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Unite! Handbook of best practices for effective mainstreaming of open science and innovation at Universities

DOI:
10.5281/zenodo.10262984

Published: 01/12/2023

Document Version
Publisher's PDF, also known as Version of record

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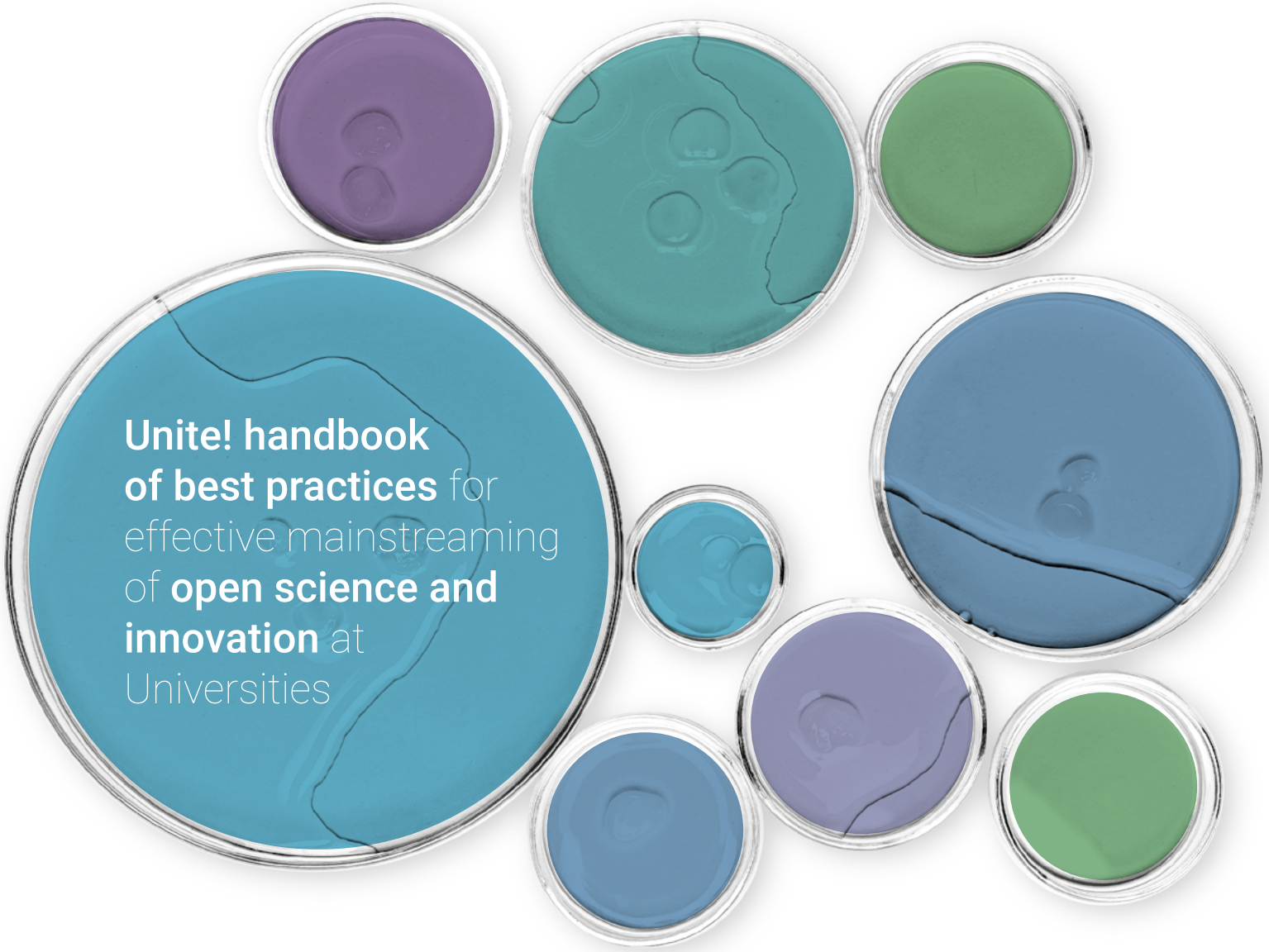

Unite! handbook of best practices for effective mainstreaming of open science and innovation at Universities

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101017408

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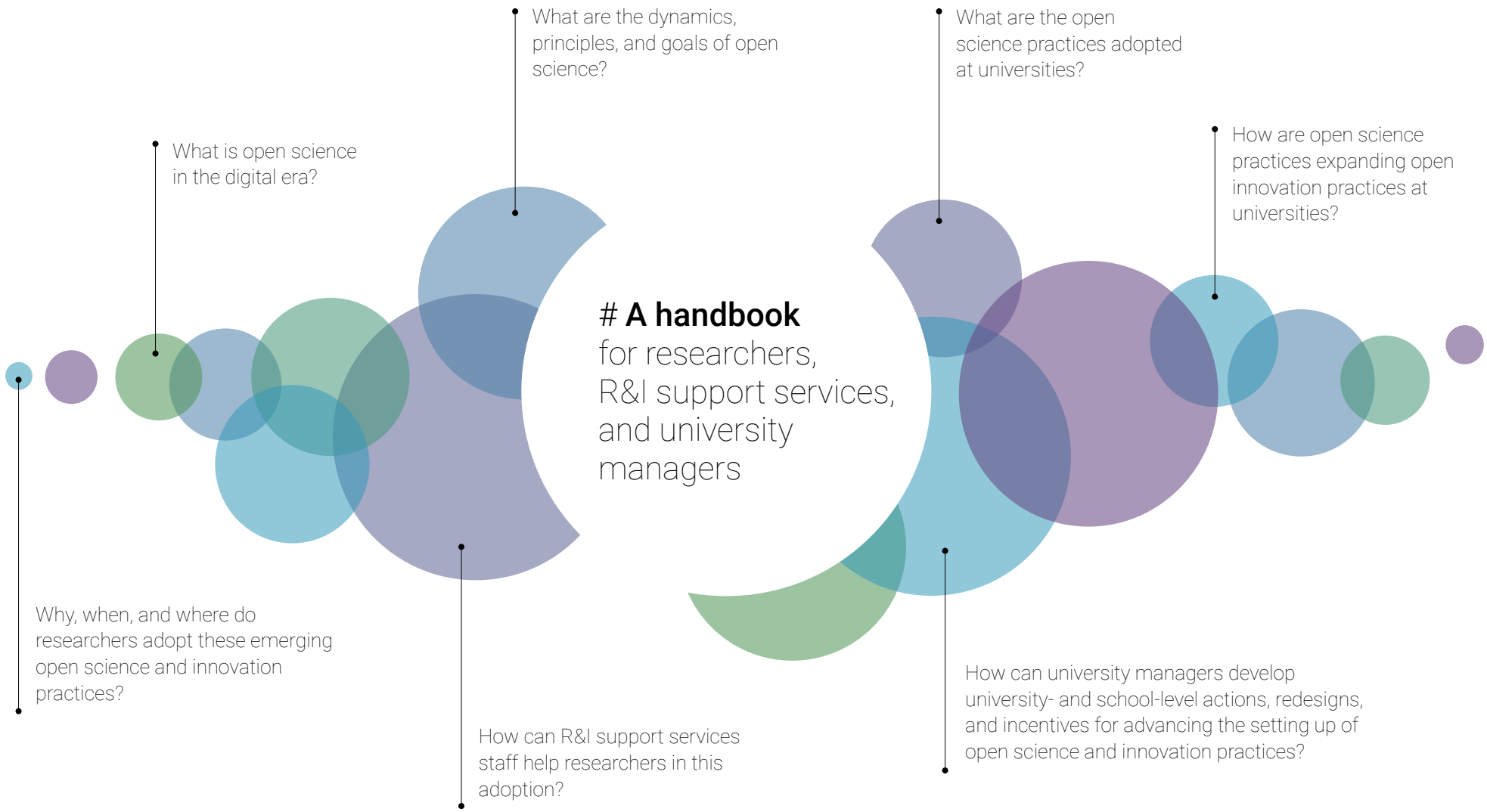
To all researchers,
to all the courageous
women and men
who throughout history
have challenged and are
challenging the edges
of conventions
of science

