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Herding cats: integrative leadership strategies in inter- and transdisciplinary research programs

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Abstract

This paper focuses on the critical role of integrative leadership in inter- and transdisciplinary (ITD) research programs. ITD programs have become one of academia's responses to address contemporary sustainability challenges. Fulfilling the promise of such programs is extraordinarily challenging for all involved participants, but especially for program leaders who have to ensure that the perspectives of the involved program participants become truly integrated and that final and useful synthesis outputs are created. We present six core leadership challenges and respective strategies to address them to advance integration within ITD programs. These challenges include (1) mastering complexity and ambiguity, (2) advancing decision-making with lateral leadership, (3) ensuring responsibility and accountability, (4) setting program boundaries, (5) selecting suitable projects, and (6) dealing with misconceptions. We derived these challenges and respective strategies from both leading and studying in-depth three ITD programs focusing on sustainability issues in Switzerland. With this paper, we intend to promote awareness about the range of leadership challenges in ITD programs and provide actionable knowledge, which can support in particular fellow and future leaders, but also funders and heads of research institutions in their efforts to realize the integrative potential of such programs.

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Graphical abstract

HERDING CATS

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Introduction

Various studies have argued that inter- and transdisciplinary (ITD) integration does not happen automatically, but needs to be proactively led (Berger 2019; Caviglia-Harris et al. 2021; Defila et al. 2006; Deutsch et al. 2021; Gray 2008; Hoffmann et al. 2022b; Lyall et al. 2011; Oliver and Boaz 2019). While interdisciplinary research intends to integrate the knowledge of different disciplines to address

joint complex research questions (Klein and Newell 1997), transdisciplinary research aims to integrate the perspectives of actors from science, policy, and practice to address complex societal problems (Hirsch Hadorn et al. 2008). What distinguishes multidisciplinarity from inter- and transdisciplinarity is that the former does not include the proactive step of integration of different perspectives (Klein 2010). We define integration as a process where different and previously unrelated perspectives interact with each other and assembled into something new (Pohl et al. 2021). Outcomes can include, but are not limited to, a new or more comprehensive understanding of a complex problem, novel solutions to such problems, or new institutional partnerships (Westberg and Polk 2016). Outputs can entail, for example, inter- and transdisciplinary publications, policy briefs, or synthesis videos tailored to different target audiences (including recommendations and potential ways forward) as well as new methods or tools (Hoffmann 2024). 'Synthesis' is thereby one type of integration, which is pursued with the purpose of creating the final targeted products (Hoffmann et al. 2022b).

Leading large-scale ITD endeavors has continuously evolved throughout the last years from being an avocational, on-top-of-things position toward a full-time position in itself (Defila et al. 2015). This can be explained, among other factors, by an increase in major ITD programs on supranational (e.g., Horizon 2020 or Interreg Alpine Space Program by the EU), national (e.g., the German Excellence Initiative, national research programs in Switzerland) (Defila et al. 2015; Kloet et al. 2012), cross-institutional (e.g., Joint Initiatives within the ETH Domain), and institutional level (e.g., strategic focus areas by universities or institutes such as Extremes and Wings; see "Method" section). However, leading an ITD team through an integration process bears often underestimated challenges, as leaders need to make 'extraordinary efforts' (Volckmann 2014, p. 254) on a cognitive level (e.g., bridging different disciplinary or professional knowledge fields, including their related languages, methods, and logics) (Hendren and Ku 2019), social-interactional (e.g., fostering a group identity, finding complementary team roles, and dealing with different working styles and expectations) (Boix Mansilla et al. 2016; Hoffmann et al. 2017b; Klein 2014), as well as emotional level (e.g., creating a positive and respectful atmosphere to ensure psychological safety) (Boix Mansilla et al. 2016). These efforts are essential for boundary-crossing ITD endeavors to thrive in their multi-dimensionality (Pohl et al. 2021). These challenges are further increased in the context of research programs, where program leaders not only need to ensure integration at the program level, but often also need to support it at the project level. A research program usually comprises several projects, which are more or less related to each other and jointly contribute to an overarching goal or question

(Hoffmann et al. 2017a; Schneider et al. 2019). The compilation of several projects under one roof is a key strength of research programs, as it has the potential to address such a goal or question from various angles. Accordingly, more robust contributions to addressing complex problems might be generated, if the leaders of such programs make sure that the involved individual projects do not diverge from each other and that the wide range of heterogeneous project results are integrated over time (Weith et al. 2019).

Leadership itself is a contested concept and has been approached from various angles (Blackmore and Kandiko 2010, p. 57). This can be exemplified by the fact that the concept of 'leader' is sometimes equated with 'leadership'. Etymology suggests that there is a conceptual distinction between the two, defining the leader as the person who guides and shows a way forward (Barnhart and Steinmetz 2000, p. 584), while the supplement "-ship" indicates a quality, condition, or relationship between something (Barnhart and Steinmetz 2000, p. 998). Hence, while 'leader' points to a certain position and a role characterized by certain competencies, attitudes, and expertise, leadership is a multidimensional process of social influence oriented toward the achievement of a certain goal (Boone et al. 2020; Chemers 1997, p. 5; Kempster and Parry 2011). In this process, the individual leader plays a crucial role in setting and enforcing the boundary conditions for such integrative efforts and in triggering, enabling, and sustaining such efforts over time to attain such a goal (Harvey et al. 2018; Hoffmann et al. 2022a, b). However, realizing the potential of such integrative efforts is influenced by the interactions with team members, and other contextual factors (Chemers 1997; Deutsch et al. revised & resubmitted; Kempster and Parry 2011). Based on the distinction between leaders and team members, and insights from creative leadership research, we here define integrative leadership in ITD contexts as the process of mobilizing supportive contributions and integrating heterogeneous creative contributions from both leaders and team members toward a common goal (Mainemelis et al. 2018). Supportive contributions mean "providing psychological, social, and material support for creativity" (Mainemelis et al. 2018, p. 4), while creative contributions entail generating, refining, or linking new ideas (Mainemelis et al. 2018, p. 4). Integrative leadership is thus an interplay of creative and supportive contributions from both leaders and team members. However, it is up to the program leader to show a way forward and orchestrate the various contributions to achieve together with team members new and final creative outcomes and outputs (Mainemelis et al. 2018).

Interestingly enough, whereas "[l]eadership is one of the most widely researched and discussed topics in all areas of organizational sciences" (Yammarino 2013, p. 149), there is scant literature on leading ITD programs in general (Defila et al. 2006) and even fewer empirical studies on leading

integration in such programs in particular (Hoffmann et al. 2022b; Palmer 2018). Given the importance of ITD integration in advancing sustainability studies (Kauffman and Arico 2014; Lang et al. 2012; Polk 2014), the increase of individuals (or small teams of individuals) taking over this role (Black et al. 2023; Defila et al. 2015) and the importance of leadership for attaining overarching program goals (Berger 2019; Norton et al. 2022; Salazar et al. 2019), it is key to take a closer look at integrative leadership and how it is enacted in ITD research programs. This paper therefore asks:

What leadership challenges do leaders of inter- and transdisciplinary programs need to deal with during integration processes and what strategies proved fruitful to address them?

