Reflections on Transdisciplinary Research

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Abstract In this chapter, the project coordinators reflect retrospectively upon the most important elements of the transdisciplinary collaboration in the "Rethinking Prototyping" project. On the macro level, the fundamental importance of reflective-coordinating support is outlined against the backdrop of ambivalent exp

eriences with inter-/transdisciplinary research, and the assumed added value of transdisciplinary research for this project—the integration of knowledge—is described. A general overview provides the challenges within the science system that reflecting-moderating support of transdisciplinary processes must address in various ways, depending on the project. With recourse to project-internal documentation, empirical values and the results of an accompanying study, the most important elements of the collaboration are then elucidated on the micro level and assessed with regard to their potential for the promotion of the process of knowledge integration. Based on the results of this evaluation, beneficial factors for knowledge-integration and transdisciplinary collaboration are worked out. Throughout the course of the project, the guiding principle that each transdisciplinary project is unique and must be understood as prototypical was developed. Transdisciplinary projects are implemented in the form of a continuous development process that, as summarised at the end, is to be understood as part of a global prototyping process in transdisciplinary research. This paper makes a contribution to this subject.

1 Introduction

The technologically-produced complexity of our world is increasingly penetrating into every sphere of our lives. Also intertwined and interdependent are the questions, challenges and problems that this world gives rise to. The answers and

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solutions required for this must do justice to this complexity and therefore also be developed systematically and in a context-related way according to a holistic approach. For science, this consequently requires a research principle exceeding the limits of individual disciplines. With the simultaneous participation of multiple scientific and artistic-creative disciplines as well as society, new approaches must be sought, innovative solutions should be developed and new knowledge produced. Although the necessity of transdisciplinary research is demonstrated in this, it is not self-explanatory or simple to carry out inter- or transdisciplinary projects. For example, in order to go beyond the limits of disciplines, institutes, universities and non-academic establishments that generally work in isolation, it is necessary to have additional time, staff resources and financing as well as a special infrastructure.

The research project entitled "Rethinking Prototyping" was able to overcome many adversities that transdisciplinary research is exposed to in the university context, but had to prove itself in the implementation of some challenges. This paper has been written from the perspective of the project coordinators[1] in the research group of "Rethinking Prototyping" and addresses observations and knowledge gained from supporting this project. The focus is on the factors that are related to achieving *knowledge integration* that leads in in an ideal case to the achievement and/or answering of the transdisciplinary goal/question as well as to new knowledge and assessments by the individual participant. These results can have an impact not only in the project context, but also in the respective disciplines due to the participants' use of them.

In the following, the focus is more on the framework of organisation and support that influence the integration of knowledge. We describe *formats* and *design elements* that were used in order to successfully pave the way for the transdisciplinary research process on the level of the organisation of collaboration in a *coordinated*, *integrated*, *supportive*, *advisory* and *facilitating* way. These explanations can serve as sources of inspiration and orientation aid for conducting other transdisciplinary research projects.

The basis of this chapter is the idea that each transdisciplinary project can be understood as a prototyping process of transdisciplinary research. Consequently, we do not assume that there is *one* right way in transdisciplinary collaboration. In this sense, no normative claims are made in this chapter, nor is a final evaluation of the research project provided. This paper refers to one single transdisciplinary research project involving the Technische Universität Berlin (TU Berlin) and the Berlin University of the Arts (UdK Berlin), reflecting on the work in this specific university context and considering the extent to which it can serve as a model.

The basis for this paper consists of the documentation of the course of the project, the work meetings, accompanying research[2] and the observations and

[1]The project coordinators consisted of a project manger and a project administrator, who worked together closely on the conceptual level during the course of the project.

[2]The dialogic and process-accompanying research was conducted by Maria Oppen from the Social Science Research Center Berlin (Wissenschaftszentrum Berlin für Sozialforschung/WZB) on behalf of the "Hybrid Plattform" from January to December 2013. This involved an accompanying

analyses of the project coordinators. To start with, a theoretical framework is provided on the macro level (Sect. 2): the transdisciplinarity term adopted for this project is explained, the concept of knowledge integration is specified, and the levels of influencing the design of knowledge integration are outlined. This is followed by an enumeration of the possible challenges which transdisciplinary research may potentially face in the university context and which can influence the intensity of the collaboration and thus integration of knowledge (Sect. 3). Then, on the micro level, i.e. on the level of the organisation and design of the concrete "transdisciplinary scientific practice" (Balsiger 2005, 170), the formats used in the service of knowledge integration are analysed retrospectively and the factors for success in the achieved integration of knowledge in the "Rethinking Prototyping" project are worked out (Sect. 4). In conclusion (Sect. 5), we summarise our most important experiences and discoveries.

2 Theoretical Framework

2.1 Inter-/Transdisciplinarity: An Ambivalent Phenomenon

It is not easy to fully develop the potential of interdisciplinary research in practice: "Based on their own extensive experience in research, various authors have described interdisciplinarity as an ambivalent phenomenon" (Laitko 2011, 1). The same applies to transdisciplinary projects. This is because the expectation that extraordinary results will be achieved by bringing together various disciplines cannot be easily met under even the best conditions[3] (cf. Laitko 2011, 9f.). When the limits of a discipline are exceeded, scientists enter an area in which they are often confronted with unusual or unfamiliar processes that differ from project to project. In an ideal case scenario, project participants have the will and motivation to work across disciplines, but they can rarely fall back on familiar or established procedures. This situation has been the cause of ambivalent experiences. The comments made by one of our project participants demonstrated this, for example. He said that most scientists wanted to research across disciplines, but nobody could resolve the difficulties to an adequate extent, although they are all well known. The ambivalence in transdisciplinary research is due to the fact that the high expectations for inter-/transdisciplinary research on the macro level are difficult to fulfil on

(Footnote 2 continued)

process evaluation of the work for the "Hybrid Plattform" in the context of which the "Rethinking Prototyping" research project was included and examined. The scientist briefed the project coordinators multiple times, interviewed eight project participants and presented the intermediate results of her research to the entire research group within the context of a large colloquium. The results were published in 2014.

[3]Hubert Laitko analyses the history of the Starnberg Max Planck Institute for Research on Living Conditions in a Scientific-Technical World.

the micro level of university research because there are (still) no successful realisation strategies for implementation. The success of transdisciplinary projects is often random. The initiators hope that the project participants will provide knowledge of possible work and organisational forms for functioning collaboration in the group and can initiate and maintain knowledge-generating processes. But this is frequently not the case. This often produces confusion and irritation and has a demotivating impact on the participants (cf. Schmithals et al. 2011, 28, 56).

The ambivalent experiences that result from the divergence between the high expectations and the lacking realisation strategies show that successful collaboration does not function or only rarely functions by itself within an trans-/interdisciplinary research group. This is also what Gert Dressel et al. say: "Inter- or transdisciplinary research is not without conditions, it does not happen by itself, but rather must be organised systematically" (Dressel et al. 2014, 207). We see the need to accompany inter-/transdisciplinary research processes in a coordinating and supportive way. The outlined phenomena for the discrepancy between high expectations and the (still) lacking realisation strategies for inter-/transdisciplinary research should be countered with reflective processes and suitable formats in order to develop and exhaust the desired added value of inter-/transdisciplinary research.

