them verbatim.

Participant interviews. To gain insight into the experiences of participants in the dialog sessions, we conducted four semi-structured interviews. We relied on voluntary response sampling, as we invited all participants of the event to sign up for a follow-up interview, and interviewed all participants who agreed. We interviewed two representatives of a local organization, one resident, and one academic participant. In the interviews, we covered the topics of general impressions of the event, expectations, group composition, communication, and power dynamics. We conducted the interviews in Dutch and they lasted between 30 and 60 min. We audio-recorded the interviews and transcribed them verbatim.

Post-event staff reflections. The staff members present at the event ($n = 7$) completed written reflections of their experiences of the event and the sessions they attended and supported. The reflections were guided by questions provided by the research team, which prompted topics such as: atmosphere, group dynamics, communication, power dynamics, student performance, and their own role.

Data analysis. Through our data analysis we aimed to find out: 1) what engaging in transdisciplinary learning requires (assets); 2) how students develop towards the ability to do so (mechanisms); and 3) which learning activities supported this development (strategies). To gain insight into the students' transdisciplinary learning in our course, we took a multi-level approach by analyzing the data per dialog session, and within that for each student. We organized the data into seven clusters corresponding to each parallel dialog session. Each cluster included the data from the corresponding dialog session (transcript of the session, post-event FGD with the students, post-event reflection by the teacher, and—if applicable—interview with participants), and the data from each individual student participating in that session (reflection exercises throughout the course, and written post-event reflection). By doing this, we could triangulate and analyze data from different perspectives and collected through different methods. This allowed us to gain comprehensive understanding of each student's behavior holistically, and the methodological and data triangulation improved the credibility of our findings (Golafshani, 2003; Harvey and MacDonald, 1993; Korstjens and Moser, 2018). We, as first and second authors, separately analyzed one data cluster and discussed our interpretation. As the inter-researcher consensus was very high, we divided the remaining six clusters and each analyzed three clusters of data. The involvement of, and continuous communication between,

various researchers helped improve the confirmability of our study and helped overcome possible researcher bias (Korstjens and Moser, 2018).

We took an inductive reasoning approach, in which we analyzed theory and empirical data through continuous recursive iteration (van Van Breda and Swilling, 2019; Ridder, 2017). But in contrast to purely inductive approaches, we started with pre-existing conceptual ideas from substantive literature on transdisciplinarity and transdisciplinary learning; such as the conceptualizations of the transdisciplinary individual (Augsburg, 2014), transdisciplinary competencies (Nash et al., 2003; Nurius and Kemp, 2019), and transdisciplinary orientation (Misra et al., 2015). However, none of these conceptualizations provided a single analytical framework that allowed us to make sense of our data in which assets were highly intertwined and often did not fit within a single category. Therefore, we used the concepts from these conceptualizations—for instance, openness, confidence, modest positionality—as sensitizing concepts in our three-step inductive analysis.

Identifying building blocks: assets, mechanisms, and strategies. In the first step, we wrote summaries for each session, and within that for each student, to synthesize the insights from the different data sources. In these summaries, we juxtaposed the different sources of data so as to complement and corroborate reports from different sources. We reported statements from different data sources that confirmed or contradicted each other explicitly in the summaries, as a way to identify interesting instances of divergence and convergence. We identified assets, learning mechanisms, and learning strategies, for instance, plural understanding of real-world issues, real-world experiences, and awareness of transdisciplinarity. Throughout the Results section these “building blocks” (assets, mechanisms, and strategies) of transdisciplinary learning are indicated in bold.

Synthesis into themes: transdisciplinary action and attitude. Subsequently, in the second step, we identified higher-level themes into which the building blocks could be organized. The two higher-level themes that emerged were that we saw students learning in two domains:

1. ability to facilitate the sessions during the community events; and
2. stance towards transdisciplinarity and transdisciplinary collaboration.

Based on these two categories that emerged from our data, we returned to the literature. We were struck by the similarity to Klein's (2004) conceptualization of transdisciplinarity as “*simultaneously an attitude and a form of action*” (p. 521). Although she provided little substantiation of how to operationalize attitude and action in this definition, the distinction resonated with the pattern that emerged from our analysis. We therefore decided to follow this distinction and terminology. It is important to note, however, that attitude implies a narrower understanding than we intend to report, as we mean the entire ‘stance’ of students towards transdisciplinarity, transdisciplinary collaboration and non-academic partners in transdisciplinary collaboration, including attitudes, beliefs, assumptions, convictions, mindsets, values, and motivations. This distinction between themes action and attitude shaped the first two main subsections (“Acquiring the Ability to Engage in Transdisciplinary Action” and “Developing a Transdisciplinary Attitude”) in the “Results” section, in which we subsequently discuss the assets, mechanisms, and strategies for transdisciplinary action, and transdisciplinary attitude respectively. We did not aim to provide an exhaustive and straightforward list of assets, mechanisms and strategies, but rather provided

a description of assets, mechanisms, and strategies that emerged from our data on the action and attitude dimension, doing justice to the interactions between them and non-linear manner in which they manifested.

Analyzing transdisciplinary learning trajectories. Once we had identified the overarching themes of transdisciplinary action and attitude, we returned to the data for third step of analysis, in which we revisited the clusters of data for each student and conducted an analysis at a higher aggregation level. We inductively identified patterns in the changes in transdisciplinary action and attitude over time, to understand the transdisciplinary learning trajectories that students took. Those findings are reported in the last subsection of the Results (“Transdisciplinary Learning Trajectories”), and are at a higher aggregation level in which we compared and combined different data sources from different students to identify and report patterns of difference and similarity across the student cohort. Although these findings follow from the empirical data, individual quotes from the raw data fall short of supporting individual claims, as those arise from the combination of different data, rather than from individual data sources.

Ethics. All participants in this research (students, teaching staff, and participants at the community event) participated in the study on a voluntary basis and provided consent for the use of their data for research purposes and—if applicable—for audio recordings. They were allowed to discontinue their participation or withdraw their data at any moment. Students could take the course without participating in the research study, and people could participate in the event regardless of their participation in the study. This did not affect their relationship with staff. We anonymized all data by assigning numerical identifiers for each participant within the categories of students (S), teachers (T), and participants (P). Subsequently, we processed and analyzed all data anonymously. To ensure the anonymity of the students in reporting, we refer to all participants in the female form. The BETHCIE ethical committee of the Science Faculty of VU Amsterdam gave exemption from ethical approval for the research project to which this study belongs.

Results

In this section, we describe for each of the domains of transdisciplinary learning that we identified—action and attitude—what they entail (assets), how students developed (mechanisms) and which learning experiences and materials played a role in their development (strategies). Based on these insights, at the end of this section we present a conceptualization of “Transdisciplinary Learning Trajectories” that brings together the insights about each domain, development on each domain, and learning activities for each domain.

Acquiring the ability to engage in transdisciplinary action. The dialog sessions at the community event were moments at which we gained insight into the students’ ability to engage in transdisciplinary action. We understood the ability to engage in transdisciplinary action in this context as the ability to facilitate the dialog sessions with diverse actors to collect inputs in which their various perspectives were represented in order to inform the research agenda they developed.

