Transdisciplinary Research in Marine Science: What's the Added Value of Involving Stakeholders?

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Abstract: *The holistic solution of complex, global problems in marine topics requires innovative research formats - which can be served by transdisciplinarity. To assess the success of the transdisciplinary approach for marine research, several case studies from marine research at Kiel University (Germany) were analysed for this study. Interviews with both scientists and stakeholders were carried out to 1) clarify whether stakeholder involvement in scientific projects provides additional knowledge and to 2) identify the underlying success factors. Both groups see added value in transdisciplinary projects and name positive aspects of cooperation, mutual interaction and information exchange. Essential are the applicability of research results, and the formation and maintenance of networks enabling further joint activities. Stakeholders add practical contexts to scientific knowledge so that the results of this transdisciplinary research can be translated into practical actions. Resource availability sets clear limits within the project framework. Successful transdisciplinary approaches require standardized definitions of terms, the selection of suitable participation formats and continuous, clear communication. Transdisciplinary projects proved suitable as a tool for sensitizing the general public and raising awareness of complex marine challenges.*

Keywords: Transdisciplinarity, marine science, stakeholder involvement, networking, co-creation, evaluation.

1 Introduction

Oceans and coastal waters have heterogeneous user and interest groups (e.g. fishing, tourism, offshore windfarms, nature protection), resulting in different demands on space and resources. This often leads to conflicts between the stakeholders. Moreover, oceans and coastal waters are complex systems, which challenges the implementation of measures and may restricts the achievement of sustainability goals, for example Sustainable Development Goal SDG 14 "Conserve and sustainably use the oceans, seas and marine resources for sustainable development". Academic research plays a key role in this context by providing knowledge on these topics (Lawrence et al., 2022). Nevertheless, owing to the intricate nature of the challenges (so called "wicked problems" (Lawrence et al., 2022; Grünhagen et al., 2022)), academia alone has not yet achieved the identification of comprehensive and optimal solutions for all stakeholders that can be implemented by practitioners (Lawrence et al., 2022).

An alternative to the conventional scientific approach is the proactive involvement of the various societal actors (stakeholder engagement), who are directly affected by transformation processes, into the research process (Lawrence et al., 2022). Numerous international and national declarations underscored the importance of increased university engagement with society and heightened accountability to society within the framework of social responsibilities. Important steps are the explicit identification of stakeholders, their classification and the identification of their potential interests and demands on academia. On this basis, the working methods of universities have been adapted to better meet the needs of their stakeholders (Seres et al., 2019).

A society-science approach as contribution to solve the challenges of the Anthropocene is often referred to as transdisciplinary research and has gained much attention in recent years, resulting in a vast literature on transdisciplinarity. This in turn has led to a variety of different understandings of transdisciplinary research and transdisciplinarity (see Lawrence et al., 2022).

Previous research on stakeholder engagement as part of the reSEArch-EU project (European University of the SEA, see Wagner-Ahlfs et al., 2021) identified several key main arguments for the involvement of stakeholders in the scientific endeavors of universities:

- strengthening the relationship between science and society,
- bridging the gap between universities, science and economy,
- building mutual understanding and trust,
- supporting scientific work and the application of new knowledge,
- increasing the scientific impact and
- ensuring innovation and transformation.

Other arguments refer to the additional knowledge provided by stakeholders about practical contexts, so that the results of this collaborative research can be used as a basis for practical measures (Baumgärtner et al., 2008).

Even if the significance of transdisciplinarity is already documented for many cases, there is still a literature gap concerning the marine context and especially the stakeholder perspective. Marine research at Kiel University (Germany) offers a good starting point for investigating the success of a transdisciplinary approach using several case studies. Both in the Cluster of Excellence Future Ocean (2006-2018) and in Kiel Marine Science (KMS) (since 2013), which is the Centre for Interdisciplinary Marine Science at Kiel University, the involvement of stakeholders in academic projects plays an important role and has been fostered.

In order to assess the success of the transdisciplinary approach for marine research, several case studies from Kiel University (Germany) were analyzed for this study. Based on interviews with both scientists and stakeholders, we investigated two questions: 1) Does stakeholder involvement in scientific projects yield additional knowledge, and 2) what are the success factors in facilitating this collaboration?

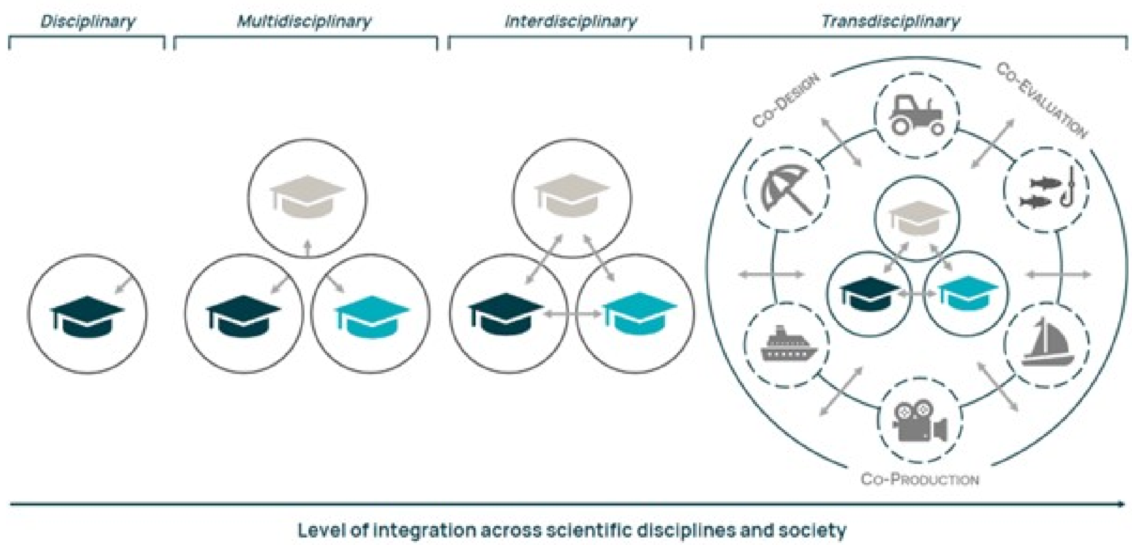

Figure 1: Conceptual differentiation between disciplinary, multidisciplinary, interdisciplinary and transdisciplinary research in relation to the actors involved in marine research (Grünhagen et al., 2022).

2 Theoretical Foundations and Terminology

In the following section, the key terminology used for the analysis will be defined.