We explored this question in three ITD programs focusing on sustainability issues in Switzerland and provide conceptual insights into integrative leadership as well as actionable knowledge, which can (1) support fellow and future leaders of ITD programs and larger ITD projects in their integrative efforts and (2) provide insights for funders and heads of research institutions with respect to designing ITD program calls, selecting projects and setting up leadership structures. Thus, we position our article at the interface between the theory and practice of leadership in ITD research, in general, and integrative leadership in ITD research programs, in particular. We thereby contribute to the expressed need by various scholars in the field of ITD and sustainability studies to acquire a better understanding of their work realities within which they operate, including ideas on how to advance integration within their programs. For this purpose, this analysis aims at generating more empirical evidence to derive strategies and recommendations for enacting and supporting integrative leadership in ITD research programs (Bruce et al. 2004; König et al. 2015; Lawless et al. 2024).

For the purpose of simplification, we will subsequently only refer to 'leaders' when we refer to the individuals, who assumed the role of leading integration within the respective ITD programs, and use the term 'participants' when referring to the program team members. We distinguish between junior participants to refer to early-career researchers (i.e., scientific assistants, PhDs, postdocs) and senior participants to refer to team members with a higher hierarchical status, who are often superiors of the junior participants (i.e., group leaders, department heads, directorate members). We are well aware that in other ITD project or program contexts, the officially designated leader and the actual leader of integration processes (e.g., designated integration expert) (Hoffmann et al. 2022a, b) might not coincide. We believe that the six presented leadership challenges apply to these contexts as well. However, such a constellation might pose additional challenges, such as the need for additional interaction and coordination efforts between the official leader and the designated integrator.

Research design: case studies, methods, and role of authors

A qualitative accompanying research design was used, as it allowed to explore in depth how integrative leadership is practically enacted in three different ITD programs on sustainability issues in Switzerland and how the manifold challenges attached to it were addressed (Yin 2014). The case studies include the ITD program *Extremes* at WSL (Swiss Federal Institute for Forest, Snow and Landscape Research), the cross-sectoral ITD program *NCCS-Impacts* within the network *NCCS* (National Centre for Climate Services) with the secretariat hosted at MeteoSwiss (Swiss Federal Office of Meteorology and Climatology), and the ITD program *Wings* (Water and sanitation innovations for non-grid solutions) at Eawag (Swiss Federal Institute of Aquatic Science and Technology) (see Table 1).

The three programs were selected, because

(1) they are all based in Switzerland which made them accessible to be studied in depth due to the geographical location of the authors,
(2) they all deal with sustainability issues and aim to integrate perspectives across disciplines, and also science, policy, and practice,
(3) they all represented a valuable source of experiential knowledge on the challenges of leading integration as all co-authors were involved in the program leadership,
(4) the leaders of the Extremes and NCCS-Impacts program were very interested in being part of the suggested accompanying research by the lead author and willing to dedicate substantial time to it, and
(5) all programs faced similar challenges in terms of integration, but differed slightly in their setup and how the program came about, which allowed for the exploration of different design options for future ITD programs.

The research process was set up in the following manner. The lead author of this paper conducted accompanying research (Defila and Di Giulio 2018) in these three ITD programs between 2020 and 2023. As the term 'accompanying' implies, it meant that she was present in these three case study contexts on a regular basis over a long period of time, studying the integration processes of the respective programs by triangulating qualitative methods (i.e., semi-structured interviews, reflection questions, focus groups, and participant observations). Throughout this time, she took on different roles with varying degrees of insider and outsider positions depending on the program. Within Wings, she assumed an integrator role (Hoffmann et al. 2022a), which meant that she was involved in supporting the leadership of the Wings program in advancing

Table 1 Overview of the three studied ITD programs in Switzerland

Case study	Extremes	NCCS-Impacts	Wings
Topic	Future extremes	Cross-sectoral climate impacts	Sustainable urban water management
Home Institution of Program Lead	Swiss Federal Institute for Forest, Snow and Landscape Research (WSL)	Swiss Federal Office of Meteorology and Climatology MeteoSwiss (host of the secretariat of the NCCS), together with the Swiss Federal Offices of Public Health, of Civil Protection, for the Environment, for Agriculture, for Food Safety and Veterinary Affairs, for Energy and the two federal research institutions ETH Zurich and WSL. These nine organizations (seven federal offices and two research institutions) constitute the permanent network NCCS	Swiss Federal Institute of Aquatic Science and Technology (Eawag)
No. of projects	5	7	10–14
Assigned work percentage to leadership	60% (two positions of each 30%), later 100% (distributed among 3 positions)	160–180% (distributed among two positions)	100–150% (distributed among three positions)
Background of program leaders (gender, position, discipline(s), work experience outside of academia (if yes: field), motivation)	Co-lead 1: male, group leader, Land Change Science and Macroecology, motivated to lead inter- and transdisciplinary teams, enjoys bringing different perspectives together and reflecting upon the how-to of leadership in such contexts Co-lead 2: female, Office of the Director or member, Environmental Sciences, Knowledge and Technology Transfer, work experience outside academia (development cooperation), motivated by the opportunity to open up new topics, to embrace complexity with creative methods and to facilitate dialog in large settings	Main lead: male, deputy group leader/head of NCCS program, Atmospheric Physics and Climate Modeling, work experience outside academia (public administration), motivated by looking at climate impacts from several angles, the inter- and transdisciplinary (leadership) challenges involved, the innovative character and potential of the program, and the elaboration of actionable products in the form of climate services Deputy lead: female, communication and project management specialist, Earth Sciences and communication/management, work experience outside academia (public administration), motivated by networking with different actors, connecting different knowledge areas (thinking broadly), bringing climate-related solutions forward, coordinating communication activities and supporting management with efficient tools	Main lead: female, group leader, Geoecology and Inter- and Transdisciplinary Studies, work experience outside academia (development cooperation), motivated to work with different people across hierarchies, and to bring different perspectives together in terms of targeted synthesis outputs, enjoys doing work at the interface between different disciplines as well as between science, policy, and practice and reflecting upon the leadership challenges involved Deputy lead: male, group leader and directorate member, Environmental Engineering and Solid Waste Management, work experience outside academia (development cooperation), motivated to work on the topic of sustainable urban water management from different angles, creating the bigger picture and deriving overarching lessons learned
Steering Committee	Yes (annual meetings)	Yes (bi-annual meetings)	No
No. of collaborators	~20–25 (core team) ~100 (core team plus partners from science, policy, and practice)	~20–25 (core team) ~100 (core team plus partners from science, policy, and practice)	~6 (synthesis team) ~20–25 (core team) ~80 (core team plus partners from science, policy, and practice)

Table 1 (continued)

Case study	Extremes	NCCS-Impacts	Wings
Interactions between program and project leaders	Bilateral project meetings (4 times per year, 1.5–2 h) Program meetings (3 times per year, half day) Annual program meeting with guests (full day)	Regular meetings between program lead and project leaders (every two months, 1.5 h) Annual program meeting (full day)	Monthly meetings (2 h) Interdisciplinary workshops (~ 3 times per year, 2 h) One retreat per year (1.5 days)
Disciplinary background of program participants	Biodiversity, cryospheric sciences, ecology, forestry, hydrology, and environmental psychology	Medicine, veterinary medicine, ecology, agronomy, economy, sociology, forestry, hydrology, energy, climatology, and geography	Environmental engineering, environmental health psychology, decision analysis, human geography, innovation and transition studies, inter- and transdisciplinary studies, political science, process engineering, and urban planning
Sectors involved	Agriculture, animal health, ecology, environment, forestry, and hydrology	Health, animal health, environment, hydrology, ecology, energy, and civil protection	Urban water management, art and design, technology companies, development and cooperation
Duration	2021–2025	2022–2026	2016–2018 (Phase I) 2019–2022 (Phase II)
Funding source	WSL internal funds	Joint funding by involved Swiss federal offices and federal research institutions	Eawag Discretionary Funds, Swiss National Science Foundation, Bill & Melinda Gates Foundation, Swiss Federal Office for the Environment, Swiss Agency for Development and Cooperation, and in-kind contributions of involved researchers

