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Design, one piece of the puzzle: A conceptual and practical perspective on transdisciplinary design

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Abstract: Transdisciplinary research is claimed to be essential in tackling today's complex societal challenges. Transdisciplinarity includes collaboration and integration across academic disciplines, non-academic ways of knowing, and the 'real world' of citizens, professionals and other stakeholders. Design can contribute to transdisciplinarity by framing complex challenges, integrating knowledge towards synthesizing solutions, and providing participatory practices to engage with the real world. However, for design to be successful in transdisciplinary research contexts, a better understanding of transdisciplinarity and design is required. In this paper I present a conceptual and practical perspective on transdisciplinary design. I show how design relates to three different conceptions of transdisciplinarity: a multi-level disciplinary practice, a participatory practice, and a practice focused on complexity and social learning. Furthermore, I propose a set of transdisciplinary competences that enhance designers' ability to contribute to tackling complex societal challenges, including epistemic intelligence, worldview awareness, power literacy and reflexive and dialogic skills.

Keywords: transdisciplinary design; complexity; epistemology; transdisciplinary competences

1. Introduction

The complexity and wickedness of today's societal challenges cannot be adequately tackled from the sphere of individual disciplines. While disciplines are essential to generate specialized and deep knowledge, the way we have set up higher education institutions into siloed disciplines, hampers the integration of knowledges required to tackle complex challenges. In addition, just academic knowledge is not enough to address real-world challenges. Instead we need *transdisciplinarity*, which "[integrates] disciplinary insights and non-academic insights of various sorts" (Repko & Szostak, 2017, p11). Such transdisciplinary (TD) work requires contextualized and experiential knowledge, which cannot be provided by "the generalising, decontextualising and reductionist tendencies of disciplinary inquiry" (Horlick-Jones & Sime, 2004, p. 445).

The term 'transdisciplinarity' has been around since the early seventies when it was discussed at a seminar on interdisciplinarity in universities in Nice, organized by the OECD

(Apostel et al., 1972). The goal of the event being to explore the "innovations required in universities to meet the intellectual and social demands of the present time" (ibid, p1). The term 'transdisciplinarity' has evolved since the seminar in Nice and many definitions of the term exist (see for an overview Pohl (2011) and Thompson Klein (2013)), but all definitions share a focus on socially relevant issues, and an approach that transcends and integrates disciplinary paradigms (Pohl, 2011). Ideally, TD research grasps the complexity of the issue, takes diverse perspectives of the issue into account, links abstract and case-specific knowledge, and develops descriptive, normative and practical knowledge that promotes what is perceived to be the common good (ibid).

The term transdisciplinarity is still becoming increasingly popular, evidenced by for example special issues and edited books in future studies (Lawrence & Després, 2004), technology innovation (McPhee et al., 2018) and design (Blessing et al., 2013), and also recently promoted by the OECD as an approach that "offers a practical way to address issues that are highly contested, and where stakes are high."(OECD, 2020, p9). At the same time, knowledge and expertise about TD research integration and implementation is fragmented and dispersed across different fields (Bammer et al., 2020).

As indicated in the call for this track at the DRS conference, the role of design in TD knowledge spaces has been claimed by designers to provide the 'binding glue' (Kelley & VanPatter, 2005). Additional roles of design found in literature include to serve as a 'broker' in TD work between science and industry through its people-centric approach, and supporting multi-stakeholder co-creation activities (Gonera & Pabst, 2019); to serve as a bridge between academic discussion and real-world problem solving (Dorst, 2013); to enable the envisioning of alternative futures and pathways to support co-learning in transdisciplinary teams (Hoolohan & Browne, 2019). Finally, design is one of the areas of scholarship proposed by Horlick-Jones and Sime (2004) to engage in what they call 'border-work' between scholarly inquiry and the sphere of tacit and experiential knowledges, particularly when design is "informed by ethnographic and other insights into human behaviour" (p445).