2.1 Transdisciplinary Research

The term transdisciplinarity was first introduced to the public debate in the 1970s. However, it was not until almost a quarter of a century later that the topic gained broader recognition, marked by the first global congress on transdisciplinarity in 1994, which was documented in the "Manifesto of Transdisciplinarity" (Grünhagen et al., 2022; Nicolescu, 2002; Lawrence et al., 2022; Hernández-Aguilar et al. 2022). Nevertheless, a consensus on the definition of transdisciplinary research and its distinction from interdisciplinary research is still lacking. In contrast to disciplinary research, which comprises only one discipline, multi- and interdisciplinary research includes several disciplines. The difference between multi- and interdisciplinary research lies in the interaction of scientific work (see bi- and one-directional arrows in Fig. 1): In multidisciplinarity, a scientific question is investigated separately by different disciplines in their respective fields, while in interdisciplinarity, different disciplines collaborate interactively to investigate a question (see Fig. 1). In transdisciplinary research, non-university interest groups are included, e.g. groups from tourism, agriculture or fisheries for the marine research sector (Grünhagen et al., 2022). Therefore, transdisciplinary research functions as an addition to rather than a substitution for the well-established disciplinary, multidisciplinary, and interdisciplinary scientific approaches (Lawrence et al., 2022). This more comprehensive and inclusive concept serves as the basis for the present study.

In addition, transdisciplinarity should generally be understood as an interplay between science and society (Baumgärtner et al., 2008; McGregor 2023). This understanding of transdisciplinarity intends to meet the growing expectations of academic research and is therefore seen as essential for achieving the Sustainable Development Goals (SDGs) set out by the United Nations (UN) (Moallemi et al., 2020 in Strand et al., 2022).

2.2 Stakeholder & Stakeholder Engagement

In transdisciplinary research, the term stakeholder is defined as a person, group or organization that is either influenced by an activity (or a scientific project) or can influence an activity (or a scientific project) (OECD, 2020; Partridge et al., 2005; Seres et al., 2019; Wagner-Ahlfs et al., 2021; Morf et al., 2017 in Giacometti et al., 2020). This paper adheres to this definition and focuses on non-university stakeholders.

The term stakeholder engagement is defined by Partridge et al. (2005) in their manual as an umbrella term for all efforts by an organization to understand stakeholders and involve them in activities and decisions. Based on this, the terms stakeholder participation, involvement, engagement, and integration are used in this study as synonyms for all endeavors of Kiel University.

Individuals and groups can be involved in different ways, "with each approach often tied to different intentions and outcomes" (Shirk et al., 2012). Degree and quality, as key aspects of participation, determine roles, relationships, and needs in the overall consortium (Wagner-Ahlfs et al., 2021). The present work is based on the categories of collaboration shown in Figure 2:

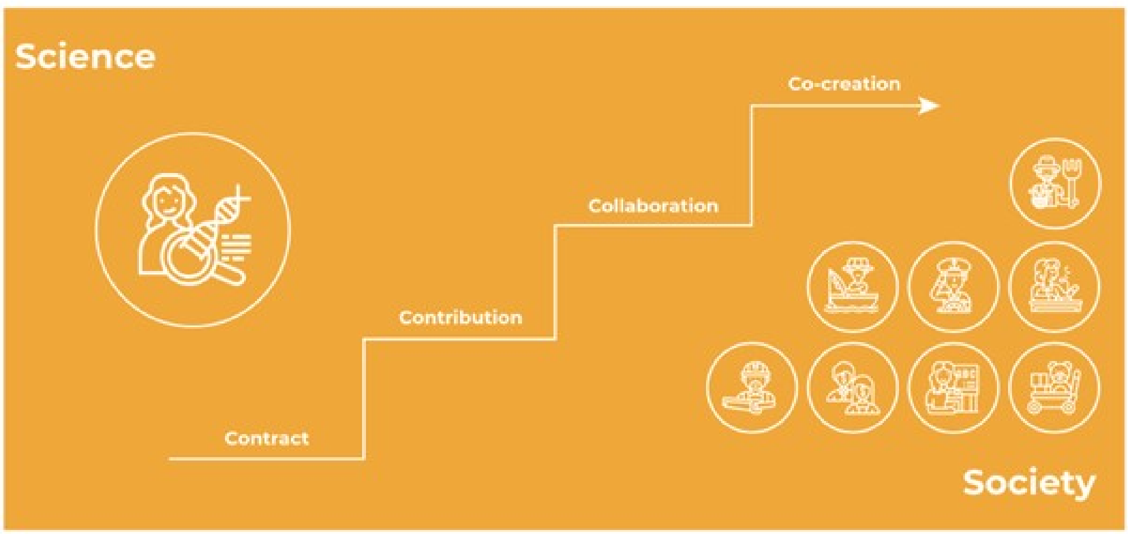

Figure 2: Different levels of interaction between scientists (left) and stakeholders (right) (Wagner-Ahlfs et al., 2021).

The spectrum of stakeholder involvement in research encompasses various levels. Involvement by **Contract** applies, where the research is commissioned by stakeholders and completed by the university. The funder (= stakeholder) is accordingly not actively involved in the research. This represents the traditional model of publicly funded academic research, known as contract research. If stakeholders contribute data, information or similar to the project, while scientists primarily handle the planning, implementation, and evaluation are still carried out by the scientists, it is referred to as **Contribution**. A typical example of this level is citizen science. **Collaboration** applies when stakeholders participate actively in the research and/or evaluation, while scientists remain primarily responsible for project planning. **Co-creation** represents the pinnacle of stakeholder involvement, where scientists and stakeholders jointly design a project. The participants are engaged from the start and are considered as equal partners within the consortium (Shirk et al., 2012; Wagner-Ahlfs et al., 2021). For transdisciplinary research, collaboration and co-creation are the main levels of participation.

2.3 Distinguishing Transdisciplinarity from Knowledge Transfer, Technology Transfer and Science Communication

Transdisciplinarity is also frequently mentioned in the context of knowledge and technology transfer. The boundaries between these terms are blurred. The analysis carried out in this study is based on a bidirectional, dialogue-based understanding, as mentioned above, which means that there is an interactive exchange between the scientists and stakeholders in both directions. Transdisciplinarity is seen as a joint learning. Transfer and science communication, on the other hand, are more one-directional. In this context, the term transfer describes the transmission of scientific and technological knowledge to the non-university environment, for example to society, culture, business and politics. This transfer to stakeholders can take place via various transfer activities, such as public discussion forums, social media, etc. It is therefore an important lever for making research results comprehensible and effective for society (Leitfaden Nachhaltigkeit, n. d.; DAM, 2021).

Even though knowledge and technology transfer as well as science communication emphasize the importance of the exchange between science and society by increasingly establishing elements of dialogue (see also the self-image of the German Marine Research Alliance DAM 2021 and the position of the German Council of Science and Humanities in 2016 and 2021), transdisciplinary research focuses more strongly on the joint creation of knowledge. Transdisciplinarity therefore exceeds the traditional boundaries of knowledge and technology transfer.

3 Methodology

This paper examines the concept and practice of transdisciplinarity in a marine context by analyzing case studies from the Cluster of Excellence "The Future Ocean" (2006-2018) and Kiel Marine Science (KMS, established at Kiel University in 2013). Central is the assessment of project leaders and stakeholders on whether transdisciplinarity is actually achieved, how this concept is best implemented and how it influences the projects.