Table 1 (continued)

Case study	Extremes	NCCS-Impacts	Wings
Application and selection process	WSL internal call developed bottom-up in a co-creation process involving WSL researchers to delineate system boundaries; projects were assessed by external evaluation board; final selection by the steering committee Selection criteria included: 1) clear focus on extreme impacts on environment and society, 2) relevance to stakeholders, 3) inter- and transdisciplinarity, 4) knowledge integration activities within and beyond project boundaries	Two-stage process of procurement. First, an NCCS-internal call was run to mandate research groups within the NCCS. Second, an open call under WTO requirements was published with different lots for different projects to be funded. The consortia per project/lot were selected by project-specific external evaluation boards Selection criteria included (among others): 1) accordance with the objectives of the project, program, and NCCS, 2) innovation potential, 3) expected impact on climate services landscape, 4) plausibility of the work plan and suitability to reach the project goals, 5) experiences in inter- and transdisciplinary cooperation and experience in the climate service sector The criteria were assessed based on the submitted concept and reference form as well as virtual presentations. The price of the offer was also evaluated and weighted with 20% in total	No call; Wings emerged bottom-up by an interdisciplinary group of senior researchers at Eawag, who submitted several interlinked research proposals on sustainable urban water management to the Discretionary Funding Call by the Eawag Directorate. Additional existing projects (funded by other sources, see row above), relevant to the program's topic also became part of Wings Selection criteria included 1) strategic importance to Eawag, 2) potential to strengthen Eawag's capacity for inter- and transdisciplinary research, 3) potential to initiate or strengthen collaborations with external partners, and 4) lack of external funding sources
Website	www.wsl.ch/extremes	www.nccs.admin.ch/impacts	www.eawag.ch/wings

integration, while also assuming a meta-researcher role, which implied that she observed and reflected upon her integrator role in particular and the integration process within Wings in general (Defila and Di Giulio 2018). Within the other two case studies (i.e., Extremes and NCCS-Impacts), she did not proactively advance integration, but assumed a mere meta-researcher role observing and studying the integration processes. Balancing these two roles and being involved in the leadership of the ITD program Wings entailed opportunities as well as challenges for the lead author. Assuming an integrator role (Defila and Di Giulio 2018; Hoffmann et al. 2022a) within Wings allowed the lead author to gain in-depth experiential knowledge about co-leading integration processes instead of just observing others leading such processes or relying on their self-reports. On the other hand, switching from an integrator role to a meta-type research role (Hoffmann et al. 2022a, b) was not straightforward and meant consciously altering her "positionality in relation to the team" (Freeth and Vilsmaier 2019, p. 58). A critical reflection on ongoing processes within Wings and her own leadership role was especially challenging during meetings, workshops, retreats, or workload-intense weeks. It was therefore important to create explicit reflective spaces to take a step back from the integrator role and to document observations and reflections using a reflection tool developed for that purpose (Deutsch and Hoffmann 2021). The lead and last author of this paper applied the tool in several instances, but did not always succeed in documenting their observations and reflections in the 'heat of the moment' of daily program workloads. For this reason, the bi-annually scheduled focus groups with the leaders of the other two programs were crucial as complementary reflection spaces. What is more, experiences gained within Wings necessarily influenced the lens through which the lead, penultimate, and last author viewed the other two programs. It was therefore key to contrast the experiences from Wings with those of the other ITD program leaders (i.e., Extremes and NCCS-Impacts).

The co-authors of this paper were or are the leaders of the presented programs and met on a regular basis during the biannual focus-group meetings within the frame of the lead author's accompanying research.[1] All programs were or are run on the basis of a co-leadership structure, which was either designed from the very beginning, or evolved

throughout the course of the program. Although the co-leaders of each program closely worked together, one person was officially designated core leader, while the other was designated deputy leader in the case of NCCS-Impacts and Wings. All co-authors met five times for biannual three-hour focus-group meetings between May 2021 and May 2023 to jointly reflect on challenges of leading integration in ITD research programs, sharing empirical insights, lessons learned, and exchanging ideas about strategies and concrete actions to address them. Insights gained throughout those focus groups were fed back into their own program leadership practices, in particular by including new integration methods or considering new design principles and/or evaluation criteria in assessing research proposals. In addition to this focus-group series, the lead author addressed the research question by conducting *bilateral interviews* with five to eight participants from each program (duration 1.5 h) and all program leaders between April 2021 and September 2022 (see interview guideline in the appendix). In addition, she performed *participant observations* by attending program meetings, retreats, and events at least three times a year per case study between November 2021 and May 2023. Insights from the interviews and participant observations informed the content and structure of the subsequent *focus groups* with the program leaders. Triangulating these qualitative methods throughout the research process proved very beneficial for studying the topic from different angles, mutually informing and complementing each other. In addition, it allowed studying the perspectives of both program leaders and participants, which is in line with our definition of integrative leadership, i.e., as an interplay of creative and supportive contributions from both leaders and participants along the integration process (Mainemelis et al. 2018).

All interviews were recorded with the permission of the interviewees and subsequently transcribed. As both program participants and the respective leaders of these programs were interviewed, it was crucial to ensure anonymity. For this reason, only the lead author, who had conducted the interviews, also analyzed them. However, the findings were validated and enriched by the six program leaders as will be explained in the following:

Step 1: The lead author collected and noted challenges, which were reported by the program participants as well as leaders with respect to leading integration processes in ITD programs from the transcripts, explored them in Nvivo 12 (QSR International), and coded them in Excel.

Step 2: The lead author then triangulated the findings from the interviews with her notes from the focus-group meetings and participant observations to derive overarching themes, i.e., leadership challenges which represented reoccurring themes related to leading integration across the three different case studies as well as across program leaders and participants. The overall goal was to derive overarching leadership challenges,

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[1] AMH is the director of the NCCS from which the program NCCS-Impacts originated. She was strongly involved in designing and setting-up the NCCS-Impacts program together with AF, and therefore also became co-author of this paper. The current NCCS-Impacts deputy lead joined at a later point when the accompanying research was already about to be concluded and was therefore not part of this manuscript writing process.

which are common to ITD programs more generally despite the different setups (see Table 1), but then explore the different 'room for maneuver' that each program has to deal with them (see step 3).

Step 3: The lead author presented six overarching themes to the program leaders in the focus group in May 2023 and provided empirical evidence (i.e., anonymized quotes from the interviews and observations from attending meetings) for each challenge. The program leaders (and co-authors) concluded that these themes represent core (and often unresolved current) challenges in their daily leadership practice in ITD programs, although they do not necessarily represent an exhaustive list. During this focus-group meeting, the six leaders enriched these themes with practical examples about how these challenges can be potentially addressed in the future or already have been addressed by them with the resources they had at their disposal in the past.

Step 4: In the subsequent months, the lead author and six leaders jointly wrote the manuscript at hand, thereby iterating and refining the six challenges and the practical strategies further by mirroring it with the existing literature on leadership in ITD programs.

Step 5: The manuscript was sent to the interviewed program participants before being submitted to the journal to allow them to check our analysis and conclusions. Two program participants responded, but did not ask for any modifications.

