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Co-production of knowledge in transdisciplinary doctoral theses on landscape development—An analysis of actor roles and knowledge types in different research phases

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ABSTRACT

Transdisciplinarity as a new paradigm in research on societal, landscape and environmental change is characterised by the integration of scientific and non-academic knowledge for complex problem solving. Less information has been published on the specific challenges for implementing coproduction of knowledge in doctoral studies. Based on a structured ex-post reflection of PhD-students and their advisors and on the comparison of four transdisciplinary doctoral projects completed in the "Doctoral School Sustainable Development" at BOKU University of Natural Resources and Life Sciences Vienna, Austria, this article analyses what types of actors contributed what kind of knowledge in which research phase. The results indicate certain patterns which could form the basis for further research but also for the planning of transdisciplinary projects. Professional practice experts, for example, had a key role in structuring the problem and the selection of case study areas in early project phases. Strategic case actors had an essential role as gatekeepers to local case actors, whereas local case actors contributed mostly context-specific, phenomenological and experiential knowledge. Furthermore, we identified the following challenges of transdisciplinary doctoral projects: shared responsibilities, originality versus continuity as well as dependence on commitment and schedules of actors. Actor integration, however, provides opportunities and learning effects going far beyond a traditional doctoral project, due to social competences gained and knowledge accumulated by interacting with different groups inside and outside academia.

1. Introduction

With the surge of complex societal challenges, there is an increasing interest from researchers in, and demand from society for a re-thinking of research strategies and concepts for coping with these situations. As a result, researchers engage in transdisciplinary research, which is characterised by the integration of disciplinary scientific and non-academic knowledge into an inter- and transdisciplinary research framework for complex problem solving. Knowledge exchange, cross-fertilisation and research collaboration across academic knowledge systems are seen as particularly relevant in complex fields such as landscape and urban development, global change and sustainability research (Tress, Tress, & Fry, 2009). Sevenant and Antrop (2010, 374) even characterise transdisciplinarity as "a new paradigm in landscape research", and for Wu and Hobbs (2002) it is a key priority for future landscape research. Research-funding organisations in these fields also often explicitly emphasise the implementation of transdisciplinary approaches in their program lines. In the past decade, numerous contributions on the concept of transdisciplinarity have been published in different thematic and interdisciplinary contexts (Balsiger, 2004; Bergmann et al., 2005; Bergmann et al., 2010; Defila & Di Giulio, 2001; Hirsch Hadorn, Hoffmann-Riem et al., 2008; Hirsch Hadorn, Pohl, & Bammer, 2010; Jantsch, 1972; Max-Neef, 2005; Nicolescu, 1996; Nowotny, Scott, & Gibbons, 2001; Pohl & Hirsch Hadorn, 2007; Thompson Klein, 2001; Wiek, 2007). The diversity of studies and their different disciplinary backgrounds offer a broad spectrum of understandings, interpretations and operationalisations of transdisciplinarity. Therefore, it cannot yet be seen as a well-established

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research paradigm with consistent theory, terminology and methodology (Graybill & Shandas, 2010; Rosenblum, 1997; Tress, Tress, & Fry, 2007; Zierhofer & Burger, 2007).

While earlier publications on transdisciplinarity pointed at a general transcendence of the limits of scientific disciplines, most more recent contributions emphasise (1) addressing life-world problems, (2) promoting the common good and (3) integrating non-academic actors in knowledge generation (Hirsch Hadorn et al., 2010). Scholz, Mieg, and Oswald (2000) describe transdisciplinary research as a process of mutual learning between science and society, and Mobjörk (2010, 866) understands transdisciplinarity "as an extended knowledge production process including a variety of actors and with an open perception of the relevance of different forms of information produced by the scientific and lay community." There are two major motivations to opt for a transdisciplinary approach: the hopes that one's research will have a greater impact on society, and that a higher quality research will be produced due to a broader knowledge base. The following paragraphs briefly sketch these two motivations. For a deeper insight into the reasoning underlying transdisciplinary research see for example Fuqua, Stokols, Gress, Phillips, and Harvey (2004), Häberli et al. (2001), Hirsch Hadorn, Biber-Klemm et al. (2008), Hirsch Hadorn et al. (2010), Mobjörk (2010), and Raymond et al. (2010).

Regarding the first motivation, Häberli et al. (2001, 9) argue that "the personal involvement of partners from practice [...] in the process of knowledge production is more effective than older models in which experts first produce knowledge then teach 'the others.' If involved groups are 'taking ownership' of the outcomes of a new 'common research,' the chances of follow-up for acceptance and decision making are enhanced." This is also due to the normative and instrumental function of participation (Fiorino, 1990). Raymond et al. (2010, 1766) identified the current challenge for researchers in the development of 'user-inspired' and 'user-useful' approaches, "whereby local knowledge is considered alongside scientific knowledge". Such a collaborative process of knowledge production that involves multiple disciplines and actors of other sectors of society has also been termed "co-production of knowledge" (Callon, 1999; Pohl, 2008).

The other frequently mentioned argument for transdisciplinary research is the intrinsic value of local knowledge and the resulting need for non-academic actor involvement. For example, Fiorino (1990) points out that "[...] lay people have specific knowledge and experience and are sensitive to socio-political issues which often are not acknowledged by experts models" (Krütli, Stauffacher, Flüeler, & Scholz, 2010). In this line, Raymond et al. (2010, 1766) argue that prevailing "systems of scientific knowledge production are not able to deal with the complexity of environmental management". Transdisciplinary research is particularly helpful when a socially relevant problem is characterised by uncertainty and complexity, when the concrete nature of problems is in dispute ('ill-defined problem', see Scholz & Tietje, 2002), and when there is a lot at stake for those concerned with these problems (Pohl & Hirsch Hadorn, 2007). However, the integration of non-academic actors does not mean that the scientists' work can be replaced, or that lay knowledge is in competition with technological, scientific knowledge systems; rather, it can be seen as a complementary element resulting in more robust economic and technical solutions, which are socially more accepted (Flüeler, 2006). Collins and Evans (2002, 270f) argue for "Studies of Expertise and Experience" to clearly distinguish the sphere of expertise from the democratic decisions in the political sphere involving the whole public; i.e. they stress that not all lay-knowledge can be relevant in the sphere of expertise. The projects analysed in this article, too, did not involve the general public, but rather those analogous to Collins' and Evans' phrase "*certified*" and "*uncertified specialists*" (Collins & Evans, 2002, 249ff). Krütli et al. (2010) also state that "[...] public participation needs consideration as to the right form at the right time rather than *the more participation the better*."

