Inter- and Transdisciplinary Learning – Theory and practice

Nikki Brand, Marcel Hertogh and Fransje Hooimeijer

Contemporary societal challenges demand an approach to urban infrastructure, environment, and mobility projects that integrates a variety of fields of expertise and different organisations. However, in academia, a sector known for its specialisation, professional expertise is often even more segregated in disciplinary silos than in practice. This segregation may explain academics' concerns about a possible lack of positive societal impact and the drive towards inter- and transdisciplinarity (ITD) by many universities. In the case of the Delft Deltas Infrastructures and Mobility (DIMI) portfolio, transdisciplinarity was embraced in academic projects to align with the required societal impact. Moreover, a prerequisite for the projects was the involvement of both societal organisations (public, private, social) along with the scientific, and the various relevant disciplines.

But what do inter- and transdisciplinary collaboration and learning entail in theory and practice? This section explains key concepts of ITD and their theoretical background, as there are different perspectives on these notions and how they are understood. More importantly, we focus on three fundamental issues of ITD that are often underestimated: task dependency and integration as key variables to distinguish between multi- and interdisciplinarity, the use of shared or 'boundary-crossing' deliverables that enable such integration, and the variety of integration processes in practice. To conclude, we arrive at the hypothesis that for all organisations, public, private, academia, and society, to build positive societal impact, a closer, detailed analysis and practice of knowledge integration processes should be on the agenda.

Trans-, Multi-, and Interdisciplinarity: Task Dependency and Integration are Key

Contemporary societal challenges demand an approach to urban infrastructure, environment, and mobility projects where a variety of fields of expertise and organisations work together in a knowledge consortium to enable the making and realisation of different design decisions. Interdisciplinarity, as a mode of knowledge production that is effective in addressing and 'solving' challenges with the ambition of sustainability, has been an academic policy goal for decades. Unlike multidisciplinarity, *interdisciplinarity* refers to a way of working where there is task dependency between contributions from different disciplinary origins. For reference, see Nissani's 2004 textbook paper on 'fruits, salads, and smoothies'; or Bammer et al. 2013, *Disciplining Interdisciplinarity*.

Transdisciplinarity can be viewed in two ways: first, as referring to the highest rank in a hierarchy of stages of integrated cooperation (e.g., September 2018) or, as this publication adopts, as a cross-sector way of working where contributions from academic and societal partners are combined. This is a natural approach for some academic fields, such as urbanism and governance, which work with practice and what is known as 'grey' literature, including policy briefs. However, for more fundamental technical expertise that is further removed from practice, referring to 'trans' only occurs when using grey literature.

For this reason, inter- and transdisciplinary approaches are often used interchangeably and referred to collectively as 'ITD'. In this publication, the label 'trans' specifically indicates cross-sector involvement with practice, not the level of interdependency, while 'inter' denotes a high degree of interdependence, but not necessarily if multiple organisations were involved. The term transdisciplinarity is often employed to anticipate a significant difference between the types of expertise that are expected to collaborate, suggesting it is more challenging to work across organisations than between departments within the same organisation, such as a university.

Within the Delft Deltas and Infrastructures & Mobility Initiative, both boundaries are considered very challenging. Since societal challenges necessitate interdisciplinarity and collaboration with societal partners, DIMI has adopted transdisciplinarity to achieve a positive societal impact more swiftly.

The collaboration in transdisciplinary strategies within research can manifest in two main forms: multi- or interdisciplinary. In urban infrastructure, environment, and mobility projects, monodisciplinary approaches are not prevalent, though they may occur in research projects. In a multidisciplinary context, contributions are pursued either parallelly or sequentially (without and with task dependency, respectively), leading to assembled outcomes without the imperative of integration, such as financial or smarter solutions. However, multidisciplinary projects, such as road maintenance, do exist.

Interdisciplinarity involves combining cross-sector contributions to ensure task dependency, resulting in shared, integrated outcomes. This approach is common in the DIMI portfolio. However, this does not imply that interdisciplinary is inherently 'better' than multidisciplinary; the appropriateness of each depends on the nature of the challenge. Moreover, if a multidisciplinary approach suffices, complicating matters by opting for interdisciplinarity is unnecessary.