Structure


What are the dynamics, principles, and goals of open science?
What are the open science practices adopted at universities?
What is open science in the digital era?
How are open science practices expanding open innovation practices at universities?
A handbook for researchers, R&I support services, and university managers
Why, when, and where do researchers adopt these emerging open science and innovation practices?
How can R&I support services staff help researchers in this adoption?
How can university managers develop university- and school-level actions, redesigns, and incentives for advancing the setting up of open science and innovation practices?

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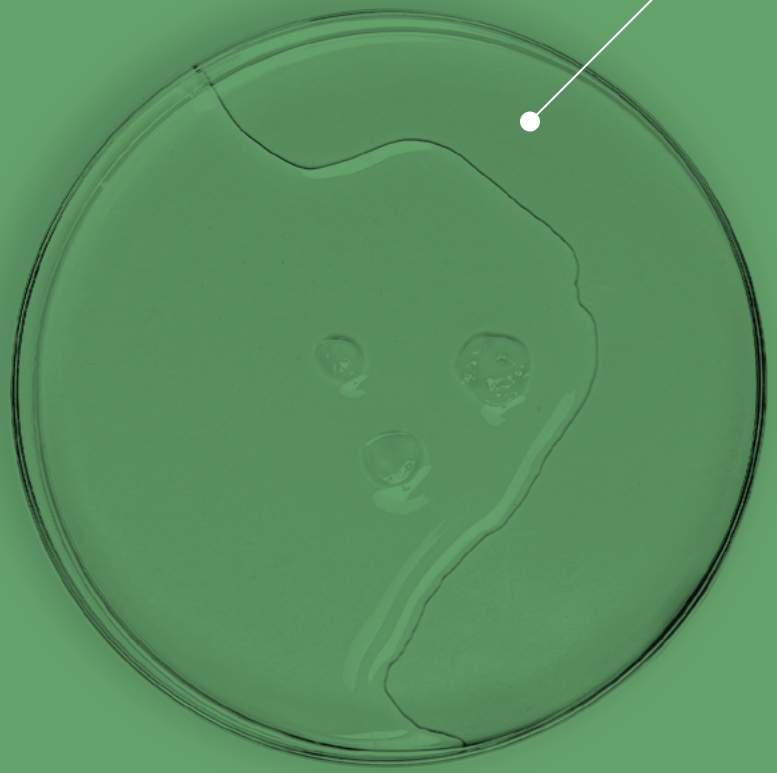
Introduction
From modern science to open science



01

Our aim: facilitating the transition from modern science to open science

The goal of this handbook is to answer these questions by providing helpful guidance on how to plan, test, and implement emerging open science and innovation practices at universities. By means of a bottom-up approach, this handbook reveals how pioneering researchers conduct research and innovation in novel ways in the digital era. This handbook illustrates how emerging open science practices adopted by Unite! researchers, such as open data sharing or transdisciplinary research practice with citizens, professionals, and emerging academics, are evolving well-established modern science practices, such as publishing in scientific journals or participating in exhibitions, and how these novel open science practices are also expanding open innovation practices in universities. This handbook illuminates the change of paradigm (Kuhn, 1970)[1] happening in the institution of science in our society today and its impact on the governance of research and innovation in universities. This handbook is a tool for managing open science and innovation in university research teams.

Our commitment: shaping the future of open science

This handbook is meant as a practical guide for researchers, R&I support services, and university managers for implementing in universities the open scientific paradigm that is emerging in the ongoing evolving digital era. Based on a comparative case study of 70 Unite! research teams, this handbook reveals a high-impact understanding of the best open science and innovation practices on Unite! research teams, exposes Unite! guidelines for the adoption of these practices, and shapes a new governance model for the management of open science and innovation in universities. This Unite! handbook advances the implementation of the Unite! open science and innovation strategic roadmap,[2] contributes to fostering the new European Research Area,[3] and sets in motion and expands the international framework for policy and practice set up by the UNESCO Recommendation[4] on how to boost open science.

1 Kuhn, T. S. (1970). The structure of scientific revolutions. Second edition. Chicago, London: The University of Chicago Press

2 https://www.unite-university.eu/media/pu_deliverable-6-1-unite-open-science-and-innovation-roadmap.pdf
3 European Commission, Directorate-General for Research and Innovation (2022). A pact for research and innovation in Europe, Publications Office of the European Union.
4 https://unesdoc.unesco.org/ark:/48223/pf0000378841

Why open science and innovation?

Open science is transparent and accessible knowledge, shared and developed through collaborative networks (Vicente-Saez and Martinez-Fuentes, 2018).[5] It involves sharing ideas, data, methods, prototypes, reviews, and results with local, national, regional, and global collaborative networks of research participants. It also goes beyond this to encompass the scientific knowledge produced and used by these collaborative networks.

Science is being reshaped by advances in digital technologies and tools, artificial intelligence, big data, the Internet of Things, 3D printing, and quantum computing, along with open digital and physical infrastructures, including open labs, open libraries, cultural heritage, digital knowledge bases, diamond open-access journals and open university campuses. These technologies and infrastructures, together with EU, national, and university-level open science initiatives and policies, have, in turn, allowed researchers to experiment with, develop, and adopt new open science practices, principles, and goals for tackling grand societal challenges.