An increasing number of doctoral projects also aims at applying integrative transdisciplinary research concepts (Fry, Tress, & Tress, 2006; Graybill & Shandas, 2010). However, little information has been collected and published on the specific challenges of implementing transdisciplinary approaches in doctoral studies within traditional university settings (Graybill & Shandas, 2010; Hunt, Bell, Wei, & Ingle, 1992; Pohl et al., 2010). We – three former doctoral students and their supervisors – assume that doctoral students are confronted with additional and – at least partly – different challenges (Graybill & Shandas, 2010), because of the specific organisational framework of doctoral projects and the need to gain an individual qualification within a tight time schedule. On the other hand, doctoral students might possess the specific potential to develop new forms of actor integration. Therefore, it is important to reflect upon the situation of doctoral students with a transdisciplinary research focus in order to provide a framework, which supports them in successfully completing their doctoral studies (Tress et al., 2009).

Four research questions guide this article:

- Who were the relevant actor groups and what were the specific roles of these actors in transdisciplinary doctoral research projects?
- In what research stages, by which approaches and to what extent were actor groups involved?
- What actor groups contributed and generated which types of knowledge?
- What characterises actor integration in doctoral projects and what are the consequences for the planning of a PhD-process?

These questions will be discussed using experiences from four selected transdisciplinary doctoral projects completed at the "Doctoral School Sustainable Development" at BOKU University of Natural Resources and Life Sciences Vienna, Austria.

2. Analytical framework

Based on the literature and our own experiences from our doctoral school, we developed an analytical framework for the comparative analysis of transdisciplinary case studies. According to our research questions introduced above, this framework consists of the following elements (see Fig. 1): (1) typology of actor roles, (2) research phases, (3) objectives and forms of actor integration, and (4) types of knowledge.

2.1. Typology of actor roles

Collaboration is a "core feature of transdisciplinarity" and comprises both the collaboration between researchers from different disciplines and between actors within and outside academia (Mobjörk, 2010, 869). Actors can come from diverse practical or scientific backgrounds and experiences, have different interests and take on different roles functionally and in group dynamic. Our typology of actor roles first differentiates between academic and non-academic actors and, furthermore, whether actors focus on general or case-specific aspects of a topic. Based on this differentiation, we adopt the five categories of actor roles proposed by Ritter, Muhar, and Fiebig (2010):

- *Core scientists* are the main scientific actors throughout the course of a project who – in the case of doctoral thesis projects – usually are one or more doctoral students and their supervisors.

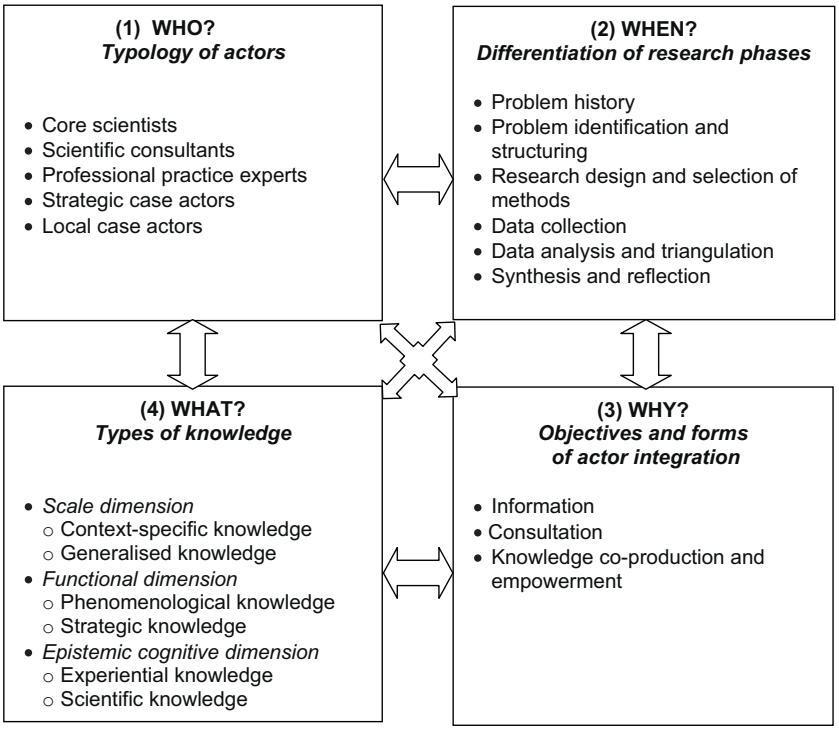

Fig. 1. Analytical framework for describing and analysing transdisciplinary research projects.

- *Scientific consultants* support the core group in particular project phases. These academic experts often come from external organisations working on similar projects in other locations and offer expertise that is not well enough covered by the core team.
- *Professional practice experts* are practitioners, typically working in public agencies or NGOs. They are often very familiar with the practical and political aspects of the issues investigated, but not necessarily with the specific local case context.
- *Strategic case actors* are practitioners involved at case level with a specific formal or informal responsibility (e.g. local politicians, leaders of stakeholder groups) or professional competence (e.g. regional managers); some of them might also be involved in organising, developing, and financing a research project.
- *Local case actors* are all other actors involved in the processes at the case level. They can be actors without specific thematic knowledge of the case such as residents affected by a sustainability issue or actors with sometimes comprehensive specific case knowledge, such as farmers or members of local conservation groups.

It needs to be considered that one single person can act in two different roles, e.g. a representative from a regional authority might at the same time also be a local resident in the study area.

2.2. Research phases

Pohl and Hirsch Hadorn (2007) differentiate three phases of a transdisciplinary research process: "problem identification and structuring", "problem analysis" and "bringing results to fruition". We expand these three phases and add a preceding phase, which we call "problem history": a life-world problem usually exists before the researchers arrive on the stage. Prior to the initiation of a research project many actors had already been confronted with several aspects of a problem field due to their professional or private background. These persons have individual perspectives and accumulated knowledge, which influences the way in which they act in a research process. In many cases the "problem history" might also be a conflict history, which needs to be known in order to understand the behaviour of and relationships between certain actors. To allow a detailed presentation of actor integration, our analytical framework is expanded and sub-divided from that described by Pohl and Hirsch Hadorn (2007). It consists of the following phases (see Fig. 1): (1) problem history, (2) problem identification and structuring, (3) research design and selection of methods, (4) data collection, (5) data analysis and triangulation, (6) reflection/interpretation and synthesis, and (7) dissemination of results.