This discussion is pertinent, given academia's challenges in facilitating interdisciplinary learning. Several factors contribute to this, including biases against scholars specialised in interdisciplinarity during recruitment and assessment procedures in academic departments, and key differences in language, methods, notions of validity, and general culture between disciplines – especially between the exact and social sciences (EURAB, 2004; National Academy of Sciences, 2005; Balstad, 2010; Von Wehrden et al., 2017). Based on Pfirman & Martin (2017), scholars specialised in interdisciplinarity often find themselves frustrated by the underestimation of the coordination load and transaction costs associated with ITD. This suggests that many efforts labelled as interdisciplinary are, in fact, multidisciplinary. For that

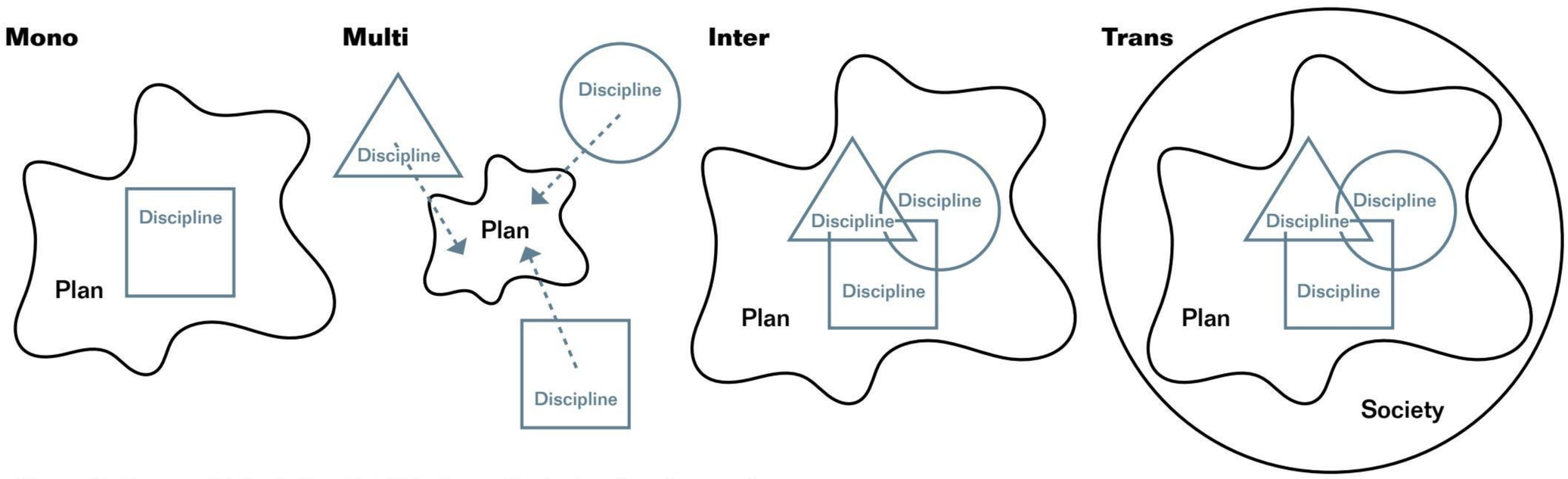

Figure 2: Forms of 'disciplinarity' This figure illustrates four forms of disciplinarity, with transdisciplinarity depicted as interdisciplinarity, enclosed in a circle of relevant actors from society. Transdisciplinarity may also appear in combination with multidisciplinarity.

reason, Von Wehrden et al. (2017) argue that presenting projects as multidisciplinary remains common, and academic policy tends to reward the premise of ITD rather than the hard work it entails. This risks diminishing the credibility of genuine interdisciplinary work and dismissing the value of interdisciplinary learning for the wrong reasons (Brand & Hertogh, 2021).

The projects featured in this publication are both inter- and transdisciplinary. For instance, in the Yuriage case, student teams developed an integrated approach to post-tsunami reconstruction, engaging with various disciplines and local stakeholders. Similar collaboration was evident in the Texas case and the City of the Future project, where teams explored alternatives for coastal protection for Galveston Island and Dutch cities, respectively, alongside local stakeholders. Other more interdisciplinary examples include 'research-by-design' studies, such as the prototypes for the bio-based bridge and the solar-powered charging station.