First, the case studies from marine research in Kiel (see info box) were selected based on the Kiel University project data base. Then an online survey was designed for scientists involved in these projects, focusing on the research complexes (1) understanding of the term transdisciplinarity, (2) involvement of stakeholders, (3) benefits of transdisciplinary projects and (4) success factors of transdisciplinary projects. Finally, subsequent in-depth interviews were conducted with scientists and in addition with the involved stakeholders.

3.1 Selection of Case Studies

The selection of projects followed the principle of theoretical sampling align the grounded theory methodology, thus in a targeted and non-random manner (Hunger & Müller, 2016; Häder, 2015), with regard to the following criteria:

- Participation of KMS members within the Future Ocean framework,
- projects starting from 2006 on (start of Future Ocean),
- projects considered as transdisciplinary with stakeholders involved in the research,
- projects should be completed.

3.2 Online Survey

The online survey was conducted with a total of 86 scientists and project leaders from projects with stakeholder involvement. This survey was intended to provide an initial insight into the experiences gained (what went well and what did not, etc.) as well as to create a base from which to choose case studies for a

Info Box: Marine science in Kiel, Germany

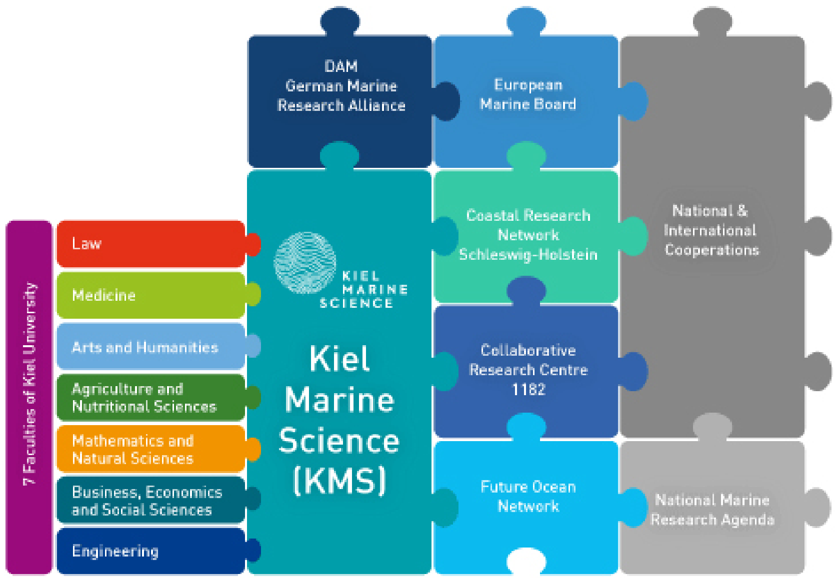

Figure 3: Structure of the Kiel Marine Science priority research area, involving researchers from seven faculties at Kiel University.

Kiel Marine Science, the Center for interdisciplinary marine science at Kiel University (CAU), established 2013 as a priority research area, brings together more than 70 working groups from over 26 institutes at seven faculties. In addition, KMS is integrated into regional, national and international scientific and research policy networks. Transdisciplinary research is mainly carried out at the cross-faculty platform Center for Ocean and Society (CeOS) and by some working groups (Kiel University, Research and Technology Center, West Coast).

The Cluster of Excellence "**The Future Ocean**" at Kiel University was funded in line with the German Excellence Initiative and was a Kiel based interdisciplinary research project. Partners of Kiel University were the GEOMAR Helmholtz Centre for Ocean Research Kiel, the Kiel Institute for the World Economy and the Muthesius University of Fine Arts and Design. The aim of the Future Ocean cluster was to use the results of multidisciplinary scientific research on the past and present ocean to predict the future of the Earth's marine environment. This involves understanding changes of the ocean as well as the interaction between society and the ocean with regards to marine resources, services and risks. This aim entails an obligation to develop and assess scientifically-based global and regional ocean governance options, taking legal, economic and ethical aspects into account.

The Future Ocean Cluster of Excellence put great emphasis on dialogue and exchange with groups outside the scientific community, as well as on science-based formats for engaging with the general public.

more in-depth study. Over the two-week runtime, 33 individuals responded, resulting in a response rate of 39%. Among these, 9 respondents completed the survey, while 23 provided incomplete responses. The incomplete surveys were excluded from further analysis due to their lack of completeness. Additionally, two

Info Box: Marine science in Kiel, Germany (continued)

As part of various outreach and science support activities to engage with specific audiences such as companies or political decision-makers, Future Ocean researchers experimented with a range of transdisciplinary formats to initiate this process. Particular attention was given to ensuring comprehensibility for different societal groups. This resulted for example in the dialogue format "Kieler Marktplatz" (Kiel Marketplace), the maritime technology platform "MaTeP", the exhibitions Future Ocean or a number of publications (https://hr.futureocean.org/supporting-science/stakeholder-dialogue-the-road-to-transdisciplinary-research.html). These include the World Ocean Review series, which since 2010 has taken up the topics of the Future Ocean Cluster and prepared them for numerous target groups such as education, research and politics (www.worldoceanreview.com).

After the end of Future Ocean Cluster of Excellence in 2019, Kiel researchers joined forces in the **Future Ocean Network**, which is being coordinated by the KMS head office. Since then, the interdisciplinary and cross-institutional activities have also included the targeted transfer of research results to stakeholders from various interest groups in politics, business and civil society.

of the fully completed questionnaires were omitted from content analysis because the respondents indicated in comments that non-university stakeholders "*do not play a role*" or that the collaborations within the project do not "*fall within the field of transdisciplinary research*" (in this article, we indicate comments and quotes from scientists and stakeholders in italics). Accordingly, the remaining seven questionnaires have been considered relevant for the evaluation of the online survey (N=7).

3.3 Interviews

The scientists and relevant stakeholders from business, administration and civil society whose contact details were available through the administrative office within the research networks, were contacted and asked to give an interview. 6 scientists and 5 stakeholders agreed. The subsequent in-depth interviews referred in two cases to experience gained from several projects and specifically to four individual projects: FucoSan, Nordfriesland Süd, EVOKED and GoCoase. These projects will be characterized in the following paragraph.

The interviews were mostly conducted in person as semi-structured interview by using an interview guide. The interview guide for scientists was slightly adopted to the interviews with stakeholders.

3.4 Presentation of Case Studies

The analysis of this study comprised projects with the following thematic focuses:

1. Development of adaptation strategies to climate change in coastal regions,
2. Environmental assessment of the Baltic Sea through remote sensing, mapping and monitoring of seagrass,
3. Definition, characterization and mapping of "species-rich gravel, coarse sand and shingle beds in the marine and coastal area" of Schleswig-Holstein,
4. Research on brown algae for applications in health and well-being,
5. Investigation of shelf structure and distribution of sand bodies for coastal protection,
6. Ocean observation and forecasting,
7. Geoinformation technology for agricultural resource protection and risk management.

A detailed analysis was possible for the projects FucoSan, Nordfriesland Süd, EVOKED and GoCoase.