Facilitation of structured and safe dialog sessions. In general, students managed to guide the sessions towards *collecting inputs for their agenda-setting project*, as well as to *create a safe and pleasant atmosphere* for the participants. It seemed easier for students with strong communicative skills and experience with

qualitative methods to adopt the approach taken in the course. But overall, students demonstrated the ability to provide *structure* to the sessions and *build rapport* as they showed enthusiasm, were inviting, and made encouraging remarks to make participants feel at ease. For instance, one of the teachers reported the following: “*The group atmosphere was great from the start. Psychological safety was achieved pretty much naturally*” (Teacher 6). In particular, students paid attention to the distribution of speaking time by giving turns and particularly inviting people who were underrepresented in the conversation to share their viewpoints. The fact that most of the participants were willing to share and react to other perspectives also shows that students succeeded in creating sessions that sparked the participants’ interest and made them feel sufficiently comfortable to actively participate.

Knowledge acquisition, practice, and tools. We saw that the learning materials we provided in the course made the *students aware of transdisciplinary approaches*, while this was new to most of them – “*Why don’t all programs include a course focusing on participatory research? (As I never heard of it before!)*”, (reflection week 2 - Student 14). The learning materials also familiarized them with key concepts that are central to transdisciplinarity, which helped them understand transdisciplinary approaches, and reflect on the implications for their own projects. For instance, in the following reflection, student 7 used some of the concepts (“complex problems”, “unknown unknowns”, “rapport”) to reflect on their project and on how to engage in transdisciplinary action in collaboration with societal actors:

“I think that there is no ‘recipe’ or standard solution to complex problems because these are problems that have not been solved previously before. Being transparent about these unknown unknowns towards the stakeholders is going to be important to build rapport and trust between actors.”
(Reflection week 3, Student 7)

Moreover, we saw that *practicing with transdisciplinary methods* prior to the event helped students to be better prepared for engaging in transdisciplinary action. Students expressed that practicing the dialog sessions through a simulation exercise helped them to feel more prepared for the actual event as it familiarized them with the set-up and the scripts. Moreover, the simulations made them aware of some of the challenges that they could encounter at the event, such as balancing providing structure and building rapport: “*After the [event simulations], it definitely became evident that there’s a balance between structure and connecting with people*” (Reflection week 6, Student 8).

And lastly, we saw that the students’ ability to engage in transdisciplinary action during the event was supported by the structures that were provided for the event. The dialog sessions were pre-designed and students were provided with *ready-to-use written out scripts*. The students said that they appreciated the detailed script and facilitated the session with more confidence as a result: “*...the fact that the [dialog sessions] were already so well thought-through and that the structure was so clearly typed out helped me a lot [...] To a large extent the bed was already made, we just had to sleep in it*” (Student 24 written post-event reflection). Following this structure and interactive design proved to be supportive in nurturing a stimulating conversation and engaging all participants. One of the participants at the event also highlighted the importance of the design of the session: “*So that [the work form] was really good. I think that if we had to have a conversation without the work forms that were used, nothing would have happened*” (interview Participant 1).

Instrumental facilitation. Although in general the dialog sessions were experienced as pleasant and were successful at collecting

inputs, the students showed a predominantly instrumental way of facilitating the session. This manifested itself as much of their attention was taken up with *procedural activities*, such as following the structure of the session, collecting inputs on sticky-notes, managing time, and dividing speaking time among the participants. Consequently, we saw that the conversations often remained limited to isolated statements, few follow-up questions were posed and the participants were not actively invited to respond to each other. This limited the interactivity as well as depth of the sessions.

It was often noted (by students, teachers, and participants) that the students showed little leadership in taking full charge of the conversation. At times, the conversation seemed to ‘happen to them’, rather than them actively guiding it. Often the student facilitators carefully waited for responses, but did not step in to guide the conversation. Teacher 7 reflected on the facilitation in their session (by Student 21): “*The student was clearly nervous and highly focused on giving everyone speaking time, letting them have their say and was highly careful with her words, but this slowed everyone down and did not become a conversation*”.

Moreover, many students did not interrupt when the conversation drifted too far off-topic or individual participants dominated the conversation. In one session, a participant heavily influenced the conversation with personal contributions with little relevance to the topic of conversation and to the other participants. This behavior overshadowed the other participants, as it steered the conversation away from the general concerns, and because she took up a lot of speaking time. The student facilitator, Student 1, did not step in to break this pattern. She says the following about this herself in the student FGD: “*I was of the opinion that I should let her finish her story. She had a lot on her chest, so I thought it would be good to let her vent*.” Teacher 3—an experienced transdisciplinary researcher—made a different call. She stepped in to interrupt (and invited the particular participant to continue in the coffee break) in order to bring the conversation back to the topic and give room to the other participants to share their views, an intervention that the student reflected in hindsight was beneficial to the conversation.

This shows that Student 1 did not step in as assertively as an experienced transdisciplinary researcher deemed appropriate and effective. She seemed to struggle with this situation that required going off-script, even though the simulation session included practicing dealing with difficult and dominant participants (role-played by teachers). It also shows that she seemed to prioritize being inclusive and inviting at the individual level, rather than wielding an interpretation of inclusivity that considered the larger group dynamics, which meant that it is sometimes necessary to cut one person short to give a chance to everyone. This demonstrates that transdisciplinary action demanded the ability to strike the delicate balance between stepping in and stepping back, identifying moments to break in and do so with *vigor yet respect*.

Translating knowledge into behavior. The students’ instrumental behavior at the event shows that they had the ability to execute the task of following the script but not the full ability to engage in this transdisciplinary action independently and dynamically. We often saw that students developed awareness and understanding of transdisciplinarity, but that they struggled to translate this into behavior. For instance, through the learning materials about dialog facilitation and practice sessions, Student 22 developed awareness about her role as a facilitator:

“I learnt that it is important [that] the facilitator only facilitates the discussion and makes sure it does not deviate too much. I found it challenging to not take the lead too

much (for example in guiding the grouping) but still keeping the pace high enough for the task to be completed.” (Reflection week 6, Student 22)

However, at the event we saw that she did not put those lessons that she reported into practice. She was quite directive, speaking extensively at the expense of listening to the participants and encouraging them to speak. She herself wrote the following about this in her reflection after the event:

“I think that as a facilitator you should not bring in your own views into the discussion. However, I caught myself by surprise by doing exactly that. At some point someone said something, and I had to respond to that with my own insights. As I was doing that I already realized I had stepped out of my role.”

This shows that although becoming aware, gaining insight into how to engage in transdisciplinary action, and acknowledging one’s own pitfalls are a first step towards learning to engage in transdisciplinary action, it does not necessarily also translate into the ability to engage in transdisciplinary action.

Overall, the students demonstrated some ability to engage in transdisciplinary action through facilitating the dialog sessions. They managed to facilitate the sessions to collect insights from the participants and create an atmosphere that participants experienced as safe and pleasant. Acquiring knowledge about transdisciplinarity, practicing, and the availability of structures and tools helped them engage in transdisciplinary action at the event. However, their behavior remained relatively instrumental, as it proved challenging to take charge of the conversations and further and deepen the conversation beyond collecting isolated statements.