To mitigate confusion and acknowledge academics who genuinely want to integrate knowledge across disciplines and organisations, a more precise, day-to-day understanding of distinguishing between inter- and multidisciplinarity is called for. We argue that interdependence (task dependency) is a critical variable in this differentiation: there is no recognisable knowledge integration if the outcomes of one task do not influence the outcomes of another. This brings us to the second fundamental: the importance of shared deliverables. Such deliverables help us identify genuinely interdisciplinary products and offer insights into how integration functions in practice.

The Importance of Shared or Boundary-Spanning Deliverables

Knowledge integration is facilitated by working together on a shared deliverable. Understanding the importance – and the challenges – of creating shared deliverables, where diverse forms of expertise are brought together, can be partly illuminated through the boundary-spanning theory. Slob and Duijn (2013) identify four key conditions within the concept of the boundary-spanning theory beyond merely recognising the premise and boundaries: the boundary-spanning objects, boundary spanners, and the boundary-spanning process. These elements are indispensable for a joint production process.

'Boundary-spanning objects' can take various forms, such as maps, action plans, or policy notes, yet they all share common characteristics: they 'connect involved communities', contain knowledge, and provoke action. Notably, boundary-spanning theory seems tailor-made for communities of practice because of cultural,

Concepts in boundary-spanning theory		Examples from the organisation of the DIMI portfolio
Premise	Communities are separated through boundaries that hamper communication and joint action.	Academics are rewarded within their disciplines (e.g., journal articles, funding); Practitioners work mainly from 'siloed' organisations.
Boundaries	Perceived boundaries between communities that are different in terms of organisation, culture, geography, etc.	Ways of working (routines); language (jargon); separation of location (buildings); attitude, unfamiliarity; existing workload.
Boundary spanning	Activities undertaken to cross boundaries, such as communication or joint activities.	DIMI as a facility, directly supported by the board of the university; Introduction of DIMI Special Projects for ITD collaboration; DIMI seed money for DIMI Special Projects; community building within the university, and with societal partners on societal challenges; facilitating joint activities (e.g., conferences, training courses, interdisciplinary student teams, publications, website).
Boundary-spanning objects	Tangible products of joint activities that satisfy the communities involved, such as maps, action plans, policy notes, etc., because they contain knowledge and provoke action.	Development of ITD methods, such as the 'research by design' series; development of interactive ways of working (e.g., Yuriage); dissemination of effective methods, tools, etc., across the DIMI community.
Boundary spanners	People who cross boundaries and intermediate between different communities. They may, for instance, be accepted in this role by the communities involved because they are part of those communities.	DIMI programme team; coordinators of DIMI special projects; 'self-motivated' colleagues who want to collaborate despite the discipline-oriented rewards within their organisational unit; professionals from sectors with enthusiasm for ITD working to achieve societal impact.
Boundary-spanning processes	Processes that are needed in order to produce the boundary-spanning objects with the communities involved.	Development and communication of dissemination tools; Long-term community building within academia and with societal partners.

Figure 3: The most important concepts of boundary-spanning theory (Slob and Duijn, 2013).

geographical, or organisational boundaries that hamper communication. This theory equally applies to inter- and transdisciplinary communities of practice, where the primary goal is knowledge production, and action is secondary.

This observation presents two issues. Firstly, within the academic sphere, with its emphasis on peer-reviewed journals, what type of boundary-spanning object effectively connects the involved disciplinary sectoral communities? Does this differ in integrative efforts across different sectors, where a wider variety of shared deliverables might be both possible and welcomed? And does the key to successfully facilitating transdisciplinary collaboration, involving both academics and non-academics, lie in diversifying accepted academic output beyond peer-reviewed publications to include those with societal impact and learning? Ultimately, does the potential for knowledge integration not increase significantly with transdisciplinary efforts?