2.3. Objectives and forms of actor integration

Forms of collaboration are characterised by different hierarchies of relationships between those involved and therefore between the areas of knowledge that participants can offer (Pohl & Hirsch Hadorn, 2007). Mobjörk (2010, 870) distinguishes two types of transdisciplinarity: In "consulting transdisciplinarity" actors have the task of "responding and reacting to the research conducted", and researchers bear actors' "thoughts and perspectives in mind during the research; the societal actors are not actively incorporated into the knowledge production process." In "participatory transdisciplinarity [...] societal actors are fully included in the knowledge production process and their knowledge is equally valuable to scientific knowledge" (Mobjörk, 2010, 870). Considering the wide range of literature on participatory processes (see e.g. Arbter, Handler, Purker, Tappeiner, & Trattnigg, 2005; Arnstein, 1969; Carlsson & Berkes, 2005; Höppner, Frick, & Buchecker, 2007; Pretty, Guijt, Thompson, & Scoones, 1995; Rowe & Frewer, 2005; Stauffacher, Flüeler, Krütli, & Scholz, 2008; Tress, Tress, & Fry, 2009), we distinguish three types of involvement:

- *Information.* Actors are being informed about the research project, e.g. at a public meeting or through a written report. The aim of involving actors informatively is to make plans or research decisions and results that are known and comprehensible to a wide

public – which in turn has little or no opportunity of influencing the research decision in question, the research aim or output.
- *Consultation*. Actors comment on proposals and contribute ideas and suggestions. The aim of consultative actor integration is to obtain actors' knowledge for and reactions to proposals, plans, and decisions or research questions, so that these can be taken into account in the research process.
- *Knowledge co-production and empowerment*. Actors have a say in developing, implementing and running the research project. This often means deliberate and responsible participation, where actors are empowered to be partners in the project according to the principles of participatory social research or action research (Breuer, 2009). Discourse, open debates, and common decision making processes between different actors characterise these interactions.

2.4. Types of knowledge

There is a large body of literature on the categorisation of knowledge in transdisciplinary research and its relevance for environmental management (Fazey, Fazey, Salisbury, Lindenmayer, & Dovers, 2006; Grunwald, 2004; Raymond et al., 2010). Commonly used distinctions for identifying knowledge contributions of different actors are *scientific* versus *life world (experiential)* knowledge, *implicit* versus *explicit* knowledge, and *local* versus *global* knowledge (Böhme, 1997; Nonaka & Takeuchi, 1997; Polanyi, 1985). A frequently cited categorisation by Pohl and Hirsch Hadorn (2007) refers to the usability of knowledge in a research process: *systems knowledge* ("What is the case?"), *target knowledge* ("What should be achieved?"), and *transformation knowledge* ("How can the desired change be accomplished?"). However, this categorisation is not very helpful when analysing the contributions of individual actors. If, for example, in the course of a research project on regional development a survey of the residents' opinions on the future of the region is conducted, then the collected knowledge will be regarded as target knowledge from the residents' perspectives, however from the researchers' perspectives it will be regarded as systems knowledge.

Raymond et al. (2010) propose five dimensions of knowledge types derived from the environmental literature: (a) local versus generalised knowledge, (b) the level of formal processes used to generate knowledge (informal–formal), (c) extent of expertise (novice–expert), (d) extent to which knowledge is articulated or accessible to others (tacit–implicit–explicit) and (e) extent to which knowledge is embedded in and reflects traditional cultural rules and norms (traditional–local ecological–scientific ecological). Based on this categorisation for our analytical framework we identified three relevant dimensions for describing the knowledge contributions of different actor groups at various stages of the project.

- *Scale dimension*:
  - *Context-specific knowledge* refers to the concrete setting of the individual case. With regard to landscape development projects this usually means spatially localised knowledge. This knowledge can be very detailed, both in terms of spatial and temporal resolutions and is usually masked by "data noise": i.e. context-specific conditions, local phenomena which are seen as unique and non-generalisable.
  - *Generalised knowledge* claims to be universally valid. It is expressed in a systematic way and free from context-specific conditions and constraints. However, its application to a local context often requires translation and adaptation. Sometimes it might even be in contradiction to local or context-specific knowledge.

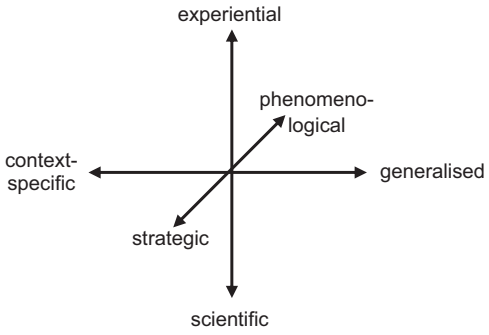

Fig. 2. Knowledge types in transdisciplinary research projects.

- *Functional dimension*:
  - *Phenomenological knowledge* addresses (local) social and environmental phenomena and their description. It often focuses on the description and explanation of particular elements of the analysed system (a typical example might be the knowledge of amateur ornithologists, or local chroniclers).
  - *Strategic knowledge*, contrasts by focusing on connections and interrelations of system elements. It often addresses organisational, functional and network issues for changing the system, and is essential for structuring research processes (e.g. knowledge of regional managers about key players to be involved).
- *Epistemic (cognitive) dimension*:
  - *Experiential knowledge* is derived from one's own life experience or adopted traditional knowledge, and is often tacit or implicit and therefore usually not formalised or systemised.
  - *Scientific knowledge* is based on empirical evidence or scientifically acknowledged theories; it is systematic, formalised and of course explicit.

The inner differentiation of these dimensions is not intended to produce an either/or classification of knowledge, but rather a positioning along a continuum between two poles (Muhar, Vilsmaier, & Freyer, 2006; see Fig. 2 and discussion in Section 5).

3. Methods, selection and description of the analysed projects

3.1. Organisational setting and framework conditions

Our paper is based on experiences from doctoral projects completed within the Doctoral School Sustainable Development (Doktoratskolleg Nachhaltige Entwicklung, dokNE: www.dokne.boku.ac.at) at BOKU University of Natural Resources and Life Sciences, Vienna, Austria. dokNE is a structured doctoral program, initiated in the context of the Austrian Sustainability Research Program proVISION. This research program specifically aims at establishing transdisciplinary sustainability research as a "dialogue between science and society" (ProVision, 2010). Inter- and transdisciplinarity are central research principles of the doctoral program. The doctoral program enables and promotes rich communication between the students and supervisors of diverse disciplinary backgrounds such as in seminars, regular presentations of research progress and informal meetings. The individual doctoral student and his/her supervisors are responsible for the three years project, which was planned and managed to result in a doctoral degree, but also in a fruitful transdisciplinary research process for the non-academic actors involved. These specific conditions distinguish the four projects presented here from transdisciplinary research projects with a large consortium of research partners as well as from traditional disciplinary PhD-theses.

