Making mutual learning tangible: Mixed-method Delphi as a tool for measuring the convergence of participants' reciprocal understanding in transdisciplinary processes

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ARTICLE INFO

ABSTRACT

This paper proposes an approach to capture mutual learning within transdisciplinary research to develop future-oriented sustainability solutions to land use conflicts. While quality criteria for transdisciplinary research projects are increasingly discussed, there is still ample methodological potential to enable and better understand mutual learning as a key component of transdisciplinarity. Changes in the specific developments of perceptions of the participants are difficult to be tamed and tracked. To address this shortcoming we propose to apply the Delphi method for longitudinal tracking of mutual learning within transdisciplinary research. We present the application of the methodological approach as part of a transdisciplinary project on sustainable land use in the district of Lüneburg (Lower-Saxony, Germany). Evaluation of semi-structured interviews with seven participants translated into a three-round Delphi survey. A concluding round of semi-structured interviews was performed to validate and deepen the findings. The results showcase that the Delphi method can facilitate the operationalization of the convergence of understandings as a relevant outcome of mutual learning within transdisciplinary projects.

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1. Introduction

This study applies the Delphi method to broaden the understanding regarding changes of knowledge and mutual understanding of participants throughout a process of mutual learning within a transdisciplinary (td) project on future-solutions for sustainable land-use. Within sustainability studies and transdisciplinary research mutual learning is increasingly recognized as a core aspect (Jahn et al., 2012; Mitchell et al., 2015; Scholz & Steiner, 2015a). Mutual learning is defined as 'the basic process of exchange, generation and integration of existing or newly-developing knowledge in different parts of science and society' (Scholz, 2001). This includes the willingness and capacity to exchange with others and learn from each other (Peukert et al., 2021; Scholz & Steiner, 2015a). The potential to bring a diverse range of actors together for the co-creation of knowledge and the establishment of a joint understanding promises grand prospects for future consensus-building in complex societal fields of transformation (Norström et al., 2020). When purposefully integrating and differentiating diverse cultural, social and institutional backgrounds for processes of joint problem definition and knowledge generation, mutual learning facilitates the creation of solution-oriented, socially robust knowledge (Vilsmaier et al., 2015; Polk & Knutsson, 2008; Walter et al., 2007).

The facilitation of mutual learning processes between the diverse range of participants from science and society is a key component of transdisciplinarity (Mitchell et al., 2015; Peukert et al., 2021; Renn, 2021). Mutual learning enables the participants to achieve shared progress during the different phases of a td project: while framing the problem; while building a team and raising awareness for the positions of the others; and also while integrating the situated knowledges (Lang et al., 2012; Vilsmaier et al., 2015). There is a strong focus on informal knowledge and experience exchange in a reciprocal manner in mutual learning processes (Polk & Knutsson, 2008). Even more, the learning requires reflexivity by everybody involved; it is helpful if participants develop an understanding of the 'otherness of others', the acknowledgment of one's own epistemic boundaries and the situatedness of knowledge (Mitchell et al., 2015; Vilsmaier et al., 2015). Mutual learning is therefore tightly connected to joint processes and the co-creation of knowledge in td research projects, enhancing the 'knowledge of all participants […], including local knowledge, scientific knowledge, and the knowledge of concerned industries, businesses, and non-governmental organizations' (Häberli et al., 2001, p. 7). A core aim of mutual learning is therefore to 'collaboratively generate new rich insights that remain undetectable from a single disciplinary […] perspective' (Mitchell et al., 2015, p. 93), in order to 'improving the situation through transdisciplinary research' (ibid.).

It is widely acknowledged that such cooperation between different actors from society as well as of different academic disciplines is necessary to provide robust and actionable knowledge to solve interconnected life-world problems (Liu et al., 2015; Norström et al., 2020; Pohl & Hirsch Hadorn, 2008). This is especially true for a 'post-normal' age that is defined by high uncertainties regarding future developments, calling for broadened and joint knowledge production (Funtowicz & Ravetz, 1993). Transdisciplinary research enables such a cooperation between different academic fields and realms of knowledge, also from non-academic societal actors. The changes in perspectives and relations towards the other td-participants may have long-term effects, especially as they are often continuing work relations after the end of a project (Schäfer et al., 2021).

Evaluation of td projects can be separated into the assessment of the scientific outcomes of a project as well as its impact to sustainability transformations (Lawrence et al., 2022). At the same there is a contribution to the acquisition of knowledge about td-research, which may in itself have implications on the design of future td projects (Lang et al., 2012; Lawrence et al., 2022). It is still widely discussed how the diverse impacts of td research can be evaluated (Lux et al., 2019; Schäfer et al., 2021). Difficulties arise among others because of complex, intertwined systems, the diversity of actors and the difficulty to capture the long-term consequences (Kny et al., 2023; Scholz & Steiner, 2015b).

When looking at the evaluation of the impacts of mutual learning within td research, the situation is even more blurry. To date, only a limited amount of papers describe how mutual learning actually takes place and there are very few trying to assess the outcomes of mutual learning empirically (Peukert et al., 2021; Scholz & Steiner, 2015b; Vilsmaier et al., 2015). This is surprising, when thinking about the core importance of mutual learning in td processes. At the same time, it is very difficult if not altogether impossible to find objective, value-neutral measurements of the mutual learning that has taken place within a project. Indeed, the whole point of mutual learning is to assume that there is not just one "right" knowledge, but that there is a 'symmetry of enlightenment' (Maasen & Lieven, 2006, p. 404) between the participants and that the learning-process leading to socially-robust solutions is not pre-defined. However, there is a shared assumption that succesfull mutual learning practices lead to shared 'generation and integration' (Scholz, 2001, p. 118) of different situated knowledge, providing 'new rich insights' (Mitchell et al., 2015, p. 93).

While the 'tangible products' (Lang et al., 2012, p. 29) of a td process, e.g. strategies or agreements, provide one output dependent on mutual learning, one might ask how it is possible to make the process of mutual learning itself more tangible. Besides the generation of new insights, which we do not focus on in this paper, one important outcome of a td process is the transformation of participants' perspectives regarding the respective topics over time. Such a transformation of understandings may be analyzed on an individual level as well as on a group level (Polk & Knutsson, 2008) through repetition of data collection at defined points in time. Hence, not only the alteration of individual perspectives can be captured, but also a convergence or distancing between the participants' perspectives over time. In order to promote understanding of the processes of mutual learning in td projects, it is necessary to find new ways to enable clear and helpful analysis of participants' changes in perspective over time.