Open innovation is the use of purposive inflows and outflows of knowledge to accelerate internal and external innovation (adapted from Chesbrough et al., 2006; Chesbrough and Bogers, 2014).[6] Novel open science practices for the sharing and production of knowledge have created extraordinary possibilities for this knowledge value creation and transfer process. These practices are expanding not only the ethos of science, but also the ethos of innovation in universities. Open science practices are transforming science and innovation practices in universities.

5 Vicente-Saez, R., Martinez-Fuentes, C. (2018). Open Science now: A systematic literature review for an integrated definition. Journal of Business Research 88, 428–43

6 Chesbrough, H., Vanhaverbeke, W., West, J. (2006). Open innovation: Researching a new paradigm. Oxford University Press on Demand Chesbrough, H., Bogers, M. (2014). Explicating open innovation: Clarifying an emerging paradigm for understanding innovation. In: Chesbrough, H., Vanhaverbeke, W., West, J. (Eds.), New frontiers in open innovation. Oxford: Oxford University Press, pp. 3–28

Unite! Alliance as a European engine of open science and innovation

We present three building blocks to help constitute Unite! Alliance as a European engine of open science and innovation. These three building blocks can lead researchers, R&I support services staff, and university managers towards the mainstreaming of open science and innovation practices on university research teams, the researcher-centred design of university open science support services, and the transformation of university research and innovation governance models in the digital era.

State of the art – What, Why, When, and Where
We provide a high-impact understanding of the best open science and innovation practices pioneered by Unite! research teams.

Recommendations – How
We present practical guidelines on how Unite! research teams can adopt open science and innovation practices.

Summary
Shaping a new university open science and innovation governance model – We reveal how Unite! research teams can administrate, organise, and conduct open science and innovation in the digital era.

The three building blocks advance the opening of science and innovation in Unite! Alliance for a sustainable culture, economy, environment, society, and technology: for a sustainable world.

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Methodology and data

Unite! Alliance as a testbed for universities

02

Unite! Alliance as a testbed for the renewal of university research and innovation governance models in the digital era

This handbook builds on a qualitative empirical research study (Gephart, 2004)[1] which aimed to understand how emerging open science practices are transforming the modern science and innovation practices of Unite! research teams when developing solutions for achieving UN SDGs 2030. We conducted a comparative case study of 70 research teams oriented towards open science – which were forerunners, active, or interested in it – across 7 European universities in Unite! Alliance: Aalto University in Finland (Aalto), Darmstadt Technical University in Germany (TU-Da), INP-University Grenoble Alpes in France (UGA), KTH Royal Institute of Technology in Sweden (KTH), the Polytechnic University of Catalonia in Spain (UPC), the Polytechnic University of Turin in Italy (Polito), and the University of Lisbon in Portugal (ULisboa). The sample was selected by the university managers, delegates, and R&I support services staff working for the adoption of open science practices at each partner university, taking into account Unite! principles for gender equality, diversity, and inclusiveness. The selection criteria included research teams from all the disciplines of science, business, design, engineering, technology, architecture, and humanities at Unite! universities. We replicated and expanded the case study of research teams studied at Aalto University in 2019 (Vicente-Saez et al., 2021)[2] by including and comparing a new setting of data from other European universities. We conducted face-to-face semi-structured interviews with the research team leaders and had several informal conversations with team members of the research groups when we visited the groups.

Due to several Covid-19 exposures, 7 interviews were organised online. We developed a protocol[3] to guide the interviews. Finally, we used thematic analysis (King and Brooks, 2018)[4] with a hybrid process of inductive and deductive analysis to code, identify, and provide a high-impact understanding of the best practices of open science and innovation practices in Unite! research teams. We integrated our findings into a comprehensive model for the governance of open science and innovation in universities in the digital era.

Unite!H2020-WP6 as a spearhead platform for creating a European Open Science and Innovation University

This "bottom-up handbook" gives a voice to researchers for sharing, explaining, and revealing how they conduct open science and innovation in universities in the digital era, how R&I support services staff can help them to adopt these practices, and how university managers can develop university- and school-level actions, redesigns, and incentives for advancing the setting-up of open science and innovation practices.

1 Gephart, R. P. (2004). Qualitative research and the Academy of Management Journal. Academy of Management Journal 47, 454–62

2 Vicente-Saez, R., Gustafsson, R., Martinez-Fuentes, C. (2021). Opening up science for a sustainable world: An expansive normative structure of open science in the digital era. Science and Public Policy 48(6), 799–813

3 For the development of the handbook, we analysed the data collected in four questions of the interview protocol:
1. Is your research team engaging in open science?
2. How is your research team openly sharing their research outputs with other researchers, research institutes, companies, municipalities, citizens, or international organizations?
3. How is your research team openly producing their research outputs with other researchers, research institutes, companies, municipalities, citizens, or international organizations?
4. Are open science practices changing the innovation practices of your research team?

4 King, N., Brooks, J. (2018). Thematic analysis in organisational research. In: Cassell C., Cunliffe, A. L., Grandy, G. (Eds.), The Sage handbook of qualitative business and management research methods. London: SAGE Publications Ltd

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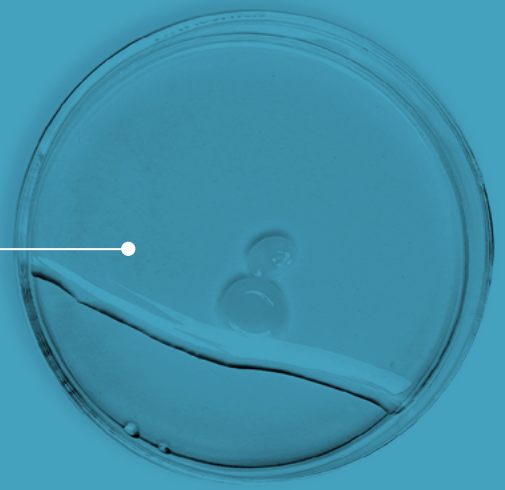
State of the art
What, Why, When, and Where
Best Unite! open science and innovation practices



03

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In this section, we provide a high-impact understanding of the best open science and innovation practices pioneered by Unite! research teams.

We explore how the advances in the use of new digital technologies and tools, together with new open physical and digital infrastructures and EU, national, and university-level open science initiatives and policies, have arisen in emerging open science and innovation practices, principles, and goals at Unite! universities. We reveal what open science and innovation practices are adopted, and why, when, and where Unite! research teams adopt them.