Developing a transdisciplinary attitude. We understood transdisciplinary attitude in the context of this study as the attitude required to engage in equitable and reciprocal interactions with societal actors, including appreciation of experiential knowledge as legitimate and indispensable for understanding and addressing complex societal issues. We saw that the notion of involving community actors and valuing their knowledge and perspectives as a meaningful contribution to shape research efforts, was new to many students. They were coming from a view of community actors as recipients of academic knowledge (“*[participation] is about the spreading of information and knowledge, participation could also support the access to such information and knowledge*” (Reflection week 2, Student 14)), and/or of community actors as a source of research data that they could reap (“*the community can be deployed to collect data*” (Reflection week 2, Student 9)). These students’ attitudes seemed mainly informed by the specialist disciplinary and scientific cultures they were enculturated in during their education, in which participation of non-academic actors is not the norm.

Shifts towards a more transdisciplinary attitude. In our course we saw that a shift occurred in some students’ attitudes towards community actors and experiential knowledge. We observed that some students started to *value the contributions of community actors* (and specifically members, such as citizens) more highly. For instance, we saw a change in the view Student 18 held towards community actors and their role in research. At the beginning of the course she wrote the following: “*I feel that the role of community in my field is that of encouraging further research and accelerating the rate of scientific advances*” (Reflection week 2, Student 18). This shows that she saw the role of community actors as users or beneficiaries of research and as political stakeholders in setting research priorities, but not as

holders of knowledge and active participants in the research process. By the end of the course, her view on community involvement in research seemed to have shifted, as she said the following: “I found out that a focused discussion with genuinely interested people can produce unexpected and surprising results - for example, the direction or solutions you wouldn't think of before” (Reflection week 7, Student 18). This shows that she became more cognizant of the potential role of societal actors as co-producers of knowledge, and started to value their inputs as a valid source of knowledge to shape research efforts, which may also be reflected in the choice of words evolving from the abstract and distant ‘community’ to the relatable ‘people’.

Another student showed how she began to accept different, possibly incompatible but valid lived realities. This demonstrates that she embraced a *plural understanding of real-world issues*, and is indicative of a more equitable understanding of experiential and scientific knowledge: “One thing that was made very clear to me, especially from the interviews, is that people's opinions on plastic pollution are perfectly valid even though they may contrast with each other” (Reflection week 5, Student 19). In her reflection she showed an appreciation of experiential knowledge in its own right, exactly *because it represents the participant's view rather than a universal truth*.

Real-life experiences sparked attitude shifts. We saw that at the root of the attitude shifts were *real-world experiences* at the transdisciplinary encounters that gave students a sudden, new insight. These experiences challenged their previously held views. Student 24 made explicit that she experienced an “eye-opener”: “[the interview] woke me up to the fact that to some people waste is not a topic of concern. This is interesting because to me it seems super obvious that this is something with high priority” (Reflection week 4, Student 24). The interview made her aware that others may hold completely different views from her own and that this is a reality that needs to be addressed in studying real-world issues. By the end of the course, she wrote the following:

“The iCSL-course has broadened my horizon further and opened up new means of knowledge production. [...] it [transdisciplinarity] is very valuable on the way to understanding reality and improving life for the beings on earth (which I think are the ultimate purposes of science).” (Reflection week 7, Student 24)

This demonstrates that she has experienced the course and the corresponding encounters as an experience that radically changed her view. Besides the interviews, the community event seemed to also hold this potential for eye-opening experiences:

“Our group [of participants at the event] did not discuss the consequences of plastics on the environment/nature/health at all, whereas funnily enough that was all we [students] focused on [...] Perhaps we, the students, were too distant from the direct ‘real life’ implications whereas the focus group lacked the knowledge of the grander narrative.” (Reflection week 7, Student 5)

Through the event she became aware that her reality as a student was far removed from the experiences of the participants at the event. It made her aware of the complementarity of these different forms of knowledge, acknowledging the limitations and strengths of both.

What these instances have in common is that they sprang from real-life experience with transdisciplinarity, particularly when doing a community interview, and at the community event. These events were transdisciplinary encounters, which exposed students to views beyond their usual experience.

Venturing into the unknown to seek out learning experiences. Eye-openers thus seemed to play a key role in sparking attitude shifts. Real-life experiences outside their usual ‘bubble’ that exposed students to views different from their own showed that they hold the potential to challenge students’ priorly held views. These experiences cannot be scripted, but we designed the course to expose students to real-life transdisciplinary encounters—community interviews and event—that held the potential of experiences with this transformative quality.

For instance, Student 21 said that she learned because she took risks and ventured into unknown territory despite the discomfort this caused:

“I decided myself that I wanted to be a moderator [student facilitator in the dialog sessions]. Not because I thought I would be good at it, but mainly because I knew I didn't have that much experience in taking on a role that requires some form of leadership. Especially because of this, it has been such an educational experience.” (Reflection week 7, Student 21)

The eagerness to learn that motivated her to *seek out this learning opportunity* and the resulting experience seem to also have translated into a new view on the research, supporting her development towards being more receptive to transdisciplinarity by the end of the course:

“A thing that changed my views is that I really experienced the influence a researcher might have on the world. By discussing problems with inhabitants or stakeholders, I experienced that not everything can be captured into a mathematical model (even if it is simplified).” (Reflection week 7, Student 21).

This contrasts with what we saw in Student 15, who said that she was struggling with the interventionist nature of the course that is inherent to transdisciplinary approaches: “In [my field] the role of the fly on the wall is promoted, having a more objective way of looking/participating in a field. Participation can even ‘contaminate’ the field” (Reflection week 2). Although as teachers we urged the students to take on an active role and Student 15 showed she was aware of that, she did not step out of her comfort zone to take on a different role than the one she was used to: “During the event, I will be in the role of a secretary, this is an appropriate role if I want to act as a fly on the wall” (Reflection week 6). Rather than exploring the approach taught in the course that was new and awkward to her, she stuck with the role and approach with which she was familiar. This prevented her from questioning and potentially revising or broadening her view about the positionality of the researcher and thus developing towards a more transdisciplinary attitude.

Openness to learning. Although exposure to new, real-world experiences seemed to play an important role in sparking attitude shifts, we also observed that the experiences with the interviews and event sparked eye-openers in some but not in other students. For instance, in contrast to the examples we saw before, Student 11 said the following about her experience with the interview: “The interview gave some new insights and different perspectives of the problem, but I think people discuss what they feel like what the problem is. [...] In my interview I don't think the argumentation of the people was backed with scientific knowledge” (Reflection week 4, Student 11). Similarly, Student 9 said the following about her experience at the community event: “The discussion was [...] a bit too much focused on personal experiences. You feel that a lot of knowledge is ‘missing’ and that we have to educate people more” (Reflection week 7, Student 9). This shows that these students—also by the end of the course—judged the value of the information acquired from the community encounters by the standards of

scientific knowledge, rather than appreciating community perspectives in their own right. So, among these students, the transdisciplinary encounters in the course did not challenge and spark revision of their views.