We propose that the Delphi method has potential to help grasping the convergence of understandings, if it becomes embedded into the td process (Flood et al., 2023). Delphi is an interactive research method for gathering the opinion of a panel of experts concerning a specific topic to validate forecast of upcoming trends and changes based on thematic convergence of respondents (Hallowell & Gambatese, 2010; Shariff, 2015; Turoff & Linstone, 2002). In this paper we present insights from a study in which we used a mixed-method Delphi (Delphi questionnaires combined with qualitative interviews) to 'make mutual learning tangible' in a td research project.

This study aims to find new ways to assess the mutual learning progress in transdisciplinary research. For this purpose we address three research questions:

1. How can the convergence of opinions of different stakeholders of td projects be longitudinally measured by the Delphi method?
2. How can the Delphi method be embedded in mutual learning to inform transdisciplinary processes?
3. What are challenges of applying the Delphi method in a case study focused on mutual learning contexts?

In the following, we first introduce our case study, including the research project and its regional context (Section 2) as well as the applied methods (Section 3). The results of the mixed-method Delphi are described in Section 4. In the discussion (Section 5) the interpretation of results in correspondence to mutual learning within td research and proposals for future research are presented. We end with some conclusions (Section 6).

2. Case study

Land is a limited and contested resource, that is claimed by a wide range of socio-economic actors (Tudor et al., 2014; Verburg et al., 2015). Heterogeneous actors from backgrounds such as industry, construction or renewable energies are in search for more land. Others (e.g. agriculture or nature conservation) are warning that too much land is being converted into less desirable states (Peerzado et al., 2019). Even more, climate change as well as mitigation and adaptation necessities contribute to the exacerbation of land use conflicts in the future (Froese & Schilling, 2019). In Germany, politics are seeking measures towards the reduction of land sealing and the creation of a more effective land use (Die Bundesregierung, 2021). Due to the complexity of land use dynamics a deeper understanding of underlying drivers of change as well as identification and implementation of solution approaches is needed (Von Der Dunk et al., 2011). In order to co-develop socially-robust solutions with land use actors for a sustainable future there is an urgent necessity for mutual learning, co-creation of knowledge and collaborative action. Such transdisciplinary processes may help to explore synergies, develop compromises for difficult conflicts of interests and facilitate good dialogue within the broad landscape of land-use stakeholders. It is particularly important to reveal the assumptions and anticipations of the stakeholders about the future issues and conflicts of land use and to bring them into a constructive, solution-oriented dialog.

This study was conducted as part of the five years transdisciplinary research project SUSTIL *(Scenarios for the Implementation of the United Nations' Sustainable Development Goals in the City and District of Lüneburg: Implications for Land Use Management)* focusing on sustainable land use and competition for space in the district of Lüneburg. The district is located in the North-Eastern region of the German Federal State of Lower Saxony and is a part of the Metropolitan Region of Hamburg. The district of Lüneburg is defined as a 'sparsely populated rural district', which is the most rural of four categories (BBSR, 2018). 187,000 inhabitants are living in an area of 1328 km^2 in the district (LSN, 2022). A third of the German population lives in predominantly rural areas (including its cities) (Danielzyk, 2017). The district of Lüneburg is therefore characterized by land use-related issues that a lot of Germanys predominantly rural regions have to face. Accordingly there are mainly rural types of land use in the Lüneburg district: Agriculture is practiced on 51.1% of the area and 33.6% is composed of forest. This is followed by land use for mobility (4.2%), settlements (3.9%) and industry and commerce (3.2%) as well as water bodies (2.7%) and green spaces (1.3%) (LGLN, 2021).

The district consists of eleven municipalities, containing two cities (Lüneburg and Bleckede). The city of Lüneburg and some of the adjoining municipalities are experiencing a growing population and positive economic indicators (BBSR, 2019). They profit by the proximity and infrastructural connectivity to the city of Hamburg. Other municipalities in the district are affected by a decline in population and therefore experience fewer conflicting interests regarding land use (LSN, 2021). However, these municipalities often lack resources to maintain or expand their basic infrastructure. Such a lack of resources also results in an increasing dependence on Lüneburg city and the Metropolitan Region, which is reflected in rising number of commuters, that are leaving the district (BA, 2022). With the central role of the city of Lüneburg as an anchor point and different levels of periphery within the district of Lüneburg, land use related issues are very diverse and multi-faceted (Danielzyk & Priebs, 2020).

The city is characterized by a broad range of NGOs and civil society actors, that are often concerned with issues revolving around ecology and sustainability (Bernert et al., 2016). Numerous transdisciplinary sustainability projects were conducted by the Leuphana University Lüneburg and its partners in the city of Lüneburg in the last decade, having had impact on the cities' further development (Kirst et al., 2019; Zukunftsstadt Lüneburg, 2023). The project SUSTIL added a new td process to the region.

The process was split in two phases: Project phase 1 (2020–2023) served to develop scenarios for land use in the district of Lüneburg and to design implementation options to foster sustainable land use against the background of these scenarios. Here, four plausible future scenarios were co-developed to assess and discuss the possible future implications of current decisions. The future scenarios were focusing on a range of interconnected challenges and possibilities for land use in the district. Important aspects were: Whether equivalent living conditions in the whole district were possible or a growing disparity between the city and the rural areas would emerge; if rural communities could develop themselves by upholding local supply and gaining job opportunities; if land sparing for nature conservation would be strengthened or weakened; if commuting would rise or fall; if mainly individual mobility or local public transport and rail passenger transport would expand; how the future development of renewable energies would influence land use; in which ways new construction would happen and if would mainly be developed on the outskirts and if there would be a well-functioning inner-center development.

In addition, a convergence of the different interests regarding land use and a better mutual understanding of the actors were central aims and a precondition to continue the project in the second phase for two more years. Phase 2 (2023–2025) aims at the implementation of selected implementation options, that build on the co-produced knowledge of phase 1. The collected data from the first

project phase serve to answer the research questions of this paper.

To address the diverse issues of land use conflicts in the district of Lüneburg, a group of seven institutions work together in the project. They each stand for different interests regarding the resource land as well as sustainability issues. The group includes actors from the municipal administration of the city of Lüneburg as well as from the administration of the district of Lüneburg, representatives of nature conservation, agricultural, craft and industrial associations as well as from a housing association. Due to the transdisciplinary character of the project, the selected actor groups are characterized not only by their specific expertise with regard to the local and regional conditions and characteristics of the project region, but also by their diversity. Shared activities within the transdisciplinary project were group workshops on specific topics, shared elaboration of future scenarios, regular input presentations and joint planning on how to proceed the project. In addition, group strengthening activities like monthly meetings, field trips, creative workshops and celebratory activities were carried out.