Openness in science in the digital era follows two dynamics. First, openness in the sharing of scientific knowledge is based on principles of transparency and accessibility. Second, openness in the production of scientific knowledge is ingrained in the principles of the participation and legitimacy of new collaborative networks of participants in research. Open science goes beyond the traditional extension of certificated knowledge and disclosure and dissemination of knowledge among scientists of modern science (Merton, 1942, in Merton, 1973).[1] Open science in the ongoing evolving digital era aims to inform and extend the co-creation of scientific knowledge by all humanity (Vicente-Saez et al., 2021).[2]

According to the two dynamics of open science in the digital era, we distinguish two categories of open science practices taken up by Unite! research teams: open sharing practices and open collaborative practices. We also distinguish how these open science practices adopted by Unite! research teams are expanding open innovation practices. We encounter two novel inbound and outbound approaches, which can be considered two novel open innovation practices.

1 Merton, R. K. (1973). The normative structure of science. In: The sociology of science: Theoretical and empirical investigations. Chicago: The University of Chicago Press, pp. 267–278
2 Vicente-Saez, R., Gustafsson, R., Martinez-Fuentes, C. (2021). Opening up science for a sustainable world: An expansive normative structure of open science in the digital era. Science and Public Policy 48(6), 799–813

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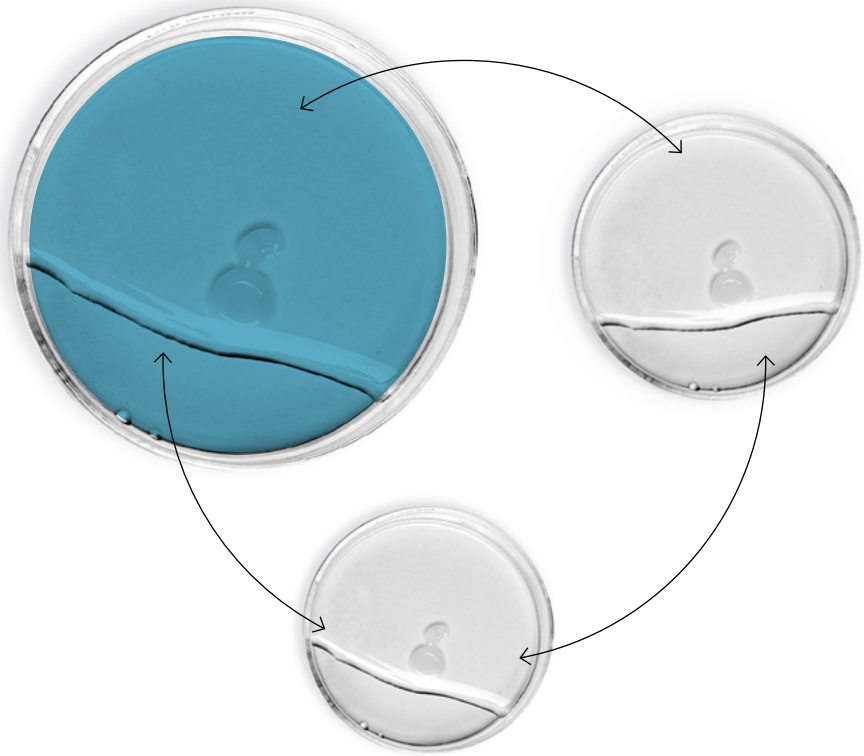
3.1

Open sharing practices

We identify that Unite! research teams pursue openness in the sharing of scientific knowledge – ideas, methods, data, prototypes, reviews, and results – for collaborative networks of participants in research by planning, testing, and implementing open sharing practices, such as open protocol sharing, open data sharing, open access publishing, open-source research software sharing, and open multimedia sharing.



3.1.1 Open protocol sharing

What is...about?

We define open protocol sharing as the research practice of making the research design – research idea and methods for data gathering and/or analysis – available as transparent and accessible outflows of knowledge for collaborative networks of participants in research, prior to data gathering, and by the means of interoperable digital infrastructures. We recognise different distinguishable manifestations:

Study pre-registration, making the research design available in open platforms without peer review, as illustrated by Luís Tinoca, team leader of the Education Research and Development Group at ULisboa: *"We started by publishing our research protocol […] – there's this website where you can publish this type of research protocols"*.

Registered report, submitting the research design, including introduction, methods, and analysis plan, for peer-review in a scientific journal, as highlighted by Alessandro Sparacio, former team member of the Social Cognition research group at UGA: *"The second meta-analysis study is a registered report. It's similar to a pre-registration, but we also have peer reviews from a journal that basically provides some feedback. After their approval, you can start with the data collection"*.

Why...?

We encounter that Unite! research teams adopt open protocol sharing practices with the aim of **fostering transparency, enhancing the reproducibility of specific research results, and increasing scientific rigour**, as pointed out by Alessandro Sparacio, former team member of the Social Cognition research group at UGA: *"I think you understand that it's necessary to do this additional work to improve the way of doing science. Otherwise, the risk is to do projects that are not rigorous from a methodological point of view"*.

When is there...?

We identify that Unite! research teams make open protocols available as outflows of the **conceptualisation and design stage** of the research process, as exposed by Alessandro Sparacio, former team member of the Social Cognition research group at UGA: *"the first meta-analysis and the multi-site project are preregistered. Basically, we wrote the introduction, the method, and the analysis section before conducting the data collection"*.

Where is there...?

We found that Unite! research teams implement open protocol sharing by utilising the connectivity and interoperability of digital infrastructure, such as:

Research team's website, as explained by Evelyn Gius, team leader of the fortext lab at TU-Da: *"We do also publish things like annotation guidelines […] it's a mixture of definitions of categories for analysis and of procedures for annotations. It's a mixture. We do publish these as well"*.

Open science framework (OSF) platform, as emphasised by Hans Ijzerman, former team leader of the Social Cognition research group at UGA: *"I ask from them that they do a pre-registration or, preferably, a registered report for confirmatory research. For all empirical work, I ask them that they share their analysis scripts and that they use the OSF to share their (anonymized) data, their research materials, and anything else others need to reproduce their work"*.

3.1.2 Open data sharing

What is...about?

We define open data sharing as the research practice of making data and databases available as transparent and accessible outflows of knowledge for collaborative networks of participants in research across several stages of the research process, and by means of interoperable digital infrastructures.

Why...?