3.2. Methods and material

This article is based on ex-post reflections of PhD-students and their advisors. The analytic framework proposed by the authors was discussed by the four students and three advisors – some of whom are authors of this article – in search of an identical interpretation and application of the analytical categories. The students used the analytical framework for a structured ex-post reflection upon their research processes. They filled in questionnaires to provide data about the types of actors involved in the different phases of their research process (closed questions) as well as their respective contributions and activities in terms of knowledge production (open questions). In an iterative process, the results where condensed and discussed amongst the group of authors, PhD-students and advisors both for comparative interpretation of the results and to better understand the causes for commonalities and differences between the four projects. To help counter-check the ex-post memory based judgments, they were compared with the results of a qualitative text based analysis of existing documents written during the three years of project implementation (e.g. final theses, annual progress reports – particularly the section on the transdisciplinary embeddedness of the projects).

3.3. Selection and description of research projects

In the first program phase from 2007 to 2010 fifteen doctoral projects and one post-doc project were conducted at the thematic interface between the fields of climate change, quality of life and spatial development. In order to answer our research questions, we selected four projects with different strategies of actor integration. The selected projects were chosen because all of them involved transdisciplinary social actors at a local level to a great extent and made specific reference to a single geographical space and to concrete landscapes. The common landscape focus enhances the comparability of the projects.

Project A: "Summer mountain tourism in climate change – scenarios and need for action using the example of the high Alpine trail network" (Braun, 2009; Ritter et al., 2010).

The extensive trail network in the Austrian Alps is the infrastructure basis for summer mountain tourism such as hiking and mountaineering. Impacts from climate change such as glacier retreat and permafrost melt create risks for mountaineers and affect the accessibility of the terrain as well as the maintenance requirements of the trail system. The objective of the project was to investigate the need for action to adapt the trail network to these phenomena, and to develop measures for regional tourism strategies. The project was conducted in three geographic areas of the Austrian Alps. Different actor groups and associations involved in the management and maintenance of the trail network, e.g. alpine clubs, national park administrations, local mountain guide associations and tourism boards, joined the project as transdisciplinary partners. Based on discussions with the transdisciplinary actors about their perspective of the topic, the research questions and aims of the project were identified. In three pilot studies different aspects of former and current changes in the trail network were investigated. These included historical dynamics of the trail network, documentation of glacier retreat in critical sections, and the categorisation of phenomena. At this stage of the research, the transdisciplinary partners provided their specific expert knowledge about the local development in the study areas. Subsequently, scenarios were jointly developed in collaboration with selected transdisciplinary partners to investigate possible future effects of climate change on the high Alpine trail network. These scenarios described different imaginable conditions for summer alpine tourism, and possible impacts of climate change on the trail network in the study areas until 2040. In regional workshops the scenarios were presented to all transdisciplinary partners, who enhanced and evaluated them. Afterwards they discussed the need for action and their ideas to adapt the high Alpine trail network. These ideas were finally summarised as recommendations for different actor groups.

Project B: "Climate change adaptation of maintenance systems in urban public parks" (Drlik, 2010).

Urban agglomerations with their specific climatic situation, and the public parks that are a central aspect of urban life, will be particularly affected by climate change. The planning and maintenance of a park has to cover a long time period, in particular with regard to vegetation growth: trees planted today must be suited to meet the climatic conditions, as well as the use patterns, of coming decades. Using the City of Vienna as the study area, this project examined sustainable adaptation of urban municipal parks to climate change, with a particular focus upon maintenance aspects. The main transdisciplinary partners were employees at different hierarchical levels of the municipal parks administration department. These included a range of participants from local park gardeners to the department head. For the problem definition also members of other municipal departments such as town planning and environmental protection were involved. In the course of the project catalogues of both current and expected future effects, and of possible adaptation measures were jointly elaborated. Specific attention was given to the internal communication processes between the individual parks and management. Finally, a checklist identifying vulnerabilities and fields of action to cope with climate change in parks was developed.

Project C: "Civic engagement for the landscape: the concept of voluntary work for landscape maintenance" (Mühlmann, 2010).

The development of cultural landscapes in Central Europe is characterised by both intensification on sites well suited for agriculture and abandonment on marginal sites. Landscapes on marginal sites, consisting of elements such as hay-meadows or hedgerows, are not only fodder sources for cattle, or important habitats for a variety of wildlife species, but are also attractive for recreation, and significant for regional cultural identity. This project investigated the voluntary engagement of local non-agricultural residents in the maintenance of cultural landscapes. Transdisciplinary partners were members of pre-existing initiatives and persons intending to organise such activities. A survey of existing initiatives in Austria, Germany and Switzerland was conducted, on which a classification of the organisational forms of voluntary work was based. In order to gain further details and insights, the PhD-student actively participated in maintenance work with two of these initiatives. Central themes in the discussions with the organisers and individual participants were the motivation for participation, the social experience of their engagement, and the effects of the initiative on social life in the local communities. Based on these findings an implementation study was conducted in two municipalities in the province of Lower Austria, where there are plans to start such activities. A quantitative survey of the residents showed the potential for voluntary action and also provided important input for the recommendations regarding the design of the activities.

Project D: "Participatory landscape governance – cost-benefit–risk-relations from the perspective of participants" (Enengel, 2009; Enengel et al., 2011).

In landscape governance, participatory processes have gained importance mostly due to discussions of the legitimacy and effectiveness of stakeholder participation in decision-making. Despite the potential and possible advantages of participatory decision-making, co-management will only be successfully carried out if

Table 1
Description of project specific involved actors.

Actor groups	Project A	Project B	Project C	Project D
Core scientists (*involved disciplines*)	Student and advisors *Landscape and recreation planning, geology and geomorphology* $n=3$	Student and advisors *Landscape planning, landscape architecture* $n=2$	Student and advisors *Landscape and recreation planning, regional development, organic farming* $n=4$	Student and advisors *Regional development, landscape and recreation planning* $n=3$
Scientific consultants (*involved disciplines*)	*Climatology, glaciology, landscape and recreation planning* $n=3$	*Meteorology, climatology* $n=5$	*Spatial planning, cultural landscape research* $n=2$	*Landscape architecture, agricultural economics, environmental management* $n=5$
Professional practice experts	Persons from (non-) governmental and research organisations with expert knowledge about the development of summer-mountain tourism $n=3$	Persons from municipal departments (environmental protection and parks administration) $n=9$	Persons from (non-) governmental organisations with expert knowledge about landscape development and civil engagement $n=3$	Persons from (non-) governmental and research organisations with expert knowledge about participatory landscape-governance $n=14$
Strategic case actors	Persons from central offices of Alpine clubs; provincial governments responsible for management of trail networks $n=11$	Persons from the municipal park administration $n=3$	Founders or leaders of voluntary landscape maintenance groups $n=2$	Nature and environmental protection departments from provincial governments; managers of protected areas, external project advisors $n=5$
Local case actors	e.g. voluntary trail keepers, local branches of Alpine clubs, mountain guides, managers of alpine huts, national park management $n=37$	Gardeners of the municipal gardens department $n=35$	Voluntary landscape maintainers $n=33$	Farmers, hunters, local citizens, village renewal association, voluntary nature rangers, nature protection association, local tourism association $n=70$