While design practices have clear strengths with regard to tackling complex societal challenges, I argue that rather than seeing design as 'the binding glue', it is also just 'one piece of the puzzle'. Applying design in TD contexts leads to various challenges. For example, a study by Gonera and Pabst (2019) of design applied in TD contexts, shows that these challenges include a lack of credibility of design research in the science field; tensions created by differences in desired project outcomes, i.e. publishable papers versus innovation outcomes; cultural differences in terms of mindset, language and tools; and the challenges caused by science-driven linear thinking versus the iterative non-linear process of design. To make the 'design piece' fit the transdisciplinary puzzle, I therefore argue that design needs to adapt to the space of transdisciplinary research and innovation by becoming more transdisciplinary itself. This includes developing a better understanding of the positioning of design in relation to the field of transdisciplinary studies – including the relation of the design discipline to

other academic disciplines and non-academic ways of knowing-, as well as supporting designers in building transdisciplinary skills, knowledge and attitudes. To contribute to this goal, I will present a conceptual and practical perspective on transdisciplinary design in this paper. The conceptual perspective is based on a literature review of transdisciplinary studies and includes an analysis of design in relation to three conceptions of transdisciplinarity. The practical perspective promotes a set of transdisciplinary competences that enhance designers' skills to work in transdisciplinary contexts. The competences are illustrated by examples from my own experiences in transdisciplinary education and research.

2. Design in relation to three conceptions of transdisciplinarity

To relate design to transdisciplinary studies and to other disciplines and ways of knowing, I here introduce three different conceptions of transdisciplinarity, based on similar categorizations as presented by Pohl (2011) and by Thompson Klein (2013). Please note that these categorizations do not focus on the difference between multi-, inter- , cross- and trans-disciplinarity, which has been discussed in other papers (Jantsch, 1972; Max-Neef, 2005; McPhee et al., 2018; Wright Morton et al., 2015).

The conceptions of transdisciplinarity that I present in this paper can be related to which ways of knowing are integrated in the conception, and how they are related to each other (figure 1). I here distinguish 1) knowledge as generated by academic disciplines, 2) real-world situated and experiential knowledge in relation to the complex challenge at hand, and 3) other non-academic ways of knowing such as indigenous and spiritual ways of knowing. Disciplines are "scholarly communities that specify which phenomena to study, advance certain central concepts and organizing theories, embrace certain methods of investigation, provide forums for sharing research and insights, and offer career paths for scholars"(Repko & Szostak, 2017, p4). Disciplines include the traditional disciplines of the natural sciences, social sciences and humanities, while disciplinary status is also claimed by the fine and performing arts and applied and professional fields (ibid, p5). Real-world situated and experiential knowledge in relation to the complex challenge at hand is knowledge of citizens, users, and stakeholders such as industry partners with regard to the complex problem situation from which the challenge emerges (Horlick-Jones & Sime, 2004). Finally, TD research also includes programs that reduce the gap between Western and non-Western traditions as well as esoteric knowledge and indigenous knowledge (Thompson Klein, 2004).

Figure 1. Three domains of knowledge that can be included in transdisciplinary research

The three domains of knowledge described above are integrated in different ways in three different conceptions of transdisciplinarity. The conceptions are based on the three groups of definitions of transdisciplinarity presented by Pohl (2011), which I define as: 1) multilevel, purposive transdisciplinarity, 2) participative transdisciplinarity as interaction between academic and non-academic stakeholders, and 3) transdisciplinarity as complex, emergent and embodied, supported by a social learning practice. In this section I will further elaborate on each of those three conceptions and discuss how the design discipline relates to these types of transdisciplinarity.

2.1 Design as knowledge integrator within multi-level, purposive transdisciplinarity

According to Thompson Klein (2002), of the three main concepts of transdisciplinarity presented at the OECD seminar in Nice in 1970, Jantsch' model of transdisciplinarity was the most influential. Jantsch (1972) developed a multi-level model of transdisciplinarity which was further refined by Max-Neef (2005). The model shows how disciplines each have a different purpose in a multi-level, multi-goal hierarchical innovation system aimed at a common human and social purpose.

The levels in the multi-level, purposive model of transdisciplinarity build up from a practical empirical level (what exists), via a pragmatic (what we are capable of doing) and normative level (what we want to do), to a purposive or value level: the level of meaning. Transdisciplinarity here considers integration across all levels: a multi-level, multi-goal co-ordination toward a common system purpose (Jantsch, 1972). Max-Neef categorised disciplines according to the four levels, and placed design explicitly at the normative level (what we want to do), see figure 3.