2.2 Potential of Transdisciplinary Research: Knowledge Integration and Self-Renewal of the Disciplines

If we return to Jürgen Mittelstraß's definition of transdisciplinarity, we can see the added value that the "Rethinking Prototyping" research project pursued with its transdisciplinary approach. Mittelstraß argues that there is a need to go beyond disciplinary limits in (at least) two factors on the macro level. On the one hand, individual disciplines could no longer provide comprehensive answers to the growing complexity of problems in everyday life (cf. Mittelstraß 2003, 8). On the other hand, disciplinary research benefits in terms of innovation since new knowledge arises "on the edges, between various subjects and disciplines and in their connection to each other" (Mittelstraß 2008, 5).

For our understanding of transdisciplinarity, its contextualisation in application-oriented research plays a subordinate role although there was reference to practice in the sub-projects. According to our understanding, "transdisciplinary research is not application-oriented per se" (Schmithals et al. 2011, 46), but rather we observe its innovativeness in terms of the development of new knowledge and the related self-renewal power of disciplines as its primary quality and function. Its innovativeness is defined primarily in the project context itself: New knowledge is produced through collaboration with the project participants. This internalised knowledge and the experiences of the participants also reflect back on the individually-involved disciplines; the power of self renewal of the disciplines provoked by transdisciplinary research has an impact here. In the following, we

concentrate on how new knowledge arises in a specific transdisciplinary connection and what can be described primarily through the process of *knowledge integration* according to our approach.

The concepts of multi-, inter- and transdisciplinarity demonstrate what is meant by *knowledge integration* in our analysis. We shall characterise these three forms of cross-disciplinary practice, starting with their desire to integrate knowledge. In the process, we fall back on the three levels of integration according to Günter Ropohl: *encyclopaedic integration*, *interpersonal integration* and *intrapersonal integration* (cf. Ropohl 2010, 4f.).

Multidisciplinarity is characterised by no integration of knowledge or a minimal amount. In multidisciplinary constellations, only the level of *encyclopaedic integration* is achieved. This approach collects "the important disciplinary perspectives in an additive way" (Ropohl 2010, 4f.; cf. Laitko 2011, 11) and does not require any collaboration on a collective issue. The results of multidisciplinary research are usually included in collections in the form of individual papers and are "arranged without theoretical interconnections and in an unrelated way" (Ropohl 2010, 4f.).

By contrast, the term *synthesis* describes the sought degree of knowledge processing for *interdisciplinarity*. Various approaches should "merge" into a collective answer to a research question (cf. Ropohl 2010, 4f.). Furthermore, Ropohl explains:

> If the results of the work […] should go beyond being an aggregate of specialised expertise, the participants must have good communication skills and a strong ability to learn in order to synthesise their individual contributions (Ropohl 2010, 4f).

Interdisciplinarity requires a joint research question, learning and communication skills and finally a synthesis. Ropohl calls this form of integration *interpersonal integration*. He notes critically in this regard that the results of interdisciplinary research frequently only achieve the level of encyclopaedic integration, so the research remains, if defined strictly, multidisciplinary. He views the reason for this as being the lack of "methodological tools" and suitable competencies (cf. Ropohl 2010, 4f.).

Transdisciplinarity refers to interdisciplinarity with a completed act of integration—or as Mittelstraß puts it:

> Interdisciplinarity in a correctly understood sense does not move between disciplines or hover, like the absolute spirit, over the fields and disciplines. Rather, it eliminates disciplinary narrowness where this stands in the way of the development of the problem and corresponding research action: speaking accurately, it is transdisciplinarity (Mittelstraß 2003, 9).

Accordingly, interdisciplinarity, in a falsely understood sense according to Mittelstraß and without interpersonal integration according to Ropohl, is simply multidisciplinarity. Following this interpretation, the term interdisciplinarity becomes superfluous (see Fig. 1) and is described here as transdisciplinarity for the project work of "Rethinking Prototyping".

The degree of knowledge integration in transdisciplinary research can be explained on the level of *intrapersonal integration* according to Ropohl (2010, 5). This requires, according to our interpretation of Ropohl, not only the aspects for

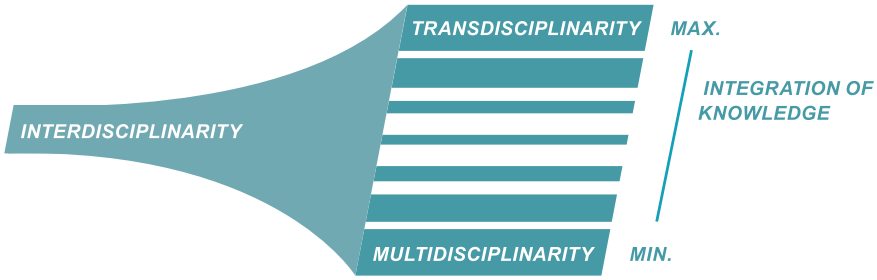

Fig. 1 The level of knowledge integration defines the character of the joint research ranging between multi- and transdisciplinarity

interpersonal integration (willingness to exchange and communicate in order to produce a synthesis), but also "individual multi-field competency" (Ropohl 2010, 5) from the project participants. For Ropohl, this includes the ability of the participants to be able to understand and integrate knowledge from the widest range of disciplinary origins on an individual, i.e. intrapersonal level. Intrapersonal integration also means that "this person passes on the synthesis of knowledge not only receptively in him- or herself, but also effectively to others" (Ropohl 2010, 5).

Building on Ropohl's definition, according to our interpretation, transdisciplinary projects pursue the goal of answering a question through synthesis of the knowledge available in the project, which is continuously renewed and changed through individually completed integration processes. The integration of knowledge, as we understand it, means that project participants record new knowledge and new methods on the intrapersonal level, integrate them into an existing body of knowledge and gain new knowledge, new processes of knowledge attainment and new discoveries through the analytical processes of differentiation and synthesis. On the individual level, it is a critical-reflective absorbing and understanding of other perspectives in the reflection of one's own body of knowledge and requires a certain willingness to revise and expand one's own perspectives. The discoveries made in this way are repeated and "thought-through" for their potential by the other project participants. The integration of knowledge is thus understood as a circular-dialogic process that runs like a spiral and leads to the answering of a joint question in this way. This process of handling knowledge has an effect, both within a project and beyond its limits. The intrapersonally processed, newly attained knowledge flows back into the respective disciplines through the project participants. Therefore, knowledge integration processes also stimulate a circulation of knowledge between a transdisciplinary project and its involved disciplines and institutions, which may be inspired or changed as a result of this.

The possibilities for promoting the difficult and multi-layered integration of knowledge are heavily influenced by the specific framework conditions in the scientific system; this has been confirmed by our experiences and the results of the dialogic research that has accompanied the "Rethinking Prototyping" project. In order to pave the way to knowledge integration, it is important both for the

participants and on the coordination level to develop awareness for these framework conditions in order to determine the room to manoeuvre. In the following, we shall address the most important influential factors in the scientific system for transdisciplinary projects.

3 Context-Related Challenges: Finding Room to Manoeuvre

Every scientist involved in a transdisciplinary project is embedded in an environment that consists of systems with higher-level goals and values.[4] In this section, we will examine some examples of factors that (a) determine the leeway both for individual project participants and for reflecting-moderating support and (b) can influence the process of knowledge integration. These factors were worked out and analysed for the most part in the research accompanying the "Rethinking Prototyping" project (cf. Oppen and Müller 2014, 38–46). They will be complemented here by the experiences and observations of the coordinators in this project. These explanations should provide initial clarification in general of the limited options for action in project support and design as well as the incomplete degree of freedom that the participants have in a transdisciplinary project not isolated from external influences. They create the framework for the subsequent project-specific explanations (Sect. 4) that allow for reflection upon the most important elements in the collaboration on this project and an assessment of their potential for the promotion of knowledge integration.

