# Towards Team Science

Caspar J. Van Lissa, Esther Keymolen, Sasha van den Hoek, Annika Klingner, Lilly Schurman, Marjan van Hunnik

# Towards a Vision for Team Science at Tilburg University

Team Science Working Group
Use (Y)our Talents Program
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# 1 Introduction

Much of the work conducted at Tilburg University already occurs in a team context. But the term "Team Science" has taken on a new meaning and relevance in the context of the Recognition & Rewards program. The university has committed to establishing a vision on Team Science in 2023. To meet this mandate, a working group "Team Science" was established within the university-wide program "Use (Y)our Talents" (of which Recognition & Rewards is a part). The working group Team Science was asked to write a policy brief to inform the future of Team Science at Tilburg University, paying attention to the following:

1. **Define** team science in the context of Tilburg University (with special attention to the Social Sciences & Humanities, SSH);
2. Explore the scientific **literature** on team science;
3. Develop practical starting points for the **implementation** of team science;
4. Chart national and international **best practices** for team science.

## 1.1 Team Science and Tilburg University

What does Team Science mean for Tilburg University? To answer this question, we first turn to the University's "Strategy towards 2027", which states that our organization is guided by its four core values of curiosity, caring, connectedness, and courage. These values are intrinsically related to the topic of Team Science.

### 1.1.1 Curiosity

Curiosity motivates us to ask challenging questions that require more than a single mind to answer. It drives us to seek each other out and learn from each other's perspectives and expertise.

### 1.1.2 Caring

Caring reflects a respectful and supportive work environment, with attention to diverging perspectives, social safety, and the wellbeing of team members at all career stages. We also care about society at large, and strive to make a positive and ethical impact through our research.

### 1.1.3 Connectedness

Connectedness is fundamental to team science, which requires strong, collaborative ties among team members from different areas of expertise across all parts of the organization. It also reflects our relationships with other regional, national, and international stakeholders.

### 1.1.4 Courage

Courage in team science is about daring to challenge conventional wisdom and take intellectual risks. It involves critically evaluating existing knowledge, being open to novel approaches and methodologies, and sometimes going against established views. Teams benefit if members take on complementary roles, and courage empowers members to challenge established views and voice minority opinions, epitomizing the university's commitment to innovation and excellence.

## 1.2 Defining Team Science

In the academic literature, *Team Science* is defined as a mode of scientific collaboration where research is conducted by more than one individual in an interdependent fashion (Cooke, Hilton, and Council 2015). Most common is collaboration within small *science teams*, typically comprising 2 to 10 individuals, but *large teams*, sometimes involving hundreds or even thousands of scientists, also occur. Smaller teams are more agile and can drive disruptive innovation, while very large teams can achieve unrivaled impact. A thriving research ecosystem requires a balance of these approaches (Wu, Wang, and Evans 2019). Large teams typically have a differentiated *division of labor* and an integrated *structure* essential for coordinating the efforts of many team members. Although team Science is often interdisciplinary, the two are not synonymous: team science may be characterized by different degrees of interdisciplinarity and different levels of *integration* across disciplinary perspectives. It has been argued that (interdisciplinary) team science is absolutely essential for tackling some of the world's most pressing problems (Ledford 2015), whether it be climate change, peace and security, socio-economic inequality, health and wellbeing, or even spiritual renewal (Korthals Altes 2014).

While the academic definition of team science in terms of team size may be objective, it does not convey the core ideals of team science as envisioned by the working group Use (Y)our Talents. In the context of Use (Y)our Talents, this working group defines team science as:

**Definition**: Team Science can be defined as collaboration with a larger number of partners than is standard in a particular domain of study, addressing a goal that transcends what could be achieved by a single scholar, capitalizing on team members' strengths, with attention to their diverse perspectives, and members from multiple branches of the organization (including scientific and support staff), and/or other stakeholders.

## 1.3 Benefits and Challenges of Team Science

### 1.3.1 Benefits

Team science has many advantages for individual team members, the organization, and academia and society at large (C. Allen and Mehler 2019). As part of a team, scholars can address larger (societally relevant) challenges than they would be able to tackle individually. In this time of unprecedented social, economic, and ecological crises, this is more urgent than ever before (Cannon 2020). Within the context of *Use (Y)our Talents*, it is also relevant that team science allows people to contribute according to their strengths and share the benefits - some excel in writing, others in data collection, analysis, or public engagement. Team science creates opportunities to join forces, rather than each individual needing to excel on all fronts. Team science allows researchers to pool resources, thus increasing the statistical power to detect an effect and enabling them to systematically examine heterogeneity in effects (R. A. Klein et al. 2014). Team science also offers enhanced depth of insight by integrating diverse perspectives - in terms of both interdisciplinarity and intersectionality. Interdisciplinary research teams exhibit increased creativity, productivity, and impact (Cannon 2020; Hinrichs et al. 2017). Still, interdisciplinary team science faces funding challenges due to bias in grant evaluations, favoring narrowly focused proposals (Bromham, Dinnage, and Hua 2016). Science teams can comprise academic and support staff, enabling specialization and a more efficient division of labor. Science teams can also incorporate societal stakeholders or corporate partners, amplifying impact and potential valorization, respectively. Team science benefits individual researchers because resulting publications have a citation advantage (Wuchty, Jones, and Uzzi 2007); an advantage that may be particularly attractive to early career scholars. It also benefits early career scholars by creating opportunities for mentoring by more experienced staff (DeHart 2017). Collaboration in science also significantly benefits employee well-being and empowerment, while addressing issues like workplace isolation and underperformance (Mydin, Radin A. Rahman, and Muna Ruzanna Wan Mohammad 2021). Team science benefits the work culture by cultivating a sense of community. It can also increase the sense of social control and accountability, benefiting the reproducibility and trustworthiness of results. Teams offer networking opportunities and foster peer-to-peer skills transfer, as members are exposed to various methodologies and perspectives. A diverse, collaborative environment is not just a catalyst for innovative research but also a bedrock for cultivating well-rounded scientists equipped for the multidimensional challenges of contemporary research.

**Summary**: Team science benefits both individual team members, the organization, and society at large, and allows scholars to provide complex solutions to large-scale public challenges. It promotes collaboration, cohesion, and knowledge exchange within organizations, increases impact, and may benefit research quality.

### 1.3.2 Challenges

Team Science, while beneficial for advancing research, presents several challenges that can impact its effectiveness. Like any change in workflow, it incurs initial "start-up costs", to individuals and the organization, in terms of building relationships and aligning perspectives. Of course, these investments may pay off in the long-term through the aforementioned benefits. Some have argued that the average quality of team work is lower compared to the average quality of highly specialized individual research (Bromham, Dinnage, and Hua 2016). Individual scientists might be able to explore ideas with greater focus, free from the need to coordinate with others (Forscher et al. 2023). At the same time, team science involves more checks and balances to detect errors or even malpractice than individual work (Vazire 2020). Science teams also face challenges in measuring and comparing team science performance (Gibson, Daim, and Dabic 2019). In the literature, seven specific challenges of team science have been identified (Cooke, Hilton, and Council 2015). Firstly, the high *diversity* of membership in terms of disciplines, cultures, and backgrounds, while enriching and promoting innovation and creativity for impactful discoveries (Nielsen et al. 2017), can also lead to communication barriers and differences in methodologies or perspectives, which can negatively impact the research process and result quality (Kosmützky 2018; Wallerstein et al. 2019). Teams should be sufficiently diverse to ensure different perspectives are represented, engage in reflexivity - considering how the researchers' perspectives influences the research, and considering whether relevant perspectives are represented - and strive for successful communication and mutual understanding. Secondly, deep *knowledge integration* across various fields requires overcoming intellectual silos, demanding a synthesis of diverse theories, tools, and data (Conn et al. 2019). Teams should actively synthesize contributions from different members. Thirdly, managing *large teams* poses logistical challenges in coordination, communication, maintaining a unified vision, and the fair distribution of resources (Conn et al. 2019; Campbell-Voytal et al. 2015). The paradox of team size is that smaller teams are typically better coordinated, while larger teams nonetheless outperform in publications, patents and citations (Cummings 2018). Furthermore, *goals* can often become misaligned, both within the team, and between teams within the organization, which can lead to conflicts in priorities and directions. When private partners are involved, goal conflicts can also arise from the tension between scientific best practices and commercial interests. To overcome this challenge, participatory goal setting is advised (Campbell-Voytal et al. 2015; Patel et al. 2021). Particularly in light of the precariousness of (early-career) academics, teams can have *permeable boundaries*, with members transitioning in and out of teams, requiring the rest of the team to adapt and realign. *Geographic dispersion* of team members across different time zones and locations requires the use of digital tools, hybrid work, and asynchronous collaboration. The distance can be a challenge for communication and team cohesion - but at the same time, the past years have seen extensive professionalization of hybrid work infrastructure, which helps overcome some of these challenges (Earley and Mosakowski 2000). Lastly, high *task interdependence* means that the success of the entire project depends on each member's contributions, amplifying the effects of any discordance or inefficiency within the team. Overcoming these challenges requires institutional support, strategic management, and effective communication (Conn et al. 2019; Surratt et al. 2023; Read et al. 2016; Jeong and Choi 2015; Forscher et al. 2023; Campbell-Voytal et al. 2015; O'Rourke et al. 2023; Ghamgosar, Nemati-Anaraki, and Panahi 2023).

**Summary**: Any science team should be aware of, and reflect on how they relate to, the seven challenges of team science: diversity, knowledge integration, team size, goals, permeable boundaries, geographic dispersion, and task interdependence.

# 2 Good Practices

To observe good examples of team science projects, we can take a local, national, and global perspective. Within our own university, there are many great examples of team science in different forms.

## 2.1 Local Perspective

The University Library provided data on authorship of scholarly output produced at Tilburg University between 2017-2023. While these data have some limitations - for example, not all authors may have registered their output, and not all team science contributions are reflected in co-authorship of scholarly output - they nonetheless provide some insight into the state of team science at TiU. The main conclusion is that team science already comprises a substantial part of research conducted at Tilburg University. When analyzing publication records of our staff of the past five years, we observe that the majority of publications has two or more authors; the proportion of single-authored publications is decreasing steadily, and the proportion of publications with more than 5 authors is increasing steadily, see Figure Figure 2.1.

Team science is thus quite common at TiU, but analysis of author affiliations provides a more nuanced picture. Specifically, only 3% of publications between 2019-2023 included authors from more than one school. By comparison, 66% of publications in the same timeframe included authors from outside TiU. In terms of societal stakeholders, 18% of publications in this timeframe included authors not affiliated with any university (government employees, those at independent research institutes, corporate stakeholders, medical professionals, those working in media, and at private non-profits).