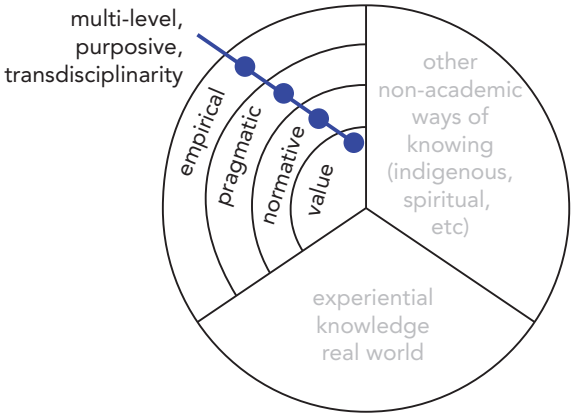

Figure 2. Multi-level, purposive transdisciplinarity is aimed at integration across the empirical, normative, pragmatic, and value level toward a common system purpose.

By placing design at the normative level, design is presented as a synthesizing practice within this multi-level knowledge system. As (Pohl, 2011) argued that TD research's purpose is to develop both descriptive, normative and practical knowledge, design would be predominantly aimed at this practical knowledge, integrating knowledge towards practical solutions. However, more 'academic' types of design as described by Dorst (2013) would also include informing descriptive and normative types of knowledge. At the same time, it can be argued that design is not just about the normative level, but that it integrates and often includes gathering knowledge across all levels, in particular design practices that adopt considerations of the ethical implications and societal impact of design (Vermaas et al., 2014).

The levels are not strict categorizations, as many disciplines bleed into other layers, e.g. it could be argued that architecture does not just sit at the pragmatic level as Max-Neef suggests. Jantsch (1972) furthermore describes how the four hierarchical levels are further subdivided into a fine structure of hierarchical sub-levels. What is essential is that these levels are coordinated and that "transdisciplinary concepts and principles for the whole system change significantly with changes in the 'overall system purpose'" (ibid, p105). The framework is also useful to position disciplines in relation to each other, and to raise awareness about epistemic differences. I will further discuss the need for such 'epistemic intelligence' in the next section.

Finally, Jantsch (1972) claimed that transdisciplinarity can be supported here by mutual enhancement of epistemologies in certain areas. Dorst (2018) presents a similar idea of mutual enhancement by describing how each discipline consists of various layered practices and that disciplines can adapt practices of other disciplines to break free from 'best practices' that do not work in complex and rapidly changing domains (see also Snowden & Boone, 2007). For example, Dorst (2018) describes how other disciplines can learn from the design practice of framing and more generally 'looking ahead', while at the same time design can learn from practices of other disciplines, e.g. the sophisticated practice of 'precedents' used in law to systematically deal with 'memory'.

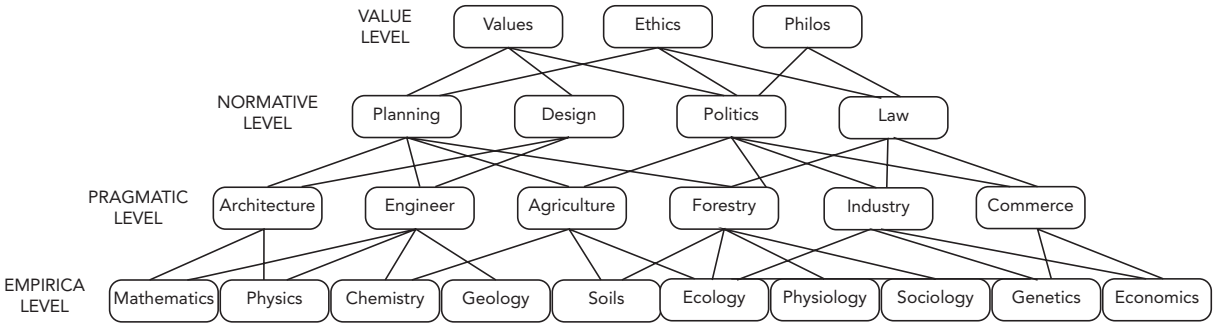

Figure 3. Example of how disciplines come together in a multi-level knowledge innovation system, adapted from Max-Neef (2005)

2.2 Design as collaborative practice in participative transdisciplinarity

While the multi-level perspective predominantly focuses on the relationship between and integration of academic disciplines, a more recent type of transdisciplinarity is focused on the relationship between academia, society and technology, and highlights the need for participation across sectors. This type of transdisciplinarity is based on the premise that societal problems need to frame research questions and practices instead of academic disciplines (Thompson Klein, 2013). Different practices have been proposed to promote participation of non-academic stakeholders, often referred to as 'participatory research' (Pohl, 2011). Mobjörk (2010) distinguishes participatory transdisciplinarity and consulting transdisciplinarity where the former concerns research conducted including all kinds of actors on equal terms in the knowledge production process, while consulting transdisciplinarity is about having actors from outside academia responding and reacting to the research conducted.