The first influential factor that has an impact in transdisciplinary projects can be called the international scientific system. Its influence extends from its subsystems according to the subsidiarity principle to the micro level of a research project. The zeitgeist of international scientific work (e.g., trending subjects that are rewarded with great attention and funding) can influence, for example, the formulation of a research question or the motivation of individuals independently of their disciplinary affiliation.

The subsystems of the scientific system, as well as the disciplines, universities and research facilities with their departments and institutes have an impact on individual scientists not only during their scientific career, but also in the course of a transdisciplinary research project. Accordingly, scientists are shaped by their discipline, for example, through their theoretical background and the language in their field, and bring a specific internalised discipline culture into the project. In the course of their socialisation in their respective discipline, scientists acquire a specific intellectual and research culture that can be juxtaposed diametrically in a transdisciplinary group such as, for example, quick focussing versus a cautious approach, linear causal models versus non-linear creative theoretical approaches,

[4]Based on Talcott Parsons' theory of social systems (cf. Stark 2009).

specific versus holistic analysis, risk willingness versus planning security, discussions with a change in perspective versus work in isolation, creative freedom and individual design versus meticulous planning and hierarchically-controlled project organisation (cf. Oppen and Müller 2014, 42ff.). The different degree of compatibility in these theoretical and communication patterns can influence the working atmosphere in a project. Project participants differ in their willingness and ability to be aware of one's own internalised patterns and to expand or revise them. Usually, participants must be open to new work methods. Institute-specific methods can assume a place of "sovereignty" in a project if the place of research is primarily tied to only one location, for example.

In transdisciplinary collaboration, the different discipline cultures become very evident and can lead to implicit hierarchies within the research group. Accordingly, project participants in a transdisciplinary framework can be mapped in a hierarchical structure that corresponds to the disciplines and is also taken for granted in the project. Prejudices with respect to other disciplines or disciplinary stereotyping play a significant role here (cf. Oppen and Müller 2014, 42ff.).

Furthermore, differences between documentation cultures and knowledge management present a challenge for the accessibility of the available knowledge within a project. Accordingly, for example, there is the danger that project-relevant knowledge remains in the archives of the individual institutes. Limitations in the exchange of data on account of data protection requirements can also cause complications in the continuous flow of information and the exchange of knowledge between project participants. Furthermore, the respective organisation structures, communication forms, management cultures and control mechanisms in an institute (e.g., hierarchical or democratic) should be named here as factors. They determine, in particular, the exchange of information between professors and research assistants. In this regard, the quantity and quality of the project participants' knowledge input differs significantly, which also causes the participating disciplines to have a different presence.

Last but not least, there are the involved scientists who can themselves determine their own room to manoeuvre within a certain framework and thus also influence the coordinating-reflective support in transdisciplinary research projects. Accordingly, each scientist pursues individual goals with respect to his or her activity in the scientific system (cf. Oppen and Müller 2014, 40). If the focal points of the project participants' research is more in the core research areas of the discipline, transdisciplinary research is less conducive for the given scientist's own interests since transdisciplinary research questions usually only relate to the disciplinary questions to a limited extent. The success of a transdisciplinary project can also depend on the extent to which the individual participants view the collectively-achieved transdisciplinary collaboration as useful for themselves. The feedback of the knowledge integration into the participant's disciplines can affect the fact that the disciplinary assessment of the collective, transdisciplinary question is viewed positively if the developments and results of the transdisciplinary group are also relevant for the discipline. In order to strengthen the integration of the knowledge between the project and the disciplines, it appears sensible, for example,

"to relate the results of an interdisciplinary project to general questions and problems in the individual disciplines" (Arnold et al. 2014, 117). This strategy makes it possible to also pursue personal goals that may have a stronger disciplinary focus within the framework of a transdisciplinary "affair".

This section described some central influential factors that determine the course of a transdisciplinary project and the leeway in the promotion of knowledge integration. It is clear that the challenges resulting from them cannot be considered in full for designing the process of a transdisciplinary project and cannot always be successfully encountered. Awareness of these factors is, however, indispensable for an assessment of the degree of freedom that project participants have in transdisciplinary work and the actually available range for reflecting and coordinating support. In the "Rethinking Prototyping" project, they were constantly reflected upon and considered in the realisation of the research project. Against this backdrop, the following experiences from the implementation of this project shall be evaluated.

4 Transdisciplinary Research Elements in the "Rethinking Prototyping" Project

In addition to the previously outlined, generally systematic and actor-based factors for transdisciplinary collaboration, the specific realisation of the "Rethinking Prototyping" project will now be described here in more detail, particularly with regard to the formats and elements of collaboration that were used for the support and promotion of the transdisciplinary integration of knowledge. Initially, the fundamental project structure will be explained. It reflects specific framework conditions under which the implementation of the transdisciplinary collaboration was to be achieved in this project. Then the formats and elements of collaboration are illustrated in their form and realisation, and their effect on the integration of knowledge is assessed.

4.1 Basic Structure

"Rethinking Prototyping" was the first project carried out by the TU Berlin and the UdK Berlin on their joint transdisciplinary "Hybrid Plattform".[5] Transdisciplinary collaboration between various disciplines at the two universities was achieved on two levels in the "Rethinking Prototyping" project.

In each of the three sub-projects, research assistants[6] from at least two fields at the UdK Berlin and the TU Berlin worked under the lead of at least one professor at

[5]Cf. introduction to this book and the platform www.hybrid-plattform.org for more information.

[6]The term "research assistant" is understood to be the engagement of the involved architects, designers, softwaredevelopers and engineers.

each university and addressed individual aspects of the prototyping (sub-project level).[7] Furthermore, the overarching object of research was the question of whether there is a joint concept of prototyping (overall project level) (see Fig. 2). This question was formulated during the concept and application phase as, so to say, the *objective* and the *basis* of the joint research on the limits of the disciplines. The required agreement on the meaning of central terms, methods and concepts was tied on the one hand to theoretical discourse with the goal of defining the term prototyping. On the other, this theoretical-methodological reflection was understood as an opportunity to gain new ideas for research in disciplines that are in part not related to each other. In the initial project application concept, epistemological expectations were defined for the involved scientists and designers, but primarily application-oriented disciplines were represented in the project. Besides the claim to theoretical discoveries, there was also great interest in practical solutions.[8]

In the project application, coordination was planned to support the project by working with the heads of the project and closely collaborating with the research group. The project coordination level represented the organisational framework in order to determine and support the collaboration in the terms of theoretical and practical knowledge interests and to promote the integration of knowledge both on the overall project level and at the interface to the sub-project level (see Fig. 2). At the kick-off meeting to start the project, the formats for collaboration in the sub-projects and for all the participants, as set forth in the application, were specified for the entire course of the project, and their implementation planned. The formats were partially handled in a flexible way during the course of the project and successively adjusted to the existing needs in the project. Methodological impulses and offered formats for knowledge-integrating cooperation between the sub-projects on the overall project level were primarily developed and implemented by the coordinators (external organisation), but also came from the project participants (self-organisation), which increased accuracy and acceptance within the group. The desire for self-organisation required that the project participants address not only purely content collaboration, but also organisational-methodological issues in transdisciplinary collaboration, which consequently also made up a focal point of the joint meetings.