We encounter that Unite! research teams adopt open data sharing practices with the aim of:

Validating and enhancing the reproducibility of specific research results, as illustrated by Giovanni Squillero, team leader of the MLbites research group at Polito: *"we put our code on some open repositories like GitHub, and all our data are open and the experiment can be reproduced […] it's a win-win situation because people using your code can help you, can find bugs, and can boost your citation, for instance".*

Accelerating data reuse by other researchers, as highlighted by Participant 32 at TU-Da: *"we really provide source code, provide extensive documentation on how we collected data and [make] the data available. Making the entire pipeline of how we process the data available so that other people can just take this research and, first of all, validate our claims, but potentially build on it".*

Fostering value for stakeholders beyond the academy, as reflected by Piero Boccardo, team leader of the SDG11 Lab at Polito: *"[…] we are trying to define also some protocols in order to share this data with the – for example, the municipalities and the local authorities, and all the – of course, to also give them the possibility to use this data for their current operation and for what they have in mind to perform".*

Increasing the impact of their research, as pointed out by Dorota Iwaszczuk, team leader of the Remote Sensing and Image Analysis research group at TU-Da: *"if I create my benchmark data, of course first I want to make my tests myself for many good reasons. At the end, I would publish everything, and other people can use the data, so they are faster with developing their methods. It is still advantageous for me and my visibility. They cite me because it's in [the] terms of use that they have to cite a specific paper, which was done with the publishing of this benchmark".*

Improving the process of knowledge production, as exposed by Daniele Marchisio, team leader of the Multiscale Modelling for Material Science and Process Engineering research group at Polito: *"Part of the motivation in doing so was [to] improve the way in which the developed knowledge, which is in part data in software, was stored and preserved after the student left, so that was one part of the motivation".*

When is there...?

We identify that Unite! research teams make data and datasets available as outflows of different stages of the research process:

Data gathering, as explained by Miina Rautiainen, team leader of the Remote Sensing research group at Aalto: *"we open some of our data when in repositories in our own field when the project is completed or when we know that there isn't a competing group which would publish something based on our data before we are able to do it ourselves […] Sometimes we publish datasets already during the project, otherwise when the project is ending"*.

Report writing, as also exemplified by Miina Rautiainen, team leader of the Remote Sensing research group at Aalto: *"but in general, I would say both in forest sciences and remote sensing, it has been common, for the past twenty years or so that I've been working in the field, that any time your foreign colleague contacts and asks for a dataset because they read an article, to share data -- even if we haven't met, or we don't really know each other. So it has been common to share in this way"*.

Dissemination, after an embargo period, as emphasised by Helle Pedersen, team leader of the Waves and Structures research group at UGA: *"yes, because whenever we have seismic experiments, the data, they enter the databases, and they become available. We are allowed to have a short embargo time for 2 years or 3 years. You collect the money, you do all the data, you go in the field, you get the data back, your quality control, and stuff like that. There is a period where we put the data in the databases, but we close them with a password for a while"*.

Where is there...?

We find that Unite! research teams implement open data sharing by utilising the connectivity and interoperability of digital infrastructures such as:

Discipline-specific repositories, as shared by Fabien Malbet, team leader of the LabEX Focus research group at UGA: *"in astronomy, it has been a long trend already more than 50 years ago. We already had a database. We have a database at the worldwide level for virtual observatories […] Everybody that produce[s] data in astronomy, he knows that at the end, he will put the data [in] the virtual observatory"*.

Institutional repositories, as explained by Sónia Frota, team leader of the Lisbon Baby Lab at ULisboa: *"there are different platforms that we are using. We have the labs website, and [on] the labs website, we have the different projects, and so some things are connected to a specific project and are available directly from the website of the project. Others are just in the lab or website. We use the University of Lisbon repository as well"*.

GitHub or GitLab platform, as clarified by Peter Pelz, team leader of the Institute for Fluids Systems Technology at TU-Da: *"when we are allowed to do that, we have all the software and the data in repositories like GitLab. The software and the data and our results do have a persistent identifier and they are findable, accessible, interoperable, and so on, so on repositories"*.

The general-purpose repository Zenodo, as mentioned by Daniele Marchisio, team leader of the Multiscale Modelling for Material Science and Process Engineering research group at Polito: *"basically, what we try to do is what I told you before, the data on Zenodo, simulation data, data for tables and plots, the software on GitHub, and then the paper [is] published"*.

3.1.3 Open-source research software sharing

What is...about?

We define open-source research software sharing as the research practice of making source code/research prototypes and large community software available as transparent and accessible outflows of knowledge for collaborative networks of participants in research, across several stages of the research process, and by the means of interoperable digital infrastructures.

Why...?

Open-source research software is not classical open-source software. The lifecycle, usage, visibility, size of development teams, and motivations are quite different. We encounter that Unite! research teams adopt open-source research software sharing with the aim of:

Achieving reproducibility of their research results, as illustrated by Marc Pfetsch, team leader of the Optimisation research group at TU-Da: *"My viewpoint or my emphasis is on being reproducible. We're doing software. We need software to test our methods. To implement them, we want to, of course, also see how they behave in real life […] The most important part is to make them reproducible. The main goal is to make science reproducible in this area. That's my emphasis, right? It doesn't mean that the other parts are not important, but that's my emphasis".*

Increasing the transparency of the research process by filling the gap between the figures in research articles and the raw data, as highlighted by Bruno Raffin, team leader of the Datamove research group at UGA: *"we do a lot of experimental science. One specificity [is] that we run our experiments on supercomputers. We try to make things reproducible, but it's really hard. We try, it's new. I would say that, if you go back five or six years ago, we were not really publishing the code or the data of the experiments; when you have a graph and a paper, we were not publishing anything else than just the graph. I'll try making the efforts and, 'Okay, we provide the original data, the codes that were used to process the data and go up to the graph'".*

Fostering open-source research software reusability to create a deep societal impact, as reflected by Participant 32 at TU-Da: *"Some of our research software allows repurposing the chips that are in off-the-shelf smartphones. Instead of now having to buy an expensive software-defined radio platform, your smartphone or your notebook can step in, because we basically opened up those black boxes within those devices. Hundreds maybe even thousands of other researchers are using our software, because it gives them an ability to perform [a] certain kind of research that they could not have been doing before, that would have been rather expensive before."*

Adhering to the global open-source movement well-rooted in their research disciplines, as pointed out by Vicent Acary, team leader of the Modeling, Simulation and Control of Nordsmooth Dynamical Systems research group at UGA: *"I want to say that perhaps I enter into open science through software. I use a lot [of] open-source software. For me, it's quite important that people share some free software and open-source software. When we started to develop some software because we are developing some software for modelling and simulation within the group, we decided to really work into [an] open*

environment just to share and to promote what we're able to do to share stuff and to be able to collaborate. It seems quite natural now. Twenty years ago, it was not so natural. There is still some problem with that in some communities. The communities are not on the same level. [In] computer science [it] is quite natural to hear about open-source software".

Securing the accessibility and reusability of their research work by other researchers, with special emphasis on early career researchers, as exposed by Harri Koivusalo, team leader of the Water and Environmental Engineering research group at Aalto: *"Open sourcing of our models has been kind of a way to secure that, that the model can be used anywhere, and anybody can use it, and also the student after the student is leaving the university can use the model".*

Building the reliability of their work, which contributes to building a good reputation in their research discipline, as explained by Marc Pfetsch, team leader of the Optimisation research group at TU-Da: *"All of the PhD students. Of course I force them to make their software public. At least we adhere to the usual storage of data results software. They benefit from this, right? If they apply for a job after their PhD, they can say, 'Okay, here, this is the software I wrote on GitHub or somewhere else'".*

When is there...?