While the case study focusses on one specific German district, we consider the insights on the assessment of mutual learning within a td research project as transferable to other regions as well as to further issues of sustainability transformations.

3. Methods

3.1. Delphi method

Through the Delphi method the opinion of a panel of experts is surveyed regarding a specific topic. It is featured by merging individual research and practical knowledge from selected experts (Grime & Wright, 2016; Loo, 2002). Commonly, the Delphi method is used to forecast possible developments through discovering consensus between the respondent experts (Diamond et al., 2014; Hallowell & Gambatese, 2010; Shariff, 2015). In an iterative process, several rounds of inquiries are used to collect expert opinions concerning a specific topic. The results of the respective rounds are summarized and presented anonymously to the participants in the subsequent rounds. Hence, the participants are taking decisions under the influence of the general trend of the respondents (Cuhls, 2019; Häder & Häder, 2000; Turoff & Linstone, 2002). In such a process, anonymity is important to avoid the dominance of individuals
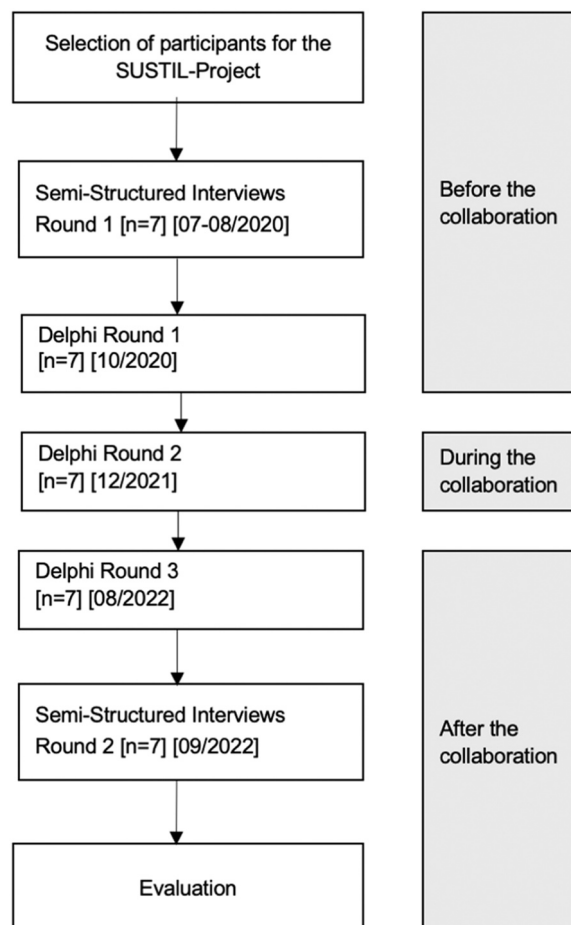

Fig. 1. Process of inquiries for the Delphi survey.

and to offer a possibility to change opinions without need to explain (Aengenheyster et al., 2017). The survey structure and content thereby stay essentially identical, so that comparison throughout the rounds is feasible (Häder & Häder, 2000). The period of observation and the number of survey rounds to be conducted during this period is determined in advance. There should be at least two rounds and usually three rounds are adequate (Brockhoff, 1975; Rohrbaugh, 1979).

The aim of our Delphi modification is to add a new impact assessment opportunity to td research by making the mutual learning of the different actors tangible. The quantitative Delphi surveys were supplemented by an analysis of semi-structured interviews with the same participants. The interviews reveal further layers of knowledge and may underline or contrast findings from the Delphi survey (Bryman, 2006; Creswell & Clark, 2017). The combination of methods allows to acquire knowledge on changes overtime and on the different subtopics investigated. Even more, they can put the self-assigned change of competences in relation to the thematical choices throughout the time of the td process.

While Delphi surveys commonly aim at anonymity between the respondents, the here proposed Delphi in td projects builds on participants that know each other. In this case perceptions and knowledge of each participant can be determined before the project and their individual changes throughout the project can be observed. The answers given in the surveys, however, are still presented anonymously in the following rounds to avoid interference.

3.2. Application of Delphi in the case-study

3.2.1. Sample

The sample was based on the participants of the first phase of the SUSTIL research project. One representative of each of the seven participating institutions was included in the Delphi process, to measure mutual learning among the SUSTIL project partners. If a participating institution was represented by several people, one person represented the respective institution in the surveys. A criterion was that the person was well networked within the institution and able to make statements regarding the interests of the institution.

3.2.2. Data collection process

The sample was surveyed over a period of two years. The process is illustrated in Fig. 1. It started with a round of semi-structured in-person interviews. After that the Delphi-online-survey was conducted in three rounds at the beginning, during the collaboration and at the end of the first project phase (October 2020, December 2021, August 2022). As the formative scenario analysis process happened in the same time frame, mutual learning processes also influenced the results of the Delphi survey. The collected responses were included anonymously in the form of graphs and statements in the respective next rounds. Appendix A.2 showcases the interview questionnaire; appendix A.3 presents the Delphi questionnaire. Finally, a second round of semi-structured interviews took place and the collected data was evaluated.

3.2.3. Qualitative data collection

Qualitative data served as basis for the quantitative survey and at the same time enabled deeper insights into the convergence of positions during the survey period. Accordingly, two rounds of interviews were conducted with the sample in summer 2020 and autumn 2022, before and after the quantitative Delphi rounds. The first round in particular aimed to explore the initial perspectives and experiences of the actors. The advantage of the selected semi-structured, guided interviews is to offer the interviewees the opportunity to present their respective perspectives in a free format. This allows a broad range of knowledge to be accessed, while ensuring a framework for continuous treatment of all relevant topics.

The guideline, which served as orientation for the interviewer and for structuring the interview, was divided into three blocks. The first block illustrated the status quo regarding land and land use in the district Lüneburg from the perspective of the interviewees. Thereby interests, perspectives as well as the subjective perception of the development and trends of influencing factors concerning a sustainable land use were surveyed. The second block was about the respective ideas of the future state of land use. Thus, data on the insights and demands of the actors as well as on conflicts and (potential) synergies between land use forms and the respective stakeholders were acquired. The third block covered views on potentials, instruments and ways to achieve the subjective ideal-type future perspectives of the actors. Here, drivers of change, but also barriers and potential measures were addressed.