In designing the research process, the coordinators (on the coordination level) were always dependent on the participants' consent and the willingness to act. A particular challenge also consisted in the fact that not all the project participants were equally involved on the overall project level. The intensive exchange on the joint research question primarily took place on the level of the research assistants. They were subject to the instructions of the professors who were more heavily involved in the sub-projects. To make sure these instructions were in the interests of

[7]Cf. sub-project results from "Hybrid Prototyping", "Blended Prototyping" and "Beyond Prototyping" in Part II of this book.

[8]Cf. the system-theoretical analysis of the engineering sciences for more on this, additional information in Ropohl (2010).

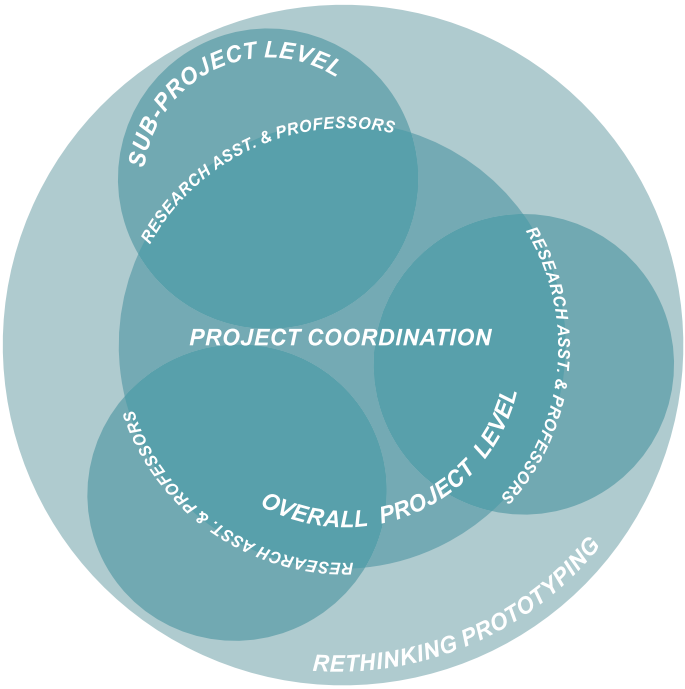

Fig. 2 Basic structure of the project "Rethinking Prototyping"

the project as a whole, the professor level was regularly informed about the integration processes on the overall level. This made it possible to simultaneously expand the circulation of knowledge integration to the involved institutes.

The parallel guidance of research collaboration and the methodological-organisational procedure with consideration given to the relationship between the overall project level and the sub-project level meant that the coordinators also had to take into account these supporting organisational frameworks. The cooperation between the research work level and the coordination level had to be balanced out over the course of the project and mutual expectations had to be clarified so that there was no confusion in terms of the respective roles and responsibilities in externally-determined and self-determined matters with regard to the form and content in the transdisciplinary research. The collaborative work between the two levels was developed in integrative collaboration that proved retrospectively to be very constructive for the integration of knowledge.

Fig. 3 Formats used in this research project respective to their effect on knowledge integration

4.2 Formats of Scientific-Creative Collaboration

The continuous reflection of the formats of collaboration was an important part of the coordinating support. In the course of the project, the formats were adjusted or supplemented on the basis of meta-discourses in order to intensify the integration of knowledge. The following presentation of the used formats is based on the degree of their effect on the integration of knowledge, beginning with the lowest (see Fig. 3).

4.2.1 Virtual Exchange

In projects across multiple institutions, the use of a web-based cooperation platform is important for internal collaboration. This is because it is possible to add and intensify the exchange of content on a virtual level, which makes organisation and documentation easier. For collaboration in the "Rethinking Prototyping" project, a co-working platform was set up after approval was given in the project group.

This encouraged the exchange of content by creating discussion forums for central terms in the project, for example.[9] Creating a comprehensive list of literature was also possible on the joint work platform. Furthermore, joint projects such as teaching events were also planned and subsequently addressed via the platform. The project group also virtually organised parts of the joint work process on the publication concept. For example, it developed and collected collective content for a prototyping quartet card game. The co-working platform also acted as a knowledge archive; the project meetings were documented and the work steps and results were recorded for the project participants. This happened, for example, via protocols and audio recordings of joint meetings or the archiving of presentations on the latest status of the sub-projects with brief summaries of the results from the discussions.

[9]It also initiated discussions of fundamental and higher-level questions such as "What does prototyping mean for you?" and encouraged the clustering of the results on the online platform.

In the course of the project, the co-working platform was viewed increasingly and, toward the end, primarily in its function as a knowledge archive and used for the documentation of the project through coordination. In regard to the potential for the platform to be a knowledge base for the integration of knowledge, the following retrospective challenges had to be addressed in the project.

The successful implementation of such a co-working platform assumes that its functions and its use are considered collectively as useful and it meets with broad acceptance in the team, and the team members are willing to use it. This was only the case to a limited extent in the project. We see the following reasons for this: In the actual course of this project, the theoretical discussions shifted somewhat, away from purely verbal exchange and increasingly toward the practical area of the joint prototyping, which functioned via personal presence. In the course of this shift, we saw the limits of the virtual co-working platform, which was less effective for this practice-based discourse on joint research questions and was also used less as a result. The documentation of the findings and results that the participants achieved in practice through their experiences would have required their linguistic or visual preparation. However, the participants' capacities and also their general willingness was lacking in the project.

In order to make sensible additions to the already existing, but separate institute-specific documentation structures (cf. Sect. 3), continuous use of the platform by all the project participants would have been important in order to guarantee completeness in content, for example. But it was difficult to establish this continuity since the consistently present capacity of the individuals was lacking for the updating of a double documentation structure (institutional and project-related). It was seen, however, that the motivation to use the platform was high in phases when joint work steps or joint projects were started (e.g. review conferences, joint public events, colloquia), but it remained sporadic and levelled off shortly afterwards. Knowledge documentation did not take place to a complete extent as a result.

Despite our only limited positive experiences, we are of the opinion that it is necessary to establish a joint level of knowledge management for transdisciplinary projects in order to virtually add processes of knowledge integration through this knowledge management. It is important to include the use of such platforms from the beginning in the planning of transdisciplinary projects and to set them up shortly after the beginning of the project. It should also be stressed that the sum of the individual, partially institution-related documentation (encyclopaedic integration) without integrative moments can still produce no knowledge-integrating comprehensive documentation. If the use of a virtual co-working platform is not solely motivated by archiving intentions, but should support knowledge-integrating processes, regularly-documented results should be continuously subject to further processing and moderated evaluation in order to activate the bodies of knowledge and let them systematically flow into the project work.

The motivation on an individual level, a fundamental willingness to use the platform, and available capacities for the respective project participants determine whether and how continuously updated virtual infrastructures are used for

knowledge-integrating collaboration in the project. Since separately set-up platforms can be completely new for all participants and thus go beyond the individual's customary information and work infrastructure, they require additional time and the willingness to learn how to benefit from the new structures and possibly discontinue or relearn personal work habits within the framework of the project.

4.2.2 Colloquia

Colloquia were held on both of the project's work levels. The small colloquia were focused on the involved research assistants and took place with the involvement of the project coordinators roughly every four weeks. All the project participants, meaning the research assistants and professors, were invited to the large quarterly colloquia.