there are tangible benefits for the local groups involved. The aim of the project was to investigate the private effort of, and benefits and risks to participants and to link these three dimensions. For the empirical analysis, five local participatory processes from different provinces of Austria served as case studies (Natura 2000 steering groups, LIFE-Nature projects and Cultural landscape projects). The transdisciplinary partners consisted of the coordinators and members of the processes, and other experts and practitioners. Actors from supra-regional, regional and local administrations environmental protection, agriculture, forestry and tourism, as well as local residents were also involved. The doctoral project employed diverse methods throughout the research process. Explorative interviews, surveys of both participants of the analysed project teams and the steering groups, problem centred interviews with previous participants, qualitative interviews with process leaders, open participant observation and document analysis were applied in a triangulated mode. Recommendations in terms of possible enhancements of the analysed landscape-steering-mechanisms and for a more cost-effective design of co-management processes were derived. These recommendations were discussed with process leaders in an opportunities-restrictions analysis.

4. Results and comparison of actor integration in doctoral project cases

Similar to the description of the analytical framework, the result section starts with the characterisation of the actor groups involved in the four projects, and continues with the forms of actors' involvement, and their roles in different research phases.

4.1. Involved actor groups

The first step of our reflection on the transdisciplinary processes is an analysis of involved actors as summed up in Table 1.

Table 1 shows that each project involved all types of actors. However, the local actors in the case studies represented the largest group in all projects. The timing of the involvement of the different groups and the communication lines between them are shown in Fig. 3. This compilation does not differentiate between formalised and planned communication (e.g. committees with specific responsibilities, meetings, or workshops), and informal communication for the continuous exchange of relevant information along alternative lines such as e-mail or telephone.

Fig. 3 highlights communication patterns. There was a concentration of actor communication at the initial and final phases of the project. The exception was project A, which due to a transdisciplinary scenario process had a higher actor involvement in the data analysis and reflection phases compared to the other three projects. Almost all communication involved the core scientists. Nevertheless, there were also independent lines of communication between the strategic and local actors, and less frequently between the strategic case actors and the professional practice experts. This is a first indication that strategic case actors play a crucial role for the success of transdisciplinary projects.

4.2. Forms of actor integration and actor activities

All the projects involved all combinations of the three categories of integration: information, consulting and knowledge co-production, and thus met the general standards of transdisciplinary projects (see Table 2 and Fig. 3). However, they followed individual strategies in the way they integrated transdisciplinary partners.

As the comparison in the right column in Table 2 shows, the four doctoral projects used similar approaches for informing and consulting actor groups. However in contrast, implemented knowledge co-production and empowerment activities differ widely between the projects. This may be due to diverging research questions, but also to the preferences and constraints of the actors involved. Professional practice experts and strategic local actors had many responsibilities and tasks, such as participating in discussions regarding the structuring and focus of the research project.

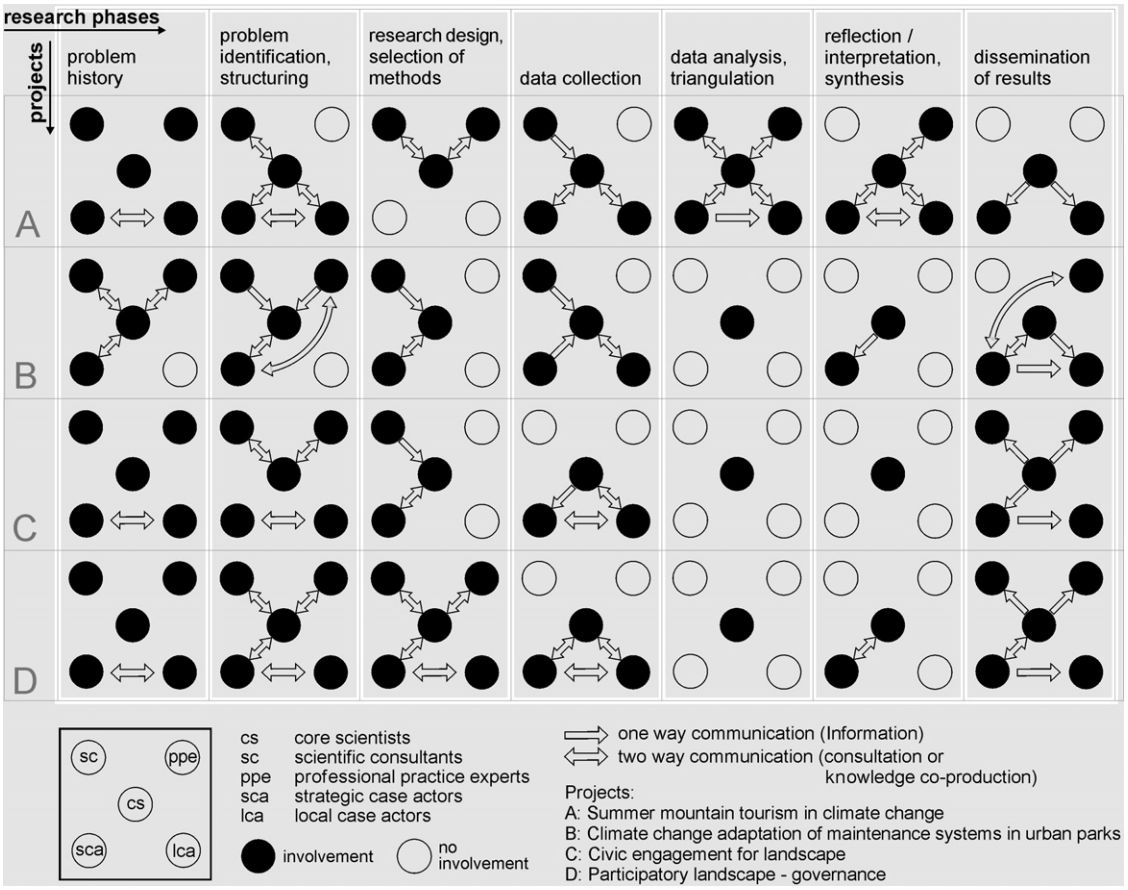

Fig. 3. Actor integration as well as communication types and lines according to research phases. Communication is symbolised by arrows between different actor groups, where unidirectional arrows stand for information and bidirectional for describing interactive communication. Involvement without communication lines means that communication with other actor groups did not take place, such as in the phase of problem history, as a life-world problem existed before researchers arrived on the stage.