What we saw in the students who did demonstrate a shift in attitude, is that they were *truly open to other ideas and views*. When they were confronted with information or approaches with which they were unfamiliar and that potentially clashed with their views, they *suspended their judgment*. They did not see it as “wrong”, but rather attempted to understand where the other perspective was coming from and asked themselves whether their own view should be revised in light of the new information. For instance, Student 4 wrote the following about her experience in conducting an interview with a community member: “*Despite my initial doubts about the value they [societal actors] add to our project, I was surprised to find that the information provided by the citizens opened my eyes to the structural aspects of the problem*” (Reflection week 4, Student 4). This example shows that she parked her initial skepticism about the value of experiential knowledge to their project and approached the interview openly with a community member. Thanks to the surprising experience, she appears to have adopted a more *modest position towards (her own) academic knowledge*.

So, we saw that the difference between students who did and did not go through an attitude shift seemed to arise from differences in openness, humility, and reflectivity. Jointly, these different assets seem to make learners receptive to question and potentially revise their views, in order to adopt a more transdisciplinary attitude.

Transdisciplinary learning trajectories. Based on the observations described in the previous subsections and the distinction between transdisciplinary action and attitude made by Klein (2004), we argue that transdisciplinary learning entails developing the ability to engage in *transdisciplinary action* and developing towards a *transdisciplinary attitude*. In the previous sections, we described that we saw that within the limited timeframe and context of our course, students developed in either or both respects. In terms of learning mechanisms, acquiring the ability to engage in transdisciplinary action through creating a safe and structured dialog, revealed to rely mostly on gaining understanding and practicing. Adopting a transdisciplinary attitude characterized by among others valuation of non-academic knowledge and plural understanding of complex societal issues, on the other hand, relied on eye-opener experiences that arose from the combination of exposure to novel experiences, and critical yet open processing of those.

When looking at the patterns of transdisciplinary learning in different students, we saw that they took different learning trajectories, as they developed transdisciplinary action and attitude to different extents, in different combinations, and different orders. For instance, we observed students who developed primarily in one dimension but hardly in the other. Those students used the tools, methods and instructions provided to them to successfully guide a productive and safe dialog that they otherwise would not have been able to do. They learned, in the context of the course, to engage in transdisciplinary action. This did not, however, necessarily go hand in hand with a development of a more transdisciplinary attitude. For example, in Student 14 we saw that she acquired knowledge and awareness of transdisciplinarity and skills in facilitating the dialog session. The teachers reported that she performed better than their expectation and used the tools that were handed to her, such as how to ask follow-up questions, invite people to speak, divide speaking time and apply the interactive formats, even though she had little to no

prior experience with those methods. In terms of attitude, we did not perceive a shift during the course, as she still expressed herself in instrumental terms when reflecting on transdisciplinarity and seemed to have a one-way understanding of community involvement. And also she herself reported that her perspective has not really changed throughout the course: “*I think my views have not really changed*” (Reflection week 7, Student 14).

In contrast, we also observed students who did develop a more transdisciplinary attitude, but in whom this did not concur with a change in behavior during the dialog sessions. For instance, in Student 4 we saw that she acquired knowledge, awareness and sensitivity about transdisciplinarity and experienced shifts in her views about community. As reported earlier, she had initial doubts about the value of interviews and citizen perspectives, but was surprised about what she learned. In addition, the readings in the course served to spark a realization about transdisciplinarity in her, as she wrote in her reflection in week 2:

“Communities are not homogenous! I think this is one of the most important lessons to take away from this week. Working in collaboration with communities means that there should be an understanding of tensions and processes that are at work within the community even before the research has started. Also to think about different stakeholders in the community seems important.” (Written reflection week 2, Student 14)

These shifts in attitude did not, however, necessarily also translate into the ability to engage in transdisciplinary action when facilitating the dialog session at the community event. Her contributions were mainly procedural and instrumental, in terms of time-keeping and collecting sticky notes, and not so much deepening questions to further the understanding of the participants’ lived experiences.

This demonstrates that with different types of interventions and in line with students’ different points of departure (prior competencies) and learning styles, students develop differently in the transdisciplinary action and attitude dimensions, and thus also that development on both dimensions can take place relatively independently from each other.

However, we saw that beyond a certain point, the interdependency between the two dimensions increased. The development of more refined and advanced abilities depended on the interplay between, and uniting of, transdisciplinary action and attitude. For instance, when following the script did not suffice for dealing with the situations that the students encountered, we saw that strategies had to go beyond mere ‘recipe-following’. In those situations, providing structure and being kind and polite (action) seemed to not suffice, but success also relied on the students’ attitudes. We saw that the ability to navigate empathy and vigor, and to wield a sophisticated definition of inclusion which also embraces the fact that giving space to everyone sometimes means restricting some, requires an attitude that unites confidence and assertiveness with humility and sensitivity to power imbalances. Similarly, the development of attitudes beyond a certain point also relied on action; we saw the example that a student’s view of transdisciplinarity plateaued when she reflected on and read about it, but did not seek out new experiences that challenged her views. Beyond a certain point, we therefore argue that development should therefore take place by combining the development in action and attitude simultaneously and in interaction.

Based on our findings, we propose a generalized framework of Transdisciplinary Learning Trajectories. Although our findings were acquired in the context of transdisciplinary agenda-setting, we hypothesize that some of our findings about transdisciplinary learning may also apply to other context of transdisciplinary learning and research. But this is tentative and requires additional

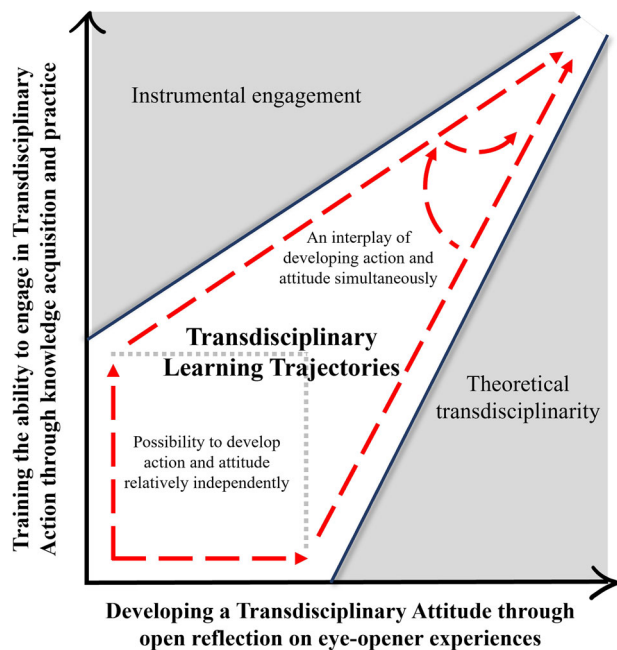


Fig. 1 Transdisciplinary learning trajectories. A schematic representation of the Transdisciplinary Learning Trajectories. Transdisciplinary learning comprises development of the ability to engage in transdisciplinary action (vertical axis) and the development of a transdisciplinary attitude (horizontal axis). Acquisition of knowledge and practice support the development towards the ability to engage in transdisciplinary action, whereas eye-opener experiences support the shift towards a more transdisciplinary attitude. We observed that initial development may take place in both domains relatively independently, but argue that advanced learning requires ‘diagonal development’ of developing action and attitude simultaneously and in interplay.

research. We have visualized the diversity of transdisciplinary learning trajectories in Fig. 1. It shows the learning in the two dimensions— action and attitude—on the two axes, vertical and horizontal, respectively. We argue that the more an individual moves towards the top right in this visualization, the more prepared they become for engaging transdisciplinarity, combining high ability in action and a strongly transdisciplinary attitude. The learning trajectories for engaging in transdisciplinarity are marked as a diagonal band throughout the figure, which narrows towards the top right. This narrowing represents the interdependency between action and attitude for advanced transdisciplinarity, to develop towards uniting both dimensions of transdisciplinary assets within the individual. Whereas, the square shape in the bottom left illustrates the possibility for relatively independent development of action and attitude up until a certain point. However, beyond those points the further development in one axis, whereas the other stays behind may demonstrate as what we described as the instrumental implementation of transdisciplinary approaches, or theoretical understanding of transdisciplinarity that does not translate into transdisciplinary action.