FucoSan: In the "FucoSan - Health from the Sea" project, experts examined the bioactive ingredients, fucoidans, of various types of brown algae and tested their usability for medicine and cosmetics. The project ran from February 2017 to August 2020 with a total funding volume of 3.8 million euros from the Interreg Germany-Denmark EU program. A total of eight partner organizations from Germany and Denmark were involved: University Hospital Schleswig-Holstein (Campus Kiel), Kiel University, Coastal Research & Management oHG, oceanBASIS GmbH, GEOMAR Helmholtz Centre for Ocean Research Kiel, the Technical University of Denmark, the University of Southern Denmark and Odense University Hospital. The objectives of the project were (a) the development of economically and ecologically sustainable processes for the provision of brown algae biomass from the Baltic Sea, (b) the processing of the algae and extraction of fucoidans, (c) scientific testing of different fucoidans with regard to their chemical and biological properties, from which (d) a database with information on the fucoidans investigated will subsequently be created in order to (e) identify suitable fucoidans for scientific investigations for applications in ophthalmology, regenerative medicine and cosmetics. In addition, (f) a German-Danish network should be established around this topic for possible new projects and research opportunities. Project management, public outreach as well as organizational and business models form fixed project components in addition to these focal points (Klettner, 2020a; Klettner, 2020b).

Nordfriesland Süd (NF Süd): The Nordfriesland Süd project, "The geological/sedimentological structure and habitat distribution in the transition area between the mudflats and shelf between Amrumbank and the Eider channel", served to combine the tasks and investigation requirements of the Schleswig-Holstein Water Management Administration, represented by the Schleswig-Holstein State Agency for Coastal Protection, National Park and Marine Conservation (LKN-SH), the State Office for Agriculture, Environment and Rural Areas (LLUR) and the Institute of Geosciences (IfG) at Kiel University. The aim was to achieve added expertise and cost savings for all partners involved. To this end, a joint cooperation agreement with a research plan was concluded, covering the period from March 2017 to September 2022. With the aim of a "sediment inventory" in the area between Amrum and Helgoland in the North Sea, seismoacoustic measurements from various cruises were combined with a drilling project and the data interpreted in an integrative manner. The results were presented at several internal project meetings and at scientific conferences and prepared for future applications and further processed in scientific publications. Work on the data from Nordfriesland Süd is continuing actively in order to be able to make an important scientific contribution to understanding the range of tsunamis (Schwarzer et al., in press).

EVOKED: As part of the EVOKED (Enhancing the value of climate related data) project, researchers from Kiel University, in cooperation with the city of Flensburg, modelled the effects of future sea level rise in order to support the city in developing adaptation plans to cope with the future effects of sea level rise. The project ran from September 2017 to December 2020, with funding from the BMBF and the European Union (as part of ERA4CS). The aim was to develop climate services for the city of Flensburg in a real-world laboratory context. To this end, the Shared Socioeconomic Pathways (SSPs) were expanded at a global level in order to use local SSPs as a tool for adaptation decisions (climate services). The results were prepared for the general public and further developed with the help of user feedback. This was realized through formats such as focus group discussions, a scenario workshop, a „story map", and email feedback. The EVOKED framework methodology is based on a multi-stage user-centered co-production approach. In addition, integrated transdisciplinary research and promoted dialogue between stakeholders should build a bridge between climate science and policy makers and users (Reimann et al., 2021; Oen, 2021).

GoCoase: The GoCoase project (Governing climate change adaptation at the Baltic Sea Coast) comprises the investigations from August 2018 to September 2021 on possible adaptation strategies to climate change for the German Baltic Sea coastal region in Mecklenburg-Vorpommern. The existing and planned coastal protection infrastructure in this region should be reviewed with regard to new load parameters and, if necessary, supplemented in order to be able to withstand the long-term rise in water levels and an increased occurrence of extreme events (storms, swell, precipitation). From a primarily economic perspective, the

GoCoase project was intended to provide an example of how adaptations to the consequences of climate change can be assessed in advance. The project was funded by the BMBF with a total budget of 737,266 euros and coordinated by the Kiel University. Other project partners were the Technical University of Berlin, the Ludwig-Franzius-Institute for Hydraulic, Estuarine and Coastal Engineering at the University of Hanover, the Institute for Ecological Economy Research and the Coastal Union Germany (EUCC). The State Office for Agriculture and the Environment of Central Mecklenburg (StALU MM), the Mecklenburg Baltic Seaside Resorts Association (VMO) and other decision-makers from municipal to state level support the project as associated project partners. The project was accompanied by the Dialogue on Climate Economics project in order to intensify the exchange and transfer of knowledge between research and practice. One of the five major work packages was explicitly dedicated to stakeholder engagement, communication of the results and knowledge transfer, for which stakeholder workshops were organized and information materials produced (EUCC-D, n. d.; Rehdanz et al., 2022).

4 Results

4.1 Results of the Online Survey

We analyzed responses from 7 online survey. Non-university partners involved in the project were most frequently assigned to the category administration (86%), followed by economy (57%), NGOs (29%) and others (29%). Authorities were categorized as other. One comment stated: "*We have involved various other stakeholders that were not covered in the survey. For example, we have organized events for citizens, maintained contact with local politicians or produced videos for the interested public.*". With one exception, all (86%) categorized the stakeholder involvement within their project at the highest level of participation, Co-Creation (see Fig. 4).

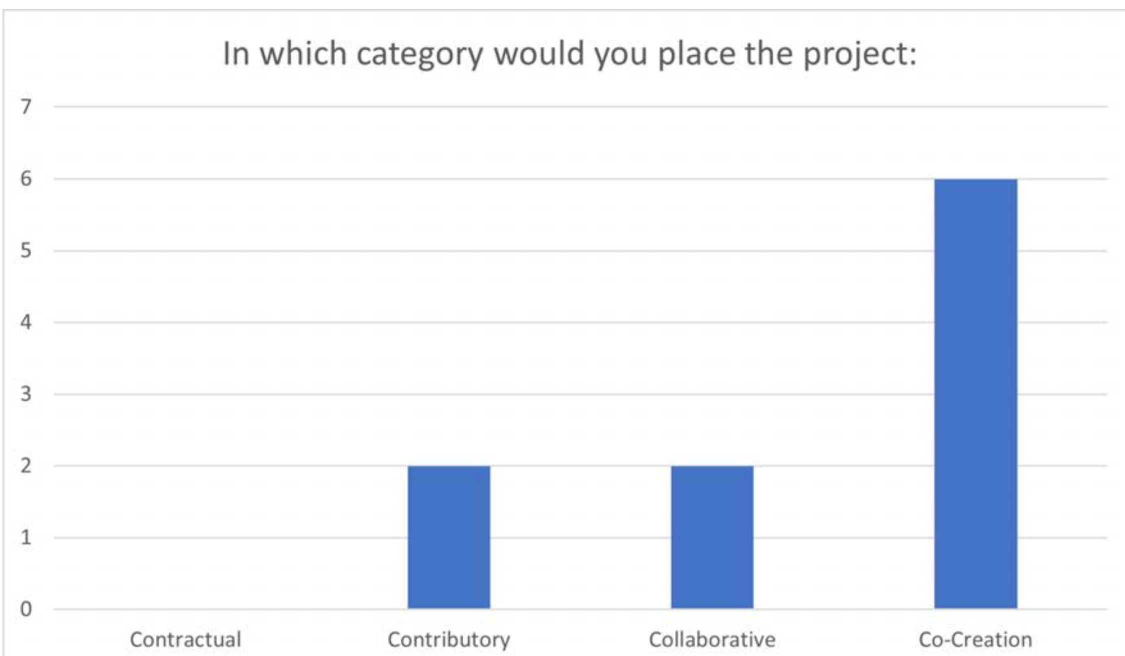

Figure 4: Compiled answers to question 2 of the online survey (own graph), multiple answers allowed, n=7.