If connecting the schools is a desired goal, then these statistics suggest that there is still much room for improvement. Especially considering that TiU is a relatively focused institute - all schools fall within scope of the social sciences and humanities - fostering stronger ties between the schools is highly feasible and should be considered low-hanging fruit. TiU appears to do well in terms of collaboration with external partners, which makes sense considering it is an impact-driven university, which strives to connect to society, and is strongly embedded within the province. Initiatives like the recent Regio Deal Midden-Brabant, “Ondernemen, innoveren en experimenteren met de mens centraal” continue to raise awareness about impactful projects that can involve multiple schools and societal partners. According to research, well-established senior researchers

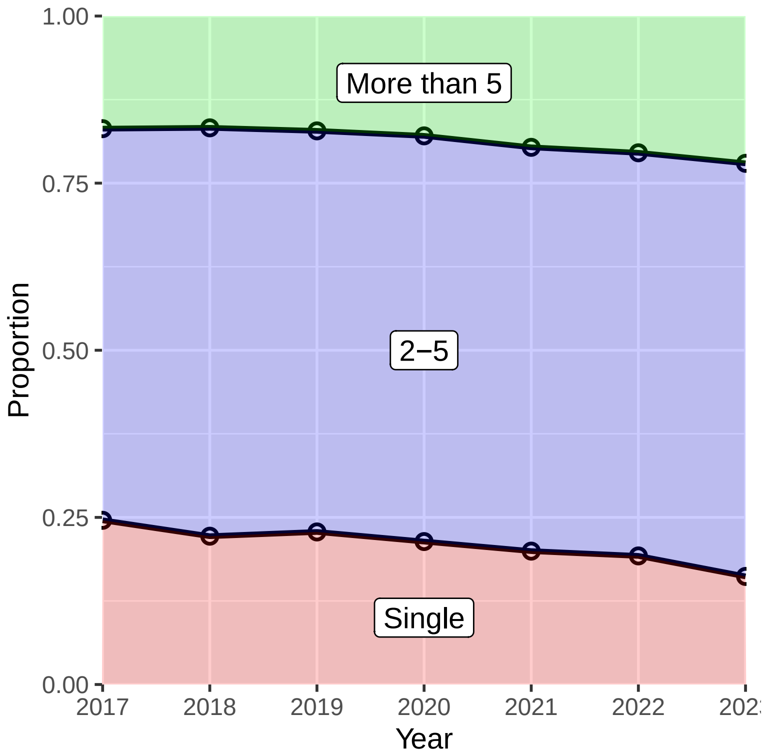


Figure 2.1: Proportion of team science publications at TiU

are more likely to collaborate with societal partners, but face obstacles like differing goals, reduced government support, and concerns about intellectual property, and uncertainty about both the economic and academic success of team science involving industry partners (Anić 2017). If the goal is to further enhance collaboration with external partners, the first step is to identify promising areas of potential collaboration, organizing opportunities to meet external partners, and facilitating effective information exchange with societal partners (Capaldo et al. 2016). Finally, these statistics show that collaboration with external scholars already abounds, and may thus be less of a priority.

Of course, these quantitative data have many limitations; not all scholarly output is accounted for by the University Library, not all contributions are reflected in authorship (e.g., support staff might not be named as co-authors), and affiliations are not always correctly listed.

**Consideration**: At present, only 3% of academic output involves authors from multiple Schools. If connecting the schools is considered important, then promoting team science initiatives that connect the schools is low-hanging fruit.

Existing initiatives aimed at fostering collaboration across the schools are the academic collaborative centers in which researchers from different disciplines are invited to collaborate, together with societal partners, on socially relevant problems. Also, the Digital Sciences for Society program requires the involvement of two or more different schools in projects supported by their funding instruments (Icon, growth projects). These existing initiatives could potentially yield a wealth of relevant insights regarding the challenges and opportunities of team science conducted at TiU locally. These insights should be collected and evaluated to build knowledge on best practices regarding the conduct (and the funding of) team science in practice.
Within some schools, (e.g., TSHD, TSB) there is seed funding for interdepartmental collaborative projects on several themes. Of course, as these instruments are provided at the school level, the scope of collaboration is somewhat limited.

To provide a more complete picture of what constitutes team science at our university, and give some insight into the lived experience of team members and leaders, we conducted qualitative interviews with colleagues involved in several such initiatives, which are described in the vignettes below:

**Digitalization of Health and Wellbeing (a) [several team members]**

**Goals**. Establishment an interdisciplinary research program/group about digitalization of health and wellbeing.

**Team Composition**. Six assistant-professors from various schools of the university + the dean of TSHD.

**Successes**. The team has built relationships, secured internal ICON funding, and made progress in defining practically achievable goals.

**Challenges**. Establishing the team was complicated by lack of clarity about membership and functioning when members signed their contracts. The project's goals have been unclear, and attempts to clarify them are sometimes hindered. There is tension due to the hierarchical structure. This leads to an information asymmetry between leadership and members. Some members would prefer a more egalitarian peer-to-peer network. Some noted conflicts due to misalignment between team members' individual interests and the project's scope, feeling as though the group was formed more for administrative reasons than in pursuit of a shared research goal. A grant application that many team members had contributed to was shelved because the core team received ICON funding, leaving other contributors to feel passed over after investing effort.

### Digitalization of Health and Wellbeing (b) [vision manager]

**Goals**. Establishing an interdisciplinary research group to collaborate with partners, exchange knowledge, create academic and societal impact, and work towards long-term improvements in mental wellbeing.

**Team Composition**. The research team is in progress, aiming to unite all five schools at Tilburg University. Currently, TSHD, TSB, and TLS are actively engaged, while TiSEM and TST are less involved. The goal is to also eventually involve all relevant external parties, but some contracts are still being finalized.

**Successes**. Many want to join this open project without strict criteria, fostering interdisciplinary exchange. Partners are equal, though the core team holds more control and tasks are divided by the core team but with team member's consent.

**Challenges**. Participating in the research team alongside existing work is challenging due to resource constraints. Aligning goals with partners can be a challenge, but joint goal-setting based on overlapping challenges and missions seem to be successful. Age diversity exists among team members, but there's limited cultural diversity.

### Brabant Study

**Goals**. A large longitudinal cohort study of women, from pregnancy to 5 years postpartum. The aim is to improve mothers'/children's/partners' biopsychosocial well-being.

**Team Composition**. Collaboration between 7 departments of TSB. Currently there are 4 PhD students and 2 postdocs involved. The core research team consists of experts from various disciplines involved in perinatal well-being. The project was based on existing collaborations, and attracted new partners.

**Successes**. Interdisciplinary research and high output. Collaboration is central, so data are analyzed from different perspectives. Another success is the close collaboration with midwifery practices and hospitals in the region, which helped recruit a large sample (N=2800).

**Challenges**. Due to the many collaborators, it is important to keep an overview so that everyone can provide equal input. This also complicates swift action and decision making.

These vignettes illustrate the status quo of team science at our university, across different schools and levels of the organization. They also provide real-life examples of lessons learned in terms of rigid hierarchy (see Section 4 and Section 3.2), shared goals and representations (see Section 3.1) and transparency and fairness (see Section 3.3). Future team science efforts at TiU should build upon these lessons learned, and build in a flexible hierarchy, transparency and procedural fairness from the start, and engage in shared activities and/or trainings to establish shared goals and representations.

## 2.2 National Perspective

Of course, team science is not confined to collaboration within the university. Especially since our assignment was to look at national best practices, we also conducted interviews with members of nation-wide team science initiatives (see the vignettes below). Both initiatives do have ties to our university; the first involved members of our staff, and the second involved staff members from four schools ODISSEI (TLS, TiSEM, TSHD, and TSB).

**Voting advice applications (EU funded project)**

**Goals**. Understanding the effect of voting advice applications on the population, and society at large.

**Team Composition**. Three universities in three different countries (NL, UK, TR). A core consortium convened a larger research team and partners.

**Successes**. The project was successful: training three PhD students, collecting substantial data, and publishing papers. It had social impact through conference participation and non-academic output. The initial goal was further concretized over time. Interdisciplinary communication challenges were overcome, providing learning opportunities. The team's disciplinary and demographic diversity did not hinder collaboration.

**Challenges**. Communication challenges arose due to team members being geographically dispersed. Phone and internet communication were perceived as less effective than in-person interaction. Scheduling conflicts and varied commitments across countries complicated collaboration. Involving companies added complexity since aligning business goals with the academic focus on publications is not always straightforward. While there was no goal misalignment, strategies to pursue those goals differed. Task interdependence occasionally caused delays, but wasn't a major issue.

### ODISSEI

**Goals**. This national research infrastructure supports ~300 interdisciplinary projects annually. It facilitates collaboration among social science and economic faculties in the Netherlands, removing barriers for researchers, such as connecting them with interdisciplinary expertise and data.

**Team Composition**. Every social science faculty and some economic faculties in NL, and ~80 team members working at ODISSEI. The 300 annual projects each have teams with about 1-4 team members.

**Successes**. The successes lie in its efficient online communication which promotes flexibility, a simplified and (disciplinary and demographically) diverse team, and a horizontal, federated structure that empowers individual researchers, fostering bottom-up innovation. The project has successfully united an interdisciplinary diverse group, enabling groundbreaking research through collaborative expertise.

**Challenges**. Managing the complexity of diverse disciplines with distinct languages and taboos remains a challenge. Task-interdependence requires effective communication, with regular interventions to keep team members informed and engaged. The project tries to emphasize the effort needed to avoid assumptions and maintain collaboration, as it's easy to overlook progress and responsibilities within a complex team-environment.

## 2.3 International Perspective

Team science that spans country borders is relatively rare, with approximately 90% of papers published by authors from a single country (Akbaritabar & Barbato, 2021). Many of the most notable international team science examples hail from the natural and physical sciences. But still - there are inspiring examples of global team science initiatives in the SSH domain. One of the most well-known examples is the "Many Labs" project, established by former TiU-employee Richard A. Klein. Motivated by the so-called "replication crisis" (Open Science Collaboration 2015), this crowdsourced initiative recruited several hundred social science departments around the world (R. A. Klein et al. 2014). The consortium set out to replicate published psychological effects, increase power and ensure methodological rigor, and study variation in replication results across samples and settings. Similar "Many Labs" projects have been established in developmental science (ManyBabies, Byers-Heinlein et al. 2020) and neuroscience (EEGManyLabs, Pavlov et al. 2021). A more general consortium has been established to empower future many labs studies: the Psychological Science Accelerator (PSA) is a globally distributed network of researchers (2468 researchers from 73 countries) that pool their resources to replicate submitted studies. Another example of SSH team science is the PsyCorona consortium, an ad-hoc collaboration with over 130 scholars from 70 different countries, established within the first week of the COVID-19 pandemic (Leander et al. 2020). Before vaccines were developed, behavioral measures were the only countermeasure to slow the spread of the virus, and this consortium set out to collect social scientific data to advise policy for effective behavioral interventions. PsyCorona was founded at Groningen University by Pontus Leander, and its data science team was headed by TiU-employee Caspar van Lissa. By making all analysis code and datasets FAIRly available, the PsyCorona consortium was able to increase productivity and publish 23 papers. These examples highlight the potential of large-scale consortia in the social sciences in terms of increasing methodological rigor, statistical power, impact, and output.