Discussion

In this study, we gained insight into how students can be familiarized with and sensitized for transdisciplinarity, through an experiential learning course in which they engaged in research agenda-setting with local communities. Our findings support a more in-depth understanding on which assets require training when preparing students and future professionals to engage in

transdisciplinary agenda-setting (assets), how those be acquired (mechanisms), and what learning and teaching activities can support diverse transdisciplinary learning trajectories (strategies). We saw that the students developed in one or both of the following respects: i) their ability to engage in transdisciplinary *action*; and ii) a transdisciplinary *attitude*. Based on these findings we proposed a conceptualization of “*Transdisciplinary Learning Trajectories*”, in which transdisciplinary learning consists of learning in both the action and the attitude dimension, either independently or in an interplay. We enriched the conceptualization of Klein (2004) by making sense of what action and attitude mean and require in the context of dialog sessions for transdisciplinary agenda-setting, such as the facilitation of a structured and safe dialog and valuing non-academic knowledge and embracing knowledge plurality. We argue that those insights potentially also provide insights into transdisciplinary learning for other contexts, as the action-attitude entwinement can be considered characteristic of transdisciplinarity and transdisciplinary learning (Klein, 2004). In accordance with this, we expect many of the mechanisms and strategies to also apply to other contexts, although the precise activities will differ. Additional research will be necessary to make sense of those similarities and differences and the level translatability of our findings to other transdisciplinary learning contexts and processes.

We saw that our course supported transdisciplinary learning in our students. Although their starting points, trajectories, and competence by the end of the course varied widely, every student was at the very least made aware of transdisciplinary research and what it entails. This awareness is a first step in transdisciplinary learning, as at the outset of the course, most of the students were entirely unfamiliar with transdisciplinarity and its potential for addressing complex challenges. The course thus met the learning objectives for students to become familiar with transdisciplinarity, gain (basic) experience with community involvement in research, and gain insight into complex issues and multi-actor systems through real-world experiences. In light of the complexity and multifaceted nature of transdisciplinarity that we saw and is reported in the literature (Guimarães et al., 2019; Nash et al., 2003; Nurius and Kemp, 2019; Pohl et al., 2021; Wall and Shankar, 2008), we deem it not realistic to expect students to develop full transdisciplinary competence in a mere 80-h course. Even for experienced professionals, engaging in transdisciplinarity has been reported to be highly challenging (Fam and O’Rourke, 2020). Moreover, it may not fit everyone’s personality, strengths and ambitions to pursue transdisciplinary approaches (Augsburg, 2014). An introductory course like the one we offered therefore seems a suitable way to familiarize students with transdisciplinarity, to spark their interest to continue transdisciplinary learning or engage in transdisciplinary research, or to make them aware that transdisciplinarity exists but may not be something that they themselves seek to continue in their career. Future research is needed to understand how such first, introductory experiences with transdisciplinarity shape learners’ future career choices and views beyond an initial introduction, as it was beyond the scope of this project to conduct a longitudinal alumni study for the course we studied.

We find it essential to stress that we have to be careful with sending unexperienced students out into the wild without considering the learning trajectories and other implications for communities and involved societal actors, such as community fatigue (Visser et al., 2023). Yet this also poses a challenge, as we saw that much of the transdisciplinary learning in our course found its roots in exactly those real-world experiences that the students were exposed to; how can learning from practice and responsible engagement with local communities go hand in hand? Through our set-up we allowed students to engage in real-world

transdisciplinary encounters that had the potential of challenging their own views, and that they experienced as motivating, while participants also reported having benefited (Tijmsma et al., 2022). With the help of the “ready-made bed” of a detailed script with interactive work forms, and the safety net of teachers being present to step in if necessary, the students managed to run a community event that was experienced to be both productive and inclusive.

This demonstrates that it is not necessary for facilitators to be fully competent in transdisciplinary action before they can start engaging in transdisciplinary action and learn through experience, and thus allows for learning in an interplay between action and attitude. The structures and support that we implemented, therefore, hold the promise of being implemented in a “scaffolded” approach in which the level and type of support is adapted to the competence levels of learners (Andersson and Palmer, 2023; Coulson and Harvey, 2013). As such, we hope that our approaches and experiences may inspire ways to deal with critiques that engaged learning can be exploitative (Butin, 2015), as with the proper structures and support, students seem to be able to engage in transdisciplinary real-world learning responsibly (Visser et al., 2023). More detailed studies into the experiences of community participants’ involvement in higher education activities would help further understand possible outcomes and impacts of approaches like the one we applied. Future research into programs designed in the spirit of transdisciplinarity could support a deeper understanding of how involved societal actors can truly benefit from such educational programs, embarking on their own transdisciplinary learning trajectories.

Furthermore, we saw that transdisciplinarity requires adopting a different attitude towards research, knowledge, and collaboration, that cannot be learned from a book. The required attitudes are complex, hard to disentangle, and are highly dependent on the context. This complexity and multidimensionality of attitudes toward transdisciplinarity echoes the diversity of assets that are reported in the literature to be key for transdisciplinarity (Augsburg, 2014; Guimarães et al., 2019; Misra et al., 2015; Nash et al., 2003; Nurius and Kemp, 2019). We even saw that the assets that transdisciplinarity requires can be paradoxical, and seemingly difficult to unite in an individual professional. For instance, the combination of assertiveness to step in, and humility to step back, seemed hard to navigate. This is in line with earlier findings about competencies required for interdisciplinary collaboration and integration (Horn, Urias et al., 2022). Future research should seek to shed light on how these seemingly contradictory behaviors can be united in single individuals and how higher education can support the development of the associated assets.