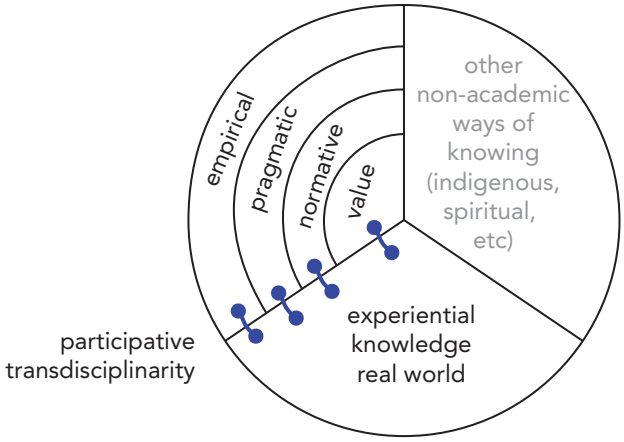

Figure 4. Participative transdisciplinarity is aimed at collaboration between the real world with experiential knowledge of citizens and other stakeholders, and researchers from academic disciplines. Different disciplines include different participative practices.

In this conception of transdisciplinarity, design plays a relevant role with its participatory practices. End-user participation in design processes has been common since the introduction of participatory design practices in Scandinavia in the early seventies (Gregory, 2003),

and over the past fifty years this has developed into an (academic) field of practice in its own right with an ever-expanding body of knowledge and its own community and platforms for knowledge dissemination. Participation has evolved from end-user only to broader groups of stakeholders. As such, the application of participatory design to TD contexts is a small step.

However, design is not the only discipline to include participatory practices (figure 4). In a previous study we, a group of colleagues from a transdisciplinary higher education organization, investigated what role participation plays across academic disciplines and fields of practice, what differences and similarities we can identify across these participatory practices, and what we can learn from each other's participatory practices (Baumber et al., 2019). These participatory practices include for example 'co-management' in environmental management (Berkes, 2009), 'socially engaged art' in the arts (Helguear, 2011), 'students as partners' in education (Mercer-Mapstone et al., 2017), and 'citizen science' in the sciences (Mitchell et al., 2017). Aspects on which these different disciplinary participation practices differ include for example the level of agency of the participating audience, the level of reciprocity in learning, the required expertise of participants (e.g. language and technology), context and setting of engagement with the audience, and the level of activism in participatory practices (Baumber et al., 2019). For example, in the article (ibid) I shared a reflection on how the agency of participants in participatory design tends to be restricted to the design phase and their power in synthesizing solutions is low, while for example co-management in natural resource management emphasizes ongoing co-management in which stakeholders (e.g. farmers) have high agency in adopting certain innovative management practices. An elaborate and nuanced analysis of what design can learn from these other participatory practices is beyond the scope of this paper. However, these examples show that participatory design is one of many different ways to have a non-academic audiences participate in TD work.

Another way in which design relates to the TD practice that sits between the academic and the real world is the 'academic design' practice proposed by Dorst (2013). Dorst argued that design as an academic discipline is fundamentally different from other academic disciplines, as its reasoning patterns (design abduction) differ from fields that are predominantly based on analysis (deduction, induction) and engineering (normal abduction). Design abduction includes 'framing' which, according to Dorst, is at the core of design, and can travel across disciplines (Dorst, 2011). In academic design, Dorst (2013) claims that framing can serve as a bridge between academic discussion and real-world problem solving. For example, Dorst described how the work at the Designing Out Crime research centre informed both real world public space design as well as contributing to academic discussions and new paradigms in criminology.

2.3 Design as part of a transdisciplinary social learning process

The third conception of transdisciplinarity does not start from particular combinations of disciplines and ways of knowing (i.e. multi-level and academic versus non-academic), but from

the idea that transdisciplinary knowledge can be characterized as complex, emergent, and embodied, based on Nicolescu's perspective on transdisciplinarity (Nicolescu, 2002). It includes people with any type of real-world, academic and/or non-academic knowledge (figure 5).