3.2.4. Quantitative data collection

Three rounds of questionnaire-based surveys were conducted between autumn 2020 and summer 2022. Basic data were gender, organizational affiliation, place of residence, and which stakeholder group is represented in relation to land use. The quantitative survey was divided into six clusters. The cluster and items are shown in Table 1.

Through the analysis of interviews we identified factors which influence sustainable land use in the case study area. Regarding the first cluster these influencing factors were divided into four categories (economy, infrastructure, personal lifestyle and nature protection). Each of these categories consists of 3–7 influencing factors. In the three survey rounds, participants rated the importance of these influencing factors on a seven-point scale (0 (not at all) to 7 (very strongly)). After rounds 1 and 2, additional influencing factors could also be mentioned, so that their importance was also evaluated in the subsequent rounds.

The second cluster contained ten aspects of sustainable land use, which were also extracted from the interviews. Participants assigned a total of 100 points according to their personal assessment of the importance of these aspects. In addition, new aspects could be mentioned, which were also rated in the follow-up rounds. Further, the participants were asked to explain their own allocation of points in relation to the three aspects with the most points.

In Clusters 3–5 participants were asked in round 1 with open-ended questions to name the respective necessities to act, barriers and

Table 1
Clusters and included items of the Delphi questionnaire.

Influencing factors for sustainable land use				Necessities to act	Barriers (towards sustainable land use)	Drivers (of sustainable land use)	Aspects (of sustainable land use)	Synergy pairings from different areas of land use
Economy	Infrastructure	Personal Lifestyle	Nature Protection					
Economic development within the Hamburg Metropolitan Region (E1)	Expansion of regional rail transport and public transport (I1)	Use of private motorized transport (L1)	Popularity of nature tourism and local recreation (P1)	Development of joint concepts for future land use that go beyond the spatial-planning at regional level ('RROP) (N1)	Land competition created by land compensation measures. (B1)	Production-integrated compensation (PiK) to promote ecological agriculture (D1)	Reduction of resource consumption, including land use (A1)	Agriculture and nature conversation
Settlement and expansion of large-scale commerce and industry (E2)	Construction of the Elbe bridge (Neu Darchau to Amt Neuhaus) (I2)	Commuting habits (L2)	Creation of interlinked biotopes (P2)	Far-sighted urban land use planning that is adapted to different site conditions and business types (N2)	Land prices (B2)	Promotion of multifunctional land use in urban areas (D2)	Preservation of soil quality; avoidance and compensation of soil sealing (A2)	Housing and nature conservation
Tourism in the Hanseatic City of Lüneburg (E3)	Extension of the highway A39 to Wolfsburg (I3)	Demand for housing space per person (L3)	Compliance with the 'Water Framework Directive' (P3)	Comprehensive strategies and measures that enable sustainable land use throughout the district of Lüneburg (N3)	Trade tax (B3)	General overview of urban wasteland (D3)	Preservation and expansion of green spaces for local recreation (A3)	Forestry and nature conservation
Land and estate prices (E4)	Expansion of renewable energies and its' supply infrastructure (I4)	Consequences of the Corona pandemic (e.g. home office) (L4)		Conflict of land use must be prevented (N4)	Real estate transfer tax (B4)	Sealing index per area of business land use in combination with cost reduction, e.g., for business taxes (D4)	Increasing the share of sustainable forestry (A4)	Industrial land and Nature Conservation
Cultural and functional centralization to the Hanseatic City of Lüneburg (E5)	Development of broadband access (I5)			Land sealing must be reduced and avoided e.g. through multi-functional land use, concentration and conversion. (N5)	Disparities in infrastructure (B5)	Financial incentives and sponsorship (D5)	Preservation of agriculturally used areas (A5)	Industrial land and Housing
Demographic development (E6)	Measures for flood protection (I6)			Development of settlement areas while protecting open space structures in the surrounding area. (N6)	Individualization of road users (B6)	Raising awareness among the population and relevant stakeholders (D6)	Increase of the share of ecological agriculture (A6)	Areas for energy production and supply and Agriculture
	Measures for adaptation to dry periods (I7)				Increase in large vehicles (B7)	Demand-oriented land use designation (D7)	Preservation and expansion of green spaces for the protection of nature and biodiversity (A7)	Areas for energy production and supply and Housing
	Extraction and utilization of renewable and non-renewable resources (I8)				Cost-effective new construction before old renovation or reuse (B8)	Self-commitments (D8)	Creation of affordable housing (A8)	
					Different strategies in individual municipalities (B9)	Village renewal program (D9)	Expansion of public transport and bicycle paths (A9)	

(*continued on next page*)

Table 1 (*continued*)

Influencing factors for sustainable land use				Necessities to act	Barriers (towards sustainable land use)	Drivers (of sustainable land use)	Aspects (of sustainable land use)	Synergy pairings from different areas of land use
Economy	Infrastructure	Personal Lifestyle	Nature Protection					
					Lack of inter-municipal cooperation (B10)	Land use certificates (D10)	Investment - and planning security for business enterprises (A10)	
					Lengthy planning procedures (B11)		Prevention of soil erosion (new from Round 1) (A11)	
					EU agricultural policy (related to agriculture) (B12)			
					Lobbying and speculative interests (related to construction and housing) (B13)			
					Requirements for building renovations (B14)			
					Lack of cooperation between city and county (B15)			
					Lack of availability of suitable areas for settlement development (B16)			
					Protests from citizens lead to longer procedures (B17)			
					Very high land and real estate prices in Hamburg increase the demand in the Hanseatic City of Lüneburg (new from Round 2) (B18)			

drivers of sustainable land use. Then, participants were asked to rate the importance of these three clusters in rounds 2 and 3 on a seven-point scale. Additionally, further items were mentioned in round 2 and accordingly only rated in round 3 (as depicted in Table 1).

Land use synergies made up the sixth and final cluster. The overarching land-consuming issues (such as housing, conservation, or agriculture), were paired with each other based on the interview results. A total of seven synergy pairings were identified. Within these pairs, participants were asked to cite specific examples of synergies that occur from their respective perspectives. Additional synergy pairings could be mentioned in the follow-up rounds.

At the end of each of the six clusters, the participants were asked to rate their personal competence in evaluating the respective questions of a cluster using a five-point scale (from 1 (not competent) to 5 (very competent)).