The most frequently used participation formats are workshops (71%) and round tables (57%), while none of the respondents stated that they had used mediation or citizen councils/assemblies as a participation format (see Fig. 5). "*Joint meetings, like cooperation between scientists. It just takes longer to get to a working level, to find a language, to mutually understand processes/frameworks. However, the specialist background was basically similar, so fewer problems than with interdisciplinary projects*", commented one respondent. Another stated that they had held "*various project meetings in different forms*".

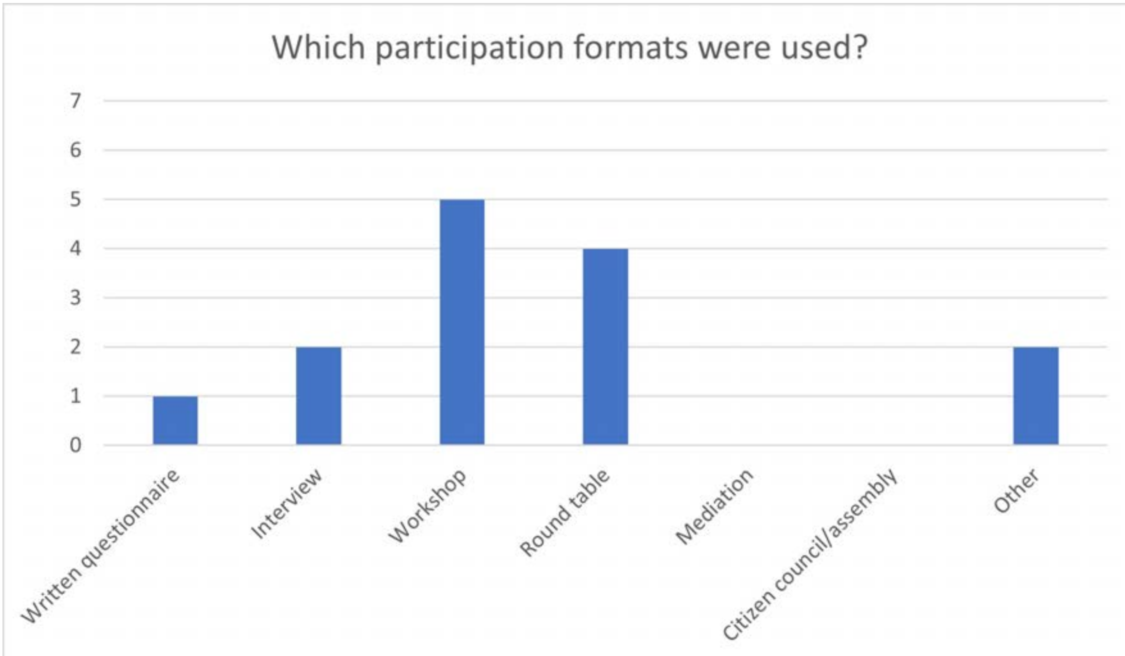

Figure 5: Compiled answers to question 3 of the online survey (own graph), multiple answers allowed, n=7.

Stakeholder involvement brought additional insights for all scientists surveyed, but only five out of seven ensured that the results were implemented faster or better.

Unexpected problems due to stakeholder involvement were reported only in one case, attributed to a lack of open communication with industry and the authority representatives regarding potential and actual problems. However, contact with the stakeholders was maintained only in four cases following the project's completion.

Ranking the proportion of transdisciplinary research in the overall project resembles a normal distribution (see Fig. 6). Notably, a medium proportion of transdisciplinary research, accounting for 42%, was mostly selected. However, it's worth highlighting that this finding contrasts with the results of the participation categories, where projects were almost exclusively categorized as Co-Creation, representing the highest level of participation.

Nonetheless, the majority of projects were rated as rather successful (86% in categories 4 and 5, if 1=not successful and 5=successful).

4.2 Results of the Interviews

For the evaluation of the interviews (6 scientists, 5 stakeholders), we applied a qualitative content analysis, utilizing coding guidelines. In this chapter, quotes from interviewees will be used to illustrate the results of the analysis. The quotations will be presented in *italics*.

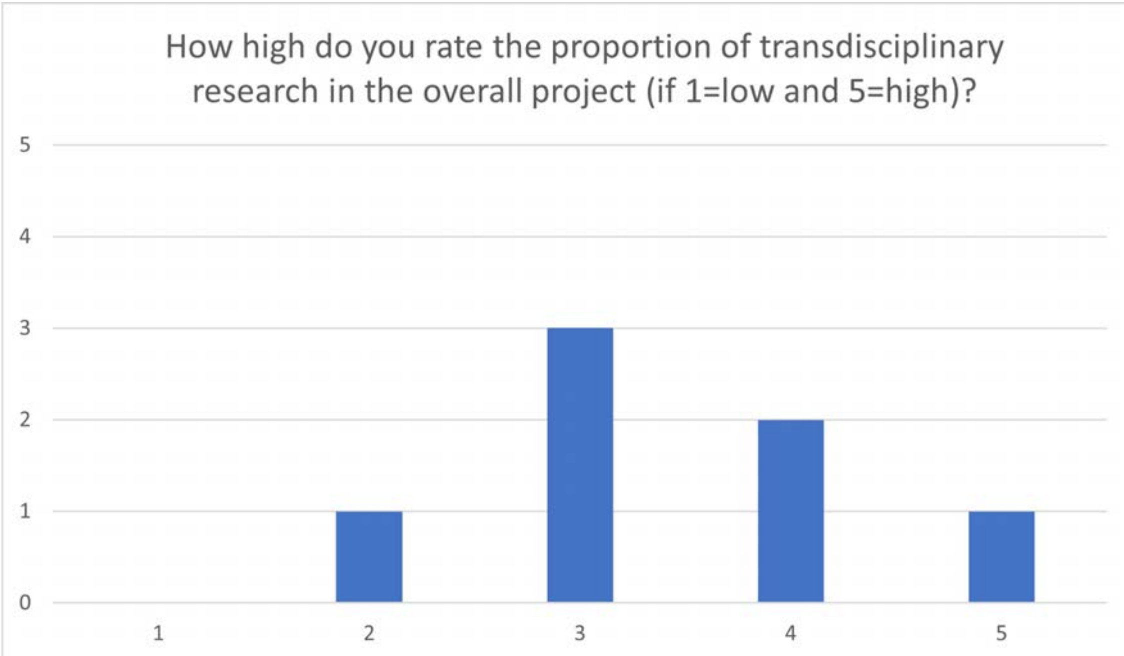

Figure 6: Compiled answers to question 8 of the online survey (own graph), single answer, n= 7.