Scientific consultants and local case actors were predominantly only consulted, and had less influence on the projects' trajectories.

4.3. Knowledge contributions in different project phases

Fig. 4 provides an overview of the types of knowledge contributed by the different actor groups. For more details on the underlying activities see Table 2. A supplementary table is provided as electronic material.

Despite the different transdisciplinary approaches of the four doctoral projects, Fig. 4 highlights shared tendencies across the four projects in how different actor groups' roles in knowledge production changed during the research processes.

Core scientists. This group was, of course, involved in all research phases. Most of the fieldwork, communication with actor groups, data collection and analysis was done by the doctoral candidate, though with continuous support and feedback from the thesis supervisors. As a result of the co-production of knowledge, the knowledge types contributed by the core group changed in the course of the projects from predominantly generalised scientific knowledge to more case-specific strategic and phenomenological knowledge.

Scientific consultants. These actors were mainly involved in the first phases. They contributed specific disciplinary and interdisciplinary scientific knowledge, particularly for the focusing of the research goals and the development of the research design.

Professional practice experts. Except for project A, professional practice experts took on an essential function only in the early project phases until the formulation of the research design and the selection of methods. They had a key role in reflecting and structuring the problem as they brought in their extensive experiential knowledge from the wider problem field. They were particularly helpful in identifying potential case study areas. Their knowledge contribution was manifold and comprised both context-specific and generalised knowledge, as well as phenomenological and strategic knowledge.

Strategic case actors. The comparison showed a heterogeneous involvement of the strategic case actors. Most had an important role in structuring the research project and in planning the research design. They participated in the cooperative planning of site visits, discussion of contents of questionnaires, and in setting interview guidelines. They also motivated other actors to cooperate. Strategic case actors thus often acted as "gatekeepers", facilitating the communication with local case actors, e.g. by providing support letters or naming potential interview partners. They brought in valuable context-specific experiential knowledge, both strategic and phenomenological, preparing the ground for co-production of knowledge in a case-specific context. With the exception of project C, they also contributed their knowledge in the final phases by reflecting upon and discussing the results and recommendations with the doctoral student.

Local case actors. We found a very heterogeneous involvement of local case actors. With exception of project A they were not involved in the formulation of the research design and selection of methods, nor in data analysis and triangulation. By describing and discussing the problem field from the local perspective, these actors contributed mostly context-specific, phenomenological and experiential knowledge. They also partly provided strategic knowledge, e.g. by identifying interview partners, motivating other local case actors to actively participate in the research project, and by

Table 2
Activities of involved actors classified according to extent of involvement.

	Actor groups				Doctoral projects			
	sc	ppe	sca	lca	A	B	C	D
Tasks and roles according to the extent of actor integration								
Information:								
be contacted and informed about the research project	×	×	×	×	×	×	×	×
be informed about progress/modifications			×			×		
be motivated for collaboration within the research project			×	×	×	×	×	×
be provided with written doctoral thesis	×	×	×	×	×	×	×	×
get scientific and popular articles	×	×	×	×	×	×	×	×
get a final presentation			×	×		×	×	
get a training in using the transdisciplinary product				×		×		
Consultation:								
provide knowledge	×	×	×	×	×	×	×	×
consult the development of the research design (interdisciplinary guidance)	×	×			×	×	×	×
discuss project aims and research questions/directions	×	×	×		×	×	×	×
state possible case studies/study regions	×	×	×		×			×
describe current problems from the supra-regional perspective			×		×		×	×
formulate needs and expectations on research project			×		×	×		
name potential interview partners			×			×	×	×
Knowledge co-production and empowerment:								
make interdisciplinary data available	×				×	×		
agree on willingness to cooperation			×	×	×	×	×	×
cooperative planning of on-site research visits			×				×	
discuss contents in the questionnaires or interview guidelines according to case specific characteristics and add further research interest			×				×	×
inform and motivate other (case) actors for collaboration within the project			×	×	×	×	×	×
provide access to local case actors			×				×	×
provide written support (e.g. cover letters for a survey)			×					×
distribute questionnaires			×				×	×
enhance and evaluate scenarios		×	×	×	×			
discuss results and derived recommendations		×	×	×	×	×		×
integrate and apply new information and raised awareness into working area				×		×		
participate in writing popular science articles		×	×			×	×	

sc: scientific consultants; ppe: professional practice experts; sca: strategic case actors; lca: local case actors. ×: involved actor groups and activities in the four doctoral projects. Project A: summer mountain tourism in climate change; project B: climate change adaptation of maintenance systems in urban public parks; project C: civic engagement for the landscape; project D: participatory landscape-governance.

taking on some tasks of communication, particularly with the local case actors.

5. Discussion of the results

5.1. Generalisability of the results

Results from comparing just four cases cannot easily be generalised. According to Krohn (2008), a knowledge base not only expands by generalising experience, but also by becoming more and more experienced in identifying the specifics of a new case and in gaining the ability to take features of the cases to be typical. The results of our analysis must of course be seen and interpreted with regard to the specific framework conditions of the doctoral projects analysed. The project drafts, for example, were designed with limited non-academic actor involvement prior to the advertisement of the doctoral grants. Thus, the possibilities of local case actors to outline the research focus were initially constrained. However professional practice experts had an important role in reflective discussions and adaptations of the research design. This will be different in settings, where the issues and goals of research come from local actor groups.

Some similarities in the four analysed projects might also be due to the regular communication between all doctoral candidates and supervisors in the doctoral program, e.g. in seminars and informal meetings. By discussing literature on transdisciplinarity and interacting with guest lecturers, the school's members developed an implicit standard of what constitutes a "good" transdisciplinary doctoral thesis. Thus a comparison of our reflections with experiences from transdisciplinary doctoral projects undertaken in different geographical or thematic regions could be very insightful. Furthermore the results are dependent on the selection of research projects. As explained in Section 3.3 amongst others we selected these doctoral projects because of their different strategies of actor integration and because all of them involved transdisciplinary social actors at a local level to a great extent. However, a variation on the extent of transdisciplinary actors might also be promising to learn about the implications for a PhD-thesis process and its outcome.

5.2. Different actor involvement according to research phases

Pohl and Hirsch Hadorn (2007) emphasise the need to involve societal actors in all phases of a transdisciplinary research project. Our analysis indicates that this may not be always necessary and suitable since different actor groups contribute differently to different stages of the research process. Generally, our results align with Elzinga's (2008) statement that participation appears to be more prominent in the initial and final phases of a research project, while the middle phases of data analysis are mostly performed by the researchers. However, the core scientists communicated and discussed the results of this process with all involved actor groups to close the loop of knowledge co-production, as postulated by Hirsch Hadorn et al. (2010). The results give indications for targeted and effective involvement of different groups at different stages of the PhD-project.