Results and discussion

> "This area of tension that there are these ideal–typical integrative processes, as described in the literature, but then the bare everyday life, it just looks a bit different. And to endure this balancing act between "what could be theoretically possible" and "what actually happens in practice", is sometimes not so easy." (Leader)

In the following, we describe six core leadership challenges derived from the empirical material and the hands-on experience of leading ITD programs for several years. While it is possible to distinguish those challenges to a certain extent conceptually, we are well aware that they interrelate and overlap in practice. We first introduce the respective challenge and then propose concrete coping strategies that proved useful to address the challenge. We structure these strategies according to (1) attitudes, (2) processes, and (3) structures.

Information overload ahead: mastering complexity and ambiguity

ITD programs have become one of academia's responses to address complex societal challenges. To fulfill their purpose, it requires a more complex and ambitious research process (van Kerkhoff 2014). Therefore, ITD programs are by default overwhelming for all participants (Bruce et al. 2004), but in particular for program leaders. The more complex the ITD initiative, the greater are the demands on leadership, and related to that: "the greater the potential impact of effective or ineffective leadership" (Hall et al. 2019a, p. 596).

First, content-wise program leaders face an immense information overload due to the large number of disciplinary topics that are in part also new to them. While they can selectively dive into the deep sea of disciplinary and sector-specific knowledge, they do not have to become experts in these areas. By contrast, it is their responsibility to keep the overall program goals and system boundaries in mind and counter potential diverging developments that could cause the program to fall apart (see subsequent subchapters) (Defila et al. 2006, p. 142). This implies that, throughout program implementation, they fluctuate between the bigger picture (program view) and in-depth expertise (project and work-package view) as expressed by one junior participant:

> "The program leader is the one who has the bird's eye view…and the group leaders are the ones who have the tunnel vision, the narrowness that's required for the topic…" (Junior Participant)

Program leaders therefore need to be capable of envisioning how the different perspectives involved actually overlap and interplay with each other (Gray 2008). Doing so requires interactional expertise (Collins and Evans 2007) implying that program leaders need to master the language of the various disciplines involved to a certain degree without necessarily being able to contribute to these disciplines in depth. However, to manage this type of co-creation and not getting lost in sight of this immense challenge, it is imperative for program leaders to keep warding off the feeling of inability to ever grasp the complexity in every detail, as expressed by one program leader:

> "Sometimes it feels like an information overkill, to understand all projects and what else is going on … There are so many big new topics. That is also very stimulating, but sometimes I have the feeling that, "wow, I just want to read something [in my area] again", "have safe ground under my feet again." (Leader)

Working in large-scale ITD initiatives inevitably leaves behind a feeling of imperfection and incompleteness (Black et al. 2023) that can never be fully solved. This is further intensified as ITD programs are not only demanding in terms of handling diverse content, but equally in terms of handling differing social, political, legal, and institutional contexts. This was a challenge for the NCCS-Impacts program as leaders and participants were confronted with setting up a program despite very different regulatory frameworks of the involved federal offices.

Hence, ITD programs need to serve many interests. When a new program is developed within or across institutions, first the funders—in some cases the respective directorate or federal offices—need to be convinced that the program is worth being funded. This tends to lead to the fact that program calls end up making overly ambitious promises, which can be hardly met in practice. These promises include the ambition to find concrete solutions to pressing problems by doing cutting-edge research and conducting participatory processes that finally yield innovative solutions useful not only to science, but to multiple sectors and its respective actors within a short time frame (often 4–5 years). In the same vein, applicants for projects take up the wording of the call and promise much for little money to win the grant. With such an ambitious call, the expectations of the funders are immense, while participants are overly pressured from the very start. In particular, the achievement of both high scientific and high societal impact might be unrealistic within such limited time frames (Roux et al. 2010; Ruppert-Winkel et al. 2015). For this reason, expectations have to be necessarily lowered to what is realistically possible under given individual, team, project/program, institutional, financial, and societal conditions despite the complexity of the research topics at hand (Deutsch et al., revised & resubmitted).

Leadership strategies related to "mastering complexity and ambiguity":

Attitudes: Be aware of your role as integrator, not disciplinary knowledge carrier. You do not need to understand all disciplinary and sectoral fields in detail, but rather their interfaces and the bigger picture. Being able to do the latter is sought-after expertise in itself.
Processes: Do not be overambitious, but treat integration as a step-by-step process together with a dynamically evolving team and a high potential for learning. Ask program participants to synthesize and translate their current results via pitch talks or two-pagers, and use methods to render complexity comprehensible (i.e., visualizations, story-telling techniques or system methods, e.g., Theory of Change) (Deutsch et al. 2021; Hinnen and Hinnen 2017).
Structures: Organize structural support, be it through setting up a co-leadership with complementary expertise, an inter- or transdisciplinarily composed evaluation or advisory board, or by joining a community of practice with other program leaders. The latter can help to build up complexity and ambiguity tolerance.

Pulling the ship forward: advancing decision-making with lateral leadership

ITD programs usually involve a large number of participants affiliated with different organizations. Accordingly, they are used to different leadership cultures, decision-making processes, and hierarchical structures. Even within a single organization, participants are embedded in different departments and their respective cultures, and are accountable to different superiors (e.g., PhDs, postdocs, tenured scientists, department heads). An ITD program typically disrupts this established order as it aims for collaboration, decision-making, and resource flows across the common hierarchical structures (Crosby and Bryson 2010). Achieving this is a leadership challenge in itself given that tasks from the line management in the respective department or organization always 'come first':

"We don't have much formal authority to issue directives. In the federal administration, a lot of things are done via goals and line management. So how do we succeed in people treating our issues as a priority despite not being the primary focus of their respective lines?" (Leader)

As the classic leader–follower model becomes obsolete in complex ITD programs, leadership is "about understanding and influencing systems interactions" (Will 2016, p. 274). This makes lateral leadership necessary, as program leaders are confronted with the challenge of leading across hierarchies, while not necessarily having a strong formal hierarchical power position within the program's 'ecosystem' (Kühl 2017; Provan and Kenis 2008). In the most extreme case, program leaders need to lead program participants who are not only hierarchically ranked above them, but are also their direct superiors, which can lead to problematic power dynamics if the latter do not manage to separate these two roles in practice.

Such hierarchical constellations, but also the need to consult and discuss with a high number of program participants on a regular and iterative basis, bear the risk of getting stuck and causing frustration, since consensus is neither easily achievable nor always possible (Black et al. 2023) as expressed by one leader:

"So this democratic, participatory process is good, but it is of course much more time-, nerves- and energy-consuming. It needs a lot of iterative loops, I think…it is a disadvantage in the sense that sometimes you simply have these experiences of frustration much more often, [this feeling] that you don't progress." (Leader)

Many program participants want to provide opinions and suggestions concerning the program course. Yet, time-wise leaders sometimes need to take top-down decisions too, to

push the program and the respective integration process forward. Gray (2008, p. 5) calls this 'judgment calls', i.e., the leader's capability to "make discriminatory decisions about numerous issues" including for instance which ideas are most promising, what next steps are needed, and being realistic in terms of advancing integration. This can sometimes lead to discontent, as expressed by one leader:

> "As soon as you do something that hasn't already been agreed on by everyone because of time constraints or something, it blows up in your face" (Leader)

One program participant compared the practice of leading an ITD program with the challenge of 'herding cats' i.e., the futile attempt of wanting to control the uncontrollable:

> "Everyone's trying to go in their own direction and you have to bring them all together" (Junior Participant)

While ITD programs and integration processes can certainly never be under full control, integrative capabilities (Salazar et al. 2019) are key to obtain and maintain order in such a complex setting at least to a certain extent. These include high levels of reflexivity (Guimarães et al. 2019; Salazar et al. 2019), contributory and interactional expertise (Bammer et al. 2020; Collins and Evans 2007), complexity thinking (Uhl-Bien and Arena 2017) as well as specific attitudes such as openness, curiosity, sociability, and a modest positionality (Augsburg 2014; Fam et al. 2017). Next to developing integration expertise (Hoffmann et al. 2022a), this also includes assuming a neutral and benevolent position within the program, i.e., not having one's own project within the program, which competes with the other projects about academic interests and purpose, and the ability to develop good relationships with the respective program participants. The latter also includes considering that different participants have different preferences to contribute or express themselves (e.g., oral vs. written feedback).