Understanding of the Term Transdisciplinarity

The interviews showed that there is no uniform definition of transdisciplinarity among both the surveyed scientists and their stakeholders (see compilation in Table 1). This was clearly communicated in many of the interviews. Although transdisciplinarity is generally perceived as broadening of perspectives (which is rather a motivation then a definition), there are considerable differences in the profound understanding. While stakeholders typically describe transdisciplinarity as a socio-economically solution-orientated exchange, some scientists use the term "transfer" (see Section 2.3). Particularly experienced scientists stated that they had conducted transdisciplinary projects in the past without being familiar with the concept. Stakeholders emphasize the integration of the social dimension into scientific analysis and the shared objective of jointly developing solutions for society.

Involvement of Stakeholders

The majority of the surveyed scientists confirm that co-creation is the most frequently used form of current joint work (see compilation in Table 2). The first category, contractual, was not mentioned at all related to the projects. Commissioned research is excluded by the scientists in the context of transdisciplinarity. The responses of the stakeholders vary between contributory, collaborative and co-creation when categorizing the projects. In general, formally, contributory is the most common form of engagement with researchers, often occurring through grant applications. However, in practice, arrangement tends to be less rigid, and the collaboration is more likely to be categorized as collaborative or partially co-creative. As one interviewee explained: "*Whereby, of course, we don't want to influence the researchers in their results in any way and are actually not allowed to do so*".

Collaborations primarily involved authorities and government agencies (administration). However, companies from education, economy and civil society were also named as non-university stakeholders. The roles of these stakeholders vary and seem to be defined differently depending on the project. A distinction is made between participating stakeholders, who actively took part in an event, and co-designing stakeholders, who also incorporate their objectives into the overall project. For some projects, the distribution of roles

Table 1: Compiled answers to research complex (1) understanding of the term transdisciplinarity.

Research question: How is the term transdisciplinarity defined?	
University	- Expands interdisciplinarity, but inconsistent understanding of how - Involvement and collaboration with stakeholders (joint research process) - Integration of society - Transfer of knowledge from researchers to implementation - Broadening own horizon
Business	- Knowledge and technology exchange between different disciplines - Aim of jointly developing solutions for society
Administration	- ``*Word speaks for itself* `` - Cross-discipline collaboration and (data) exchange - Supplementation of science through society
Politics	- Incorporating project results into thematically related considerations - Adding a social component to scientific analyses

may be less explicit clearly delineated, while for others the distribution of roles is clearly delineated: project partners are "*with their own budget and their own tasks, their own milestones"*. Authorities usually acted as funders in the collaboration, but can also be project initiators or information providers. For the stakeholders interviewed, the distribution of roles seemed relatively clear; companies for application orientation, authorities as specialist advisors, responsible for grant applications, or "associated partner", which is understood here as a data supplier and process facilitator, or cities as organizers of workshops and "*on-site analyses*". The "*content, the scientific aspects, were of course provided by UNIVERSITY X"*.

Nevertheless, it was "*equal work"*, whereby the stakeholders as well as the university had and pursued their issues.

In this collaboration, web conferences, e-mail, and telephone calls are mentioned, which became more frequent due to the pandemic. Nevertheless, face-to-face meetings or workshops are favored, as they enable a more intensive exchange and strengthen relationships and trust. Regular project meetings are considered as the most important exchange format. These can be strictly work-related or organized independently of the project. Particularly highlighted are meetings that expand beyond the project's scope and are not solely project-related, as these meetings offer opportunities for exchange that go beyond the project framework.

According to the previous categorization of the projects in co-creation, in all cases described in the interviews, stakeholders were involved in the projects from the beginning, already during the planning phase. Only one stakeholder reported joining after the proposal submission.

Benefits of Transdisciplinary Projects

The answers on potential benefits of transdisciplinary projects are compiled in Table 3. One interviewee describes the traditional understanding of science at universities as "*Seek knowledge and do not ask what use it is*", while the additional benefit is "*Seek knowledge and ask what use it is [...] and see if you can apply it somehow, [...] utilise it commercially*". The scientists recognize the added value more in the social benefits and greater proximity to application, as well as in broadening their own horizons, rather than in the results themselves. While project results may eventually be applied, the process may not necessarily expedite, but could contribute to raising public awareness. In addition, the underlying social interest seems

Table 2: Compiled answers to research complex (2) involvement of stakeholders.

Research question: Which forms of collaboration are preferred in stakeholder engagement?	
University	- Almost uniform categorization as co-creation - Most frequently used participation formats are workshops and round tables - Regular project meetings with all participants (“Jour fixe”) - Preferably personal meetings - Other tools: telephone calls and video conferences - Project-independent meetings important for networks - Cooperation and communication with government agencies clearly at working level
Business	- Co-creation - Regular personal project meetings - Other tools: telephone or e-mail - “Social dinner” or alike for project-independent exchange
Administration	- Formally contributory (grant applications) - In reality rather collaborative or partly co-creation - Contractual excluded; contract research not desired by universities - Project meetings as pure working meetings - Other tools: written exchange, interview formats, topic-specific workshops
Politics	- Interreg-project - Municipal and inter-municipal exchange through project meetings, workshops and partner meetings
Research question: What is the role of stakeholders?	
University	- Project partners with own budget, tasks and milestones - Government agencies and authorities as funders, project initiators or information providers - Participating/ co-designing
Business	- Clear participation as SME - Leading development in the field of application
Administration	- Specialist advisor; responsible for grant applications - Equal working partner - Associated partner; data provider and process facilitator
Politics	- On-site analysis - Data supplier - Organisation of e.g. workshops - No scientific contribution - No co-financing

to provide greater opportunities to drive the projects forward, e.g. through funding. The first reaction of one scientist when asked about the additional benefits compared to projects without transdisciplinarity was “*that these projects only work if you do it together*”. One advantage of transdisciplinary projects from the stakeholder’s perspective is also the linking of different branches with each other, for a “more rounded overall picture”, which promotes understanding and acceptance of other specialist areas. This would enable profit from knowledge from other fields. However, this also harbors a certain risk, as “*you then have to* *accept things that you may not like*". Upon request, the stakeholders confirmed the additional benefit of transdisciplinary projects in the networks created, which can also serve for follow-up projects.