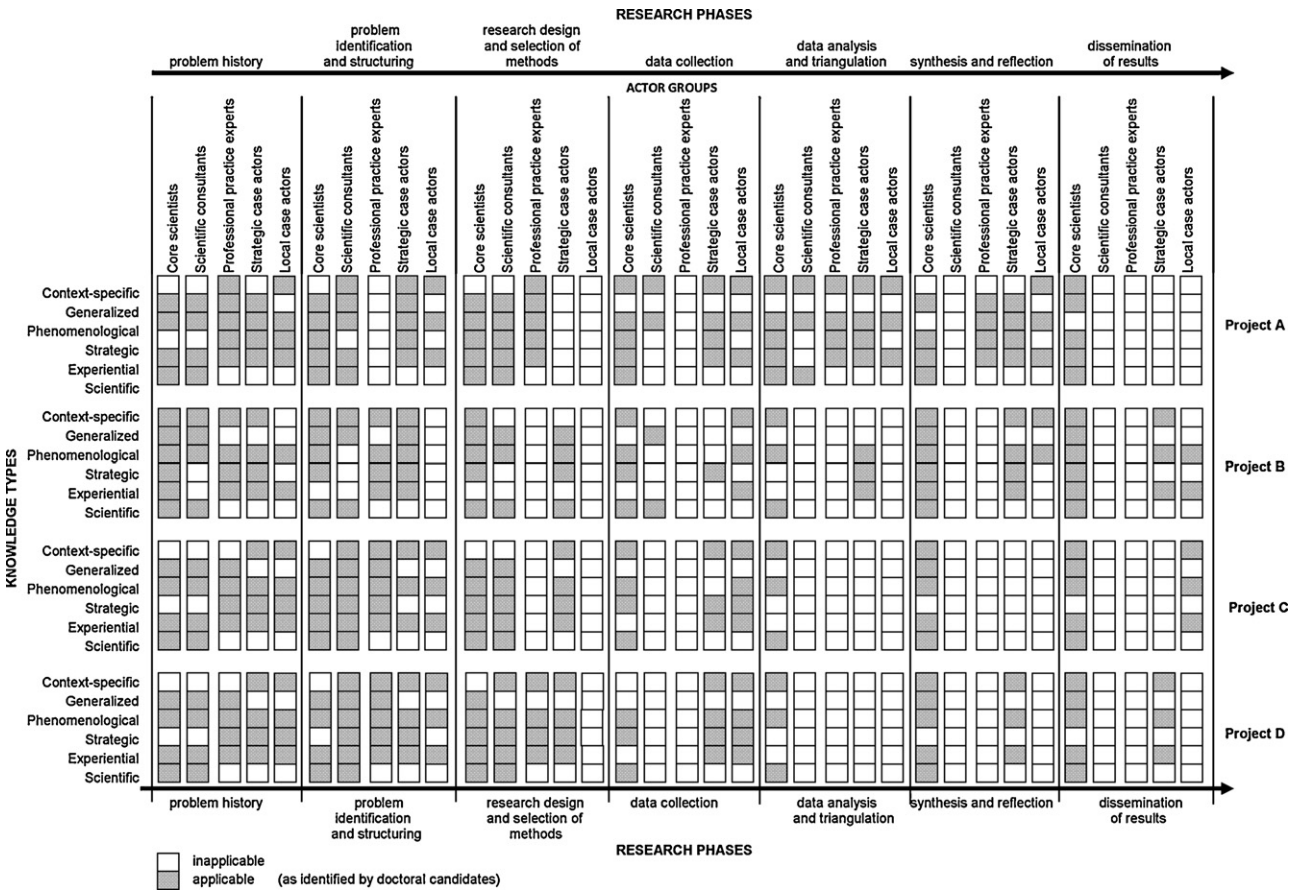

Fig. 4. Knowledge contribution from actor groups in different project phases.

5.3. Co-production of knowledge

The case studies provided insights into different ways of organising transdisciplinary research processes for the co-production of knowledge with actor groups. The input from diverse actor groups was substantial for all our projects. Due to diverging research topics and goals, the scope for comparisons between the projects is limited and one cannot judge which strategy would be best. Our results, therefore, also underline the assertion of Raymond et al. (2010, 1775) that "there is no single optimum approach" for integrating knowledge types. Rather, knowledge contribution by different actors requires research designs tailored to the research topic and the preferences and constraints of the different actor groups involved.

Apart from these more general insights we identified several fields of disagreement between the standards of transdisciplinarity and those of a doctoral project.

5.4. Shared responsibility

According to Mobjörk (2010, 870) "there is a need to acknowledge the power relationships between various actors, their ability to actively participate, and the role they play in relation to researchers." Transdisciplinary research implies a partial shift of tasks and responsibilities from scientists to non-academic actors. This shift of responsibility and control creates new dependencies, unexpected or unwanted consequences; delays may even halt the research process. This could be a major challenge for PhD-projects that should result in externally reviewed doctoral theses after three years. The scope of integration of transdisciplinary partners depends upon the acceptance of diverse perspectives and aims of actor groups, and on distributing power and responsibilities for the doctoral project without forgetting the primary purpose of a PhD-process, i.e. the individual qualification of the PhD-candidate. Thus PhD-candidates and their supervisors should consider the extent to which control can be relinquished, and a critical reflection of the tension between transdisciplinarity and maintaining control over the research process should be an explicit part of a PhD program.

5.5. Societal impact and research quality

In Section 1, we referred to the two main motivations for transdisciplinarity: higher impact of research in society and better research quality. The four cases of this article document that transdisciplinary PhD-projects can indeed include local knowledge into the research process as described in Section 1. They are well suited to bring together different academic and non-academic perspectives and to find realisable solutions that compromise between conflicting interests. Therefore, they yield well accepted results that more effectively address real world problems. The valuable "reality-check" provided by the case actors (Wickson, Carew, & Russell, 2006) as well as the broader knowledge base that allows for the triangulation of different interpretations of the same problem increase the validity and thus the quality of the research. In a nutshell, the extra time spent for transdisciplinary interaction very likely yields more valid results that more effectively address real world problems. On the other hand, students have less time to dedicate to disciplinary exchange, methodological and theoretical innovation. Therefore, they may have less impact on disciplinary progress.