Leadership strategies related to "advancing decision-making with lateral leadership":

Attitudes: Be aware of the necessity of lateral leadership and gain respect as lateral leader by assuming a neutral and benevolent role in the program. Do not expect that you will be able to always satisfy everyone. Reflect regularly on your achievements, especially the allegedly smaller ones.
Processes: Balance top-down and bottom-up leadership, i.e., show presence and act quickly when concerns arise. At the same time, always align concerns, tasks, and questions with agreed program goals. Expand your sphere of influence by gaining insider knowledge (e.g., how decisions are made in different departments/organizations), expanding your network and establishing good relationships with program participants. For avoiding a stalemate, fall back onto already agreed program goals as well as governance structures.
Structures: Get an official role in your organization's organigram assigned to gain visibility and legitimacy. Establish a governance structure of the program that is approved by all program participants, but also by their superiors as well as by a steering committee (if existent). The governance structure should clearly reveal the process of how decisions are made within the program.

Non-integration as default: ensuring responsibility and accountability

Integrating activities and results from different projects into a larger framework and developing joint synthesis products is a key purpose of ITD programs and therefore also a key indicator to assess their success. Doing so inevitably requires joint efforts of large and diverse teams with complementary expertise. Yet in academia, individual members are encouraged to foster first and foremost their own particular disciplinary research agenda. Processes necessary for knowledge integration are therefore often perceived as an unnecessary and unwanted distraction. Given this unfavorable incentive structure, it is often uncertain whether participants in ITD programs are actually willing to assume responsibility for integration processes at the program level and feel accountable toward the overall program goals as described by one senior participant:

> "You can then hide a bit in this irresponsibility, you can pass on the responsibility to someone else. Because X didn't moderate it well, right? … And I think that's perhaps a structural problem, also from a perception point of view: I'm not held accountable if things don't work out so well [within the program]. Or I think I won't be held accountable…. So maybe I still will at some point…. (laughs)" (Senior Participant)

As senior participants tend to be very busy and are involved in multiple projects, it is usually the early career researchers who perform most of the work within a program as stated by one senior participant:

> Interviewer: Did the integration method on the program level yield any new impulses for your individual project?
> Interviewee: Yes, additional tasks that I will offload to my PostDoc now. (Senior Participant)

However, early career researchers usually leave after two to four years, as they often do not have the prospect of staying at the institution until the program and its final outputs are finished due to the common practice of rather short fixed-term contracts in academia. On top, early

career researchers are sometimes discouraged by their supervisors from investing too much time in ITD integration, as it is considered to be diametrically opposed to their career development in academia.

As integration processes are quite demanding in terms of cognitive and social–emotional challenges (see "Information overload ahead: mastering complexity and ambiguity" and "Pulling the ship forward: advancing decision-making with lateral leadership"), the lack of felt responsibility and accountability may also stem from the program participants' difficulties to deal with these challenges as one leader explains:

> "For me, integration is a lot. It's back-breaking work too, very time-consuming. A process. A bit of Sisyphean work. You can't just schedule it somewhere and do it and then it's done, but you have to keep working at it and if you don't stay on the ball, then it disintegrates again or recedes into the background. Because 'the other' is so much more comfortable, the non-integrative, the disciplinary. Just do your thing and do what you've always done". (Leader)

Building on the previous subchapter ("Pulling the ship forward: advancing decision-making with lateral leadership"), a mere top-down leadership approach for fostering responsibility and accountability does not work in such contexts and is not even desirable, as integration requires creative contributions emerging bottom-up from the participants too (Uhl-Bien et al. 2007). By contrast, it necessitates a good balance of offering support and guidance while still demanding their contributions to the overall integration process and synthesis products as one senior participant explains:

> "I think [the program leaders] are forcing us again and again to take an integrative approach, to think or even to discuss a new method together. If they didn't keep up that drive and also think about how to make these retreats interactive and try to get the most out of the limited time we have, there would be less integration" (Senior Participant)

The experience from the three programs shows that when leadership comes with a positive, supportive, and encouraging attitude, yet critical stance where needed, participants feel respected and are more likely to engage and showcase the progress they have made toward integration. In light of our findings and the current conditions in place (Deutsch et al., revised & resubmitted), we agree with Boone et al. (2020, p. 1725) that program leaders "must be more persuasive than other leaders to convince researchers to follow the unsettled and novel pathways of ITD research."

Leadership strategies related to "ensuring responsibility and accountability":

Attitudes: Acknowledge the difficult incentive structures in place and do not judge immediately if people have a hard time doing integrative work. Support them as much as possible during integration processes by providing them with integration methods and training. You cannot do the integrative work for them, but you can assist them in their efforts.

Processes: Lead proactively and keep a continuous focus on integration and final synthesis products from the very beginning, i.e., hold regular face-to-face meetings and vary interaction formats (e.g., bilateral meetings, larger program meetings, workshops, retreats) to ensure that integration remains on top of people's agenda. Clearly communicate the envisioned steps and timeline for working on integration and creating synthesis products. Do not underestimate the importance of social events (e.g., joint drinks/dinners, excursions, retreats) for building ownership and responsibility toward the program.

Structures: Define and assign responsibilities and obtain commitment from all participants to engage in integrative processes and generate integrated outputs, i.e., put on record that individual projects are responsible for integration at the project level (i.e., integrating their stakeholders), but also need to contribute to the overall synthesis. Ask for and retain funds for synthesis activities to be able to flexibly use them for filling potential synthesis gaps and needs. Draw lessons learned during and after the program and share them for future ITD programs.

Keeping the program manageable: setting boundaries

When dealing with broad complex societal problems, program leaders experience the challenge of defining the program's system boundaries thematically and socially. Regarding thematic boundaries, there is the risk of trying to incorporate themes exhaustively resulting in a program that wants all and nothing at once, as many aspects and sectors are strongly interlinked due to the complexity of the topics at hand. Strongly related to the thematic boundaries is the question of social boundaries. In all three ITD programs recurring discussions emerged about 'inclusion' and 'exclusion': "Who is invited to participate in the program and who is not? What criteria are used to define and select program participants and who defines these criteria? This defines who gets empowered by the program, and, the other side of the same coin, who gets marginalised?" (Elzinga 2008, p. 357).