The second issue that emerges when applying boundary-spanning literature to understand ITD focuses on specific collaborative roles. Slob & Duijn (2013) highlight the role of 'boundary spanners', individuals who intermediate between different communities through additional communication efforts and joint activities. This concept closely aligns with Hargadon's (1998) definition of 'knowledge brokers' as "individuals or organisations that profit by transferring ideas from where they are known to where they represent innovative new possibilities." Both concepts underscore the critical tasks that foster cross-communication across organisational boundaries (Slob and Duijn, 2013).

This concept also resonates with the notion of interdisciplinary scholars bearing an additional coordination load and social transaction costs, as described by Pfirman & Martin (2017). These efforts are challenging and "prone to bias and distortion" due to excessive specialisation within organisations (Tushman and Scanlan, 1981), a phenomenon exacerbated by the division of labour aiming to boost productivity as one of the basic economic concepts. "Specialisation and the existence of organisational boundaries are also associated with the evolution of local norms, values, and languages tailored to the requirements of the unit's work" (Tushman and Scanlan, 1981). These localised norms, values, and languages also hinder communication and interaction during urban development processes and thus stand in the way of knowledge transfer. There should be a conscious act in an interdisciplinary approach to overcome the fact that "individuals use different meanings in their functional setting" (Carlile, 2002).

Given the variety of boundary-spanning objects and processes, it stands to reason that boundary spanners also come in many forms. Hoffman et al. (2017) introduced the concept of integration specialists in ITD projects. Unlike traditional academic settings where all experts are expected to have integration expertise and organically contribute to the integration process, these specialists assume a leadership role, managing more responsibilities and potentially making independent intellectual contributions beyond mere group facilitation (Hoffman et al., 2022).

This brings us to the last point: variation of integration processes in practice. The next section illustrates these theories with examples from the DIMI portfolio, such as the bio-based bridge and the solar-powered e-bike station.

Variation of Integration Processes in Practice

A closer analysis reveals that variations in shared deliverables and the division of labour in transdisciplinary work are evident. For instance, analysing the design process of two prototypes and a research-by-design competition within the DIMI portfolio indicates that integration in the front end of the boundary-crossing process facilitates effective interdisciplinarity.

Consider the ***bio-based bridge project*** (P 148). A clear division of labour among the cross-sectoral partners was made, with specific tasks assigned according to

expertise in production methods, circular economy, and structural and engineering design. This collaboration involved two universities, a centre of expertise, and an engineering company. Schuylenburg (2019) detailed the design process phases. For the bio-based bridge, where an unorthodox material was used to build a prototype, testing occurred between the 'conceptual design' (integration testing) and the 'detailed design' (unit testing), which ultimately resulted in the 'building design'. This approach allowed for the collective organisation of work while managing uncertainties about the material's behaviour. The design acted as a boundary-spanning object, and the multidisciplinary design process served as a boundary-spanning process.

A different integration process unfolded for the ***solar-powered e-bike station*** (P 138). Here, labour was divided among experts in photovoltaic system design, electric systems (including circuit & inductive charging), mechanical engineering, software support, and administration. Construction, especially the assessment of structural reliability, was outsourced. The building design served as a boundary-spanning object for all partners except the construction firms, for whom the actual prototype was the final deliverable.

The division of labour and design process for the bio-based bridge and the solar-powered e-bike station showcase significant differences, partly due to the distinct expertise required for each project. A notable distinction lies in the design process phasing. In the bridge project, iteration was planned during the 'integration testing phase', between the conceptual and the building design. Conversely, site changes in the e-bike station project resulted in new expertise requirements, causing delays and an unexpected iteration round.

Schuylenburg (2019) suggests that early integration or engaging in interdisciplinarity at the 'fuzzy front-end', enhances project performance by preventing unnecessary delays and reducing costs. Anticipating iteration, along with the associated coordination and social transaction costs of aligning expertise at a specific stage of the boundary-crossing process, appears to boost knowledge integration. This is achieved by transitioning from a broad initial concept to a detailed shared deliverable.

More variation in integration processes can be observed for the research-by-design competition of ***City of the Future*** (P 174). Based on the reconstruction of the design processes from several teams, Kroese (2019) observed differences not so much in the phasing but in the leadership of different forms of expertise throughout the process. Unlike the first two cases discussed in this section, the range of expertise in the teams was extended to include insights from the social sciences. In addition to this 'wide disciplinarity', the integration process introduced a new dimension, aiming not for a working prototype but for an interdisciplinary design incorporating knowledge from non-design disciplines.