The complex and emergent perspective draws our attention to the continuous nature of tackling complex challenges. As we explain in a preceding article (van der Bijl - Brouwer et al., 2021), complex challenges cannot be solved with quick fixes, but instead require an ongoing engagement and experimentation with the complex context from which the challenge emerges, in an attempt to guide that context or 'system' into a desired direction. This ongoing transdisciplinary work also includes a continuous social learning practice in which knowledge and innovations co-evolve with the actors and practices involved in the work (ibid.). "The resultant TD knowledge is open and alive because the wicked problem the knowledge addresses is alive, emerging from the life world"(McGregor, 2014, p. 212).

The embodied perspective of Nicolescu on transdisciplinarity is explained by McGregor (2014) as follows: "TD methodology assumes that everything is *complexus* – woven into a web, where the focus is on the relationships, not on the separate parts. Emergence refers to novel qualities, properties, patterns, and structures that appear from relatively simple interactions among people in this web. [..] The resultant knowledge is characterizes as embodied, a part of everyone who co-created it, rather than discipline-bound or sector-bound."(McGregor, 2014). The outcomes of transdisciplinary research and innovation are therefore not just externalized and generalizable knowledge and improvements in the problem situation, but also include personal and mutual learning (Mitchell et al., 2015), and changes in human relationships (Kligyte et al., 2021).

Transdisciplinarity as complex, emergent, and embodied includes a focus social learning (Popa et al., 2015). Collins and Ison (2009) explain the difference between social learning and participation as follows: "the roles, responsibilities and purposes of those involved [in tackling complex challenges] have to be re-conceptualized, not as simply participation, "but as a process of social learning about the nature of the issue itself and how it might be progressed" (p369).

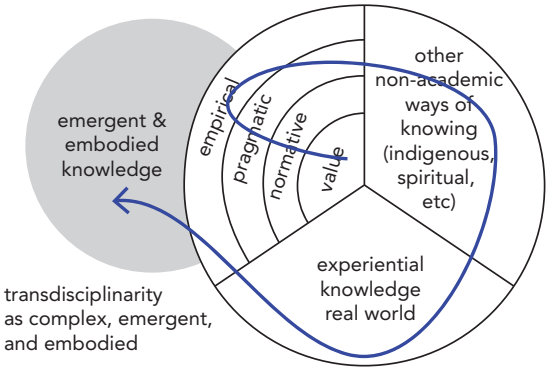

Figure 5. Transdisciplinarity as complex, emergent and embodied social learning includes people across all knowledge domains.

Studies about the role of design in social learning in TD contexts is scarce. Design has particularly been applied to design material or visual support for social learning. For example, Mellick Lopes et al. (2012) argue that design plays a critical role in facilitating social learning in TD research. They present a case in which visual design is used to support feedback loops between researchers and stakeholders in a complex system innovation project. In this case design is not just about problem solving, but about "seeking issues of concern through which to frame ongoing, provisional work within transdisciplinary projects"(p313). Another application of design in social learning is the design of serious games to include the diverse knowledge and values of all stakeholders (den Haan & van der Voort, 2018). Here, design is employed to create 'boundary objects' that enable social learning across boundaries generated by sociocultural differences (Akkerman & Bakker, 2011).

3. Transdisciplinary competences for designers

The conceptual perspective on design and transdisciplinarity as outlined in the previous section shows that design performs different roles in a TD context. While the nature of design is inherently transdisciplinary – integrating knowledge across different disciplines, and across the academic and non-academic world – I here argue that design can be used more effectively in TD contexts, if designers adopt transdisciplinary skills, knowledge and attitudes, or *transdisciplinary competences*. The transdisciplinary competences that I will present in this section include: epistemic intelligence, worldview awareness, power literacy, and reflexive and dialogic skills. I will illustrate these competences with examples from my own experience working in TD education and TD research. While these transdisciplinary competences are relevant to any academic or professional engaged in transdisciplinary work, I here specifically present them to a design audience to show how designers might be able to adapt to improve their contribution to complex societal challenges.

3.1 Epistemic intelligence

As outlined in the multi-level perspective on transdisciplinarity, such collaborations include integration of knowledge across all four disciplinary levels. An important challenge to overcome here is dealing with epistemological differences between disciplines across and within the four transdisciplinary levels. Crotty (1998) defines epistemology as the theory of knowledge that defines what kind of knowledge is possible and legitimate. In Crotty's knowledge framework, epistemology underlies the theoretical perspective, methodology, and method. The large variety in what is considered 'legitimate knowledge' across disciplines challenges collaboration across epistemologically different disciplines. For example, Gonera and Pabst (2019) showed the lack of credibility of design in science-based disciplines. TD collaboration therefore requires what I define as 'epistemic intelligence', the ability to recognize epistemological differences between disciplines and fields of practices, to accept and respect those differences and being able to explain those epistemological differences to others.