Based on our experience, we argue that setting the program's social boundaries needs consideration of the purpose, form and time of inclusion (or exclusion) as well as the issue

at hand rather than 'the more inclusive (or exclusive), the better' (Krütli et al. 2010) approach. Adopting this functional-dynamic approach (Krütli et al. 2010) to setting social boundaries might sometimes entail temporarily excluding some participants at a given point in time (and (re)include them at a later point) to sustain the integrative process and allow new ideas to flourish (Hoffmann 2024), as noted by one program leader:

> "My experience is that things move forward when you continue with a smaller group and (when you) do not always have the aspiration to do everything with everybody. (…) And then there is this tension of including new people in the program, for example, the junior members, because they are the ones who actually do most of the work.". (Leader)

As noted by this program leader, the issue of inclusion and exclusion involved also a discussion on the extent and the form of including early career researchers in the program (scientific assistants, PhDs, postdocs). Experience within Wings showed that deliberately including them in the program's thematic and strategic discussions proved beneficial, as early career researchers provided not only empirical insights on real-world examples of alternative urban water systems, but also challenged the status quo: They pointed to 'what is desirable', while senior researchers rather highlighted 'what is feasible'—two complementary perspectives which helped to enrich the program's discussion on sustainability transformation in the urban water sector substantially (Deutsch et al. 2021). Ensuring this social integration of junior and senior participants is perceived as one of the key leadership tasks as explained by one senior participant:

> "To me, it doesn't really matter whether you're a professor, a Nobel Prize winner, or a Bachelor student. If you have an idea and you have something to support it, your opinion matters as much as the other ones. I think communicating this makes integration a bit easier and more feasible because then people don't feel like they cannot talk, they cannot express their results, feeling, opinion, whatsoever." (Senior Participant)

Therefore, program leaders have a powerful role in shaping social integration or inclusion processes, especially in terms of balancing power differences (Kok et al. 2021). Establishing boundaries might appear counterintuitive to ITD endeavors, but is critical for keeping the program manageable in terms of content as well as participants.

Leadership strategies related to "setting boundaries":

Attitudes: Be aware that integrative leadership does not mean including everyone all the time. Take a step back and decide together with the project team task by task who needs to be strategically included as well as (temporarily) excluded to move integrative processes forward; then adapt and vary formal (e.g., retreats, workshops, bilateral and program meetings) and informal interaction formats (e.g., coffee and lunch breaks) accordingly and alternate group compositions.

Processes: Create protected niches for early career researchers or other sub-groups (e.g., a proper workshop or retreat with early career researchers only or cross-cutting panels by participants from different projects that focus on specific aspects of integration), so that new ideas have the chance to flourish and advance faster in smaller groups. Acknowledge and use the complementary expertise of early career and senior researchers.

Structures: Define the program's thematic and social boundaries in concrete and explicit terms, e.g., organize scoping meetings prior to publishing the call to set the program boundaries consciously. What and who is part of the program, and what and who is deliberately excluded? Collect the commitment of all participants and the program board in a written document and make it available to all.

Counteracting chance: selecting suitable projects

Program leaders have the task to make integration happen across the different projects involved. Yet, they are sometimes excluded from the project selection process. This has both advantages and disadvantages: Being excluded from the selection process allows program leaders to assume a more neutral role vis-a-vis the program participants and often colleagues. As a drawback, they have to accept suboptimal decisions by the proposal evaluation board, such as when the selected projects do not fit well together as expressed by one program leader:

> "X and I, we were not part of the evaluation board and hence couldn't decide. […] It is up to us to see how everything fits together. As the boundaries were already set through the call, we could accomplish this more or less. But what remains a challenge is that by this procedure we couldn't control who receives the funding. For instance, whether these people are willing to collaborate is out of our control." (Leader)

In a similar vein, a junior participant stated from another program context where the involved projects did not necessarily fit together in terms of content and participants:

> "[The program] is confronted with a lot of challenges…, which I would summarize as '40 people from 20 disciplines with 50 opinions and only a few common interests as well as an unknown number of

hidden conflicts come together and are supposed to jointly advance a program'". (Junior Participant)

When selected projects and the involved individuals do not fit well together at the program level, program leaders need to be creative on how to fill the gaps and how to integrate the pieces, while the temporary evaluation board is dissolved again and cannot be held accountable for its decisions anymore. In the case of ITD programs, the evaluation board usually comprises representatives from different disciplines as well as actors from practice coming from both the country of the host institution and abroad. Board members have to jointly evaluate the proposals in a relatively short time frame without having met before. An oral and written briefing helps to align the evaluation board under a common vision and strategy and to familiarize the board members with the background and intricacies of the call. However, it does not guarantee that—despite these efforts—'traditional' criteria (e.g., scientific disciplinary innovation) are given more attention than others (e.g., potential for creating practical knowledge and tools for societal actors), although the evaluation guideline and criteria are pre-defined along both lines.

The experience from all three programs shows that ITD aspects, products, and overall program synthesis tend to be given less priority by the applicants as well as the evaluators. Hence, the management of the selection process by the program leader is critically important: it requires "informed staff giving clear guidance to panels on how to evaluate interdisciplinary initiatives and appointing a panel chair with a good understanding of what is required and a strong enough control over the process to ensure that the guidance is followed" (Lyall et al. 2011, p. 4). With the program leader being excluded from the selection process, the question is who is sufficiently skilled and experienced in ITD and can ensure that ITD criteria are taken seriously (Bruce et al. 2004; McLeish and Strang 2016) and not "sidelined in favor of conventional disciplinary criteria" (Lyall et al. 2011, p. 4).

How this guidance should look like in concrete terms, and against what criteria proposals should be evaluated, often needs to be defined already when publishing a call. However, this is done without knowing to what extent the scope of the call and its objectives match the ability, interest, resources, and willingness of potential applicants. In the case of Extremes, which is an institution-internal research program, the potential future applicants co-created the call via a workshop series. This had the advantages that (a) the call was in line with the available resources of future applicants, (b) a common system understanding was developed already prior to the program start, and (c) those with no interest in ITD activities had the opportunity to withdraw early on. At the same time, having participated in the framing process, but then not having been selected for the program can cause

frustration among the respective individuals. Verwoerd et al. (2020) found benefits in combining the facilitator's and evaluator's role, and including participants in a formative evaluation approach to achieve a meaningful assessment of the projects' societal impacts. Similarly, we believe that there is added value in both including the future program leaders in the selection process and considering future applicants' perspectives when designing the call as this phase lays the foundation for later integration work (König et al. 2015).

Leadership strategies related to "selecting suitable projects":

Attitudes: Be conscious and transparent about the advantages and disadvantages of being included or excluded from the selection process. This holds true about how the process as such should be set up, as different setups provide both challenges and opportunities. In any case, the decision by the evaluation board will have a great impact on the work and consequences for the integration process and integrative leadership.

Processes: Allow enough time for briefing the evaluation board in depth, but also make sure that scientific excellence criteria do not rule out criteria such as the potential for integration and societal impact during the evaluation process, as you will later be responsible for moving integration forward. Ideally, the evaluation board covers a broad range of disciplines and also comprises inter- and transdisciplinary competences.

Structures: Engage the evaluation board early in the procurement process and ask the members to assume responsibility on a longer term, e.g., as a sounding board member. In this way, they are held accountable for their choice, which might influence their decision-making process. Make a clearly outlined integration concept a requirement for proposal submission already in the call and build in specific questions for assessing the envisioned integration in the evaluators' guidelines (Belcher et al. 2015; Pohl et al. 2011; Strang and McLeish 2015). Require projects to dedicate budget (e.g., 15–20%) for ITD activities to be eligible.