Our findings show that exposure to real-world experiences was essential to spark attitude shifts. This resonates with the widespread calls for transformative and experiential learning approaches for transdisciplinarity (Chang et al., 2020; Godemann 2006; McGregor, 2017; Mossman, 2018). Such transformational learning (in the broad sense of the term, as described and distinguished by Hoggan (2016)) requires experiential learning in which learners are exposed to real-world experiences and encounters outside their usual “bubble” and comfort zone (Tien et al., 2020). It follows from our findings that real-world, transdisciplinary encounters hold the potential to expose learners to critical moments that may function as an eye-opener. Moreover, in order to turn these real-world experiences into transformative experiences, we saw that openness played a key role, which is in line with earlier reports in the literature which emphasize the importance of openness to transdisciplinary learning (Wall and Shankar, 2008). It should also be noted, however, that transformative learning cannot be forced, as we saw in our study that the same experiences resulted in a mindset shift in some students,

and left other students unaffected. Authentic and experiential learning in combination with reflection increases the chances of critical moments (Smith, 2011), and of translating those into learning experiences, but there is no “recipe for success”. This also places a high demand on teachers to recognize and be responsive to unpredictable instances of disorientation and discomfort (Demeijer et al., 2024; Di Giulio and Defila, 2017; Vilmaier and Fam, 2022). Future research into how openness and venturing into the unknown as assets can be nurtured or developed in students within the higher education curriculum could support furthering more advanced development of transdisciplinary learning.

Our findings about the mechanisms underlying transdisciplinary learning—experience and training through theory and practice—provide promising insights for the design of future education. We saw that development towards the ability to engage in transdisciplinary action can be supported by instruction and practice, to develop understanding and practical abilities. This was necessary, but not sufficient for transdisciplinary learning. This thus argues for instruction *about* transdisciplinarity as a key component of transdisciplinary training, to support the development of awareness about transdisciplinarity and its implications. This is in line with earlier reports about the importance of offering practical and theoretical training for transdisciplinarity that are well aligned with each other and leverage each other (Lekies and Moore, 2020). More outspokenly, Barrett et al. (2019) cautioned against a purely experiential approach to transdisciplinary learning, because learners require direction, theoretical handles, and targeted practical training in a scaffolded approach to support transdisciplinary learning.

Transdisciplinary learning requires process-oriented transformative learning to develop the assets necessary for addressing (future) complex challenges. However, such process-oriented learning requires deviating from the dominant regime of outcome-oriented learning and teaching (McGregor, 2017). If Higher Education Institutes aim to prepare students to become professionals able to engage in the transition to more sustainable futures, such outcome-oriented learning and teaching must be enriched with or make way for educational activities that foster openness, humility, and reflexivity for transdisciplinary learning. Initiatives such as the iCSL course that we described in this study, may contribute to this goal by implementing a holistic approach to transdisciplinary work wherein teaching, research, and engagement components are an inseparable and integrated whole of the process to address complex sustainability issues (Hazelkorn, 2016; de La Torre et al., 2018). We acknowledge that in starting up an innovative educational inter- and transdisciplinary program adjusting towards existing structures can be helpful (in line with Chadwick and Pawlowski, 2007; Holland, 2009), but in order to challenge dominant disciplinary outcome-oriented institutional structures, there is a need for wider and deeper changes in organizational (and epistemic) culture (Tijmsma et al., 2022; Benneworth et al., 2017; Fitzgerald et al., 2012). In addition to considering the institutional conditions and incentive structures already in place (Compagnucci and Spigarelli, 2020), we particularly recommend future studies focus on the individual perceptions and personal values of students and academics, especially in relation to disciplinary adherence when aiming for this transformation in the research and educational system.

We are thus convinced that our findings provide meaningful insights to understanding transdisciplinary learning, the assets for transdisciplinarity, mechanisms of acquiring them and possible strategies to enable this in educational contexts. However, it should be noted that this study was conducted in a particular context. First, we focus on student learning, whereas transdisciplinarity is widely understood as mutual learning between all involved (Hirsch

Hadorn et al, 2008; Polk and Knutsson, 2008). We focused on the learning trajectories of students specifically in order to acquire insights for the design and implementation of transdisciplinary higher education. We are, however, aware that this is not the whole story with regard to transdisciplinary learning, and highly encourage additional research into how such mutual learning can give meaning in the context of higher education, for instance dealing with the short course periods and extrinsic motivation structures. This is thus a limitation in the applicability of our findings. Yet, we consider it also offers future potential to study how our findings about student learning translate to the learning of everyone involved in transdisciplinary processes.

Furthermore, the transdisciplinary processes described in this study were specifically dialog sessions at a community event with the goal of transdisciplinary agenda-setting, about two priorly defined broad societal issues. This is only one of many forms that transdisciplinarity can take, and we thus urge readers to interpret our findings with that in mind and to judge how it applies to their own settings. We provided thick descriptions of our experiences in order to enable readers to make transferability judgments (Korstjens and Moser, 2018). The decision to pre-define the topics of the course and event, albeit into broad themes, was an attempt to balance openness and responsiveness to the lived experiences and concerns of participants to the event on the one hand, and the generation of actionable outcomes on the other. The challenging nature of this balancing act is further elaborated on by Tijsma et al. (2022).

Conclusions

In this study, we proposed a more comprehensive understanding of transdisciplinary student learning in terms of the assets required for transdisciplinarity, the mechanisms for acquiring those, and strategies that can be deployed to support transdisciplinary learning in a higher education context. We present the distinction between transdisciplinary *action* and transdisciplinary *attitude* as two dimensions of transdisciplinary learning that can take place in relative isolation to some extent, but that require an interplay for more advanced learning. We brought these insights together into the visualization of the “*Transdisciplinary Learning Trajectories*”. In terms of developing, designing and implementing transdisciplinary higher education, the combination of learning *about* and learning *through* transdisciplinarity seems promising in preparing students (and thus future professionals) to contribute to addressing complex societal issues. We saw that the combination of these approaches—jointly and in interplay—supported the development of the ability to engage in transdisciplinary action and a transdisciplinary attitude, and thus transdisciplinary learning. Engaging in transdisciplinary action exposes learners to encounters that can trigger attitude shifts and be motivating to seek out transdisciplinary experiences again. In addition, learning about transdisciplinarity can sensitize learners to recognize relevant experiences.

As such, our findings hold the promise to contribute to better preparing university students for addressing complex societal issues through transdisciplinary approaches. This has implications for teachers and education designers, to provide structure for transdisciplinary learning, but also be responsive to unplanned, potentially uncomfortable, and challenging eye-opening moments, to support the realization of learning potential.

Data availability

No additional data from this study is publicly available.

Received: 30 May 2023; Accepted: 14 December 2023;

Published online: 20 January 2024

Note

1 As the course was followed by a substantial number of international students who did not speak Dutch (7/19), but English sessions were not accessible and inviting to all community actors, we decided to offer sessions in both languages in parallel and give participants at the event the opportunity to choose their preferred language.