We recognise different manifestations distinguishable into general open-source research software sharing, depending on the status of the research software along the stages of the research process: research prototypes developed by a single or few authors to illustrate a concept or to evaluate the feasibility of an idea vs large community software to achieve a wider and deeper impact. We identify that Unite! research teams make open-source research software available as outflows of different stages of the research process:

Data analysis, research prototype sharing, as exemplified by Björn Thuresson, team leader of the Visualisation Studio at KTH: *"The actual prototypes are in most cases demos of something. [Because] that is the main output. It is not a commercial product. They have in most cases been developed not as a product in itself, but something, it's either testable, they produced it to be able to do whatever test they need to do. Or they produce it as a demo, to show, to communicate more than anything else […]That is the knowledge base in most cases. And that is the same for, well, a research prototype is something different than a commercial prototype. In research, you only develop as much as you need to be able to test what you need to test".*

Report writing, when moving from research prototype to large community software, as emphasised by Participant 32 at TU-Da: *"In terms of the tools, again, computer code, pieces of software, we are mainly using GitHub. We do have an internal group repository, and anything that is done by each individual researcher is commited to the repository and shared internally. Before sharing with the outside world, a lot of effort has to be put into cleaning the code and documenting it; so we open to the outside world only the things that are ready to be shared, then to be actually used. GitHub is used to manage, but also to disseminate and share within the group and outside of the group".*

Dissemination, large community software, as shared by Helle Pedersen, team leader of the Waves and Structures research group at UGA: *"We have a long tradition [of] joint tools. For example, we have community software, so we tend to use [it]. We have international standards. We have community software".*

Where is there...?

We find that Unite! research teams are sharing open-source research software by using the connectivity and interoperability of digital infrastructures such as:

Research team's website, as mentioned by Marc Pfetsch, team leader of the Optimisation research group at TU-Da: *"that depends. The public ones are GitHub. The kernel, I would say, of the software, that's called Skip, that's available on GitHub. Then we also have parts of the software on our webpages […] First thing is articles. They describe the methods. Second, software. Most PhD students write software for this main framework that goes into the framework, and then it's available. If it's a specialised code, then they often publish it on the webpage"*.

Discipline-specific repositories, as clarified by Francesca Vipiana, team leader of the Wavision research group at Polito: *"on the other side, there is also another service that is called code ocean where essentially you can upload your source code or the execute one, depends on you, and [make it] again available to other researchers [on the condition] that they must cite it and to refer to your paper. This in principle is fantastic"*.

GitHub or GitLab platform, as revealed by Participant 32 at TU-Da: *"most of our software resides on GitHub, which is currently the leading platform for open-source software. In the past we hosted software on our website, but we saw that the community takes it up better if it sits on GitHub"*.

Publishing in digital journals that encourage researchers to release data, source code, and the research article all at once, as indicated by Peter Pelz, team leader of the Institute for Fluids Systems Technology at TU-Da: *"we funded a journal, which is an open-access journal, called it ing.grid. This journal is purely open access, and there is not only data and normal text, but also software can be published"*.

3.1.4 Open access publishing

What is...about?

We define open access publishing as the research practice of making research results and evaluations – preprint manuscripts, peer-reviews, research papers, books, and doctoral dissertations – available as transparent and accessible outflows of knowledge for collaborative networks of participants in research, across several stages of the research process, and by the means of interoperable digital infrastructures.

Why...?

We encounter that Unite! research teams adopt open access publishing with the aim of:

Removing boundaries to accessing research results, as illustrated by Alexander Löwer, team leader of the Systems Biology of the Stress Response research group at TU-Da: *"the most well-developed level would be in the context of publishing, of open access publishing, to remove boundaries [to] accessing research results and improving the dissemination of research among all interested people, all interested entities, and giving scientists maybe a little bit more control over how their results can be used and reused"*.

Boosting the dissemination of scientific knowledge, as highlighted by Xavier Gamisans Noguera, team leader of the Biological Treatment of Gaseous Pollutants and Odours research group at UPC: *"I could say, basically, there are different levels. The first one is open access publications. For me, this is at present one of the best tools or the best ways to spread your knowledge"*.

Increasing transparency and gaining earlier impact for young research teams, as reflected by Edoardo Piccoli, one of the team leaders of the Construction History research group at Polito: *"but for us, for our young, low-budget group, a sort of a start-up, open access has been a very relevant opportunity to make ourselves known very rapidly in the scientific community. We are yet working on how to evolve further, but I would say that without the open access policy to our publications, we would still be much more closed up on ourselves"*.

When is there...?

We recognise different manifestations distinguishable into general open access publishing, depending on the status of the research results and evaluations along the stages of the research process: open access publishing of preprint, peer-reviews, research papers, and books. We identify that Unite! research teams make these research results and evaluations available as outflows of different stages of the research process. We identify that Unite! research teams carry out open access publishing in different stages of the research process:

Report writing: green open access publishing, making preprints-manuscripts available before peer review, as pointed out by Patrizia Semeraro, senior researcher of the Probability and Applications research group at Polito: *"for open access papers, I think that, again, in my community, we always publish the arXiv preprint, which is public, so I don't feel that the fact that some journals are not open, I don't feel it as a big issue because my research is usually on public datasets"*.

Review, open peer review, publishing of reviews of manuscripts under evaluation, as exposed by Edoardo Piccoli, one of the team leaders of the Construction History research group at Polito: *"and I must say we do dissemination essentially in two ways, by referring to open-access reviews, which have now in our field growing relevance. There are reviews that are also well evaluated in terms of reputation and evaluation and have a measurable high diffusion of their content.*

Dissemination, making research papers available through:

Golden open access publishing, as exemplified by Participant 48 at UGA: *"when we can, we try to publish open access. As I mentioned already, this is something which is often related to a budget".*

Diamond open access publishing, as emphasised by Vicent Acary, team leader of the Modeling, Simulation and Control of Nordsmooth Dynamical Systems research group at UGA: *"we decided also to do something about publication and [an] open journal. By promoting Diamond Open Access, we created a journal […]. The journal started three years ago. It was [going] quite well from the standard scientific point of view. The community is quite happy to have a journal that is free for the reader, free for the author, but at the same time, we try to promote new open policy through the creation of this journal".*

Publishing open access books and doctoral dissertations, as shared by İdil Gaziulusoy, team leader of the NODUS Sustainable Design research group at Aalto: *"well, it's basically a book that covers all main approaches in design for [sustainability areas starting from] its beginning. […] it's quite a lot of information and also our intellectual thinking about the pros and cons of different approaches, in the form of one book. So I would say that it's super valuable as an open resource, because it's one resource that covers quite a lot. So anyone who wants to put their hands into design for sustainability, practitioners, student[s] or other academics, it's a great resource, and they don't have to pay for that".*

Where is there...?