## 2.4 Open Science: Lessons Learned

According to UNESCO (2021), open science is defined as follows:

> [Open science is] an inclusive construct that combines various movements and practices aiming to make multilingual scientific knowledge openly available, accessible and reusable for everyone, to increase scientific collaborations and sharing of information for the benefits of science and society, and to open the processes of scientific knowledge creation, evaluation and communication to societal actors beyond the traditional scientific community. It comprises all scientific disciplines and aspects of scholarly practices, including basic and applied sciences, natural and social sciences and the humanities, and it builds on the following key pillars: open scientific knowledge, open science

infrastructures, science communication, open engagement of societal actors and open dialogue with other knowledge systems.

It is evident from this definition that there is a fundamental correspondence between the perspectives and methods underlying team science and open science (Cheruvelil and Soranno 2018). Removing barriers to more efficient and effective collaboration, including within teams, is a prime goal of open science, and the open science movement was fueled in large part by team science efforts (Ross-Hellauer et al. 2022). The open science transition has been a widely successful paradigm shift; In 2021, the UNESCO framework on open science was adopted by 193 signatory countries (UNESCO 2021). Open science is now considered "standard practice" by the Dutch government (Ministerie van Onderwijs 2019), the EU (os4os 2023), and the United States government ("FACT SHEET: Biden-Harris Administration Announces New Actions to Advance Open and Equitable Research | OSTP" 2023). Given this extraordinary success, we can look to the "open science transition" for examples of best practices for promoting team science. One crucial ingredient of the open science transition was support of the scientific community. Implementing a desired cultural change is a social challenge that requires a critical mass of support from employees (INOSC n.d.). In this sense, the Open Science Community Tilburg can serve both as a model and an ally in promoting the desired cultural change towards more interdisciplinary team science. The book chapter "Building a Strategic Advantage with Open Science", by colleagues Hannes Datta and Harm Schütt, delves deeper into the potential value of open science for TiU (2022).

**Consideration**: The open science transition serves as a template for the transition towards more team science, and the Open Science Community Tilburg is a natural ally in achieving this transition.

Specific open science practices are also invaluable in team science contexts. For instance, the open science practice of making scholarly output (protocols, materials, data, analysis code, and reports) FAIRly shareable increases the reusability of team members' contributions and eliminates the need for time-consuming onboarding, thus improving the scalability of team science (Baumgartner et al. 2023). Transparency also allows team members to replicate and verify each other's work more easily, enhancing the rigor and reliability of interdisciplinary research. The practice of public engagement is also associated with open science, and constitutes a particular form of team science. Public engagement can add knowledge to teams, and increase the relevance of social scientific research for its target audience (Tebes and Thai 2018). The practice of preregistration serves a dual purpose of clearly outlining the scope of work to be done by a team, and preventing post-hoc disagreements about analytic decisions from arising after the data are collected (Peikert, Van Lissa, and Brandmaier 2021). Going beyond preregistration, submitting a Registered Report offers team members a "guaranteed payoff" to the effort invested (Baumgartner et al. 2023). Finally, open access publication makes scholarly output accessible to a wider audience. In team science, this can be especially valuable because the number of stakeholders is often larger; not all stakeholders may have access to certain outlets. In team science, it may be the case that not all team members are affiliated with an institution that (can afford to) pay for access to paywalled journals. Publishing open access ensures that all who have contributed retain access to the finished work, and additionally allows for dissemination to a broader community of researchers, policymakers, and practitioners. To empower team science using open science methods will require a persistent funded commitment to openness, rigor, and collaboration (Thibault et al. 2023). Recognizing and rewarding open science practices further incentivizes their adoption (see Section 6.1).

**Consideration**: Open science practices facilitate team science, reduce onboarding efforts and improve scalability, increase the reusability of materials, data, and code, increase scientific rigor, and offer a greater potential payoff to team members.

# 3 What the Science of Team Science Says

## 3.1 Team Effectiveness

Team effectiveness, or team performance, is defined as the team's ability to achieve its goals and objectives, leading not only to improved outcomes for individual team members, but also to significant team achievements, including academic breakthroughs, methodological innovation, and translational (interdisciplinary) applications of the research. The concept of team effectiveness has been extensively explored in the literature, with substantial influence from the input-process-output (IPO) model (McGrath 1964). The input-process-output (IPO) provides a way to understand how teams perform, and how to maximize their performance . Team effectiveness hinges on inputs such as the team composition and the nature of the problem at hand. The processes, involving the team members' cognition, motivation, affect, and behavior, are crucial in enabling the team to meet task demands effectively. When the output resulting from these processes aligns with the task demands, a team is considered effective.

Central to effective teamwork are processes like *team mental models* and *transactive memory*, which entail shared understanding of task requirements, procedures, role responsibilities, and an awareness of each member's knowledge and expertise (Patel et al. 2021; Ghamgosar, Nemati-Anaraki, and Panahi 2023; Mehta and Mehta 2018).
Formulating explicit goals, adaptive problem formulation, and participatory processes help build mutual understanding among team members (Vogel et al. 2014; Pennington 2016).

At the team level, team climate also plays a pivotal role, and is shaped by organizational strategies, team leaders' communications, and the interactions and shared understandings among team members. Team spirit benefits from a healthy balance between individual and collective needs and expectations (Getha-Taylor, Silvia, and Simmerman 2014).
At the institutional level, well-structured support for team science and an innovation-friendly academic culture benefit optimal transdisciplinary collaboration (Crow and Dabars 2019). There is an association between interpersonal relationships and scientific productivity on a scientific team (DeHart 2017; Love et al. 2023). Psychological safety fosters a climate supportive of risk-taking, learning and daring to speak out, which is crucial for trust, cohesion, effective error management, and achieving team goals (Edmondson 1999; Patel et al. 2021). Moreover, motivational and affective processes within a team, such as a sense of team efficacy, are essential.

**Consideration**: Team effectiveness is enhanced by thoughtful team composition, team professional development, building a shared understanding of goals, task requirements, and team member competencies, and inspiring person-focused team leadership.

## 3.2 The Role of Trust

Effective interdisciplinary collaboration and team science hinges on the establishment of trust between all parties involved (L. M. Bennett and Gadlin 2014; Read et al. 2016; Zajac et al. 2021). Increased engagement between scientists and stakeholders leads to more mutual trust as well (Meadow et al. 2015). Trust is not just about believing in each other's competence, but also involves perceptions of fairness and transparency in the organization, which is crucial for nurturing a collaborative environment. Internal ties between team members positively influence trust, which in turn contributes to higher-quality relationships and knowledge sharing among team members (García-Sánchez, Díaz-Díaz, and De Saá-Pérez 2019). Transparent communication, decision-making, and enforcement also build trust; for example, by drafting formal collaboration agreements before teamwork begins (Forscher et al. 2023). Building through joint identification of objectives, co-developed guiding principles and ongoing team reflexivity throughout the evaluation strengthens trust between project members and evaluators (Roelofs et al. 2019). Team trust facilitates coordination and cooperation, thereby enhancing team effectiveness (Breuer, Hüffmeier, and Hertel 2016). Some aforementioned challenges to team science (Section 1.3.2), such as rigid hierarchy and diverse professional backgrounds, can pose challenges to building and maintaining trust, particularly in multidisciplinary dynamic teams with changing memberships (Zajac et al. 2021). Trust is especially important in virtual teams relative to face-to-face teams, which could be attributed to the unique challenges of remote collaboration, where trust compensates for the lack of physical presence and direct oversight (Breuer, Hüffmeier, and Hertel 2016).

## 3.3 Communication and Team Success

Transparent communication is integral to team success, particularly in scientific and academic settings (Forscher et al. 2023; Conn et al. 2019; Patel et al. 2021); effective communication can facilitate interpersonal trust, increase productivity, and spark innovation. A "culture of dialogue" establishes deep listening and engagement as norms, which helps overcome challenges, achieve project goals, and establish shared representations (O'Rourke et al. 2023). Training communication skills is beneficial for trust-building, exchanging worldviews, and conflict management (Read et al. 2016). Nevertheless, intellectual conflicts are inevitable in team contexts, and if managed appropriately, these may play a role in advancing knowledge (Collins 1998). Successful science teams promote intellectual disagreement and discussion (L. M. Bennett and Gadlin 2012). Such an environment encourages ongoing dialogue, working through issues, and prevents the accumulation of unresolved problems, simultaneously fostering the development of trust (Brody et al. 2019). Via shared dialogues, teams can define a team mission, establish behavioral standards, cultural understanding, and expectations, foster cultural intelligence and realistic interpersonal assessments (Shelley et al., 2022).

Effective conflict resolution is also important (Read et al. 2016). There are two primary conflict management strategies: reactive and preemptive (Marks, Mathieu, and Zaccaro 2001). Reactive conflict management involves resolving disagreements through problem-solving, compromise, and flexibility, while preemptive strategies anticipate potential conflicts, guiding them in advance through cooperative norms, charters, or other structures. Kozlowski and Bell (2013) further emphasize the importance of these approaches in shaping conflict processes constructively. In essence, the efficacy of team communication, particularly in handling intellectual disagreements, is a significant determinant of a team's success in the scientific field.

**Consideration**: Team members should be able to disagree constructively in a safe, supportive context. When possible, preemptive conflict management strategies should be used; anticipating disagreements and establishing terms for their constructive resolution. When conflict does occur, reactive conflict management should focus on empathy, problem-solving, and compromise. Professional development opportunities should be in place to educate staff in the use of such communication techniques.

## 3.4 Procedural Fairness

Relying on trust may not always be feasible, as trust develops over time between members of well-established science teams, and between friends, introducing a potential bias in favor of "old boys networks". With this in mind, it is important to note that transparency can partly replace the need for trust (DeHart 2017; Breuer, Hüffmeier, and Hertel 2016). Perceptions of "justice" and "fairness" depends not only on objective outcomes, but also on a fair and transparent process (Zajac et al. 2021). This may partly explain why the open science movement has been so effective in promoting team science. Transparent collaboration can also ensure that results are checked and verified, increasing their trustworthiness and reliability (Larson & Chang, 2016).

One way to ensure transparency and procedural fairness is to adopt a "Code of Conduct" for team projects, which explicitly states how team members are expected to behave in order to ensure social safety for all, how disagreements are resolved, and how contributions are credited (Baumgartner et al. 2023; Favaro et al. 2016). One commonly used code of conduct is the Contributor Covenant (Ehmke 2014), but note that there has been some concern of overreach so science teams should assess to what extent their needs are met by existing codes of conduct, and if necessary, develop a custom code of conduct that is widely supported by team members.