The interviewed scientists independently differentiate between the output relevant to them and to their stakeholders; "[...]*stakeholders have different aspirations for projects than scientists.*" There are "*different needs on both sides and, of course, ideas about what such results should look like*". The results of the scientists varied between the exemplary proposed output categories "*specialized articles, media reports, public events*, ...". In addition, "*concrete measures*" or "*direct counselling*" were also listed. The most frequently mentioned outputs were international and national scientific articles, publications and doctorates. From the scientists' perspective, "*project or final reports*" were named as the most important results, but also outcomes close to application, such as a prototype of a cream. Furthermore, the project itself, with all the experience gained from it, is also valued as an output and foundation for follow-up projects and collaborations (networks). In addition to further research and influence in the respective project area, the networks gained from this transdisciplinary collaboration are emphasized as the crucial and most important outcome. These networks provide a medium or longer-term benefit for both scientists and stakeholders fostering trust, mutual understanding, and the promotion and qualification of young talent. Nevertheless, sustaining these networks requires significant effort, especially when involved in several networks. The interviewed stakeholders listed a number of concrete results or products, such as a marketable cream. The high quality and quantity of such data facilitate further processing for their own purposes. However, they also emphasized: "*This is always difficult. You enter into such a project with great intentions and usually end up with less than you hoped for.*"

Success Factors of Transdisciplinary Projects

The goals of the scientists and stakeholders differ according to the various outputs (see compilation in Table 4). All surveyed scientists are notably motivated by the application-orientated focus of transdisciplinary projects and their inherent affinity for investigating topics such as nature conservation, climate change or sea level rise, with the aim of making them accessible to the public. Furthermore, cooperation with stakeholders fulfils their „social mission" and provides access to funding. In some cases, the involvement of stakeholders in scientific projects is even mandated by the funder. The stakeholders benefit from the results and the capacity exchange for their own socio-economic tasks: "*Therefore, the question of motivation does not really arise because it was simply given*". The interviewees pick up on the cost factor as a motivation of the university: "*We have the money and the interest and the university does not have the money, but the interest. And that is how we come together.*"

Misunderstandings arising due to a lack of or unclear communication can pose challenges in transdisciplinary projects. Finding a common language to understand each partner's motivation is seen as an essential learning process in this context. For example, a different understanding of cost-benefit analysis led to challenges in one project. Scientists emphasize the importance of maintaining the scientific integrity and avoiding slipping into contract research. This reveals an inherent tension that scientists encounter in transdisciplinary projects. Consequently, it becomes imperative to reassess one's own role and conception of science to achieve a consensus that satisfies all parties involved. In addition, the financing of transdisciplinary projects often poses problems. However, some of the interviewed scientists reported that they had not experienced any problems in their transdisciplinary project.

The stakeholders stated that experiences in general collaboration with academic institutions are often slow regarding formal requirements or a "*different anticipation of time and resources*", specifically: prolonged deadlines or inflexibility in recruiting staff. Other stakeholders see the challenges less in collaboration and more in content-related issues and communicating results. The fundamental difficulty faced is that scientific results are often "*difficult to grasp*" and difficult to communicate "*outwards*". The challenge here is to maintain a balance between the scientific claim and the "*claim that everyone can understand*" and still satisfy both sides.

Table 3: Compiled answers to research complex (3) benefits of transdisciplinary projects.

Research question: Does the interaction of academic research with stakeholders provide additional knowledge?	
University	- Yes, e.g. greater application proximity - Broadening horizons - Access to publicly inaccessible information - Further research, follow-up projects and influence in the respective project area
Business	- Broadening the horizon - Expansion of knowledge and technology
Administration	- Concrete results for further processing in own tasks, follow-up projects - Higher quality and quantity of results - Profit from knowledge and staff from other areas - Promotion of understanding and acceptance of other specialist areas, foundation for cooperation (networks) - Experience in contact with university institutions
Politics	- Concrete results for further processing in own tasks, follow-up projects - Provision of information on protection and action options for the population - Enabling inter-municipal exchange
Research question: Are research findings implemented more quickly through interaction with stakeholders and does the research thus have a higher impact?	
University	- Project results are more likely to be implemented into practice - No time leads - Due to the underlying social interest, more opportunities for further project development, e.g. through funding
Business	- Different approaches by science and stakeholders tended to slow down product development - Delay due to different anticipation of time and resources of the university, e.g. staff fluctuation during project course - More application-orientation and mutual exchange of knowledge desired
Administration	- Independence of research enables use of results in public discussions - Output sometimes lower than initial intention
Politics	- Integration of partial results into a more rounded overall picture - Result must fit into the overall concept
Research question: Does academic research contribute to solving societal problems by involving stakeholders?	
University	- Contribution to raising public awareness - Concrete utilization of results for society
Business	- Developing new applications for society
Administration	- Networks enable specialized promotion/qualification of young talent - Project results sometimes difficult to communicate outwards
Politics	- Education and awareness-raising among the population - Contact opportunities with project team - Involvement of the population in the ongoing project

Table 4: Compiled answers to research complex (4) success factors of transdisciplinary projects.

Research question: What motivates scientists and stakeholders to collaborate in joint transdisciplinary projects?	
University	- Fulfilment of their "social mission" - Basic affinity to research topics and make them publicly accessible - Access to funding - Application-orientated focus of transdisciplinary projects - Gaining practical knowledge and attention in the public sphere
Business	- Own interest in research and its utilization for an application
Administration	- Data and results required to fulfil own tasks - Attempt to use synergy effects e.g. capacity exchange
Politics	- Use of results and experience for municipal concepts, e.g., for climate change adaptation
Research question: What are the challenges of stakeholder engagement?	
University	- Misunderstandings due to lacking or unclear communication - Preservation of the scientific basis - Limits of acceptance - Consensus finding - Beware of slipping into contract research - High effort for network maintenance - Acquisition of funding
Business	- Different anticipation of time and resources, e.g., not meeting deadlines - Lacking or insufficient application orientation of academic research - Different methods and prioritization
Administration	- Complex content-related issues - Difficult communication of results - Controllability of ongoing projects - Slow fulfilment of formal requirements at the university - Internal project communication and understanding - Practical relevance and application orientation of academic research - Consensus finding
Politics	- Complex content-related issues - Difficult communication of results - Finding balance between scientific and general comprehensible claim - Satisfaction of the entire project consortium
Research question: What makes transdisciplinary projects successful?	
University	- Continuous, clear communication of goals, expectations, motivations and needs throughout the entire project - Other tools: rules of interaction and risk management - (External) project management recommended - Regular, if possible personal project meetings - Planning sufficient time and money - Promoting young talent, building understanding of the functioning of transdisciplinary work - Willingness to compromise

Table 4: Compiled answers to research complex (4) success factors of transdisciplinary projects (continued).

Business	- Clear formulation of product development goals, already in advance when selecting partners and topics - Communication and risk management structure - (External) project management recommended - Knowledge exchange in both directions
Administration	- Continuous, clear communication of goals, expectations, motivations and needs throughout the entire project - Meeting deadlines - Willingness to compromise - Equal working, elimination of rivalries or hierarchical thinking - Planning more time and money - (External) project management recommended in some cases
Politics	- Clear communication and regular exchange, including smaller partial results - Planning more time and money

The general consensus from the interviews is that continuous, clear communication of objectives, expectations, motivations and needs throughout the project is crucial for problem-solving. It is important to clarify in advance the realistic expectations regarding funding, involved interests and the role of research in the project. Based on the experience gained, the scientists would intensify this if necessary and pay more attention to it from the outset. Important for this are regular, if possible personal meetings, whereby project-independent meetings are crucial for the development and maintenance of networks. The integration of project management into the projects is also emphasized as being effective. Some scientists recommend involving students in such projects or processes: "*That you in a way learn how the whole thing works, how research works, but also how transdisciplinary communication works, on the basis of practical projects"*. Communication is also important for dissolving rivalries and "*hierarchical thinking"* in order to be able to work "*at eye level"*.