3.2.5. Analysis

The first step was the analysis of the Delphi questionnaires. The focus was put on the changes in the standard deviation, which is used as a measure of convergence. A decrease in the standard deviation of the ratings with regards to an item over three rounds was considered as convergence. If convergence of answers is observable, we assume that this indicates that participants have been adapting their view points due to learning or understanding the positions of other participants. Hence, an increase in the standard deviation may indicate opposite trends.

Beside the change of the standard deviation, the actual values and mean values of the items and their changes were analyzed. It was considered how the change of the standard deviation behaved in comparison to the changed mean values of the items. In addition, it was considered whether there were respondents who had indicated strongly diverging values with regard to an item. All items in the quantitative survey were analyzed and identified regarding to whether there was a convergence, distancing, or no change. After looking at each item individually, it was evaluated if there was an overall convergence or not and whether patterns could be identified. Furthermore, the clusters were examined regarding how the self-assessed competencies of the participants have changed. Finally, the quantitative results were checked against the qualitative data.

For the analysis of the qualitative data, the interviews were completely transcribed to preserve the information content. The software MAXQDA was used to code and analyze the interviews. Since the participants' statements were only of interest in terms of content, the documentation of pauses in conversation, body language, and other nonverbal conspicuities was omitted (Blöbaum et al., 2014). For the evaluation of the transcribed interviews, a qualitative content analysis was conducted with the purpose of comparative presentation of statements (Gläser & Laudel, 2010). In this way, the extensive interview material could be systematically examined. The clusters occurring in the questionnaire were also used as categories for the qualitative content analysis.

A comparison was made to see if trends regarding convergence that emerged from the quantitative data also emerged from the content of the interviews. No direct comparisons of the different statements are possible, as they are given in free speech. However, the interviews bear a great significance in reaching a deeper level of understanding of the development of perspectives of the participants through evaluating and contrasting the data. The interviews were therefore a vital component of the analysis.
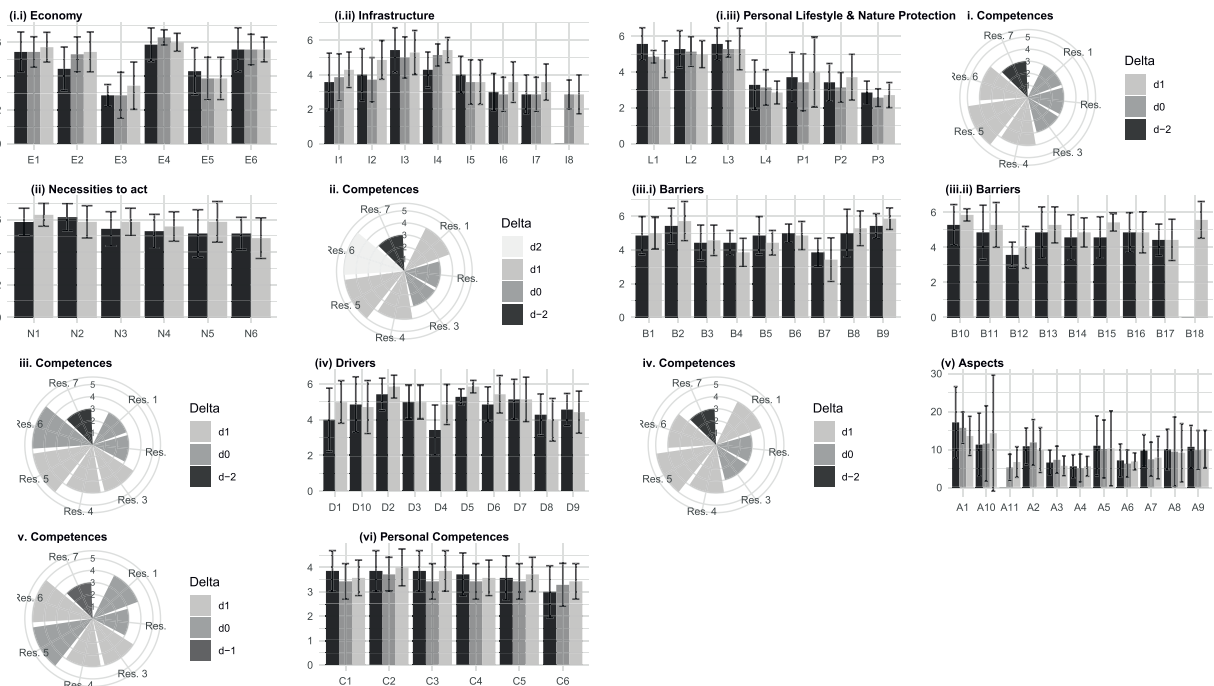

Fig. 2. Results of the Delphi survey.

4. Results

In the following we present the results showcasing the opportunities to measure developments of mutual learning using the Delphi method. It should be emphasized that the land use related results are only briefly discussed as the focus of this paper is firmly put on the development and description of the methodology. Therefore, mainly the overarching trends and the visualization of results are displayed, while we cannot provide sufficient space for individual topics of sustainable land use. For easier visualization purposes the individual items are only shown with abbreviations in the Figures. However, Table 1 allows to identify each item with its full designation.

For comprehensive summary of the quantitative data of the Delphi survey, Fig. 2 shows mean values and standard deviations of each item, sorted by category, across the different rounds as barplots with error bars. The bars are depicting the mean values, while the error bars show the range of the standard deviations. Items with only one or two depicted rounds were not scored until the second or respectively third round. As described in the Method section, all items except for Competences and Aspects are seven-scaled ($0 - 6$).

At the end of each category, there is a circular barplot, which shows the participants' self-assessed competences. The height of the bars describes the value given in the third round while the grey scale describes the change in competency from round 1 to round 3. The last barplot shows the mean values and range of standard deviation of the self assessed competences towards the categories across the different rounds.

In Fig. 3 the absolute values given by each respondent for each item in each round are shown. The items were sorted according to increasing standard deviation in round 3 (e.g., E4 has the least standard deviation in round 3 in comparison to other items of Economy). Therefore, additionally to the absolute values, a broad pattern of changes of standard deviations can be identified easily by sequence and grayscale. If there are no values shown for the first or second round, it is due to later inclusion in the question catalogue.

For a more detailed consideration, separate bar charts of the standard deviations are shown in the supplementary appendix (Fig. A.1). There, the standard deviation of each item for each round is shown individually. Thus, the changes of standard deviations are shown more clearly.

Within the Delphi survey a predominant convergence of viewpoints is noticeable, yet this is not the case for all items surveyed. There were also items where no convergence or even distancing was measurable. Results of single categories are being presented in the following.