**Consideration**: Ensure trust within team contexts to facilitate effective collaboration, for example, through procedural fairness and transparency within science teams and the broader organization, and through face-to-face interaction between team members.

**Consideration**: Consider adopting or developing a code of conduct that clearly outlines expectations for how the team members will ensure social safety, resolve disagreements, credit contributions, ensure ethical and responsible research practices, and provides recourse in case anything goes wrong.

## 3.5 Team Composition

Research on team composition and team effectiveness has yielded conflicting results, highlighting the complexity of this relationship. The importance of team composition is likely related to the complexity of the task at hand, the degree of interdependence among team members, and the duration of the project (Carter et al. 2019). The primary factor to consider is what expertise is needed to address the team's scientific goals, but interpersonal and intrapersonal factors should not be neglected either (Twyman and Contractor 2019). Another important consideration is whether team members have a proven track record of (interdisciplinary) collaboration (Stokols 2014).

The literature suggests that diversity in team composition constitutes both a potential benefit and challenge (see Section 1.3.2). On one hand, people tend to prefer being around others that are similar to them (Montoya and Horton 2013). On the other hand, variety and diversity can improve team effectiveness (Liu et al. 2020). Introducing new members who are not prior acquaintances can enhance the effectiveness of science teams, suggesting a benefit of fresh perspectives and expertise. At the same time, when teams consist of (geographic) subgroups, this can increase conflict and distrust (Polzer et al. 2006; Bromham, Dinnage, and Hua 2016). Top-down requirements on team composition imposed by science leaders or funding agencies, such as mandating the inclusion of certain individuals, disciplines, or institutions, can backfire, creating internal goal conflict. This highlights the delicate balance required in team composition to optimize effectiveness, considering both the diversity of skills and perspectives and the potential for conflict and misalignment of goals. Above all, it is crucial to implement diversity in a team for the right reasons. For example, it can be beneficial for a team to have a diverse membership when it comes to academic and professional backgrounds, in order to be able to draw from a variety of knowledge and expertise. This so-called *task-relevant diversity* positively impacts team effectiveness, fosters innovation and creativity, and increases impact (Cooke, Hilton, and Council 2015; Nielsen et al. 2017).

The literature on team composition talks about its effect on team effectiveness in terms of "the ABC's of team work"; a shorthand for describing the team climate in terms of affective states (a), behavioral processes (b), and cognitive (c) states (Bell et al. 2018). Several individual team member characteristics can positively influence the ABCs, and thus contribute to team effectiveness. Conscientious team members tend to be better at self-regulation and oriented towards finding solutions. Agreeableness can contribute to team cohesion and shared cognitions. Team members who are more collectivist and value teamwork tend to be more effective and confident in team contexts. Each team member can contribute to the ABC's of a team, and establishing clear expectations about the expected contributions helps maintain a positive team environment (Turner and Baker 2020).

**Consideration**: When composing a team, it is crucial to weigh the benefits of *task relevant diversity* against the downsides of overcoming disciplinary, institutional, or demographic differences.

**Consideration**: Starting at the undergraduate level, train young academics in interdisciplinarity and collaborative skills. (Hall, 2020)

## 3.6 Permeable Team Boundaries

Teams can be independent entities with permeable boundaries, not characterized by a fixed cast of members, but open to change (O'Rourke et al. 2023). Permeable boundaries allow teams to reconfigure in response to evolving task demands (Mathieu et al. 2014). This fluidity brings both challenges and opportunities (Tannenbaum et al. 2012; Zajac et al. 2021). On the positive side, membership fluidity can facilitate the transfer of knowledge across teams and organizational units, introducing fresh perspectives and ideas. It benefits team flexibility and adaptability (Gorman and Cooke 2011), and contributes to a richer pool of unique ideas (Gruenfeld, Martorana, and Fan 2000). On the downside, however, such fluidity can potentially weaken team cohesion and stability. Adding or removing just a single team member can change the entire team dynamic (Emich et al. 2022). Permeability should also be viewed in the light of precarity among early career researchers: If young scholars move in and out of teams, contributing knowledge and effort without retaining ownership, the burden of team membership might outweigh its rewards for them. Thus, care should be taken that young scholars are sufficiently recognized and rewarded for team contributions (Craig 2018). On-boarding new team members also involves additional effort, which can be substantially reduced by following reproducible workflows (see Section 2.4), and maintaining collaborative agreements and a code of conduct helps clarify expectations to new team members (Section 3.4).

**Consideration**: It is important to maintain a stable core membership in teams with permeable boundaries to foster team cohesion and sustained performance.

**Consideration**: For all temporary team members, in particular early career academics and those on temporary contracts, the balance between investments (in terms of time and effort) and rewards should be explicit and fair.

## 3.7 Support staff

Support staff can bring specific professional expertise, skills, and perspectives to bear on team science projects, enhancing the quality of work and enabling more efficient division and delegation of tasks (Bosch et al. 2023). At present, however, support staff are not always fully integrated and recognized within the academic ecosystem. To promote integration of support staff, Bennett and colleagues (2023) propose several changes: Firstly, in line with the principles of *Use (Y)our Talents*, to reconsider recognition and rewards from the perspective of support staff as well; valuing their contributions to team science, irrespective of the outcomes. Secondly, to take a more modular approach to research, where "intermediate output" can also be recognized and rewarded. For example, support staff may be involved in the curation of a database, which could then be made FAIRly available, allowing support staff to be recognized for the creation of this resource. Thirdly, there should be an ongoing discussion about recognizing support staff contributions to academic publications. Support staff may often be eligible for coauthorship according to discipline-specific criteria. For example, if support staff perform tasks that fall within the CRediT authorship taxonomy (see Section 6.4). If support staff are not eligible as coauthors, or do not want to take on the responsibilities of coauthorship, then it is crucial that their contributions be otherwise acknowledged, recognized, and rewarded (Craig 2018). Lastly, it is important to recognize that the traditional dichotomy of 'academic' versus 'non-academic' staff does not cover the broader spectrum of functions that fall somewhere between the two. Dissolution of the hierarchy implied by this distinction, and flexibility in terms of career paths and function descriptions, would allow for greater involvement in team science, and concomitant recognition and reward, of support staff.

**Consideration**: Recognition and rewards should affect support staff as well, ensuring that support staff are incentivized to contribute to team science.

Building relationships between academic- and support staff is also important, if the goal is to involve support staff more in team science. One way to do so is to include support staff alongside academic staff in team science-related training activities [Hall, 2008]. In a broader sense, ensuring that all staff feel welcome and included in TiU social events can help increase integration. Some universities have altogether abolished the distinction between scientific and support staff, clearly signaling a vision for further integration of these roles (Agterberg 2023). TiU, at the same time, already integrates academic and support staff in trainings and social events.

**Consideration**: Increase social and professional ties between all university staff (scientific and support) by welcoming all staff at the same training- and social events.

**Consideration**: Decentralize support staff and locate them (physically) closer to the researchers, at least temporarily - for example, by having consultation hours in different buildings - thus enabling easier collaboration (see Section 4.6).

# 4 Institutional Policies and Support

According to research, organizations can create a climate conducive to team science by providing incentives for collaboration, flexible hierarchies, a high degree of autonomy, a culture of transparency (open science), recognize and reward contributions to team science, and provide inspiring team-oriented leadership (Stokols et al. 2008; Jacob 2015). Team members should enjoy autonomy to develop ideas and carry out research, while experiencing a shared sense of responsibility (Müller, 2016; Zajac et al., 2021a). Cognitive, methodological, conceptual, and financial barriers that currently impede (interdisciplinary) team science must be mapped to ensure that the new policy adequately overcomes them (MacLeod 2018). These principles should be guiding when designing policy to promote the broader uptake of team science at TiU as well. Historically, academic policy in the Netherlands at various levels has focused primarily on "excellent individuals"; a focus that can impede collaboration and team science (Hinrichs et al. 2017). If our University's goals shift towards a greater emphasis on larger societal challenges that can only be resolved through team science, then existing policies and support structures should be re-examined with those goals in mind. Successful team science in academia requires dedicated policies (Vogel et al. 2021), commitment across departments, funding for team work, mentoring plans, assessment of operational needs, and sustained evaluation of team science success (Surratt et al. 2023). The Strategy Evaluation Protocol is a useful tool to help TiU evaluate to what extent its strategies with respect to team science are successfully adopted into policy.

**Consideration**: Organizational policies should strive to create a climate conducive to team science by incentivizing collaboration, making hierarchies flexible, supporting autonomy, embracing open science, recognizing and rewarding team science, team spirit, and inspiring team-oriented leadership.

**Consideration**: Redefine "excellence" to no longer exclusively refer to individual performance, but also provide a concrete outline of what constitutes excellence in a team context.

## 4.1 Flexible Hierarchies

Universities tend to be relatively hierarchical organizations, with clearly defined roles at each level, and a high level of differentiation into functional departments (e.g., the schools, library, etc). Although rigid hierarchy can be beneficial from a logistical perspective, and for screening and selecting the right candidates and ideas - it can also stand in the way of innovation (Keum and See 2017). Flexible hierarchies with integration across levels and departments are better suited to research-intensive fields, like academia - suggesting that rigid hierarchies are at odds with the university's core business (Burns and Stalker 1994). Flexible, informal organizations with decentralized power structures encourage creativity and innovation in team science (Sandhu and Kulik 2019). Shared leadership enhances team performance more effectively than traditional hierarchical structures (D'Innocenzo, Mathieu, and Kukenberger 2016).

Shared leadership boosts communication impact on team performance more than hierarchical structures (Marlow et al. 2018). Aligning formal and distributed leadership reduces cognitive dissonance and fosters integration across organizational boundaries, as a shared vision and influence enhance team dynamics (Rycroft-Malone et al. 2016).

In order for team science efforts to flourish, universities will need to strike a balance between hierarchy and specialization on the one hand, and collaboration and integration on the other (Lawrence and Lorsch 1967).

**Consideration**: In order for team science to flourish, TiU must balance hierarchy and specialization on the one hand with collaboration and integration on the other. Hierarchy must be flexible: it must be possible to check, question, and even challenge authority.

## 4.2 Top down and Bottom Up

Ensuring a successful shift of the institutional culture towards greater team science requires both top-down and bottom-up initiatives (Duhigg 2014). These two approaches can work hand in hand for an effective transition (Verhulst & Lambrechts, 2015). Top-down approaches might involve policy changes or even reorganization. For example, consider Arizona State University (ASU), a pacesetter of team science in the United States. ASU restructured their organization, creating new interdisciplinary schools and research centers (Crow and Dabars 2014). For an example of bottom-up change, consider the University of Southern California (USC). At USC, a seed fund was established to fund interdisciplinary team science, and promotion and tenure policies were revised to acknowledge team science (Cooke, Hilton, and Council 2015). These efforts empowered individual faculty members and teams, giving them the resources and recognition necessary to pursue collaborative, interdisciplinary work. Combining top-down and bottom-up approaches is critical to ensure effective change of the organizational culture. Top-down strategies ensure institutional support and alignment with the institute's strategic goals, while bottom-up initiatives ensure buy-in from staff.