References

- Andersson P, Palmer H (2023) The promise of scaffolding: a metaphor and living practice for transdisciplinary inquiry. In: Lawrence RJ (ed) *Handbook of transdisciplinarity: global perspectives*. Edward Elgar Publishing, Cheltenham, p 28–43
- Augsburg T (2014) Becoming transdisciplinary: the emergence of the transdisciplinary individual. *World Future* 70(3-4):233–247. <https://doi.org/10.1080/02604027.2014.934639>
- Barrett MJ, Alphonsus KB, Harmin M, Epp T, Hoessler C, McIntyre D et al. (2019) Learning for transdisciplinary leadership: why skilled scholars coming together is not enough. *BioScience* 69(9):736–745. <https://doi.org/10.1093/biosci/biz072>
- Benneworth P, Young M, Normann R (2017) Between rigour and regional relevance? Conceptualising tensions in university engagement for socio-economic development. *High Educ Policy* 30(4):443–462
- Brown VA, Harris JA, Russell JY (eds) (2010) *Tackling wicked problems through the transdisciplinary imagination*, Routledge, Abingdon
- Bunders JF, Broerse JE, Keil F, Pohl C, Scholz RW, Zweekhorst, MBM (2010) In in ‘t Veld (ed) *Knowledge democracy: consequences for science, politics, and media*. Springer, Berlin. https://doi.org/10.1007/978-3-642-11381-9_11 p 125–152
- Butin D (2015) Dreaming of justice: critical service-learning and the need to wake up. *Theor Pract* 54(1):5–10. <https://doi.org/10.1080/00405841.2015.977646>
- Chadwick SA, Pawlowski DR (2007) Assessing Institutional Support for Service-Learning: A Case Study of Organizational Sensemaking. *Mich J Comm Serv Lear* 13(2):31–39
- Chang H, Granek EF, Ervin D et al. (2020) A community-engaged approach to transdisciplinary doctoral training in urban ecosystem services. *Sustain Sci* 15:699–715. <https://doi.org/10.1007/s11625-020-00785-y>
- Compagnucci L, Spigarelli F (2020) The Third Mission of the university: A systematic literature review on potentials and constraints. *Technol Forecast Soc* 161:120284. <https://doi.org/10.1016/j.techfore.2020.120284>
- Coulson D, Harvey M (2013) Scaffolding student reflection for experience-based learning: a framework. *Teach High Educ* 18(4):401–413. <https://doi.org/10.1080/13562517.2012.752726>
- de La Torre EM, Perez-Esparrells C, Casani F (2018) The policy approach for the third mission of universities: the Spanish Case (1983–2018). *Reg Sec Econ Stud* 18(1):13–30. https://EconPapers.repec.org/RePEc:eea:eressev:18:y2018:i:1_2
- Demeijer F, Visser MJ, Urias E, Darvey LM, Horn A, Zweekhorst MBM (2024). Towards a broader mind for students? Emergent transformative learning from a university-based course in the Netherlands. *J Transf Ed*
- Di Giulio A, Defila R (2017) Enabling university educators to equip students with inter-and transdisciplinary competencies. *Int J Sust High Ed* 18(5):630–647. <https://doi.org/10.1108/IJSHE-02-2016-0030>
- Dosemagen DM, Schwalbach EM (2019) Legitimacy of and value in action research. In: *The Wiley handbook of action research in education*. John Wiley & Sons, Ltd. <https://doi.org/10.1002/9781119399490.ch8>. p 161–183
- Fam D, O'Rourke M (eds) (2020) *Interdisciplinary and transdisciplinary failures: lessons learned from cautionary tales*. Routledge, Abingdon
- Fitzgerald T, White J, Gunter H (2012) *Hard labour? Academic work and the changing landscape of higher education*. Emerald Group Publishing, Leeds
- Fritz L, Meinherz F (2020) Tracing power in transdisciplinary sustainability research: an exploration. *GAIA* 29(1):41–51. <https://doi.org/10.14512/gaia.29.1.9>
- Gieryn TF (1983) Boundary-work and the demarcation of science from non-science: strains and interests in professional ideologies of scientists. *Am Soc Rev* 48(6):781–795. <https://doi.org/10.2307/2095325>
- Gillis D, Nelson J, Driscoll B, Hodgins K, Fraser E, Jacobs S (2017) Interdisciplinary and transdisciplinary research and education in Canada: a review and suggested framework. *Coll Ess Learn Teach* 10:203–222. <https://doi.org/10.22329/celt.v10i0.4745>
- Godemann J (2006) Promotion of interdisciplinarity competence as a challenge for higher education. *J Soc Sci Educ* 5(2):51–61. <https://doi.org/10.4119/jsse-347>
- Golafshani N (2003) Understanding Reliability and Validity in Qualitative Research. *Qual Rep* 8(4):597–607