Small Colloquia The format of the small colloquia initially had little influence on the sought synthesis of knowledge for a joint research result, but its integrative force strengthened over the course of the project. A greater exchange of knowledge could not take place solely by hearing the short oral reports and subsequent short discussions. In order to encourage this, expanded and largely free theory discussion was introduced, starting with text lectures. These discussion rounds that were focused on theory initially helped with understanding between the disciplines and sub-projects, but did not fulfil the playful-experimental interest in the project. They gave way to a practice-oriented exchange outside of the colloquia and in the form of studio or lab visits as well as *work in progress showcases* (cf. Sect. 4.2.4). Furthermore, the participants were able to engage in a more intensive exchange directly on their objects of research through *joint doing*, and thus understand their objects more deeply as a result.

The monthly colloquia also represented an instrument of coordination where the group could discuss organisational questions that arose from supporting the projects. Although these questions related to the process of actual research, usually involving formats for improving the integration performance, they were perceived more as an additional burden at the beginning. In the course of the project, the acceptance and joint responsibility for the co-shaping of the research design grew after the participants learned that they could influence the development of the project themselves in this way and thus also the results of the research. In the course of the project, the small colloquia established themselves as a framework for joint reflections on the research design on a meta-level (cf. Sect. 4.3).

Large Colloquia The large colloquia facilitated a transfer of knowledge between the research assistant level and the professors as well as between the sub-projects and the overall project level. The knowledge generated in the sub-projects between the respective professors and research assistants was largely inaccessible for the overall project level. In the large colloquia, it was possible to make everyone aware of the knowledge obtained in the sub-projects and to discuss it from new perspectives.

The presentations on the interim results of the sub-projects served as a basis for a more in-depth analysis in the small colloquia. Despite meetings for multiple hours, the available time was frequently not enough in order to conclude these discussions. Nonetheless, the additional perspectives of the professors from the other respective sub-projects initiated the integration of knowledge. These ideas were taken up and addressed collectively in other formats.

The effective involvement of the professors in the large colloquia required that the information flowed continuously from the level of the research assistants to the professor level within and between the partial projects and not only selectively on the occasion of the large colloquia.

A format for exchanging knowledge that was initiated by the research assistants consisted of the idea lectures held by the professors. They encouraged the integration of knowledge between the work levels. The subjects related more to the higher-level research question, for example, the prototyping methods anchored in the disciplines, ideal-typical processes and models of prototyping processes or various concepts in the terms model/prototype. The artefacts in *work in progress showcases*, for example, typical prototypes for the disciplines or specific interim results of sub-projects, served as *boundary objects*[10] for the encouragement of differentiation processes and synthesis.

Exchanging bodies of knowledge in the large colloquia between all the levels of research had a positive impact on the synthesis of knowledge for answering the joint research question. It can be assumed that this circulation of knowledge including all the participants also allowed new discoveries to be transferred to the individual, participating institutes and disciplines in terms of the two-directional impact of transdisciplinary knowledge integration.

4.2.3 Project Meetings with External Experts

On certain occasions, external prototyping experts[11] were invited to the large colloquia in order to analyse the developments in the sub-projects, comment on the interim results and enrich them with new points of view. They were supposed to provide inspiring perspectives on the subject or encourage creativity in the group as "free radicals". At the project meetings with guests, three formats were tried and

[10] *Boundary objects* in the literature on transdisciplinary research are central terms, concepts, ideas, plans, goals or also objects that are very important for all participants in regard to the collective research question or the collective issue, but are interpreted and understood differently. Their relevance as judged by all the participants establishes the interconnecting basis for communicating and mutually understanding the different meanings and interpretations of the *boundary objects*, whereby commonalities and differences arise from this. *Boundary objects* can initiate and promote the integration of knowledge. They act as transmitters and can, on the basis of differentiation and synthesis, lead to a collective understanding of the object itself, which represents a major basis for collaboration in transdisciplinary groups (cf. Bergmann et al. 2005, 44, among others). The term *boundary objects* was introduced by Star and Griesemer (1989).

[11] Cf. list of participating experts in this volume.

revealed varying integration potential: (1) theoretical presentations, (2) participation in the work in progress showcases of the research group and discussions on the basis of the presented objects, (3) workshops.

The discussions connected to the theoretical presentations given by the external lecturers were viewed as enriching. Additional contact to the lecturers probably would have caused them to have an even more extensive impact on the project. The frequency of these productive collisions in various stages of the project can be viewed retrospectively as potentially effective in order to accompany the project work not only selectively over the course of the entire project, but also continuously through an exchange with external lecturers as a source of inspiration.

As soon as *boundary objects* were available as a basis for discussion (format 2), the exchange between external lecturers and project participants intensified. As in the prototyping processes themselves, they made it possible to illustrate concepts, localise different views or problems and identify new ideas.

In the course of the workshops (format 3), the collaboration and exchange was the most intensive. This is how it was, for example, within the framework of a focus group[12] where two fundamental questions on prototyping were answered from the perspective of the practising engineers, designers, psychologists, humanities professors and philosophers. The project participants collected the perspectives gained in this multidisciplinary set-up, which amounted to an encyclopaedic integration, in a subsequent, project-internal workshop for analysis on the level of the intrapersonal integration of knowledge. The knowledge obtained together was also integrated into a joint text (cf. Israel et al. in this volume).

4.2.4 Workshop Visits and Public Showcases

Based on the participants' experiences of being able to discuss their research intensively and effectively by going into greater depth through joint design processes or visual demonstrations on objects, i.e. through *joint doing*, formats were introduced that encourage this type of transfer. Since the research in the sub-projects, with the exception of the mutual workshop visits mentioned above, was mostly conducted in a modular way, meaning in physically separate locations, the interim results were supposed to be combined in a general preview at regular intervals. This was achieved through formats at the interface to publicity such as elaborate presentations in public *work in progress showcases*. These exhibitions took place once during the "Long Night of the Sciences" in Berlin and twice at "Hybrid Talks", an independent format connected to the "Hybrid Plattform".[13] They presented a cross-section of the current state of the research. The integration

[12]Cf. Israel et al. on this method in this volume. The workshop took four hours and raised two questions: "What is prototyping?" and "What will the future of prototyping look like?".

[13]"Hybrid Talks" illuminate a subject in short presentations of roughly ten minutes from the perspective of multiple disciplines. The free exchange with the speakers takes place after the presentation.

potential of these public events was especially high since it led to concrete discussions on the exhibition objects of the sub-projects during the planning, development, execution and follow-up treatment. Another advantage of a joint exhibition room in which the objects are presented in parallel was seen in the juxtaposing that allows for direct comparison.

In the exchange with the interested public and thus with expertise outside of the field, the actual basis of research across disciplines is expanded even further to include disciplinary polyphony. "Hybrid Talks", for example, offered a framework for exchange with the Berlin creative economy and with external scientists and designers. The reflection on new and additional perspectives expanded the horizon of the participants' knowledge in regard to the joint research questions. Speaking about individual research in a public context helped with the finding of understandable vocabulary for field-specific and transdisciplinary results, which promoted the communication and language within the project team and thus the integration of knowledge. The "communicating of the scientific results in everyday language" (Krainer and Smetschka 2014, 78) is considered to be a central transdisciplinary competency that, within the framework of these events, advanced the multi-field competency of the scientists involved and thus also their ability to engage in intrapersonal integration.