**Consideration:** To enact a desired culture change towards more team science, a combination of a top-down (through policy, funding opportunities, and recognition and rewards) and bottom-up (through informal networks like the Open Science Community, and social, academic, and networking events) approaches is necessary.

## 4.3 Funding Team Science

Financial support plays a crucial role in nurturing and sustaining team science. Via the allocation of public funds ("eerste geldstroom"), TiU can promote team science internally. There are good arguments in favor of using public funds to promote team science: The same amount of money can affect more people's careers in a more impactful way (because larger projects can be addressed), all the while promoting cohesion within the organization. In order to do so effectively, however, a comprehensive and forward-thinking approach is required. Funding is not an expenditure, but an investment in shaping the organization to become more team-oriented (Jeong and Choi 2015). The university should work with its staff communities to foster the development of innovative collaborative models like research networks and consortia. The needs of these networks and consortia can help shape new funding instruments and incentives. If funds are made available via calls for proposals, TiU should mandate that team-based research submissions include detailed collaboration plans. This ensures that researchers are not only focused on the scientific and technical merits of their proposals but also on the feasibility of effective collaboration. Team size and collaboration plans should be well-substantiated and evaluated prior to funding allocation (Cummings 2018). Ideally, applicants should have a proven track record of (interdisciplinary) collaboration (Stokols 2014). Providing guidance on crafting proposals for team science, and setting criteria for their evaluation, can enhance the quality and success rate of interdisciplinary or transdisciplinary research projects.

Given the prevalence of collaboration with public partners at TiU (Section 2), private funds ("derde geldstroom") are another salient source of (partial) funding for team science efforts. Collaborating with industry partners, as seen in the Regio Deal 'Ondernemen, innoveren en experimenteren met de mens centraal' ("Tilburg University partner in Regio Deal Midden-Brabant | Tilburg University" 2023), provides financial support, while also providing real-world use cases, and enabling knowledge dissemination and valorization. In our region, TU/e is a guiding example of public/private team science efforts, which might provide guidance for such initiatives at TiU as well. A good starting point is the Jheronimus Academy of Data Science, as this is an initiative where TiU and TU/e meet.

**Consideration**: Using public funds (eerste geldstroom) to fund (interdisciplinary) team science initiatives can affect more colleagues' careers in a more impactful way, while promoting cohesion within the organization. To do this fairly and transparently, the target audience should be included in the development of funding calls.

**Consideration**: Applications for team science funding instruments should include a collaboration plan as part of the evaluation criteria.

**Consideration**: Monitor and evaluate existing internal funding programs aimed at stimulating collaboration across the schools.

**Consideration**: Create new internal funding programs specifically designed to support interdisciplinary research projects that connect the schools.

One effective approach to fostering innovative team science is through incubator grants. Such grants are designed to support the developmental phases of team science, providing crucial "incubator space" for the generation and advancement of new cross-disciplinary ideas Council (2007). Additionally, project development or pilot funds offer flexible financing for just-in-time innovations or integrative ideas that emerge during larger collaborative projects Vogel et al. (2014). Flexible funding (smaller sums that can be applied for without too much administrative overhead) is key to accommodating the dynamic nature of team science, where needs for funding may change as research progresses. Another approach is to give individual researchers access to professional development funds, which can be used to fund collaborations, visit geographically dispersed collaborators, or contribute to the funding of a joint team effort. TiU currently already offers some seed funding grants, and these schemes could be further adapted to prioritize interdisciplinary team science projects. This would align university resources with research goals, creating incentives for shared strategic directions.

**Consideration**: Create incubator grants, seed funding, and other flexible funding schemes to incentivize team science at all levels of seniority.

## 4.4 Funding Pitfalls

A persistent challenge in this arena is the "rich get richer" phenomenon, where funding often gravitates towards well-established scholars, potentially stifling innovation and the exploration of uncharted scientific territories (Laudel 2006). Some researchers may be so successful in obtaining funding that it becomes questionable whether they are able to execute all of their funded projects. At the same time, there is much to be said for awarding funding - as much as possible - on merit. The challenge is thus to assess which projects have a high chance of success, without referring to applicants' prior record of funding to do so. Another way to counter this problem is to actively set new directions and priorities for funding, to encourage different scholars to submit novel and potentially groundbreaking research (Braun 1998). Finally, setting limits on the number of research projects per researcher can limit internal competition and the Matthew effect as well (Jeong & Choi, 2015).

Another potential pitfall occurs when science teams involve societal partners, as non-profit organizations often have fewer means than companies. When funding instruments require matching by societal partners, this introduces a bias against collaborating with non-profits. Even in-kind contributions may be difficult, since non-profits need to account for all of their expenses and have limited manpower. This is problematic because some topics that are important for society have a smaller chance of being studied.

**Consideration**: When reviewing funding applications, do not take prior funding success into account to avoid the “Matthew effect”. Focus on merit and feasibility.

Another potential pitfall occurs in the reviewing of funding applications. Known limitations of reviews are that they tend to be relatively conservative and biased against interdisciplinary research (Shapiro 2014). To counteract such biases, it is possible to recruit reviewers with a broad range of disciplinary expertise. Diversity in review panels will allow for a more balanced and open-minded assessment of novel and interdisciplinary proposals. In addition, Tilburg University should prime reviewers with information about the importance of novel research approaches, mitigating biases against highly innovative proposals. Review criteria should be expanded to encompass not just the technical and scientific merits but also the collaborative potential of the research team.

**Consideration**: When reviewing team science funding applications, ensure diverse panels of reviewers, and prime them to value innovation and interdisciplinarity.

## 4.5 Technology and Infrastructure

Information Technology (IT) can facilitate effective collaboration, particularly when teams are geographically distributed. There are several “classes” of IT tools that facilitate remote team work (Olson and Olson 2022). One important class of tools are those that enable digitally mediated communication. At TiU, the Microsoft suite (Outlook, Teams, et cetera) is used - but international collaborators often use different platforms, like Zoom (common in the USA) or WebEx (common in Germany). This can lead to compatibility challenges, and it is important that staff have access to different platforms and know how to use them, if they work with colleagues from different institutions. Dynamic platforms, like Slack, provide space for ongoing in-depth discussion, brainstorming, and idea sharing. Finally, visibility and findability through a well-maintained university website is important for external representation of (interdisciplinary) team science projects (Rentsch et al. 2014). This is especially important when such projects do or intend to involve external (private and public) partners. A well-defined external presence indicates organizational effectiveness, structure, and clear communication.

A second important class of IT services includes coordination tools, like shared calendars and date pickers. These are essential for synchronizing activities and keeping team members informed of each other’s schedules and progress. A third suite of tools are meeting support technologies, including hybrid meeting rooms with large displays and smart cameras. These are already in use at TiU and make hybrid meetings more engaging and efficient. A fourth suite of IT technologies are information repositories, such as databases (e.g., Tilburg DataVerse), file sharing services (e.g., Surfdrive, Onedrive, Google Drive), collaborative code repositories and digital laboratory notebooks (e.g., GitHub/GitLab), facilitate seamless access and collaboration on scientific information.

One important challenge in IT tools for team science is that team members may not all have access to the same software and services. This challenge can be overcome by making use of free open source software (FOSS) for essential tasks - like data analysis (Martijn 2021). In general, effective team science benefits from FAIR and reproducible workflows, where all scholarly output is, in principle, Findable on standardized repositories, Accessible at least to those involved in the science team, Interoperable so that any team member can make use of the output without requiring e.g. licensed software, and Reusable so that team members can build on each other's efforts and are not doing double the work. Van Lissa et al. (2021) presented a workflow for open reproducible code in science (WORCS) which meets these needs. Using an open science workflow greatly facilitates (distributed) collaboration, as all team members are operating on the same files, and everyone's contributions can be tracked and combined. Importantly, it is not necessary to make a reproducible project open to just anyone; access permissions can be controlled. A course is in development to teach the WORCS workflow at TiU by the DCCs.

FAIR databases of in-house expertise, like Tilburg University Research Portal, help staff identify which colleagues possess specific knowledge, which projects are relevant, and how to connect or contribute to them. A robust system for data archiving and management enables researchers to publish data in a FAIR manner, or to safely archive private data, or collaborate on data, assign Digital Object Identifiers (DOIs) for citability, manage access, and comply with (funders') data management plan policies. The Tilburg DataVerse meets some of those needs, and the Research Data Office can provide further advice on the appropriate solution for specific datasets. Whilst fair data initiatives are there for research at TiU, they are currently only a part of the guidelines on safe data-management. Other universities use the FAIR principles in their campaign to promote as much reusable and accessible data as possible for interdisciplinary research initiatives and sourcing data.

**Consideration**: Technology and infrastructure should provide support and tools for collaboration, without creating a rigid mold that science teams are expected to conform to.

**Consideration**: As much as possible, use open source software for all task-critical activities to ensure that all team members can participate and contribute, regardless of institutional licenses for specific software and services.

**Consideration**: Use reproducible workflows and make all scholarly output FAIRly shareable in order to ensure effortless (distributed) collaboration among team members, make scholarly output FAIRly shareable, increase the reusability of scholarly output, and safeguard against human error that might otherwise go undetected.

## 4.6 Team Science and the Physical Environment

The relationship between the physical environment at a university and the facilitation of team science is more nuanced than often assumed. In general, it is beneficial for science teams to work in close proximity, as a shared environment promotes interactions, sparks new connections between people, and builds trust and team spirit (Cooke, Hilton, and Council 2015). Large teams may be composed of several smaller groups working closely together, which benefit from being in close physical proximity. With these insights in mind, it is tempting for policy makers to reverse the direction of causality and assume that redesigning the physical space of the university to bring colleagues closer together will also promote more collaborative research. Unfortunately, there is little evidence that such redesigns enhance team science (Owen-Smith 2013). Quite the contrary, changes towards open office plans and flexible workplaces have met with substantial pushback at Dutch universities, as many academics value a constant, controlled, and quiet working environment (Lambeets 2023). What does have evidence-based impact on collaboration is altering the dynamics of physical proximity among researchers. For example, random relocations of researchers were found to inspire new collaborations and breakthrough ideas (Catalini 2018). Even brief periods of co-location can increase the likelihood of collaboration (Boudreau et al. 2012). Anecdotally, one winter, the heating broke at the Reitse Poort building, and the lead author of this report was relocated to the Developmental Psychology department (S building). Spending two days at this department sparked two new collaborations. These findings suggest that while the physical structure of a university environment may not be a significant factor, the strategic placement and movement of people within existing environments can effectively foster inter-disciplinary interactions and team science initiatives.