- Guimarães MH, Pohl C, Bina O, Varanda M (2019) Who is doing inter- and transdisciplinary research, and why? An empirical study of motivations, attitudes, skills, and behaviours. *Futures* 112:102441. <https://doi.org/10.1016/j.futures.2019.102441>
- Harvey L, MacDonald M (1993) *Doing sociology: a practical introduction*. Red Globe Press, London
- Hazelkorn E (2016) *Contemporary debates part 1: theorising civic engagement*. The Civic University, Edward Elgar Publishing, Cheltenham
- Hirsch Hardorn G, Biber-Klemm S, Grossenbacher-Mansuy W, Hoffmann-Riem H, Joye D, Pohl C, ... Zemp E (2008). The emergence of transdisciplinarity as a form of research. In: Hirsch Hardorn G (ed) *Handbook of transdisciplinary research*, Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-6699-3_2, p 19–39
- Hoggan CD (2016) Transformative learning as a metatheory: definition, criteria, and typology. *Adult Educ Quart* 66(1):57–75. <https://doi.org/10.1177/0741713615611216>
- Holland BA (2009) Will it last? Evidence of institutionalization at Carnegie classified community engagement institutions. *N Dir High Educ* 147:85–98. <https://doi.org/10.1002/he.361>
- Horn A, Urias E, Zweckhorst MBM (2022) Epistemic stability and epistemic adaptability: interdisciplinary knowledge integration competencies for complex sustainability issues. *Sustain Sci* 17:1959–1976. <https://doi.org/10.1007/s11625-022-01113-2>
- Horn A, Scheffelaar A, Urias E, Zweckhorst MBM (2022) Training students for complex sustainability issues: a literature review on the design of inter- and transdisciplinary higher education. *Int J Sust High Ed* 24(1):1–27. <https://doi.org/10.1108/IJSHE-03-2021-0111>
- IPCC (2022) *Climate Change 2022: impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, Pörtner, HO and Roberts, DC (eds)].* IPCC, Geneva, Switzerland
- Jacobi J, Llanque A, Mukhovi SM, Birachi E, von Groote P, Eschen R et al. (2022) Transdisciplinary co-creation increases the utilization of knowledge from sustainable development research. *Environ Sci Policy* 129:107–115. <https://doi.org/10.1016/j.envsci.2021.12.017>
- 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>
- Klein JT (2004) Prospects for transdisciplinarity. *Futures* 36(4):515–526. <https://doi.org/10.1016/j.futures.2003.10.007>
- Klein JT (2017) Typologies of Interdisciplinarity: The Boundary Work of Definition. In: Frodeman R, Klein JT, Pacheco RCS (eds) *Oxford Handbook of Interdisciplinarity*, 2nd edn. Oxford University Press, Oxford, p 21–34
- Kolb DA (2014) *Experiential learning: experience as the source of learning and development*. FT Press, Upper Saddle River
- Korstjens I, Moser A (2018) Series: practical guidance to qualitative research. Part 4: Trustworthiness and publishing. *Eur J Gen Pract* 24(1):120–124. <https://doi.org/10.1080/13814788.2017.1375092>
- Kurtulmuş F (2021) The democratization of science. In Ludwig D, Koskinen I, Mncube L, Polisel L Reyes-Garcia L (eds) *Global epistemologies and philosophies of science*. Routledge, Abingdon, p 12–21
- Lang DJ, Wiek A, Bergmann M, Stauffacher M, Martens P, Moll P, Swilling M, Thomas CJ (2012) Transdisciplinary research in sustainability science: practice principles and challenges. *Sustain Sci* 7(S1):25–43. <https://doi.org/10.1007/s11625-011-0149-x>
- Lekies KS, Moore RH (2020) Promoting transdisciplinary learning through a summer course on climate, water, and agriculture. *Nat Sci Educ* 49(1):e20023. <https://doi.org/10.1002/nse2.20023>
- Mausser W, Klepper G, Rice M, Schmalzbauer BS, Hackmann H, Leemans R, Moore H (2013) Transdisciplinary global change research: the co-creation of knowledge for sustainability. *Curr Opin Environ Sust* 5:420–431. <https://doi.org/10.1016/j.cosust.2013.07.001>
- McGregor SL (2017) Transdisciplinary pedagogy in higher education: transdisciplinary learning, learning cycles and habits of minds. In Gibbs P (ed) *Transdisciplinary higher education*. Springer, Cham, p 3–16
- Misra S, Stokols D, Cheng L (2015) The transdisciplinary orientation scale: factor structure and relation to the integrative quality and scope of scientific publications. *J Transl Med* 3(2):1042
- Mossman AP (2018) Retrofitting the ivory tower: engaging global sustainability challenges through interdisciplinary problem-oriented education, research, and partnerships in U.S. higher education. *J High Educ Outr Engag* 22(1):35–60
- Nash JM, Collins BN, Loughlin SE, Solbrig M, Harvey R, Krishnan-Sarin S et al. (2003) Training the transdisciplinary scientist: a general framework applied to tobacco use behavior. *Nicotine Tob Res* 5:S41–S53. <https://doi.org/10.1080/14622200310001625528>
- Nurius PS, Kemp SP (2019) Individual-level competencies for team collaboration with cross-disciplinary researchers and stakeholders. In Hall KL, Vogel AL, Croyle RT (eds) *Strategies for team science success*. Springer, Berlin. <https://doi.org/10.1007/978-3-030-20992-6> p 171–187
- Pohl C, Klein JT, Hoffmann S, Mitchell C, Fam D (2021) Conceptualising transdisciplinary integration as a multidimensional interactive process. *Environ Sci Policy* 118:18–26. <https://doi.org/10.1016/j.envsci.2020.12.005>
- Polk M (2014) Achieving the promise of transdisciplinarity: a critical exploration of the relationship between transdisciplinary research and societal problem solving. *Sustain Sci* 9(4):439–451. <https://doi.org/10.1007/s11625-014-0247-7>
- Polk M, Knutsson P (2008) Participation, value rationality and mutual learning in transdisciplinary knowledge production for sustainable development. *Environ Educ Res* 14(6):643–653. <https://doi.org/10.1080/13504620802464841>
- Reeger BJ, Bunders-Aelen JGF (2009) *Knowledge Co-Creation: Interaction between Science and Society. A Transdisciplinary Approach to Complex Societal Issues*, RMNO/COS, Den Haag
- Ridder HG (2017) The theory contribution of case study research designs. *Bus Res* 10(2):281–305. <https://doi.org/10.1007/s40685-017-0045-z>
- Ryser L, Halseth G, Thien D (2009) Strategies and intervening factors influencing student social interaction and experiential learning in an interdisciplinary research team. *Res High Educ* 50(3):248–267. <https://doi.org/10.1007/s1162-008-9118-3>
- Smith E (2011) Teaching critical reflection. *Teach High Educ* 16(2):211–223. <https://doi.org/10.1080/13562517.2010.515022>
- Steger C, Klein JA, Reid RS, Lavorel S, Tucker C, Hopping KA, Waiswa D (2021) Science with society: evidence-based guidance for best practices in environmental transdisciplinary work. *Glob Environ Chang* 68:102240. <https://doi.org/10.1016/j.gloenvcha.2021.102240>
- Tien DTK, Namasivayam SN, Ponniah LS (2020) Addressing global sustainability challenges: a qualitative study on factors that promote transformative learning in engineering students. *SN Appl Sci* 2(8):1369. <https://doi.org/10.1007/s42452-020-3158-5>
- Tijmsma G, Horn A, Urias E, Zweckhorst MBM (2022) Training students in inter- and transdisciplinary sustainability education: nurturing cross-faculty staff commitment and continuous community collaboration. *Int J Sust High Ed* 24(4):765–787. <https://doi.org/10.1108/IJSHE-02-2022-0049>
- van Loon R, van Dijk GM (2015) Dialogical leadership: dialogue as condition zero. *J Leadersh Acc Ethics* 12(3):62–75
- Van Breda J, Swilling M (2019) The guiding logics and principles for designing emergent transdisciplinary research processes: learning experiences and reflections from a transdisciplinary urban case study in Enkanini informal settlement, South Africa. *Sustain Sci* 14(3):823–841. <https://doi.org/10.1007/s11625-018-0606-x>
- Vilsmäier U, Fam D (2022) The responsive and constitutive character of transdisciplinarity: consequences for higher education. *J Educ Stud* 21(1):30–50. https://hdl.handle.net/10520/ejc-jeds_v21_n1_a3
- Visser MW, Pittens CA, de Vries R, Zweckhorst MB (2023) Community involvement in course-based higher education activities: exploring its definition, guiding principles, and strategies—a narrative review. *J Higher Educ Outr Engagem* 27(3):59–80
- Wall S, Shankar I (2008) Adventures in transdisciplinary learning. *Stud High Educ* 33(5):551–565. <https://doi.org/10.1080/03075070802373008>

Author contributions

AH and MV have jointly collected and analyzed the data, and prepared data collection together, with guidance from the other authors: CP, EU, MZ, and GD. The conceptualizations and interpretations were discussed thoroughly between AH and MV and in the full author team repeatedly; they thus emerged through iterative discussions. AH led the writing of the manuscript, with input and feedback from the rest of the author team. The iCSL1 course was co-designed by authors AH and MZ, with input on specific learning activities from MV, EU, CP, and GD. AH coordinated the organization of the community event, in which MZ, MV, and EU provided support. AH and MZ also played a role in the delivery of the iCSL1 course in 2019.

Competing interests

The authors declare no competing interests.

Ethical approval

This study was performed in line with the principles of the Declaration of Helsinki. Exemption from requiring ethical approval was granted by the ethical committee of the authors' institution, on the grounds that no vulnerable people were included in the study and no personal or otherwise sensitive data were collected.

Informed consent

Written, voluntary informed consent for data collection, storage, and publication was provided by all participants involved. The decision to participate in the study was not linked to the possibility to participate in education or the public event. Participants could discontinue their participation and withdraw their data at any moment.

Additional information

Correspondence and requests for materials should be addressed to Annemarie Horn.

Reprints and permission information is available at <http://www.nature.com/reprints>

Publisher's note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit <http://creativecommons.org/licenses/by/4.0/>.

© The Author(s) 2024