In every interview, the role of networks was particularly emphasized: the ability to implement transdisciplinary projects depends on partners and existing networks, which can be reactivated and expanded. They are successful when the exchange of knowledge occurs bidirectionally. The downside, however, is the enormous number of resources (money, time, personnel) required to maintain and foster such networks, especially when involved in several networks.

5 Discussion

Within the marine context, many problems tend to be wicked problems, such as ensuring the health of marine ecosystems and the livelihoods of coastal communities at the same time. Here, transdisciplinary approaches offer a possible solution. This study analyzed stakeholder engagement in marine science at Kiel University from different perspectives and in different forms using third-party funded projects. It thus represents an attempt to reveal new insights and approaches in the field of transdisciplinarity to improve collaboration between scientists and stakeholders. This study also allows for significant insights into the added value of stakeholder involvement. Despite the relatively small number of survey responders (N=7), the detailed analysis based on qualitative information from 11 in-depth interviews provides a good data base. The integration of interviews with both scientists and stakeholders offers a comprehensive assessment of the value of transdisciplinary research from the different perspectives. Such an in-depth investigation has not yet been carried out in the marine context.

Both the participating scientists and the involved stakeholders perceive added value in a transdisciplinary project. One interviewee summarized their experience in one sentence: "*…that these projects only work* *if you do it together".* This positively encompasses the aspects of collaboration, mutual interaction and the exchange of information. The recognition of the equal importance of scientists and stakeholders indicates a growing importance of stakeholder dialogue in current scientific practice since the concept of transdisciplinarity first emerged in the 1970s. Numerous successfully implemented transdisciplinary projects - such as those analyzed in this study (see Section 4.1, predominantly positive evaluation of the projects) - prove this. From a scientific perspective, access to information that is otherwise not publicly available was highlighted positively. For both stakeholder groups, key aspects are the proximity to application and the applicability of research results. Another positive aspect is the formation and preservation of networks, as this can facilitate further joint activities and projects. This advance of trust and mutual understanding manifests itself mainly in the aforementioned clear communication between the project partners. These general changes in dialogue towards more transparency, for example in the economy (away from greenwashing towards scientifically supported sustainability), along with increased financial resources, contribute to a greater acceptance of science. At the same time, science is also more in focus and under increased scrutiny. Increased acceptance through transdisciplinarity is a facilitating factor here.

Nevertheless, there is still a lack of general understanding of the concept of transdisciplinarity, among both stakeholders and scientists. Participation is seen as a key component, but the self-assessment of the degree of participation is quite different. "Dialogue" and "Contribution" are indeed a form of participation, but not necessarily at the same level as others would define "Co-creation". Also, the consideration of "transfer" as a motivation of transdisciplinarity should be seen critically, as transfer is based on a unidirectional understanding of transferring knowledge from A to B, and not of a shared taking and giving (see Section 2.2, distinguishing transdisciplinarity from knowledge transfer, technology transfer and science communication). To optimize project collaboration efficiency and to ensure mutual understanding, there is a pressing need for a standardized definition of transdisciplinarity. A first step can be taken within a project itself: the scientific partners and the stakeholders should discuss their different roles in the project and their different expectations. This can help to develop a common understanding of co-design and co-creation.

Resource availability (time, money and staff) and communication stand out in the general assessment of possibilities and limitations. They seem to be key success factors. So far, the potential seems not yet fully utilized and such findings tend to be intrinsic knowledge of individual project participants. Through studies such as this work, made publicly available, this experiential knowledge could be shared and support future transdisciplinary projects.

To utilize the opportunities of stakeholder engagement listed in Section 2.2, appropriate (design) instruments are required. Participation formats must be used at the right time with the right people (number and position). Limits are set by the effort involved; available resources such as time, costs and staff. An enormous number of resources is required to maintain and foster networks, especially if involved in several networks. In this respect, considerations on supporting structures would be useful (Wagner-Ahlfs et al. 2023). In addition, a win-win situation must be ensured for all participants in order to maintain the motivation to participate in transdisciplinary projects. It is therefore important to reflect on transdisciplinary projects, as summarized exemplarily in this paper for the Kiel marine sciences, in order to enable assessment of claim versus reality of such projects. One of the key findings of this study is the identification of continuous, clear communication of goals, expectations, motivations and needs throughout the project as a key success factor in collaboration with (non-university) stakeholders. Potential for improvement exists to intensify this factor where necessary and to ensure greater dialogue from the outset. Other useful measures would be the creation of university programs to promote young researchers and provide theoretical and practical insights into transdisciplinary working methods.

6 Conclusion

The aim of this study was to methodically examine stakeholder engagement in transdisciplinary projects of marine research at Kiel University in order to detect the added value and optimization approaches in these types of projects. Surveys of both the scientists involved and the stakeholders involved were designed and carried out for this purpose. This approach ensured that the analysis encompassed both perspectives. In each case, the focus was on the self-assessment of whether transdisciplinarity is actually being achieved, how this concept is best implemented and how it influences the projects. In this way, an attempt was made to contribute to the identification of suitable success factors for transdisciplinary research. Such success factors are:

- a clear communication of goals, expectations and needs throughout the entire project
- planning sufficient resources (time, money)

The analysis of the practical implementation however showed that there is neither a common understanding nor a common application of transdisciplinarity among the various disciplines involved. One reason for this is the inconsistent definition of the terms “stakeholder” and “transdisciplinarity”. Further investigation is required to determine the extent to which this lack has a concrete impact on the projects themselves and their internal collaboration.

The surveys conducted within the framework of this study help to evaluate and further develop transdisciplinarity in the marine context. Overall, transdisciplinary projects in the marine context have proven to be a suitable tool for sensitizing the population and raising awareness of complex challenges. The results emphasize the need to involve groups with different non-scientific backgrounds in research in order to implement more holistic solutions.

To conclude, this study highlights the value and challenges of transdisciplinary research, particularly in a marine context. The findings highlight the importance of stakeholder engagement, bidirectional knowledge exchange, and clear communication in achieving successful outcomes. While transdisciplinary projects offer numerous benefits, such as access to unique information and the formation of networks, there are also challenges, including the need for a standardized definition of transdisciplinarity and the allocation of substantial resources. Moving forward, it is imperative to address these challenges and capitalize on the opportunities presented by transdisciplinary research to address complex research questions effectively. Sharing the experiential knowledge gained from studies like this one can further support and enhance future transdisciplinary endeavors.

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