4.1. Factors influencing land use

The first category was subdivided into the factors which influence land use ("Economy", "Infrastructure", "Personal Lifestyle" and "Nature Protection"). Regarding the factors there was a balanced relationship between increase and decrease of the standard deviation, slightly leaning towards a general decrease. In 12 out of 21 items, the standard deviation decreased, indicating a convergence of interest. The overall change in standard deviation was bigger when mean values were decreasing.

Overall, the categories Economy and Infrastructure were rated as more important than the categories Nature Protection and Lifestyle. Within the category Economy, items with a higher relevance showed lower standard deviations. This indicates that the respondents overall agreed on particularly relevant factors, while rather disagreeing on the factors rated less important. Regarding the three Nature Protection factors the standard deviation increased in all cases. One item within the category Lifestyle was the impact of the Covid-19 pandemic (L4). This item had the strongest convergence of all the factors that influence sustainable land use, but was loosing relevance with each round.

The interviews add to the results of the Delphi survey and showcase the growing appreciative stance towards other actors. With regard to factors influencing land use, topics with high relevance in the Delphi survey were also addressed more frequently by the respondents in the interviews. Furthermore, especially in the second round of interviews, there was increased mention of the interests of other stakeholders and of synergies. For example, one respondent claimed in the first round that due to economic and settlement pressure, agricultural land will continue to be claimed for other uses. In Round 2 the participant said:

> 'Of course, we recognise the requirements of nature conservation, i.e. the interests of nature conservation, and also the interests of farmers, that their economic basis must remain secure, that we obviously need their open area in their function for the provision of food, but also for fresh air and open space and also for biodiversity. And that is why it is a process of negotiation as to where and what use will be possible in the future.'.

4.2. Necessities to act

The next category was the Necessities to Act. These were identified by the respondents in the first round and rated from the second round on. Therefore, there were only measured values for two rounds. Of the seven items, five showed a decreasing standard deviation. This convergence was simultaneously accompanied by rising mean scores, thus higher rated relevance in the last round. The category indicates that stakeholders aspire better collaboration and have become more aware that overarching strategies are important, which was further confirmed in the interviews. The importance of collaboration was mentioned by four of the respondents in the second round of interviews, while no one mentioned it in the first round.
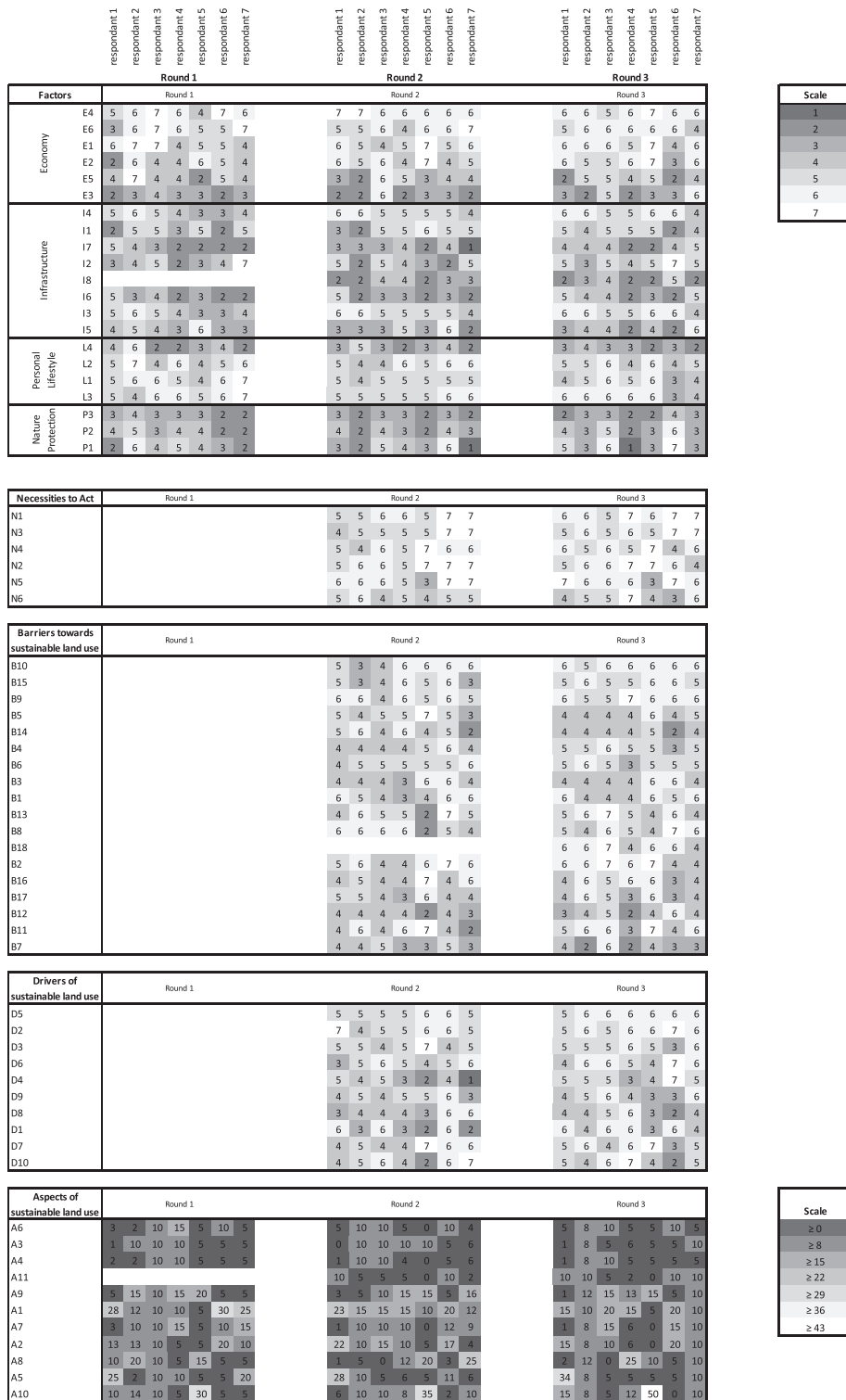
Fig. 3. Answers of the participants in absolute numbers, sorted by standard deviations.