An example of how to start developing such epistemological intelligence is confronting students from different disciplines with each other's epistemologies. In a transdisciplinary undergraduate program, we asked students to develop a 20-minute learning activity for students of other degrees to learn about the unique ways in which their discipline contributes to research and innovation. They then participated in each other's learning activities, but before doing that we asked them to draw caricatures of professionals from the other disciplines, forcing them to make their preconceptions about other disciplines explicit. After participating in the learning activity, students showed each other their caricatures and engaged in dialogue about their preconceptions and what they had learned (figure 5,6, and 7).

Figure 5. Caricatures to make preconceptions about other disciplines explicit: preconceptions about architects by science students (left) and about business by media students (right).

Figure 6. Students of different disciplines engage in dialogue after participating in each other's learning activities

Figure 7. Design students developed a learning activity for students from other degrees: a game to escape from prison using the objects (book, pillow, plunger etc.), to articulate that design involves imagining and dealing with unexpected use.

3.2 Worldview awareness

To continuously address complex challenges requires 'inner work' and development of self-awareness "to work with people around issues that touch upon our deepest aspirations and our most deeply held beliefs" (Birney et al., 2019, p. 16). A particularly important aspect of self-awareness in TD collaboration is how our personal worldview is continuously determining how each of us feel, think and act (de la Sienra et al., 2017). De Witt et al. (2016) explain that worldviews are the fundamental 'lenses' through which humans see and filter reality.

"Worldviews not only tend to shape how individuals perceive particular issues and their potential solutions, they also tend to influence their willingness to partake in, or politically support, such solutions" (ibid, p.101). An awareness of worldviews in TD contexts where collaborating people might have fundamentally different worldviews in relation to the challenge at hand is therefore essential to promote productive dialogue and collaboration. This is relevant in any of the three conceptions of transdisciplinarity introduced in section 2. For example, in a TD project about public health (transdisciplinarity as complex, embodied, and emergent) we were confronted with the individualistic nature of our Western worldviews of health and medicine when working with Australian Aboriginal representatives who adopted a holistic and collective perspective on health and wellbeing (van der Bijl - Brouwer et al., 2021).

One of the ways in which I have started to teach about worldviews in my practice as TD educator in both higher education and professional practice is the worldview workshop, developed together with Katie Ross, based on the work of de la Sienra et al. (2017). In this workshop, participants experience two different worldviews in two different games: the world as a machine, and the world as networked reality. The world as a machine game is based on the Cartesian-Newtonian paradigm and as such reflects competition, reductionism, and determinism, while the 'world as networked reality' game reflects a more systemic worldview and is characterized by connection and emergence (figure 8). By combining the plays with the worldview test (De Witt et al., 2016), and collective reflections on the experience and test, participants become more aware of world views, their impact on collaboration in complex contexts, and develop a respectful attitude towards others' worldviews.

Figure 8 In the worldview workshop about 'world as networked reality', participants explore and visualize connections in the room

3.3 Power literacy

Another aspect of inner work required to tackle complex challenges is an understanding of positionality, privilege, and power both within oneself and within group dynamics (Birney et al., 2019). This is particularly relevant in the context of participative transdisciplinarity, the second conception introduced in section 2. In a recent publication, we argued that this requires designers to adopt a 'power literacy', as most designers lack awareness of, sensitivity

to, and understanding of how power dynamics and differentials affect stakeholders, the relations between them, and the social issues addressed in and through design (Goodwill et al., 2021). Power literacy plays a role in transdisciplinarity as power and knowledge are tightly interrelated (Avelino, 2020). Maya Goodwill developed a field guide with worksheet activities that helps designers develop power literacy skills (Goodwill, 2020).