**Consideration**: Establish physical spaces that incentivize scholars from different disciplines and schools to mix. For example, Oxford-style “common rooms” with free (good) coffee and cookies, where researchers from different disciplines can meet, exchange ideas, and work on projects together.

**Consideration**: Create a university-wide calendar of colloquia, symposia, brown bag lunches, et cetera, so (academic and support) staff is incentivized to attend events from other departments. Consider incentivizing use of this shared calendar by making funds for simple catering available to participating events.

# 5 Training and Professional Development

## 5.1 Training for Team Science

The ability to collaborate effectively in a team context is not a given; it is an important *soft skill* that should be trained and developed. As any colleague involved in teaching can attest: challenges always arise when students are asked to work in groups. When they ask why we assign group work despite such challenges, the answer is often: because learning to work together is an important skill for your professional life. With this in mind, it is important to train staff for effective team science, too. According to research, science teams often address coordination and communication challenges in an ad-hoc manner, resorting to online resources or training (Stokols 2014). To properly prepare scholars for complex scientific and societal challenges, however, requires fostering a culture of continuous learning, a long-term strategy for training and professional development, and consistent institutional support (J. T. Klein 2010). The long-term effectiveness of training for teams hinges on the organization's ability to sustain the desired training outcomes, which means policies, recognition and rewards, and the organizational culture must be aligned with the desired outcomes (Rosen et al. 2018).

### 5.1.1 Training for Team Members

With regard to individual team members, it is important to start early and educate PhD candidates and early career researchers not only in scientific skills, but also intrapersonal skills (personal development), interpersonal skills (Vogel et al. 2012), and interdisciplinary learning (Fiore et al. 2019). This entails developing the competencies necessary to being able to think and work across disciplinary boundaries.

This approach can even be further extended to include (under)graduate education; making a conscious choice to include group work and interdisciplinary assignments in the curriculum to adequately prepare students for a more team-oriented future (Hoffmann et al. 2022). Additional to this, a previously mentioned idea would be to implement this structure into our diverse minor projects, drawing on the interdisciplinary background of the consortia taking the courses. For an example of this approach, consider the minor *Digitale Gezondheid: een interdisciplinaire benadering*, developed in collaboration with TSHD, TSB, TLS, TiSEM, and the Academische Werkplaats Digital Health & Mental Wellbeing, and in the minor Digital Sciences for Society, both of which are projected to start in the summer of 2024. At present, there is substantial expertise among educational support staff on how to design and manage effective education for team science (Oakley et al. 2004). However, this material is not FAIRly available, limiting its potential impact on education across schools.

**Consideration**: Teach effective collaboration skills at all levels by creating a FAIR resource page for teachers on how to effectively incorporate team work in education.

**Consideration**: Offer training and workshops on team science principles, collaboration skills, and project management. These programs can help staff develop the skills needed for successful interdisciplinary work.

### 5.1.2 Training for Teams

Aside from training individuals, there is also *team training*, defined as an intervention to improve team performance by teaching necessary competencies. This is distinct from *team building*, which focuses more on interpersonal connections and is generally less effective in comparison (Salas et al. 1999). Effective team training goes beyond fostering team spirit, addressing specific skills essential for cross-disciplinary collaboration (Dyer, Dyer Jr., and Dyer 2007). Section 3.1 suggests that team training aimed at developing shared goals and transactive memory systems, as well as exposing teams to various interaction styles, results in more adaptive and flexible teams, thereby improving problem-solving and decision-making capabilities (Vogel et al. 2014). Additionally, methods like positional clarification (explicating each member's role in the team) and modeling (trying on each other's roles) are useful for understanding team roles and tasks. Such training strategies enhance communication, coordination, and knowledge integration in science teams. Related to formative evaluation (Section 6.5), team reflexivity training may help teams align with project goals during a project's lifecycle: It involves having team members reflect on past performance to improve future interaction (Gurtner et al. 2007). Self-assessment tools, such as those made available at Utrecht University (2023), can also be used for team reflexivity and guided self-correction; recognizing and overcoming the common challenges of team science (see Section 1.3.2). Finally, online platforms like <TeamScience.net> offer modules and resources to enhance skills in interdisciplinary and transdisciplinary team science. The Toolbox Project is another innovative training intervention designed to facilitate cross-disciplinary communication through philosophical dialogue and probing statements about science.

At present, the TiU HR department offers two trainings for teams: Firstly, the workshop 'Strength-based collaboration'/'(samen)werken vanuit de sterke punten', which involves teams reflecting in how to bring out the best in themselves; increasing self-awareness; team members identifying, valuating, and using their talents in relation to others; and personal (leadership) development. Secondly, the workshop 'Connected leading' involves getting to know team members' communication styles in order to benefit effective communication and team effectiveness. A key strength of these workshops is that they are targeted towards entire teams, including scientific- and support staff. A potential limitation is that the concept of communication styles is not a focal topic in the scientific literature on training for team effectiveness; specific problem-solving, conflict resolution, and decision making skills are more salient concepts. Low-hanging fruit in terms of additional training to develop is evidence-based training tailor-made to improve team effectiveness (see Section 3.1), including trainings that focus on developing shared goals and representations. One inspiring example is the set of simple and almost gamified conversation guidelines that empower any team to engage in reflexivity and professionalization regarding team goals, recognition and rewards, and impact (Utrecht 2023). While TiU currently employs team training in various areas, extending similar training to team dynamics and interpersonal communication can significantly enhance team effectiveness.

**Consideration**: TiU should offer evidence-based, cross-disciplinary team trainings for team science. This includes training individuals in skills required for effective teamwork, and training teams as a whole to build shared goals and representations.

**Consideration**: TiU should develop simple guidelines, readily available to all staff, to help teams engage in reflexivity and professionalization.

## 5.2 Leadership Training for Team Science

Training team leadership skills is essential for navigating the complexities of diverse and interdisciplinary teams. Leadership training can help leaders identify and employ the most effective leadership style for their team, given the team's specific characteristics and objectives. This includes learning when to employ participatory- versus directive leadership styles (Rahmani, Roels, and Karmarkar 2018). In participatory leadership, team members are free to decide their effort levels, while in directive leadership, the leader demands specific contributions from members. A greater emphasis on directive leadership is appropriate when team members have low incentives, which may be the case in voluntary projects, those with a low probability of paying off, and larger teams. Participatory leadership allows team members to set their effort levels, while directive leadership involves the leader setting specific contribution demands, particularly effective in teams with low incentives. Other research identifies three leadership behaviors: cognitive leadership (providing a guiding vision), structural leadership (building bridges between individuals and disciplines), and processual leadership (fostering trust and communication) (B. Gray 2008). In larger teams, it becomes difficult for a single leader to adopt all these behaviors, and delegation may be in order. So-called "transformative leaders" embody humility, which fosters trust, and yet inspire a clear vision to inspire and direct the team, while tapping into team members' intrinsic motivation and bringing out their best self (Stokols et al. 2008). Transformative leaders can foster team members' self-efficacy by empowering them to have goal-aligned mastery experiences. They provide socio-emotional support and facilitate learning (Kozlowski and Ilgen 2006). Formal leadership training provided by universities can support this, especially in relation to societal partners. A good example of this is the module on personal leadership in Utrecht University's conversational guidelines (Utrecht 2023). This module helps team leaders identify their current leadership style and relate it to the present needs of their team. Leaders should articulate their expectations for the team through written charters or collaborative agreements, outlining tasks, communication, and handling of finances, data sharing, and credit for publications and patents (L. M. Bennett et al. 2010). Alternatively, team members can self-assemble such charters through workshops and consensus (Goncharova et al. 2023).

**Consideration**: When training connected leadership skills, emphasize transformative leadership for team science, that empowers team members to bring out their best. Recognize that, in team contexts, shared leadership can be more effective than hierarchical leadership (Section 4.1).

# 6 Recognition and Rewards

## 6.1 Recognition and Rewards in Relation to Team Science

Recognition and rewards are a key driver of desired culture changes. Thus, to promote a transition towards greater team science, TiU should establish clear criteria for the recognition and reward of staff contributions to collaborative research efforts. The dominant perspective in global academia is to perceive team science as the "cherry on top" of individual achievement. Klein and colleagues (2013) summarize this as "Tenure first, interdisciplinarity later," and "Individual reputation first, collaboration later." Such a mindset can significantly hinder the adoption of a culture supportive of team science. Instead, TiU should clearly communicate that team science is a major ingredient of the "whole cake", not just the cherry on top.

Recognizing and rewarding team science in hiring, promotion, and tenure decisions is crucial across all levels of seniority (Meurer et al. 2023). When the goals of a department or school necessitate expertise in team science, it makes sense to prioritize candidates with a track record of interdisciplinary research and a collaborative mindset. Early-career academics are likely to be reluctant to engage in (transdisciplinary) team science unless clear incentives are established in terms of prospective employment and advancement, output, and funding (DeHart 2017). According to the principle of "doctoral socialization," the academic trajectory of early career researchers is heavily influenced by their supervisors (Austin 2011). Typically, PhD candidates are expected to collaborate only with their direct supervisors, a practice that misses the opportunity for broader engagement in interdisciplinary work. Initiatives like TSB's HSRI PhD grants, which encourage collaboration between supervisors from multiple schools, represent a progressive departure from this norm. There is room to expand this approach further by integrating participation in team science projects as a standard element of PhD programs. Although this requires an investment of the PhD student's time, it benefits the candidates by better preparing them for the job market, expanding their network, and resulting in additional (often higher impact) publications. This is particularly advantageous for early-career scholars. In essence, a systemic shift towards recognizing and rewarding contributions to team science can cultivate a more collaborative, interdisciplinary, and dynamic academic environment, aligning with the evolving demands of contemporary research landscapes (Brody et al. 2019).

**Consideration**: Task a working group with developing and evaluating general principles and specific criteria for recognizing team science contributions, and transparently incorporate these criteria in vacancies, PT&D conversations, and tenure and promotion committees.

**Consideration**: Encourage engagement of PhD candidates in team science projects. Create more opportunities for the involvement of PhD candidates in ongoing teams with permeable boundaries, encourage supervisors to stimulate PhD candidates to become involved in team science efforts, and ask graduate schools to encourage supervisors to do so.

**Consideration**: Establish grants for collaborative PhD projects on thematic topics that require interdisciplinary and inter-faculty team science.

**Consideration**: Create a profile for professorships that span departments or schools, to promote interdisciplinary research and teaching.