4.3. Barriers

Also the category of Barriers was only evaluated twice. Another item was added in round 2, so here no statement can be made about a convergence. For 11 of the 17 barriers there was a decrease of the standard deviation and the items were often attributed a high relevance. Particularly, where the relevance decreased, there was also an increase of the standard deviation. Here, analogous to the necessities to act, it became apparent that non-coordinated strategies and a lack of cooperation were the barriers that were rated as particularly relevant across the rounds. This was also confirmed by the interviews. Respondents named 'insular thinking' or the lack of cooperation between municipalities or stakeholders as problems.

4.4. Drivers of sustainable land use

In the category drivers of sustainable land use, a decrease in standard deviation could only be observed for 5 of 10 items. Also in this case only 2 rounds could be evaluated. Financial incentives, from which all stakeholders benefit directly, was ranked as highly relevant and was the item with the lowest standard deviation. In addition, the standard deviation for the item multifunctional land use was very low. This is also true for the topic of cooperation, which was already very prominent in the barriers and needs for action. The views on socially controversial topics, such as self-commitments, land use certificates or demand-driven land use designations, did not change much. Nevertheless, a convergence could be indicated for some items as well as an increase of the relevance of the topic. The increased relevance for the participants was becoming clear through the interviews. It was especially in the second interview round that multifunctional land use was mentioned as an important driver of land use. It was apparent, that the participants had plenty to share towards possible drivers of sustainable land use at this point.

For example, one respondent said in the second round:

> 'In concrete terms, it means: we have to bring new sealing to zero, because only zero new sealing is sustainable. […] And that's why we're for multiple coding of land. We are for recycling of areas and we are always against new sealing from the beginning. There can only be new sealing if there is unsealing somewhere else, i.e. in a cycle. There's no other way because it's not sustainable.'.

4.5. Aspects of sustainable land use

The aspects related to sustainable land use were evaluated over three rounds with 100 points to distribute among the items. For this category, no predominant convergence can be indicated based on the data. The standard deviation decreased for 5 of the 11 items. However, the change was clearer for the items in which the standard deviation increased. These positions tend to become more extreme in the process. The items with rather lower standard deviations are those that were assigned a rather low relevance. In this case, the interviews reflected the findings only to a limited extent. Also, it became apparent in the interviews that the stakeholders were mentioning a bigger plurality of topics than in the beginning.

4.6. Synergies

For the category of synergies between different land uses, no assessments were given by the respondents. Only possible synergies and examples were collected over the three rounds. However, no synergies and examples were added by the participants after the first round. Yet, the interviews showed that in both rounds different synergies were mentioned by the respondents and that in the second round the participants focused on them in particular.

4.7. Competences

At the end of each category, the self perceived competence in relation to this category was asked on a scale of 1 to 5. Participants rated their competences relatively similarly across all categories. Over time, self-assessed competences always increased or remained the same for almost all respondents. The only decreasing result was actually due to a change of staff, so that a new person completed the survey. This suggests that the work in the td project has increased the self-perceived competence overall. The results indicate that a mutual learning process has taken place.

5. Discussion

5.1. Impact analysis of mutual learning

This study demonstrates that the embedding of the Delphi method within a td research process provides a rich amount of assessment opportunities of developments of td participants' perspectives. The most important tangible outcome of our analysis of the mutual learning process is the convergence or distancing of opinions of the participants. Even though a convergence of opinions is not depicting all aspects of the 'exchange, generation and integration of existing or newly-developing knowledge' (Scholz, 2001, p. 118), it does provide much deeper insights into the process of mutual learning. Combined with the analysis of the interviews which were conducted in different points of time of the td process, further aspects of the mutual learning process can be unfolded.

We analyzed the convergence of opinions in regard to each single item and in regard to patterns within broader categories.

Developments in different points of time can be assessed for single participants perspectives as well as for the general group. Thereby, conclusions on the implications on knowledge and perspective of the td process can be drawn. The self-assessment of competences provides further information on the individuals perspectives on their own learning within the process. The interplay of competence development and individual response change provide a further level of analysis. Interview analysis as well allows better interpretation of quantitative data. They can help in understanding what specifically enabled participants to change their perspectives in the process of mutual learning. Furthermore, the interviews provided insights that the 'appreciative stance towards difference' (Mitchell et al., 2015, p. 93) had been growing since the beginning of the td process.

Through the Delphi impact assessment the process of reciprocal learning of the group members is brought into the center of attention. As not only the individual results are analyzed, but the learning process within the group as a whole is taken into account, different layers of analysis are possible. This is especially important, as consensus-building and co-creation of knowledge of diverse actors in complex societal fields is one key to foster societal transformation (Mauser et al., 2013). Also, interim results may be used to assess ongoing td-projects, thereby enabling the subsequent steps of the project to be designed more effectful (Lang et al., 2012). Our approach thus allows to design new td research on the grounds of the gained knowledge.

To be able to supplement the Delphi method in the longitudinal measurement of the convergence of the stakeholder positions, a mixed methods approach was chosen. Therefore, the quantitative data could be validated and enriched, which is essential when analyzing a small sample (Onwuegbuzie & Collins, 2015).

The traditional Delphi is designed to be a forum of experts, tending to lead to consensus (Rayens & Hahn, 2000). Within the td project the process of answering the Delphi itself becomes embedded into the bigger process of mutual learning. Through answering the questions of a Delphi survey while seeing the results of the whole group of earlier rounds, the Delphi is not only a measurement tool, but also part of the self-reflection and learning process. Here, Delphi itself exerts influence on the formation of personal opinion of the participants. Therefore, the three-round survey is at the same time a measurement tool and a part of the td process.

Such an embeddedness, with intervention and evaluation in one unified step, into the general process is both a challenge as well as an advantage. On the one hand, it is difficult to distinguish how much of the changes have occurred in relation to the Delphi or because of other steps of mutual learning in the process. On the other hand, such separation is not actually needed within the td project. When individual and collective learning as well as new data acquisition can happen at the same time it is actually an advantage for both scientific accompaniment and for the participants, who are often only able to spend a limited amount of time. Even more, the integration of Delphi into the td process brings one more method towards consensus-building and co-creation of knowledge to the scientific repertoire.

5.2. Emergent challenges and possibilities for future research

By bringing forward a new proposal for the assessment of mutual learning, new possibilities as well as challenges arise. One general risk of the Delphi method is that participants could tend towards consensus mainly to fit in with the general mainstream of the group (*bandwagon effect*), without it actually impacting their personal beliefs (Hallowell & Gambatese, 2010; Loo, 2002). By comparing the quantitative data with the qualitative data, a link can be made of any trends identified in the survey and whether they correspond to the participants' beliefs. Additionally, the anonymous process of filling in and the anonymization of the results, reduces the factual group pressure.