Kroese observed three distinct approaches to expertise dominance within the teams, each leading to different outcomes:

1. **Designers in the Lead:** This approach saw urban designers taking the initiative to integrate expertise from non-design team members. The result was a compelling, integrated design, although the narrative explaining the design choices was somewhat limited.

2. **A Specific Design Discipline in the Lead:** (i.e. transport): Here, the particular design expertise – transport – was prioritised, and other forms of expertise were integrated afterwards. This led to an integrated design where other land uses were adapted to support a dominant function (transport), employing a strategy known in urban and land use planning as 'co-coupling'.

3. **No Dominance:** In some teams, no single form of expertise was dominant, resulting in multiple iterations of the design narrative and a less defined integrated design. Strikingly, in these cases, the narrative detailing the design considerations was more detailed than the design itself.

Two key considerations emerge from these rough reconstructions of integration processes in practice:

1. **Phasing of the Shared Boundary Crossing:** Understanding trans- and interdisciplinary learning and the role of integration within these contexts underscores the importance of the deliverable's phasing. This approach allows for the gradual matching of diverse forms of expertise through a trial-and-error process. It helps avoid the potential time loss incurred by adding too much detail early on for a shared concept that may later prove flawed. In other words, **by anticipating failure at the 'fuzzy front-end', collaboration is rendered more effective.**

2. **The Impact of Leadership and Dominance:** The nature of leadership and dominance within a team seems to **affect the form of the boundary-crossing deliverable.** Teams led by designers tend to create more elaborate designs, whereas teams without a clear dominance focus more on creating detailed narratives and less elaborate designs. This observation aligns with the composition of these teams, which often include an equal mix of design and non-design expertise.

The case studies in the DIMI portfolio reveal that integration processes are predominantly design-oriented, with designers frequently assuming leadership roles. This observation supports Van Buuren's (2023) assertion that design processes inherently involve integration since the main deliverable – the design – cannot be realised without it. The degree of integration, the diversity of knowledge, and the deliberate use of design as a boundary-crossing object to foster transdisciplinary learning vary widely. Basically, all designers have the potential to act as boundary spanners, and examining how knowledge integration unfolds in design processes can offer valuable insights into integration processes in general.

Concluding Words: a Closer Look at Design *and* Practice

In general, it can be noted that interdisciplinarity demands an open attitude of the people working from distinct disciplinary focuses, as well as across different organisations, to integrate goals, concepts, and measures effectively (Hooimeijer et al., 2021). In contrast, transdisciplinarity is centred around the integration of academic research with professional practice, requiring a unified approach to intellectual frameworks that transcends disciplinary boundaries (Huutonieme et al., 2010). Notably, literature often emphasises the diverse disciplinary origins of knowledge within academia and their interrelationships. However, there is less focus on the variety of contributions from societal actors.

While it is acknowledged that societal actors can contribute in varied forms throughout the research process (Schmidt et al., 2018; Chambers et al., 2021), these contributions are frequently presented as singular and unfragmented. The epistemological variety of societal inputs – ranging from professional to lay knowledge – may be significantly broader. Furthermore, even within individual societal actors, knowledge may be fragmented.

To conclude, we would like to make a case for a more detailed examination of the differences and similarities in knowledge integration within academia and, more importantly, beyond its boundaries.

going beyond boundaries

Colophon

EDITORS
Marcel Hertogh
Fransje Hooimeijer

CONCEPT DEVELOPMENT
Marcel Hertogh
Fransje Hooimeijer
Nikki Brand
Carola Hein
Baukje Kothuis

ENGLISH EDITING & TRANSLATION
Henriette Schoemaker

COORDINATION
Minke Themans

GRAPHIC DESIGN
Studio Minke Themans

PRINTING
G.B. ’t Hooft bv, Rotterdam

BINDING
Binderij Van Wijk Utrecht BV

This publication is funded by the TU Delft Delta Infrastructure and Mobility Initiative (DIMI)