## 6.2 What to Recognize and Reward?

How do we evaluate an individual in relation to the team(s) they are a part of? How do team evaluations relate to the evaluation of the individuals it is composed of? Recognition and rewards determines what activities staff are incentivized to engage in, and if the organization aspires to promote team science, then the way team work is recognized and rewarded should be clearly defined. TiU was one of the first Dutch universities to propose an innovative approach to recognition & rewards, by introducing the *MERIT system* at TSB. MERIT was an ambitious and progressive approach to academic performance assessment, encompassing five domains: Management, Education, Research, Impact, and Team Spirit. While the MERIT system acknowledged contributions other than only individual research excellence, there remained a need for a more nuanced approach, including specialization along some (but not all) dimensions of MERIT, more individualized assessment, recognizing and valuing the unique strengths and contributions of each staff member (J. T. Klein and Falk-Krzesinski 2017). At other universities (e.g., Utrecht, who developed the TRIPLE system based on TiU's MERIT system), there is room for employees to *specialize* along several - but not all - of the areas of the model. Such flexibility is important in the light of persistent signals of high work pressure, because it allows staff to focus their efforts in specific areas, like education or research, at different times, thereby reducing the burden of juggling multiple tasks simultaneously. This may benefit academic staff's mental health, which is affected by workloads, unattainable targets, pressure, and precarious contracts (Morrish, 2019).

An important question is how well the MERIT system is aligned with existing university-wide hiring- and promotion policies. In 2023, all schools have been working on differentiation of academic career paths, based on the four domains of academic work: Education, Research, Impact, Leadership/Management. Team spirit is a mandatory componennt. In 2024, implementation of these new career paths will follow. If properly implemented, these new career paths could offer tenure and advancement opportunities to those who contribute significantly to departmental and university objectives, beyond the traditional research-focused pathways. From our interviews, we have learned that some staff have high expectations for "Use (Y)our Talents" to deliver meaningful change. One anonymous employee said: "I am taking the SUTQ course to specialize more in education [...] If the university takes recognition & rewards seriously, I might still become 'associate professor of teaching' some day". Meeting these expectations will require adjustments at various levels of the university's hierarchy, however. The success of the implementation of the new career paths should be evaluated. Additionally, it might be beneficial to reassess the original MERIT system to determine whether it meets TiU's evolving needs, and consider developing MERIT 2.0 to align more closely with the newly developed career paths.

**Consideration**: Preparations are in the works to adopt the MERIT system as official guiding principle for PT&D, hiring, and promotions at TiU. Evaluate the success of this transition. Alongside the MERIT system, allow employees to specialize along its key dimensions, and ask organizational bodies to create vacancies that require a specific profile.

## 6.3 (Inter)national Developments

Global research assessment practices are evolving due to the influence of initiatives like the *Declaration on Research Assessment* (DORA) and Coalition for Advancing Research Assessment. These initiatives promote a more comprehensive approach to evaluating scientific research, moving away from aggregate-level metrics like Journal Impact Factors, which are not valid indicators of the quality of individual researchers' output. They recommend that institutions prioritize the scientific value of individual scholarly output and consider a broader range of research output in evaluation, including datasets, instruments, software, and practical applications, and considering a variety of impact measures. Both NWO and ERC are signatories to DORA, and have adopted the "narrative CV" format for grant applications, which allows for such diversity in output and impact measures. Note that there are valid concerns about qualitative evaluation, as it is prone to bias and gaming, and poorly suited for comparing candidates (Ioannidis and Maniadis 2023). With this in mind, TiU should remain informed about the ongoing development of reliable and valid individual-level quantitative evaluation criteria, and open source databases on which to base them (Ioannidis and Maniadis 2023).

**Consideration**: Along with other Dutch universities, TiU has committed to develop an action plan based on the international guidelines in CoARA and DORA to revise our approach to research evaluation in 2024.

**Consideration**: To ensure that TiU staff remain competitive in (inter)national funding calls from DORA signatories (e.g., NWO, ERC), TiU should abandon the irresponsible use of metrics and the use of aggregate-level metrics which are not valid for assessing individual researchers' performance. Instead, TiU should require internal performance reviews to focus on quality and individual-level quantitative metrics, and optionally, a narrative resumé.

**Consideration**: In performance review and hiring decisions, TiU should consider the impact of all research output, including datasets, instruments, software, and valorization, alongside publications, and adopt a broad range of impact measures, including qualitative indicators of research impact like policy influence.

## 6.4 Crediting Author Contributions

Standards for crediting author contributions to collaborative efforts differ widely across disciplines. Often, authorship order plays a role, but there is no consensus about who to add as a contributor, or what the order of authorship means. Journals increasingly require author contribution statements that outline the scope of each team member's contribution (Cooke, Hilton, and Council 2015).

It is important to fairly and transparently acknowledge each team member's contribution in the creation of any type of research output, while allowing for diversity in attribution, which varies across disciplines and outlets. To account for diversity in attribution, authors can explicitly state what convention was followed to credit contributions (Tscharntke et al. 2007).

While self-disclosure of contributions suffices for most projects, it is also possible to use anonymous systems for crediting and approving team members' contributions. Such systems ensure fair attribution and maintain social safety in groups with large power differentials, or a risk of nepotism, misreporting, and social loafing.

The CRediT contributor taxonomy aims to reduce the ambiguity surrounding authorship (L. Allen et al. 2014). It recognizes 14 contributor roles, which - while they may not fit all cases - cover a lot of ground. The CRediT contributor taxonomy may serve as a sensible default for all projects, unless another convention for crediting contributions takes precedence.

Another approach is to move from an authorship model towards a "contributorship" model see 3.4. In a contributorship model, specific contributions are recognized, ensuring fair credit, reducing authorship disputes, and encouraging collaboration, data, and code sharing (Brand et al., 2015).

**Consideration**: Fairly and transparently credit each team member's contribution in the creation of research output.

**Consideration**: Explicitly state what convention was followed to credit contributions, along with a reference.

**Consideration**: The CRediT contributor taxonomy is a sensible default system for crediting contributions. Translating it into Dutch is low-hanging fruit and will make the taxonomy more accessible to people outside academia (e.g. policy makers, public partners and citizens/taxpayers).

## 6.5 Monitoring and Evaluating Team Science

Monitoring and evaluating team science projects is integral to their success. Importantly, such evaluations should not rely solely on output in bibliometric terms, but also in terms of team processes, coordination, and team goals (Hinrichs et al. 2017). There are two relevant approaches to evaluation: formative and summative methods. Formative evaluation focuses on providing ongoing feedback to improve the project in real-time (Vogel et al. 2014; D. O. Gray 2008). This is instrumental in identifying areas for immediate improvement and making adjustments in goals, approaches, and team composition throughout the project lifecycle. On the other hand, summative evaluation aims to glean lessons from completed projects that can inform and enhance future programs (Liverman et al. 2013; Vogel et al. 2014). This type of evaluation provides a comprehensive overview of a project's outcomes and effectiveness, offering valuable insights for future endeavors.

**Consideration**: All science teams should plan for formative assessments at given milestones during the project lifecycle. TiU should require summative evaluation of team science projects funded by the University (eerste geldstroom).

# 7 Considerations for Team Science at Tilburg University

**Defining Team Science** (Section 1.2)

1. Team Science can be defined as collaboration with a larger number of partners than is standard in a particular domain of study, addressing a goal that transcends what could be achieved by a single scholar, capitalizing on team members' strengths, with attention to their diverse perspectives, and members from multiple branches of the organization (including scientific and support staff), and/or other stakeholders.

**Benefits and Challenges of Team Science** (Section 1.3)

2. Team science benefits both individual team members, the organization, and society at large, and allows scholars to provide complex solutions to large-scale public challenges. It promotes collaboration, cohesion, and knowledge exchange within organizations, increases impact, and may benefit research quality.
3. Any science team should be aware of, and reflect on how they relate to, the seven challenges of team science: diversity, knowledge integration, team size, goals, permeable boundaries, geographic dispersion, and task interdependence.

**Local Perspective** (Section 2)

4. At present, only 3% of academic output involves authors from multiple Schools. If connecting the schools is considered important, then promoting team science initiatives that connect the schools is low-hanging fruit.

**Open Science: Lessons Learned** (Section 2.4)

5. The open science transition serves as a template for the transition towards more team science, and the Open Science Community Tilburg is a natural ally in achieving this transition.
6. Open science practices facilitate team science, reduce onboarding efforts and improve scalability, increase the reusability of materials, data, and code, increase scientific rigor, and offer a greater potential payoff to team members.

**Team Effectiveness** (Section 3.1)

7. Team effectiveness is enhanced by thoughtful team composition, team professional development, building a shared understanding of goals, task requirements, and team member competencies, and inspiring person-focused team leadership.

**Communication and Team Success** (Section 3.3)

8. Team members should be able to disagree constructively in a safe, supportive context. When possible, preemptive conflict management strategies should be used; anticipating disagreements and establishing terms for their constructive resolution. When conflict does occur, reactive conflict management should focus on empathy, problem-solving, and compromise. Professional development opportunities should be in place to educate staff in the use of such communication techniques.

**Procedural Fairness** (Section 3.4)

9. Ensure trust within team contexts to facilitate effective collaboration, for example, through procedural fairness and transparency within science teams and the broader organization, and through face-to-face interaction between team members.

10. Consider adopting or developing a code of conduct that clearly outlines expectations for how the team members will ensure social safety, resolve disagreements, credit contributions, ensure ethical and responsible research practices, and provides recourse in case anything goes wrong.

**Team Composition** (Section 3.5)

11. When composing a team, it is crucial to weigh the benefits of *task relevant diversity* against the downsides of overcoming disciplinary, institutional, or demographic differences.

12. Starting at the undergraduate level, train young academics in interdisciplinarity and collaborative skills.

**Permeable Team Boundaries** (Section 3.6)

13. It is important to maintain a stable core membership in teams with permeable boundaries to foster team cohesion and sustained performance.

14. For all temporary team members, in particular early career academics and those on temporary contracts, the balance between investments (in terms of time and effort) and rewards should be explicit and fair.

**Support staff** (Section 3.7)

15. Recognition and rewards should affect support staff as well, ensuring that support staff are incentivized to contribute to team science.

16. Increase social and professional ties between all university staff (scientific and support) by welcoming all staff at the same training- and social events.
17. Decentralize support staff and locate them (physically) closer to the researchers, at least temporarily - for example, by having consultation hours in different buildings - thus enabling easier collaboration (see Section 4.6).
18. Organizational policies should strive to create a climate conducive to team science by incentivizing collaboration, making hierarchies flexible, supporting autonomy, embracing open science, recognizing and rewarding team science, team spirit, and inspiring team-oriented leadership.
19. Redefine "excellence" to no longer exclusively refer to individual performance, but also provide a concrete outline of what constitutes excellence in a team context.

**Flexible Hierarchies** (Section 4.1)

20. In order for team science to flourish, TiU must balance hierarchy and specialization on the one hand with collaboration and integration on the other. Hierarchy must be flexible: it must be possible to check, question, and even challenge authority.