We find that Unite! research teams implement open access publishing of preprints, peer-reviews, research papers, and books by utilising the connectivity and interoperability of digital infrastructures such as:

Discipline-specific repositories, as explained by Bart Van Tiggelen, one of the team leaders of the Physics and Modeling of Condensed Media Laboratory at UGA: *"my research lab, my research team, but my research lab is absolutely involved in open science. I think most of the physicists, we work in commerce metaphysics, and most of the people working in commerce metaphysics already put their work on open archives. That would be the green option to open access […]. In French, we have an archive hall which was founded by physicists, and it's now open to all disciplines that [were] founded by physicists, and it's now used for this more top-down policy in terms [of] conduct[ing] open science".*

Institutional repositories - green open access -, as mentioned by Francesc Martínez-de-Osés, team leader of the Maritime Transport and Logistics research group at UPC: *"we used to put our works, our reports, maybe also our papers [on] the university platform that gives access to everybody […] we suggest to our lecturers and professor[s] to do it".*

Publishing in journals with open access options, as clarified by Dorota Iwaszczuk, team leader of the Remote Sensing and Image Analysis research group at TU-Da: *"we don't say that the only possibility is to publish with open access, but I would always prefer to publish in open access if the quality of the journal is on a certain level"*.

Promoting their own diamond open access journals, as revealed by Evelyn Gius, team leader of the fortext lab at TU-Da: *"we have been founding a journal that is open access with the university library here last year, and the next one is coming up this year. It's the second, the one is an international journal, the other one is a German one, that is based on open-access principles. Also, it is without [a] fee, so it's free of cost for everybody, both for the people who publish and the people who want to read the papers"*.

3.1.5 Open multimedia sharing

What is...about?

We define open multimedia sharing as the research practice of making a new wave of scientific outputs available as transparent and accessible outflows of knowledge for collaborative networks of participants in research, in the dissemination stage, and by means of interoperable digital infrastructures and open physical infrastructures.

We recognise different distinguishable manifestations:

Social media scientific posts, videos, podcasts, or visualisations, as highlighted by Riikka Puurunen, team leader of the Catalysis research group at Aalto: *"I'm openly discussing things, for example, [on] Twitter, on work-related things, on research-related things, on funding-related things, on problematic terminology"*.

Documentary films, as shared by Participant 12 at KTH: *"Well, there's one research project that used to do film, and the documentary as an approach to understanding injustice is an interesting practice, I think. That might be open science"*.

Artistic expressions, as shared by Jorge Malheiros, team leader of the Urban and Regional Change and Policies research group at ULisboa: *"The other thing is some artistic expression [in the form of] posters or an exhibition of relevant elements for the community or the stakeholders, and you show them in a showroom [in] the community, sometimes here you bring an exhibition"*.

We identify that novel open science outputs sharing practice is expanding the rationales of societal outreach at universities, as illustrated by Joaquín del Río Fernández, team leader of the Remote Acquisition and Data Processing Systems in Marine Environment research group at UPC: *"I suppose that open science is not only the one that is published using scientific papers because probably, this use[s] some type of language and format that is not friendly [to] most of the population. I suppose that other actions of outreach and dissemination, like short videos of interviews, talks – this is a way also to open these research results to the community, depending on who these community member[s] [are] […] We are active [on] many social networks. The research group has a Facebook account, a Twitter account, an Instagram account, a YouTube channel"*.

Why...?

We encounter that Unite! research teams adopt open multimedia sharing with the aim of:

Promoting a new research evaluation system, as shared by Monica Truninger, team leader of the Environment, Territory and Society Research Group at ULisboa: *"it's submitted [documentary film] to a journal that accepted that kind of formats. We had a seminar discussing exactly this issue, papers that are in a different format, and making the documentary as valid as a paper, even for the assessment of researchers"*.

Increasing the societal impact of research, as shared by Luís Tinoca, team leader of the Education Research and Development Group at ULisboa: *"we try to diversify the way we disseminate our results in more traditional ways than just the journal publications or having the project website, try to do more*

visual things like developing short videos where teachers can speak about what they are doing, and why it worked in their classrooms […] and in that way be more impactful than what we are doing when we're publishing just journals. By doing that, I think it's more open as well".

Building the public reliability of their work, as reflected by İdil Gaziulusoy, team leader of the NODUS Sustainable Design research group at Aalto: *"I do think that being open or being an open researcher requires being active in the public, publicly visible realms as well, so writing blog posts, being on Twitter and commenting on Twitter".*

Engaging with excluded communities and creating deep societal impact, as noted by Filippo Fonio, team leader of the Dante from Yesterday to Today in France research group at UGA: *"That's more me as a researcher and not as a project leader. I like to go to the general public. I don't know, I like to take part in literature festivals for the general public or conferences in school[s] or museums or public libraries. When I was in the US, I did a lot of talks for district libraries, [in] more, let's say difficult neighbourhoods, public libraries where I met a lot of nice people".*

When is there...?

We identify that Unite! research teams make open multimedia sharing available as outflows of the **dissemination stage** of the research process, as reflected by Roger Joan Sauquet Llonch, team leader of the Centre for Research and Services for the Local Administration at UPC: *"This is very, very clear for all the society, that the conclusions of the project, of the results are basic [in] their environment. Yes. So the [documentaries], we have done maybe five, six or five [documentaries], and then the other one[s] are the expositions […]. Always expositions focus [on] the people. Sometimes students, exposed [at] the professional association of architects, or the collegial architectures. Then other times they exposed on the street, for instance. This kind of product, especially [documentaries] and [documentary] films, short films are the kind of product that we thought to approach our conclusions to the society"*

Where is there...?