4.2.5 Review Conferences

The review conferences were not planned in the application concept and were therefore not part of the project plan initially. The idea arose in the organisational and content constitution phase of the project. After the official commitment to fund the project and its start, the organisational structure had to be stabilised in a constitution phase and adjusted to the actual composition of the participants.[14] It was necessary to balance out the group dynamics and develop a joint scientific understanding of the project idea. These processes required intensive reflective support. This should allow that all the participants are aware of their own degree of freedom and that of others in the collaboration with respect to the described challenges in the scientific system (cf. Sect. 3). Based on this, a consensus should be reached on the

[14]The project and organisation structure should not be firmly set at the beginning of transdisciplinary research projects at universities. In this regard, it is necessary to briefly mention a general challenge for the organization of university transdisciplinary research projects: Since multiple months often pass between the filing of an application and the uncertain approval of an extensive project, the structures and participants for the project end up being not available at the time of the funding commitment. A basic structure for a transdisciplinary project must frequently be set up initially at universities, e.g. by hiring new staff, because the members of the application group do not have available capacities, for instance, or additional staff are required to realise the research plans. These upstream processes are both time- and resource-intensive and must largely be carried out in self-organisation and in a relatively short time before the official beginning of the project since in this phase the coordination (if planned) has usually not been determined yet.

achievable goals, and the research question formulated in the application for the project should be adjusted within the actual project group.

The colloquia for a certain period of time and at intervals of multiple weeks could not offer the framework for these processes. In the pertinent literature on transdisciplinary methods, reference is made to the time intensity and the additional effort for this (cf. Schmithals et al. 2011, 60, 70; Oppen and Müller 2014, 41). Furthermore, there was initially no awareness of this type of project constitution among the participants. Only during the project did the professor level inspire a change in course to self-reflection, which was supposed to provide more space and not be solely oriented on the contents. Particularly in the exchange with the accompanying researcher, a meta-level was established in the project where the project participants worked out important findings with regard to the collaboration and developed the idea of the review conferences with the coordinators. At intervals of roughly one year, two conferences took place, whereby the first, among other, important elements in the constitution phase were reviewed. Both conferences helped to ensure more in-depth understanding on each side, the professional-thematic exchange for the processing of the higher-level research question and the conceptual work on the joint ideas. Since it was the explicit wish of the research assistants[15] to dedicate themselves to the team building and intensive content work in a context without influential factors in everyday life, the two-day conferences took place in seminar rooms far away from the customary workplace. The isolation offered positive distance to the usual technologies and routine work methods and made the participants more open to new perspectives. A social aspect of the conferences that is important for group dynamics was also the fact that the evenings could be designed informally (cf. Schmithals et al. 2011, 32).

First Conference The first review conference was prepared and held in close collaboration with one external moderator and had two focal points: the optimisation of the project situation (team building, awareness of challenges in the context, cf. Sect. 3) and the content work on the joint research question. In the exercises and talks on the project situation, the participants addressed their personal scientific and creative backgrounds, interests, focal points in research and motivation. A stakeholder analysis revealed numerous influential factors through the large number of participants and the embedding of the project in various institutions. A potential analysis of the individual disciplines expanded the disciplinary characteristics of the cultures in the disciplines, raised awareness of stereotypical preconceptions and demonstrated specific strengths and weaknesses as well as supplementary and synergy potential between the disciplines. A capacity analysis

[15]The review conferences took place without the participation of the professors. This is to be understood against the backdrop that the research assistants wanted to meet far away from the influential factors in their daily life (cf. Sect. 3). The professor presence would have brought institutional connections with the implication of certain constraints and hierarchies into the context of a review conference. Only one guest professor from the UdK Berlin took part in the conferences since his function was to combine the two work levels.

made the available resources transparent. Starting from this, a new joint definition of the goal could be formulated on a minimum-maximum scale for the overall project level. The minimum goal was a traditional anthology of the results of the partial projects (encyclopaedic integration). The maximum goal included innovative sub-project results and knowledge synthesis in the form of a joint definition of prototyping, which should be published in an experimental format (intrapersonal integration). This self-formulated objective shows that the participants internalised the difference between multidisciplinarity and transdisciplinarity through the reflective process of the conference and derived clear transdisciplinary goals for the project. This first focal point of the conference also defined the project participants' awareness of the importance of continuous reflection on the work processes in the project over the long term, which had a positive impact on the ongoing collaboration and integration of knowledge.

The second focal point of the conference was on work related to the object of research. The idea of personal research interest brought new ideas for subjects and cooperation. The specific content work in regard to the joint issue of what prototyping is and how its concept can be reinterpreted was handled in a prototyping workshop: Initially, all the participants explained a typical prototyping process in their discipline and demonstrated this on the basis of the prototypes they brought with them. They also each presented a discipline-specific task, and in small discipline-mixed groups developed solutions in prototyping processes. Two observers documented the individual processes and simultaneously took down the central terms used in the communication. The respective scenario was recorded with a camera installed above the worktable.

The workshop was based on the concept of the *boundary object*,[16] which was the prototyping process in the conference. Individual prototyping processes formed the interconnecting basis for communicating and mutually understanding the different meanings and interpretations of *prototyping*, whereby commonalities and differences arise from this. In particular through the joint practical interaction, the diversity of the inherent concepts in the system of prototyping could be understood. The mutual understanding of each of the different meanings and processes of prototyping did not require any verbalisation. But it allowed in turn that previously, only implicitly available knowledge of each individual prototyping process and concept became known and explicit through joint experience in practice and was therefore to be verbalised for future collaboration.

The experiences and observations from these joint experiences in practice were evaluated after the end of the exercises: Terms such as prototype/model were considered in a differentiated way, and prototyping as a process rather than prototypes as objects moved to the centre of the analysis and consideration. A recapitulation and evaluation of the results from the first review conference took place in the second conference and were published in a joint article (cf. Exner et al. 2015).

[16]Cf. definition in Sect. 4.2.3, Footnote 10.

Second Conference The second review conference was designed analogously to the first. The only difference was that the conference was no longer co-designed and co-directed by an external moderator. We considered this to be a positive result of the intensive analysis on the meta-level for the project design. On its own, the research group implemented a high level of knowledge-integrating research work in collaboration with the coordinators after two years of joint research. In the second conference, the thematic focus was on the development of the concept of the final publication. Besides this publication, there is also a "package" that contains artefacts and multimedia elements that also offer additional access to research results on a popular-scientific level (cf. Ängeslevä et al. The Results of Rethinking Prototyping in this volume). The knowledge-integrating moment of the second conference was in the task of developing a joint concept for the final publication that must fundamentally be viewed as a significant element in transdisciplinary knowledge integration.

4.2.6 Joint Publications

Joint publishing of transdisciplinary research represents an important knowledge-integrating function that attaches significant relevance to transdisciplinary publishing.

In collective volumes of multidisciplinary projects, the integration of the knowledge and the synthesis are frequently left to the reader. Such a reader completes an intrapersonal integration through the lectures of individual, additively joined contributions and builds up cross references between texts that may be implicitly included, but were not addressed explicitly by the authors themselves or the editors. In the process of transdisciplinary publishing, this integration of knowledge does not take place outside of the research, but rather is done in the research process and also completed in the compositional and developmental process of the publication. The advantage is that the processes of intrapersonal integration primarily occurring in the individual also become visible and expressed as results in the text—and this finally makes the process of knowledge integration complete.

Making the results of the jointly completed synthesis of knowledge explicit in a publication requires that the project participants are willing to present experimental, i.e. atypical disciplinary solutions. This is because transdisciplinarily-formulated contents cannot be easily integrated into discipline-specific publication formats.