What others think I do: dealing with misconceptions

Program leaders are often confronted with very diverse and sometimes diverging expectations of what their role as leaders of integration processes actually encompasses. As their position involves a range of different roles, they not only need to attend to diverging expectations and manage the inherent tensions, but also have to balance and combine them consciously (Hoffmann et al. 2022a, b). Often, these role(s) and related leadership tasks are not explicitly defined and underestimated in their complexity. Leading an

ITD program is often depicted as mainly operational business, where program leaders are assigned a more executive and passive role than is actually required to advance integration, as reported by one program leader and one junior participant:

> "By statute and rules of procedure, I could withdraw fully into the operational business… but it just doesn't work that way… We are the drivers, a bit of the bracket that holds it together, sometimes also a bit of the unpleasant drivers that just annoy you. We have to play a very active role." (Leader)

> "I think the problem is, if you have a meeting, a couple of hours or something, I'm sure everyone's going to throw in some ideas, but these ideas don't necessarily all make sense together. I think someone has to sit down and really think everything through and try to make a coherent strategy rather than only brainstorming among the group. I think it is always nice to generate ideas, but it doesn't necessarily produce something which is feasible [for moving forward]." (Junior Participant)

An active role is needed beyond setting up and kick-starting the program, as integration needs to be continuously encouraged, guided, and sustained over time to attain integrated outcomes and outputs (Andrews et al. 2024; Hoffmann et al. 2022a, b; Hollaender et al. 2008; Ruppert-Winkel et al. 2015) as expressed by one leader:

> "I have now received a new work package and then I was told "the program is now initiated, it is running, now you have free capacities for other tasks". This [lack of] understanding I also find a challenge; understanding that the program becomes better when it is [proactively] led instead of just assuming that something will hopefully come out of it at the end." (Leader)

This finding resonates with Hollaender et al. (2008, p. 387), who argue that a "laissez-faire type of leadership, which hopes that the different parts of the work of transdisciplinary teams will grow together organically has not proven successful". It is therefore key that program leaders have explicit resources at their disposal, i.e., time and funds, for pushing integration forward as well as being able to reflect upon it (Roschewitz and Björnsen Gurung 2021). In the case of Wings, this meant both leading integration and also studying it (Hoffmann et al. 2017a; Deutsch et al. revised & resubmitted).

This lack of understanding from the outside is also reflected in the common performance indicator databases, where researchers have to assign their work to pre-defined and standardized tasks used for collecting and assessing researchers' annual academic outputs. The high amount of bilateral, group, or program-wide meetings, workshops, and creative processes for advancing integration and creating 'non-traditional' outputs beyond publications are hardly accounted for in such databases, causing frustration as one leader reports:

> "I had the feeling that, "wow, I've done so much in the last year, so incredibly much" and then I went into the indicator database, and I realized that I can't fill in almost anything; what I'm doing doesn't fit into the database. And I find that a bit unsatisfactory" (Leader)

Moreover, program leaders are often miscategorized as coordinators, facilitators, or administrators of integration. While coordination, facilitation, and administration are essential parts of their role, such a conceptualization reduces their intellectual contributions to scholarship to a mere "supportive service role" rather than a very essential "creative science role" (Bammer et al. 2020; Hendren and Ku 2019; Hoffmann et al. 2022a, b). Referring to this sort of miscategorization, several program leaders and participants indicated that they perceive it even as a risk to take over such a leadership role because one might no longer be regarded a "scientific expert", but rather an "academic lightweight", producing nothing of substance (Oliver and Boaz 2019) as their cognitive–intellectual contributions are largely invisible and unrecognized (Bammer et al. 2020).

Leadership strategies related to "dealing with misconceptions":

> **Attitudes**: Be aware that leading an ITD program is not an operational side task, but a proactive and creative core task. Therefore, allocate sufficient time, as it demands immense resources not only at the beginning for setting up and kick-starting the program, but throughout the whole program duration.
>
> **Processes**: Make your supportive service as well as creative science contributions visible. Make explicit what tasks this leadership role entails (see Fig. 1 in subsequent chapter) to program participants, but above all toward your superior(s). Establish 'updates from the program lead' as a firm agenda item during meetings with the project teams to report on activities and achievements.
>
> **Structures**: Propose a revision of the current performance indicator database by providing a list of activities, achievements, and process indicators to the responsible department. Demand from/suggest to your superior that leading an ITD program is—for your academic career—considered an equally important and scientific qualification step as contributing to a disciplinary community.
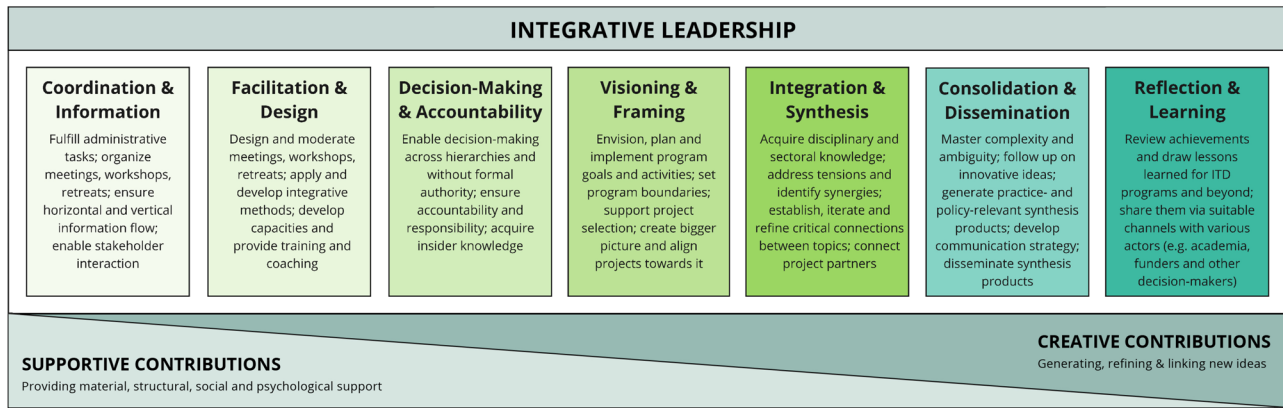
Fig. 1 Portfolio of tasks, responsibilities, and contributions of integrative leadership in ITD programs

Overall implications for integrative leadership in ITD programs

As subchapters "Information overload ahead: mastering complexity and ambiguity" to "What others think I do: dealing with misconceptions" have shown, integrative leadership comprises a broad portfolio of tasks and responsibilities in different areas. Figure 1 provides an overview of this portfolio and specifies which tasks are rather supportive and which ones are creative contributions in line with our definition of integrative leadership (Mainemelis et al. 2018). This conceptual distinction is key, as different areas of the leadership portfolio also require different expertise, experiences, and skill sets. Studies on other ITD research programs or larger ITD projects (Bruce et al. 2004; Defila et al. 2006; Hoffmann et al. 2017a; König et al. 2013; Roux et al. 2010) similarly concluded that the role of the program leader(s) is a crucial and complementary one to those of the project or work-package leaders, and requires assuming a wide range of tasks which matches our conceptualization of integrative leadership as a broad portfolio of tasks, roles, and expertise (Fig. 1). Tasks located in the realm of supportive contributions (left side) for instance require, above all, good communication, coordination, moderation, and methodological skills. The more one moves into the realm of creative contributions (right side), the more integration expertise becomes necessary to fulfill these tasks. However, skill sets necessary for supportive contributions are of course equally relevant to creative contributions (e.g., good communication skills to be able to integrate). As it is unlikely that one individual can be outstanding in all those areas (Krainer and Lerchster 2015), co-leadership with complementary expertise, experience, and skill sets becomes a fruitful way forward.

We suggest considering these areas as 'modular', meaning that depending on the program phase, certain areas might temporarily require more attention and resources than others. However, all areas are essential, and hence need to be covered to be able to realize integration in ITD programs and accordingly require sufficient time and resources. With limited time, the focus often lies merely on coordination and communication, leaving aside the application of integrative methods or the generation of final synthesis products. In light of the empirical material, our experiences and the time resources that were at our disposal (see again Table 1), we recommend assigning for these tasks at least a 100%, and up to 300% FTEs (full-time equivalent) to ITD programs of the size of Extremes, NCCS-Impacts, or Wings. The exact percentage depends on the program contexts, as some programs might already be set up from the very beginning with a higher potential for synthesis than others.