**Top down and Bottom Up** (Section 4.2)

21. To enact a desired culture change towards more team science, a combination of a top-down (through policy, funding opportunities, and recognition and rewards) and bottom-up (through informal networks like the Open Science Community, and social, academic, and networking events) approaches is necessary.

**Funding Team Science** (Section 4.3)

22. Using public funds (eerste geldstroom) to fund (interdisciplinary) team science initiatives can affect more colleagues' careers in a more impactful way, while promoting cohesion within the organization. To do this fairly and transparently, the target audience should be included in the development of funding calls.
23. Applications for team science funding instruments should include a collaboration plan as part of the evaluation criteria.
24. Monitor and evaluate existing internal funding programs aimed at stimulating collaboration across the schools.
25. Create new internal funding programs specifically designed to support interdisciplinary research projects that connect the schools.
26. Create incubator grants, seed funding, and other flexible funding schemes to incentivize team science at all levels of seniority.

**Funding Pitfalls** (Section 4.4)

27. When reviewing funding applications, do not take prior funding success into account to avoid the "Matthew effect". Focus on merit and feasibility.

28. When reviewing team science funding applications, ensure diverse panels of reviewers, and prime them to value innovation and interdisciplinarity.

**Technology and Infrastructure** (Section 4.5)

29. Technology and infrastructure should provide support and tools for collaboration, without creating a rigid mold that science teams are expected to conform to.

30. As much as possible, use open source software for all task-critical activities to ensure that all team members can participate and contribute, regardless of institutional licenses for specific software and services.

31. Use reproducible workflows and make all scholarly output FAIRly shareable in order to ensure effortless (distributed) collaboration among team members, make scholarly output FAIRly shareable, increase the reusability of scholarly output, and safeguard against human error that might otherwise go undetected.

**Team Science and the Physical Environment** (Section 4.6)

32. Establish physical spaces that incentivize scholars from different disciplines and schools to mix. For example, Oxford-style "common rooms" with free (good) coffee and cookies, where researchers from different disciplines can meet, exchange ideas, and work on projects together.

33. Create a university-wide calendar of colloquia, symposia, brown bag lunches, et cetera, so (academic and support) staff is incentivized to attend events from other departments. Consider incentivizing use of this shared calendar by making funds for simple catering available to participating events.

**Training for Team Science** (Section 5.1)

34. Teach effective collaboration skills at all levels by creating a FAIR resource page for teachers on how to effectively incorporate team work in education.

35. Offer training and workshops on team science principles, collaboration skills, and project management. These programs can help staff develop the skills needed for successful interdisciplinary work.

36. TiU should offer evidence-based, cross-disciplinary team trainings for team science. This includes training individuals in skills required for effective teamwork, and training teams as a whole to build shared goals and representations.

37. TiU should develop simple guidelines, readily available to all staff, to help teams engage in reflexivity and professionalization.

**Leadership Training for Team Science** (Section 5.2)

38. When training connected leadership skills, emphasize transformative leadership for team science, that empowers team members to bring out their best. Recognize that, in team contexts, shared leadership can be more effective than hierarchical leadership (Section 4.1).

**Recognition and Rewards in Relation to Team Science** (Section 6.1)

39. Task a working group with developing and evaluating general principles and specific criteria for recognizing team science contributions, and transparently incorporate these criteria in vacancies, PT&D conversations, and tenure and promotion committees.

40. Encourage engagement of PhD candidates in team science projects. Create more opportunities for the involvement of PhD candidates in ongoing teams with permeable boundaries, encourage supervisors to stimulate PhD candidates to become involved in team science efforts, and ask graduate schools to encourage supervisors to do so.

41. Establish grants for collaborative PhD projects on thematic topics that require interdisciplinary and inter-faculty team science.

42. Create a profile for professorships that span departments or schools, to promote interdisciplinary research and teaching.

**What to Recognize and Reward?** (Section 6.2)

43. Preparations are in the works to adopt the MERIT system as official guiding principle for PT&D, hiring, and promotions at TiU. Evaluate the success of this transition. Alongside the MERIT system, allow employees to specialize along its key dimensions, and ask organizational bodies to create vacancies that require a specific profile.

**(Inter)national Developments** (Section 6.3)

44. Along with other Dutch universities, TiU has committed to develop an action plan based on the international guidelines in CoARA and DORA to revise our approach to research evaluation in 2024.

45. To ensure that TiU staff remain competitive in (inter)national funding calls from DORA signatories (e.g., NWO, ERC), TiU should abandon the irresponsible use of metrics and the use of aggregate-level metrics which are not valid for assessing individual researchers' performance. Instead, TiU should require internal performance reviews to focus on quality and individual-level quantitative metrics, and optionally, a narrative resumé.

46. In performance review and hiring decisions, TiU should consider the impact of all research output, including datasets, instruments, software, and valorization, alongside publications, and adopt a broad range of impact measures, including qualitative indicators of research impact like policy influence.

**Crediting Author Contributions** (Section 6.4)

47. Fairly and transparently credit each team member's contribution in the creation of research output.
48. Explicitly state what convention was followed to credit contributions, along with a reference.
49. The CRediT contributor taxonomy is a sensible default system for crediting contributions. Translating it into Dutch is low-hanging fruit and will make the taxonomy more accessible to people outside academia (e.g. policy makers, public partners and citizens/taxpayers).

**Monitoring and Evaluating Team Science** (Section 6.5)

50. All science teams should plan for formative assessments at given milestones during the project lifecycle. TiU should require summative evaluation of team science projects funded by the University (eerste geldstroom).

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# Appendix A: Members of the working group

**Caspar van Lissa (project lead, TSB)**

- Associate professor Social Datascience at the department of Methodology and Statistics, TSB
- Chair of the Open Science Community Tilburg
- Board member Tilburg Young Academy
- Experienced in team science: Participated in Data vs Corona, PsyCorona, and a Stanford-based Climate Consortium; established a consortium to develop the Workflow for Open Reproducible Code in Science.

**Esther Keymolen (TLS)**

- Vice Dean of research
- Involved in team science pilot at TLS

**Marjan van Hunnik**

- Program manager Recognition & Rewards (Erkennen & Waarderen)
  - Tilburg University
  - Royal Netherlands Academy of Arts and Sciences (KNAW)

**Lilly Schurman**

- Student-assistant
- Studying Bestuurskunde
- Student advisor to CvB

**Annika Schurman**

- Student-assistant
- Studying Human Resources
- Board member of a student association

**Sasha van den Hoek**

- Student-assistant
- Studying Enterpreneurship & Business Innovation: Minoring in Finance
- Former chairman of Asset Tilburg, and External Affairs of Student Party ECCO.

# Appendix B: Methodology

### 7.0.1 Textbook

The core team first read the book "Enhancing the Effectiveness of Team Science". This book was written by a consortium of world experts on Team Science, and commissioned by the National Research Council, and funded by the National Science Foundation and Elsevier. Its mission was similar to ours.

### 7.0.2 Systematic Search

The team conducted systematic literature searches from 2015 onwards, to update the knowledge gathered from the book where necessary.

### 7.0.3 Qualitative Interviews

To gain a better understanding of the status quo of team science at Tilburg University, the core team interviewed members of existing Team Science projects throughout the organization. To gain insight on national best practices, the team additionally interviewed members of notable national Team Science projects, like the YOUTH Cohort Study (UU) and ODISSEI (national).

### 7.0.4 Publication Practices

Furthermore, the core team obtained and analyzed co-authorship statistics from University Library.

### 7.0.5 Examples

The core team gathered similar vision documents and guidelines from other Universities, most notably Utrecht University and Leiden University.

### 7.0.6 Feedback

The core team created Intervision and Feedback opportunities for stakeholders; including a bilateral meeting with Esther Keymolen, who conducted a team science pilot at TLS; the Steering Group Use (Y)our Talents; and a call for feedback on the draft document that was open to all employees of TiU, but with special attention to the Tilburg Young Academy and Open Science Community.

### 7.0.7 Integration

The Team Lead, Caspar van Lissa, integrated the results from these different approaches and wrote the final policy brief.

# Appendix C: Library Report

· Welk percentage artikelen werd geschreven door auteurs van meer dan één faculteit?

Filters applied: - Category = Scientific - Type = Article - Status = Published - Peer reviewed = Yes - Only schools, no divisions or institutes that fall under the University instead of schools.

| Year | X2019 | X2020 | X2021 | X2022 | X2023 |
|---|---|---|---|---|---|
| Articles with > 1 school * | 41 | 30 | 32 | 32 | 21 |
| Total articles ** | 1078 | 1134 | 1150 | 1161 | 650 |
| Percentage | 3,8% | 2,6% | 2,8% | 2,8% | 3,2% |

- De school (faculteit) is bekend voor huidige organisaties. Oude of overgenomen organisaties worden niet meegerekend. Wanneer een faculteit samenwerkte met een oude unit van een andere faculteit, wordt deze dus niet als samenwerking meegerekend. Dit komt door een gebrek in de aanlevering van de data vanuit Elsevier. ** Total articles zijn het totaal aantal artikelen waar minimaal 1 faculteit bij betrokken is.

· Welk percentage artikelen had minstens één co-auteur die niet aan deze universiteit verbonden was?

Filters applied: - Category = Scientific - Type = Article - Status = Published - Peer reviewed is Yes

| Year | X2019 | X2020 | X2021 | X2022 | X2023 |
|---|---|---|---|---|---|
| Articles with > 0 external persons * | 739 | 785 | 781 | 786 | 436 |
| Total articles ** | 1135 | 1188 | 1192 | 1202 | 655 |
| Percentage | 65,1% | 66,1% | 65,5% | 65,4% | 66,6 |

- Externe personen worden geteld als extern wanneer ze NIET verbonden zijn met een (bekende) interne TiU organisatie, maar wel verbonden met een externe organisatie. ** Total articles zijn het totaal aantal artikelen, ongeacht of er een faculteit bij betrokken is.

· Welk percentage artikelen had minstens één co-auteur die aan een pivate instelling (geen universiteit) verbonden was? Filters applied: - Category = Scientific - Type = Article - Status = Published - Peer reviewed is Yes - Type of external organization is not: 'Academic', 'University', 'Unknown' External organization with types that are counted: o Government o Research Institute o Company o Corporate o Medical o Broadcasting organisation o Private non-profit

| Year | X2019 | X2020 | X2021 | X2022 | X2023..20.11. |
|---|---|---|---|---|---|
| Articles with > 0 private organization persons * | 214 | 221 | 187 | 212 | 112 |
| Total articles ** | 1135 | 1188 | 1192 | 1202 | 655 |
| Percentage | 17,0% | 16,3% | 13,3% | 15,1% | 14,5% |

- Externe personen worden geteld als extern wanneer ze NIET verbonden zijn met een (bekende) interne TiU organisatie, maar wel verbonden met een externe private organisatie. ** Total articles zijn het totaal aantal artikelen, ongeacht of er een faculteit bij betrokken is.