The "Rethinking Prototyping" project pursued a prototype for a transdisciplinary publication format in which the joint research work is visibly published for a broad public and for the corresponding scientific *communities*. Based on our experience, the value of such a transdisciplinary publication for the level of knowledge integration lies in three important functions.

Firstly, the final publication on the overall project level focuses the activities and the attention of the project participants on a joint project goal early on. It bundles and focuses the collaboration of the actors on a content and conceptual level and thus opens up a framework for action in which knowledge integration is a fundamental requirement for the successful achievement of this project goal—a simple anthology should not be produced at the end.

Secondly, the goal of developing a transdisciplinary publication format within the project team represents a joint task that opens up additional space for interaction and action in which the project participants enter into the exchange and into a process of collective creation. As a result of the fact that there is (still) no established transdisciplinary publication format, it was necessary to develop an appropriate prototype for the group. Since prototyping processes themselves achieve a high degree of knowledge integration by means of joint understanding through doing and intensive communication, high knowledge-integrating force can be attributed to the development of the publication format.

Thirdly, the joint writing must be viewed as an important cognitive means of intrapersonal knowledge integration: Through the process of writing, the bodies of knowledge that must be integrated on the text level are thought through again in more depth and renegotiated in terms of the goal of joint text production. The joint composition of texts on the higher-level research question is a method in order to re-express integrated knowledge on the intrapersonal level and to integrate all the discoveries of the involved authors in a semantic unit.

4.3 Accompanying Research

For successful collaboration in the transdisciplinary project group, it was a significant advantage that "Rethinking Prototyping" was analysed in the framework of the accompanying research on the "Hybrid Plattform" by the sociologist Maria Oppen (Social Science Research Center Berlin, WZB) in a dialogic form. The focus of her research was particularly on the communication processes in connection with the existing project structures.

The interviews and responses of the scientists offered a bird's eye view of the work processes in the project that led to a critical and productive self-evaluation. The accompanying study exposed very specific problems, bottlenecks as well as opportunities and potential. Of particular importance for the accompanying research in relation to the research project was:

> The respective abstract concept of interdisciplinarity considered to be self-explanatory […] was deconstructed and filled with specific building blocks of action by using observations from accompanying research. (Oppen and Müller 2014, 57f.)

Accordingly, it was possible to have a positive impact on the identified problems in the ongoing course of the project. Consideration of the processes from a self-reflective perspective, which were revealed to the scientists in individual talks

with the researcher, created an awareness of the challenges and problems in the scientist's own transdisciplinary research process, allowing and promoting active co-designing of the collaboration. In turn, this increased identification with the project and the acceptance of the developed and applied formats.

The process of self-clarification (cf. Heintel 2006 is a pre-requisite for the success of transdisciplinary research processes (cf. Lerchster and Lesjak 2014, 82). The connected "ability to self-analyse" (Lerchster and Lesjak 2014, 82) also falls under the multi-field competency described by Ropohl, which promotes intrapersonal integration. Establishing a corresponding functional reflection space as a meta-level within a research group may be the task of a (if possible) professionally trained intermediary or moderator (cf. Oppen and Müller 2014, 45). This person should have an awareness of the special challenges in transdisciplinary research as discussed, for example, in the accompanying research and here in Sect. 3, and be sensitised for the socio-communicative dynamism in the group (cf. Oppen and Müller 2014, 45). It would be an advantage if the person has "the ability 'to think outside' the traditional disciplinary cultures" and is "familiar with diverging worldviews and conditions for producing knowledge" (Oppen and Müller 2014, 45) in order to also reflect on these individually in the process and be able to mirror the project participants. In some projects, there are researchers who can adopt this role in part or in full. This task was partially handled by the coordinators and the accompanying research in this project. In the course of the project, this function was increasingly supported by the project participants who learned the multi-field competency for transdisciplinary action and implemented this in the co-designing of the process.

4.4 Conclusion: Factors in Successful Knowledge Integration

Some of the discovered factors that are beneficial for knowledge integration can apply to other transdisciplinary research projects in the university context. A normative consolidation of our procedure would be misplaced, however, since each transdisciplinary project is designed differently, has its "own logic and dynamics" (Oppen and Müller 2014, 65) and requires a certain flexibility in its execution and various approaches. This was also seen in the finding, testing, modification, iterative repetition and occasional problems in the methods and formats implemented in "Rethinking Prototyping". In this sense, each case of transdisciplinary research can itself be considered to be a prototyping process. Transdisciplinary research is a process of continuous optimisation, and after the conclusion of the project one can learn from it as a prototype for future processes. Retrospective reflection on the most important formats in collaboration makes it possible to determine the following factors that were required in particular for the integration of knowledge in the course of this special project.

Meta-Discourse: Reflections on the Research Process The shortcomings in the lack of methodology for interdisciplinary projects as quoted from Ropohl at the beginning (cf. Ropohl 2010, 5) could be balanced out in this project through continuous discourse accompanying the project on the meta-level, since the research process itself became the object of reflection. As the prototyping processes are reflective, communicative, iterative and recursive processes, this reflection, inherent in prototyping, is also mirrored in all transdisciplinary research in our opinion. It serves to optimise the research process, the research design and, in some circumstances, even the research question.

This level of self-reflection led to an improvement in the project participants' cooperative actions in this project. In the course of the three-year reflective process, they tested transdisciplinary, as opposed to multidisciplinary, work and co-designed the corresponding research design themselves. In particular, the dialogic accompanying research for the project reflected a significant role in the formation of this reflective meta-level in the project. Last but not least, discussions with the accompanying researcher promoted the development of a productive communication and cooperation culture.

Such meta-reflection requires a high degree of self-awareness from the project participants since they themselves are also involved in the process of collaboration that they should reflect upon and co-design. This means that the participants must be aware of the specific challenges in the overall context of the project in order to be able to judge, for example, their degree of freedom to design the process and the capacities.

The co-determination and freedom to design that result from this meta-reflection help to build an identity and strengthen the collective awareness for collaboration on the joint research question. As a result, the participants' willingness to concentrate on the transdisciplinary object of research at the edge of their discipline grows. The discourse on the meta-level also encourages the formation of integrative competencies among the participants in terms of the designed integration of knowledge and synthesis. In summary, the discursive meta-level in regard to discipline-overarching collaboration can be viewed as one of the central constituent factors in transdisciplinary research with a high degree of integration force.

Flexible Question and Openness for Results In the process of the spirally-running integration of knowledge (cf. Sect. 2.2), the research question is repeatedly scrutinised and modified, which can lead to a re-orientation in the project-related research. The shifting of the research focal point on the overall level from the theoretical approach to the gaining of knowledge through joint practical doing, as in "Rethinking Prototyping", provided an example of this modification. If the question or the objective is shifted in the course of the project, it is important that this change is prepared as collectively as possible in the project team and accepted by the largest possible number of project participants. If the personnel in the application group for a research project differ from the actual team for the research project, such a change can also encourage greater identification with the project and increase the motivation to work on a joint question. The research interests of the individual

participants may also shift during the course of the project, which can likewise require an expansion or adjustment of the developed research question in order to maintain the greatest possible intersection of the overall research interest. This means that the project participants must exhibit a certain degree of flexibility in their handling of the transdisciplinary research question and a fundamental openness for the results in the project.

Prototyping as a Method and "Understanding by Doing" The shift in the focal point of the work from the theoretical level to the practical level brought about an adjustment in the purely verbal exchange of non-verbal elements in the *joint doing*. In this connection, the joint prototyping proved to be a central knowledge-integrating method between the disciplines and thus a general method in transdisciplinary collaboration.