Conclusion

ITD programs and their respective leaders need to serve many masters. The metaphor of 'herding cats' is certainly apt in these contexts, given the complexity, ambiguities, and centrifugal forces program leaders need to deal with. Hence, courage, strong nerves, intrinsic motivation, and integration expertise are a prerequisite to lead such programs. As ITD programs are large structures with a highly dynamic life of their own, many things—challenges as well as new opportunities—cannot be foreseen at the onset of their implementation (Roux et al. 2010; Ruppert-Winkel et al. 2015). The greater the ITD aspects are built into a program, the greater are the flexibility and agility required from both leaders and participants, but also in terms of time and funding.

We identified six core leadership challenges, which we encountered when designing, setting up, and implementing three ITD programs in Switzerland, and presented strategies which have proven to be beneficial for the program leaders in dealing with them. These strategies are meant as suggestions or options, but neither as recipes nor panaceas as program contexts can strongly differ. Therefore, each 'integration

concept' and related leadership approach will be to a certain extent 'unique' (Hall et al. 2019a). In addition to these six challenges, other program-specific challenges can be anticipated. However, despite the differing contexts of Extremes, NCCS-Impacts, and Wings, we were still able to identify overarching challenges and respective strategies common to all programs. We therefore think that our results yield important insights for leaders and funders of other ITD research programs or larger ITD projects (e.g., at EU/international level), which are in line with the research programs characterized by Defila et al. (2006, pp. 16–17) and Schneider et al. (2019, p. 1), i.e., ITD research programs which pursue (1) inter- and transdisciplinary integration for (2) addressing a complex societally relevant challenge and aim for (3) a joint synthesis at the program level and (4) the re-integration of results into societal and scientific practices (Schneider et al. 2019; Defila et al. 2006).

Such ITD programs, which aim to achieve scientific and societal impacts at the same time, are necessarily characterized by high heterogeneity due to numerous participants (multiple disciplines and societal actors), multiple projects or work packages, and (more or less related) research questions for addressing the overarching topic. Therefore, we believe that program leaders in the described contexts are necessarily confronted with the same, or at least similar, challenges, such as how to ensure that program participants feel responsible for contributing to integration across their individual work packages or projects and how joint synthesis at the program level can best be attained (see again "Non-integration as default: ensuring responsibility and accountability"). Integration can take different forms throughout the program's course depending on the specific purpose, scale, and scope of such programs (Hoffmann et al. 2022a; Klein 2008) and does not necessarily imply 'consensus' (Pohl et al. 2021). Moreover, integration cannot always be pursued across all projects or work packages, as not all perspectives can be reconciled, particularly at a certain point in time (Harvey et al. 2018) (see again "Counteracting chance: selecting suitable projects".)

One limitation of our study is certainly that all ITD programs are located in Switzerland—a country where research is usually financed at an above-average level compared to other countries. However, we believe that this is nonetheless an especially interesting aspect, as it shows that a greater availability of funding does not necessarily alleviate all challenges. In addition, it provides an entry point for future research, since leadership in ITD programs can be compared across different contexts and countries.

To conclude, we want to emphasize that the importance of integrative leadership in academia, in general (Cohen and Cohen 2018), and in ITD research programs, in particular (Defila et al. 2006; Gray 2008; Hoffmann et al. 2017a), tends to be underestimated when designing and setting up ITD research programs and respective leadership resources. This goes along with an underestimation of the kind of roles, responsibilities, and tasks integrative leadership involves, but also the workload it implies to fully exploit the collaborative and integrative potential of ITD programs. While distributing roles, responsibilities, and tasks for integration is key in such programs, the overall responsibility to realize that potential must reside with the program leaders (Hollaender et al. 2008). Integrative leadership can never be fully delegated, but always needs to be proactively assumed and wholeheartedly supported by program leaders to ensure that ITD programs live up to their collaborative and integrative ambition—just like herding cats.

Appendix

The interview guideline was developed in line with the overarching research questions of the research project "Wings Integrate/Lead ITD!" at Eawag, and based on Willis (2019). The questions were asked to both program participants and program leaders. However, program leaders were asked slightly different questions in some parts of the interview to explore their leadership role more thoroughly. These questions are pointed out in brackets.

Opening (10 min):

1. How did you come to be part of program/network X? (For leaders: You have been in charge of program/network X since Y. How did you get to this position?).

2. What motivates you to participate in this inter- and transdisciplinary program/network? What do you hope to contribute? (For leaders: What motivates you to lead this program/network? What contribution do you hope to make?).

Integration (20 min):

3. In the literature, "integration" is described as a key challenge and core characteristic of inter- and transdisciplinary as well as cross-sectoral collaborations. Often this term appears somewhat fuzzy. What do you understand by integration?

4. Can you give me a concrete example where integration has (not) taken place for you?

5. Example of successful integration: what was decisive for this? What conditions/prerequisites were fulfilled so that integration could take place in this case?

6. Example of unsuccessful integration: what was the decisive factor here? What conditions/prerequisites were not fulfilled in this case?

Integrative leadership (40 min):

7. How do you imagine integration to take place within program/network X?

8. Who is responsible for ensuring that integration takes place in program/network X?

9. What is the role of (the program leaders) X and Y in relation to integration? (Follow-up: i.e., in the end, who leads integration within program/network X?) (For leaders: what is your role as the program/network leader in relation to integration?).

10. What is your role in the program/network? (Follow-up: in relation to integration specifically?) (for leaders: not asked, as already addressed in question 9).

11. What do you need to fulfill this role/contribute to integration? (Follow-up e.g., skills, attitudes, expertise, conditions, etc.)

12. Can you recall a situation where you were able to fulfill your role in terms of integration in the program/network? Do you have a personal "best practice integration story"? (Follow-up e.g., in which situation did you have the impression that you were able to work very well in an integrative way? What was decisive for you to be able to meet your integrative demands?).

(For leaders: Can you remember a situation where you were able to live up to your own integrative leadership standards? Do you have a personal "best-practice leadership story"? In which situation did you have the impression that you were a good integrative leader? What was decisive for you to be able to live up to your integrative leadership principles?)

13. Do you also have a personal "integration horror story" where you could not fulfill your role in terms of integration in the program/network? What was the decisive factor here? What prevented you from working in an integrative way?

(For leaders: Do you also have a personal "leadership horror story"? What was the decisive factor here? What prevented you from leading in an integrative way?)

14. If we now consider your own "horror story" and the "best practice integration story" together, as well as the circumstances under which they took place, what conclusions do you draw with regard to the future of your integrative work in the program/network and for integration in general in the program/network? (For leaders: What conclusions do you draw with regard to your own integrative leadership practice in the future?).

Outlook (10 min):

16. What challenges do you anticipate in the program/network in the coming weeks and months and how do you think they should be addressed? What contribution can you make to address these challenges?

17. Looking back on the interview, is there anything else you would like to add? Is there any other aspect that I have not addressed so far, but would be important to discuss?

Data availability Not applicable. In line with the ethical approval granted by ETH Zurich, the authors are unable to make the data publicly available due to its confidentiality.

Declarations

Conflict of interest The authors have no relevant financial or non-financial interests to disclose.

Informed consent The plan for data collection, analysis, and storage was revised and approved by the ETH Zurich Ethics Commission in March 2020 (EK 2022-N-15). All participants gave their written consent to participate in the study. In addition, all participants were able to revise and provide feedback on this manuscript prior to submission.

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