5.6. Dependence on commitment and schedules of actors

Transdisciplinary research – particularly research which is participatory rather than strictly consultative (Mobjörk, 2010) – is time-consuming and thus a challenge for the limited time and personal resources of a doctoral project (Tress et al., 2007). The research progress is heavily dependent on the commitment and the schedules of numerous actors. This was a great concern for the doctoral candidates, who as a consequence, invested much effort in planning the actor involvement according to the available resources. This was mainly possible due to early contacts with practice experts and strategic local case actors, which piqued their interest in the research project, finally and eventually led them to perceive it as "their own project". This gives indications for the first motivation for transdisciplinary research – namely a greater impact on society (see Section 1) – if involved groups are taking ownership of the outcomes. Moreover results of the theses were discussed with all involved actor groups to close the loop of knowledge co-production. In our case, all four analysed projects could be completed within three years, but this was not possible for all dokNE projects, and is not always feasible in other situations (Fry et al., 2006).

6. Discussion on the analytical framework

The analytical framework proved helpful for examining different actor types and the variety of knowledge types they contribute. It could, therefore, be a helpful basis for the planning of other transdisciplinary projects. Furthermore, it might be an important first step of knowledge integration (Raymond et al., 2010) to categorise and identify knowledge types in ongoing transdisciplinary processes.

6.1. Typology of actor roles

The chosen typology of actor roles reflects their typical roles in transdisciplinary projects. All these roles will not be present in every research project, and some actors may have multiple roles. The same people may, for instance, be both strategic and local case actors if they have both an institutionalised and local private role in a project. As our results highlight, strategic case actors were important gatekeepers to connecting researchers and local case actors. Steering committees, made up of representatives from different actor groups, are a key part of transdisciplinary research. These committees are usually responsible for vital decision making regarding research funding, organisation, and strategies. In our doctoral school, such a steering committee guided the school as a whole, and also made a valuable contribution to individual projects. However, they were rarely involved in guiding the doctoral projects. Because we focused on the knowledge production processes, the important evaluative roles of actors in this steering committee, such as evaluating theses, were not included in our actor typology. Furthermore, our typology did not distinguish between the different categories of strategic case actors, which might be useful in other contexts, e.g. to differentiate between representatives from public authorities, private enterprises and civil society organisations.

6.2. Research phases

The description of research phases might suggest that transdisciplinary research is a strictly linear process. In the projects analysed here, however, these phases were interwoven with feedback loops, and were partly parallel or overlapping. Pohl, Lorrae van Kerkhoff, Hirsch Hadorn, and Bammer (2008) and Hirsch Hadorn et al. (2010) emphasise the recursiveness of all research phases (Pohl et al., 2008). Important recursive loops in our projects were, for instance, the explorative interviews on preliminary research designs, and the adaptations of questionnaires and discussions of recommendations with strategic case actors. With regard to knowledge types, integration of local and scientific knowledge can be perceived as "a cyclic process of reflection and learning" from problem identification up to implementation (Raymond et al., 2010, 1771).

6.3. Knowledge types

What types of knowledge individual actors contribute in different project phases does not only depend on actors' capabilities, but also on the type of knowledge they were asked for by the researchers (e.g. for context-specific or generalised knowledge), by other actor groups, or by the methods applied (e.g. scenario analysis, expert interviews, explorative interviews; see also Table 2). Different actor groups have their strengths in specific knowledge types such as local actors in experiential knowledge and scientists in scientific knowledge. Our analysis showed that it is often difficult to clearly characterise the type of knowledge contributed by individual actors – particularly regarding the epistemic dimension of experiential and scientific knowledge. According to Raymond et al. (2010, 1769) it can be argued that "all knowledge comprises a heterogeneous blend of knowledge types from different sources, as developed through personal experience, interpretation and interaction." Thus the dimensions in our categorisation have to be perceived as polarities with numerous possible intermediates. After reviewing other categorisations of knowledge we believe that our applied typology is useful for the specific purpose of analysing landscape-oriented projects. However, we hope that our analytical framework will be useful to help determine which knowledge types are required and which actors should be involved in which particular project phases of future research projects also in other fields. Such an application of the framework in other types of projects may, however, require some adaptation. For example, the analysis dimension of scale (local, case specific vs. global, generalised) would need to be translated into more generic, non-space-related terms (e.g. ideographic vs. nomothetic).

6.4. Forms of actor involvement

Our formal classification of actor involvement was developed from the project perspective in line with a broad range of literature on participation. A useful expansion of the framework, which would require an additional and extensive data collection process, could be the inclusion of the individual motivations of involved actors.

6.5. Options for further expansion

The focus of this investigation was on knowledge types and knowledge contribution. We did not specifically address or analyse conflicts and power relationships, which are of course also an important aspect of knowledge co-production, both in the context of individual research projects and on a more general level of the science–society interface (see Jasanoff, 2004). For the investigation of such issues at project level the implementation of methods from social network analysis might be useful.

7. Conclusions

While doctoral programs increasingly adopt the transdisciplinary research paradigm (Tress et al., 2009), ways and consequences of non-academic actor involvement in doctoral projects have not been discussed sufficiently so far. In this article, we – doctoral students and their supervisors – wanted to

contribute to this discussion by systematically reflecting our own experiences. We believe that the analytical framework which we developed and applied can also be useful for similar projects in other thematic or geographic settings, not only for ex-post analyses of completed projects, but also for project planning, as it helps researchers to be prepared for the challenges of transdisciplinary research.

Our typologies and the empirical results demonstrate the scope of actor integration in our projects. From the comparative analysis we conclude that there is no blueprint for transdisciplinary doctoral projects, therefore we would hesitate to provide any guidelines. Transdisciplinary doctoral projects should be seen as open interaction processes and, therefore, they will always be characterised by uncertainty – even more so than regular doctoral projects.

By reflecting as a group on the transdisciplinary process, we learnt some lessons about planning and implementing a transdisciplinary doctoral project: (1) Early involvement of different actor groups is essential for finding common objectives and priorities. (2) The comparative analysis highlighted the crucial role of strategic case actors as gatekeepers to local case actors; this needs special consideration in project planning. (3) Adequate time and labour resources must be reserved for participatory processes. (4) Short and medium term outcomes, such as a common workshop or a presentation of preliminary results, help to attract and motivate actors for continuous collaboration. (5) It is crucial to define rules for collaboration and to define and communicate the scope and purpose of participation in different phases of the research project, such as the different roles of different groups in problem definition and structuring; problem analysis, synthesis and implementation.

Both, students and supervisors of transdisciplinary doctoral projects face specific challenges and uncertainties in terms of external dependencies and the ups and downs of social interaction and communication processes. However, in retrospective, we conclude that actor integration also provides opportunities, and the learning effects for both students and supervisors go far beyond a traditional doctoral project. Particularly rewarding are the motivation and gratification provided by early feedback from potential users, the social competences gained, and knowledge accumulated by interacting with different groups inside and outside academia, and the feeling of producing results that are also relevant outside tight disciplinary or academic boundaries.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.landurbplan.2011.12.004.

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