3.4 Reflexive & dialogic skills

Reflexivity is often presented as an important social practice in transdisciplinary studies (Mitchell et al., 2015; Polk, 2015; Popa et al., 2015). It is particularly relevant to the third conception of transdisciplinary described in this paper - 'transdisciplinarity as social learning' - which highlights the complex and ongoing nature of TD work. Such TD work has many moving and evolving parts, including continuous change of knowledge about the problem space and possible intervention, the actors participating in the collaboration, the way they relate to each other, the research and innovation methods and practices they adopt, and the vision and purpose of the project or program (van der Bijl - Brouwer et al., 2021). In such fluid and evolving innovation work, reflexivity can provide a structure for learning. Reflexivity can be defined as an "on-going scrutiny of the choices that are made when identifying and integrating diverse values, priorities, worldviews, expertise and knowledge" (Polk, 2015, p114). Epistemic intelligence, worldview awareness, and power literacy can inform this reflexive practice. While reflexivity can be performed by individuals, it becomes particularly powerful in a TD context when reflexivity is executed as a collective inquiry, a creative process that generates new meanings, rather than being a 'passive reflection on the assumptions and values implicit in one's own understanding' (Popa et al., 2015, p. 48). A well-considered method is required to facilitate these types of reflexive processes; it does not simply emerge by completing project tasks (Kligyte et al., 2021).

Reflexive skills need to be integrated with dialogic skills. Dialogue is fundamentally different from a debate, presentation, or pitch, which is only aimed at transferring information from one person to another. Instead, dialogues are productive and creative. Participants in a dialogic conversation do not assume that they already know what the answer is, but they understand that the conversation can lead to new insights that none of them had before that conversation started. "The purpose of dialogue is to go beyond any one individual's understanding." (Senge, 1990, p. 223). Dialogue therefore also requires specific skills, including questioning and listening. Sennett (2012, p. 14) describes these listening skills as follows:

> "Usually, when we speak about communication skills, we focus on how to make a clear presentation. [..] Listening well requires a different set of skills, those of closely attending to and interpreting what others say before responding, making sense of their gestures and silences as well as declarations. Though we may have to hold ourselves back to observe well, the resulting conversation will become a richer exchange for it, more cooperative in character, more dialogic."

In (Kligyte et al., 2021) we describe how we applied such a reflexive and dialogic method in an innovation project aimed at improving student wellbeing, working in a team with students and staff with different disciplinary backgrounds. The method included regular reflexive team dialogue sessions. The reflexive sessions entailed discussions of shared readings, reflections on the challenge we were working on, and an analysis of our experiences of our collaboration. To inform the team dialogues we would write reflective statements about our personal learning and experiences, and share these with each other (see for examples Kligyte et al., 2021). Reflexivity helped us to surface and deliberate on our assumptions and values, including divergent perceptions of power dynamics within our team. For example, through this process, unproductive power dynamics between students and staff were confronted and dealt with early on.

3.5 Other competences

The above-mentioned TD competences are required to collaborate in complex contexts with people with different values, worldviews, perspectives, epistemologies and aspirations. Such 'boundary-spanning' TD competences need to be complemented with other skills, knowledge and attitudes to work in complex contexts. In addition to ongoing learning and integrating knowledge, TD practices include an action-orientation, ethical considerations, future-focus and holistic and systemic way of addressing complex challenges (McPhee et al., 2018). This requires additional TD competences including creative skills towards action; moral sensitivity and creativity; skills to develop visions for alternative futures; and an understanding of and ability to work with complexity and systems. These TD competences are useful to any researcher or professional engaging in TD research and innovation, including design researchers and design professionals.

4. Concluding remarks

Applying design to tackle complex societal challenges is becoming increasingly popular. Dorst (2015) argues that when disciplinary practices 'jump' to other fields of activity, they cannot be simply adopted without substantial change, but should be adapted to the needs in the target field. This includes an adaptation of design to transdisciplinary contexts. Rather than presenting design as 'the binding glue', design here is presented as a 'piece of the puzzle', while transdisciplinary, boundary spanning practices are required to make the piece fit. At the same time, it requires a clear perspective on what the metaphorical design puzzle piece brings, what other pieces look like, and what the main image of the puzzle is that we want to create, the purpose of our TD work. Rather than a one-size-fits all puzzle piece, such applications require a crafting and adaptation of the practice to the situation and purpose at hand. Ongoing learning, supported by reflexive and dialogic practices are at the core of this transdisciplinary design practice.

While the perspective presented in this paper is conceptual and based on personal experiences, more research into the role of design practices in transdisciplinary context is required. In addition, I propose an educational agenda aimed at developing design education

towards transdisciplinarity. This requires providing students with the experience to work on real-world challenges in multi- and trans-disciplinary teams, and developing educational programs aimed at the transdisciplinary and boundary spanning competences presented in this paper.

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