Typically, td research distinguishes three knowledge types (i. systems knowledge, ii. target knowledge, iii. transformation knowledge) and three process phases (i. problem identification and structuring, ii. problem analysis, iii. integration and application) (Brandt et al., 2013; Pohl & Hirsch Hadorn, 2007). Some knowledge types and some process phases are more inclined to mutual learning processes than others (Brandt et al., 2013; Lawrence et al., 2022). We believe that especially a convergence of opinions regarding systems knowledge is to be expected. Furthermore, it would be interesting to compare learning processes with regard to the different process phases or single transdisciplinary activities. Here, single Delphi surveys could be synchronized with specific phases. Even though this was not yet aimed for in the scope of this study, we believe that our proposal allows intriguing possibilities in this regard.

Another aspect to keep in mind is whether attitudes changed because of mutual learning or rather because of generally changing discourses in society within the project time frame. In the years 2020 to 2022 this was very clearly the case with the Covid-19 pandemic, as the whole situation changed dramatically. In such events, acute developments can have strong effects on opinions.

A very important aspect for the scientific team is to support the group of stakeholders within the td project to stay in an active participation mode (Lang et al., 2012). Even within an active td process, context factors may lead to data noise, e.g., institutional staff may change within a project time leading to another representation, which would lead to a change of results within the Delphi. This was the case in one of the participating institutions, so that another person was answering for the respective institution. Here, especially the self-assessment of competences in the last Delphi round changed. It would be helpful to plan an alternative evaluation option for such unanticipated events from the outset.

Furthermore, while some statements by participants are stronger influenced by personal opinions, others are rather aiming at representing the official institutional position. Tactical responses might also be given to influence the other responders and thus potentially the outcome of the project. However, as answers will be published anonymously, respondents do have the opportunity to be more open than in public interaction. Generally, the question remains to what extent participants in td processes will influence their respective institutions in return. However, an explicit focus on organizational learning in td processes was not a component of this study (e.g. Fam et al., 2013).

Criticism of the Delphi method often derives with regard to the sample design. In particular, a small and non-random sample, which

characterizes Delphi surveys, is in conflict with a quantitative approach. Within a td project there is by design usually only a small number of participants, which allows only limited use of many types of quantitative analysis. Hence, the analysis must be adapted to the possibilities offered by the sample size. The sample size in this case study allowed us to perform a quantitative analysis, but was also small enough to conduct two rounds of in-person interviews. The qualitative data added valuable insights, firstly by largely confirming the Delphi-related data and second through in-depth analysis of the perspectives and mutual learning processes of the participants. Depending on the particular td project and its evaluation goals, the weighting between the implementation as well as the analysis via Delphi and via interviews may vary. However, the interplay between both approaches provides insights beyond applying the methods separately.

Data scaling influences the types of questions in the Delphi surveys. We used two different types of predefined scales (1–5; 1–7) and questions, where participants had to divide 100 points among different categories. The questions with 100 points had another informative value as many options to distribute the points were given. However, due to the small sample size, outliers were very significant. The participants also gave feedback that this type of question was difficult to complete. Therefore, the most informative as well as comparable questions were those in which predefined scales were given. For further research, it would be beneficial to decide on one predefined scale for reasons of comparison.

Also, there were open questions to add new aspects within the greater category. After the first round, no further aspects were mentioned. This may be due to the fact that the given aspects already encompassed a wide range of topics. Another reason can be that it is easier for participants to evaluate something than to think up something on their own.

The study shows that the iterative process of the Delphi can be embedded into a multi-year group development process that is encouraging mutual learning, consensus-building and co-creation of knowledge. Even more, there are great chances to gain new insights into developments of joint and reciprocal learning over time. Through the iterative process of gaining data, the Delphi can also provide information to improve the ongoing td project. If more td projects start to embed Delphi, possibilities and challenges for impact measurement of mutual learning will become more visible. It would be very interesting to discuss further if and how comparativeness between different td projects could also become easier. All in all, we encourage to consider our research design proposal for new td research. Even more, the integration of Delphi may also be helpful for further scientific fields that include non-academic participants and support the idea of knowledge co-production (Moser, 2016).

As the call for new insights into processes of co-creation of knowledge and consensus-building has become more urgent (Norström et al., 2020), and while there is still a lack of a wide range of formal methods towards design or evaluation of mutual learning (Scholz & Steiner, 2015b; Vilsmaier et al., 2015), a stronger focus on paths to measure the development of mutual learning is needed. With this in mind, new approaches to make mutual learning more tangible like ours will fulfill an important aim of the expanding td research: To augment the knowledge on issues of sustainability and complex problems, and to support the transformation towards sustainability with clear and cohesive design methods at hand.

6. Conclusion

Transdisciplinary research and the co-production of knowledge as a contribution to solving intertwined real-world problems and developing future-solutions has gained importance in recent decades. However, there have been very few proposals how the outcomes of mutual learning can become tangible and therefore measurable throughout the different phases of the transdisciplinary process. Through embedding a mixed-method Delphi within td research, this study proposes a new framework for developing a deeper understanding of mutual learning processes. Importantly, this methodological approach combines a design rigour with a plural and topical diversity needed within transdisciplinary approaches. The Delphi method allows to monitor the viewpoints of the participants at the beginning, throughout and at the end of a project and puts them in measurable relation to one another. Furthermore, Delphi fits very well in the envisioned convergence of opinions and integration of knowledge through its consensus-building effect. Interviews with the participants add qualitative data, in order to contrast and enrich the Delphi. Consequently, the presented approach can make an important facet of mutual learning more tangible by introducing new possibilities for its measurement, and at the same time by deepening the process of mutual learning. Strengthening process, conduction and evaluation of mutual learning in transdisciplinary research is a core aspect of empowering future-oriented research to play its part in advancing solutions to the great and wicked sustainability problems of present and future.

CRediT authorship contribution statement

Adriana Ackerschott: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Software, Validation, Writing – original draft, Writing – review & editing. **Christoph Schwenck:** Conceptualization, Data curation, Writing – original draft, Writing – review & editing. **Daniel J. Lang:** Conceptualization, Supervision, Writing – original draft, Writing – review & editing. **Jannis Pfendtner-Heise:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **Henrik von Wehrden:** Conceptualization, Data curation, Formal analysis, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

None.

Data availability

The data that has been used is confidential.

Acknowledgements

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.futures.2024.103365.

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