Implicit knowledge can be revealed by joint prototyping without verbal concepts since something becomes understandable, objectified and comprehensible through prototyping for which initially there is no joint language per se, as is typically the rule in multidisciplinary contexts. The method of prototyping in the work with boundary objects as, for example, in the workshop from the first review conference (cf. Sect. 4.2.5) can make mutual understanding easier and shorten the length of the formation of a linguistic basis of understanding. In this way, prototyping initially renders linguistic translation superfluous. The process of joint prototyping also leads to the development of prototypes that can represent a partial solution for a problem posed within the context of transdisciplinary research and represents an important basis for the general discursive integration of knowledge since:

> [f]irstly, the sensory-specific, motor-related, interactive reference to physical objects makes it possible for actors to create, combine, destroy and discard mental models of meaning units or speak about them and reflect on them (Adenauer and Petruschat 2012, 17).

Besides the previously described function in regard to the meta-discourse on transdisciplinary collaboration, this possibility of using prototyping underscores its knowledge-integrating potential once again.

Joint Spaces An important factor for the intensity of knowledge integration is space. Space is understood, on the one hand, as jointly defined conceptual mental and reflective spaces and, on the other, as real spaces in which scientists and creators act. Conceptual spaces fundamentally take shape when actors who have participated in mental processes are not at the same location. In the project, however, it was difficult to fill these conceptual spaces with life during the phases of distance. Since the knowledge integration is completed in these conceptual spaces, it was necessary to bring the participants together at collective locations that intensified the cognitive processes through personal exchange and joint doing. The conception and realisation of exhibitions, workshops and teaching offers, for example, satisfied this need.

The greatest intensity in the joint work was achieved in situations in which the group met at a secluded location shielded from systematically conditioned influential factors for a longer period of time. This made it possible for the

participants to mentally enter the conceptual room without any mental disruption and spend time there. From this it is possible to derive that for transdisciplinary research at least one collective space is of great significance for the research group in order to maintain the collective conceptual space.

This space should have important properties that distinguish it from the project participants' normal workplaces. Suitable spaces in this sense are "exterritorial […] spaces" (Oppen and Müller 2014, 46), which are not defined by one specific discipline and its research and working habits. In these spaces the attempt is made to relativise the existing hierarchies and the everyday work does not interfere with concentration on the transdisciplinary research (cf. Oppen and Müller 2014, 46). Ideally, these spaces allow for collaboration based on interaction and communication as well as withdrawn, concentrated work since this dualism is essential for creative and innovative stimulus in transdisciplinary work (cf. Phillips 2014, 99). The more time that is spent at these locations in order to open up collective knowledge space, the higher the degree of knowledge integration. Such space could be defined by a very independent work culture and create a truly transdisciplinary, third space between the participating disciplines. The Hybrid Lab,[17] which was available for the project in the last third of the project period, offered such a space. The review conferences corresponded most of all to this ideal space where at all times a conceptual or practical task was handled collectively and the space constellation isolated from the usual work environment brought about intensive intrapersonal integration. This had an impact beyond the conference itself, extending to the individual workspaces of the project participants, since an unparalleled rise in the capacities of the group was observed in the initial weeks after the review conference.

Besides these separate real spaces within the project, spaces at the interface to the public can also develop conceptual space and thus promote the integration of knowledge. There are spaces like the created *showcases* and exhibitions that expand the communication with external perspectives and focus and promote exchange with outsiders. The communication processes here, which were foreign to the disciplines and outside of science, require an expansion of the individual language on the object of research and promote the verbalisation and exchange of the gained experiences—central aspects of transdisciplinary multi-field competency.

[17]The Hybrid Lab is a space within the "Hybrid Plattform", which places this at the disposal of transdisciplinary project groups, among others. Various project partners and promoters, scientists and artistic staff at the UdK Berlin and the TU Berlin, members of the "Hybrid Plattform" Association (Hybrid Plattform e.V.) and the public come together here for the joint work or events. The Hybrid Lab is located on the Charlottenburg campus in the building EB of the TU Berlin.

5 Outlook

Our work demonstrated, in addition to other factors, the central importance of reflective analysis in transdisciplinary research on the micro level. Concluding this third part of the book, we also want to highlight its significance on the macro level and understand our reflections in a larger context.

The meta-reflective level taken up in this text on the project counters a phenomenon that is described as black boxing in the literature. At the end of an intensive research project, the sum of the steps taken, the entire way to the goal, appears to be self-explanatory (cf. Bammé and Spök 2014, 42): "[T]he process in the course of which the consensus was jointly produced is increasingly forgotten. It is invisible, so to say" (Bammé and Spök 2014, 42). We are persuaded that the interactions, dead ends and partial failure of this development process in successful transdisciplinary research should be reflected upon and documented for three reasons: (1) the reflection makes us aware of unconscious processes and contributes to the participants' reinforcement of acquired multi-field competencies. The documentation sets the findings in the reflective processes and develops a knowledge archive of experiences that all participants can rely on in future projects. (2) The documentation is also an orientation aid for future coordinators and supporters of transdisciplinary projects. (3) If each completed project is understood as a prototype (and simultaneously a product) of transdisciplinary research, this encourages a global prototyping process in transdisciplinary research in which the realisation strategies are tested, evaluated and optimised. In this context of prototyping, we can confirm the thoughts of Hubert Laitko:. He argues that trans- or "interdisciplinarity is not a local quality of the individual research process, but rather a global holistic disposition in an entire scientific system that is produced and reproduced by this" (Laitko 2011, 8). This global disposition must ensure that an individual's ability to think transdisciplinarily is formed systematically, continuously and in a controlled way. As a result, the goal is to enable participants in the transdisciplinary processes to create a synthesis, on the one hand, and to increase their potential, on the other, by bringing new and stimulating knowledge into the individual disciplines via intrapersonal integration. Furthermore, the prototyping process of transdisciplinary research must be theoretically emphasised and supported by the sub-systems of the scientific system.

For the "Rethinking Prototyping" project, the close collaboration with the "Hybrid Plattform" represented a supporting systemic requirement that is rarely found in the university context. Finally, reference is made to the particularly advantageous situation of coordination for the design of the meta level in the "Rethinking Prototyping" project, which emphasises the model-like character of the project. The success of the project was not solely placed in the hands of the scientists and creators; coordination was planned from the beginning. This was set up on the transdisciplinary "Hybrid Plattform" of the TU Berlin and the UdK Berlin, which facilitated the reflecting-moderating support of the project. Both the platform and the project benefited from the synergy effects that resulted from the

spatial proximity, organisational interweaving and the regular exchange of content. Particularly valuable for the coordinators was the access to the experiences of other transdisciplinary projects and participation in the accompanying research of the "Hybrid Plattform". Retrospectively, we view the "Hybrid Plattform" as making an important contribution to the global disposition of transdisciplinarity in the scientific system as postulated by Laitko.

In conclusion, it should be noted that: This project did not by any means run on its own, but was also not left alone in order to develop the desired transdisciplinary added value. The will and motivation that most of the project participants demonstrated in this project was an important basis for successfully conducting it. The additionally developed knowledge-integrating formats and instruments, the particular spatial advantages, the flexibly managed overall interest in the research and the significant meta level of the process reflection prevented this project from becoming an ambivalent interdisciplinary experience. Rather, it is possible to say here in summary that this complex and diverse project led to a successful transdisciplinary conclusion of the project.

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