We find that Unite! research teams implement open multimedia sharing by:

Utilising the connectivity and interoperability of digital infrastructures, such as the research team's website and multimedia-, image-, and video-based social media platforms, as shared by Joaquín del Río Fernández, team leader of the Remote Acquisition and Data Processing Systems in Marine Environment research group at UPC: *"We have an Instagram account also, and the website. We are in this case managing different websites, one for the research group, that is a generic one, another website for the observatory. We are operating another water observatory, and most of the activities about research are developed in this infrastructure".*

Utilising open physical infrastructures, such as open university campuses, open libraries, and public heritage, as illustrated by Björn Thuresson, team leader of the Visualisation Studio at KTH: *"We collaborate a lot with museums […] we have also […] joined research projects, where we built something for them. So we have in Tekniska Museumet […] I think currently we have two or three different permanent setups there […] So they have a permanent exhibition on the history of games there, but a part of that exhibition is novel ideas, what is happening right now. Typically my students in game design, they are recruited to be part of that. So that is a very concrete thing that also leaves a mark to some extent".*

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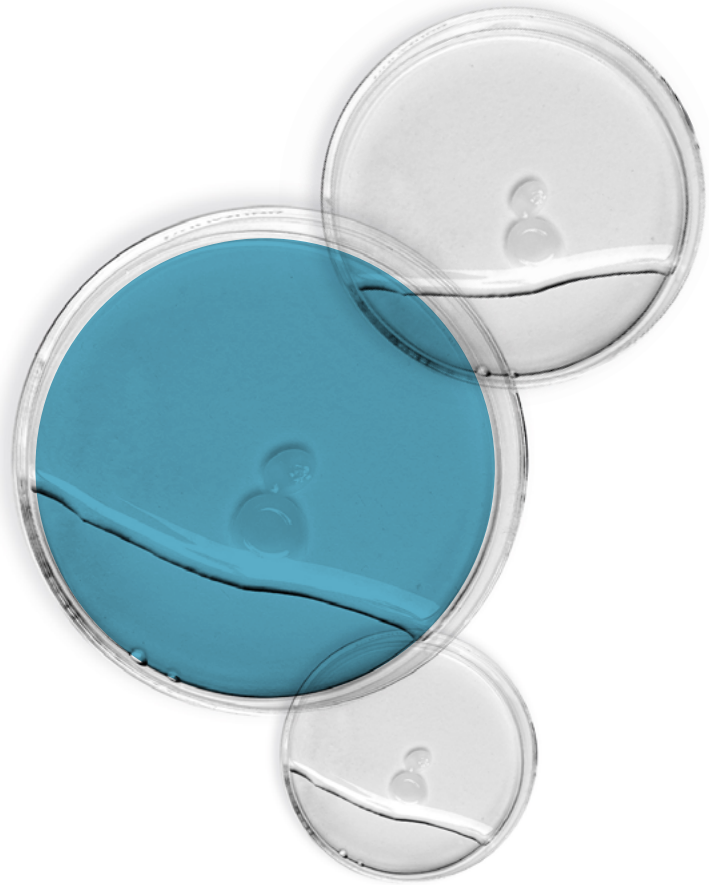
3.2

Open collaborative practices

We identify that Unite! research teams pursue openness in the production of scientific knowledge – ideas, methods, data, prototypes, evaluations, and results – among collaborative networks of participants in research by planning, testing, and implementing interdisciplinary research practice, transdisciplinary research practice with emerging academics, professionals, and citizens, and by recombining open science outputs. These open collaborative practices can also be referred to as open inviting practices (Vicente-Saez et al., 2020)[1] and open innovation in science practices (Beck et al., 2020).[2]



1 Vicente-Saez, R., Gustafsson, R., Van den Brande, L. (2020). The dawn of an open exploration era: Emergent principles and practices of open science and innovation of university research teams in a digital world. Technological Forecasting and Social Change 156, 120037

2 Beck, S., Bergenholtz, C., Bogers, M., et al. (2020). The open innovation in science research field: A collaborative conceptualisation approach. Industry and Innovation 29(2), 136–85

3.2.1 Interdisciplinary research practice

What is...about?

We define interdisciplinary research practice as the mode of co-producing scientific knowledge among collaborative networks of academics – lecturers, consolidated researchers, postdoctoral researchers, and doctoral candidates – from two or more research disciplines, across all stages of the research process, and by the means of interoperable digital infrastructures and open physical infrastructures.

Why...?

We encounter that Unite! research teams adopt Interdisciplinary research practice with the aim of:

Fostering creative problem-solving by bringing together different disciplines' expertise and perspectives, as illustrated by Evelyn Gius, team leader of the fortext lab at TU-Da: *"in the first place, you must understand where [it] comes together from, what kind of whatever, research interests, and typical methods would they have. In my team, we have a computer scientist, a philosopher, a cultural studies person, a linguistics person, we had a quantitative linguist. It's quite interdisciplinary"*.

Enhancing research quality, as diversity might lead to more rigorous research by providing alternative viewpoints and constructive criticism, and therefore leading to higher-quality open science outputs, as highlighted by Peter Pelz, team leader of the Institute for Fluids Systems Technology at TU-Da: *"this is typically so. Chemists, physicists, or mathematicians or colleagues from the law department, they are working together on one topic"*.

Innovatively addressing real-world complexities which require a comprehensive understanding of cultural, economic, environmental, social, and technological factors, as reflected by Bart Van Tiggelen, one of the team leaders of the Physics and Modeling of Condensed Media Laboratory at UGA: *"I have been active in research groups involving mathematicians, medical doctors, mathematicians, people from laser physics, and so on. It takes time to understand each other's language. It takes really time, but it can be done"*.

When is there...?

We identify that Unite! research teams carry out interdisciplinary research practice along all stages of the research process:

Conceptualisation and design, as pointed out by Dorota Iwaszczuk, team leader of the Remote Sensing and Image Analysis research group at TU-Da: *"we develop new methods which can be applied to remote sensing data. Most of those methods is oriented on the machine learning and computer vision. We adopt a methodology from those disciplines and develop new methodologies for remote sensing"*. She further continued: *"we actually work close to computer science, use a lot of methods from computer science, that is why we also use those practices"*.

Data gathering, as exposed by Alexander Löwer, team leader of the Systems Biology of the Stress Response research group at TU-Da: *"we believe that the combination of experimental sciences and theoretical sciences is very, very important. We often collaborate with the research groups that are using the theoretical approach. With them we, basically, fully share our data. They have access to our experimental data. We have access to their simulations and their models. We then together try to produce more meaningful insights"*.

Data analysis, as explained by Filippo Fonio, team leader of the Dante from Yesterday to Today in France research group at UGA: *"our research methods for both projects come rather from anthropology and sociology […] we work with some brackets on a literary object, our method[s] come from other fields"*.

Reporting, as emphasised by Martin Törngren, *one of the team leaders of the Mechatronics and embedded control systems research group at KTH: "Also with other research groups with different disciplines. That's the minimum that will give you new perspectives that could lead to new problems, just one example we have a collaboration with a professor, she works with roads, so she's an expert in asphalt and the making of maintenance. And then, we work with automated vehicles and then, if we put these together when then vehicles are on the roads, they can create data that could be used for predicting maintenance and even for reducing wear by controlling how the automatic vehicles drive"*.

Review, as shared by Sónia Frota, team leader of the Lisbon Baby Lab at ULisboa: *"you need to develop this common language, right? […] We have psychologists, psycholinguistics, people doing psycholinguistics, people doing speech therapy. We collaborate with people doing neurolinguistics"*.

Dissemination, as mentioned by Jorge Malheiros, team leader of the Urban and Regional Change and Policies research group at ULisboa: *"I try to bridge physical and human geography […] GIS facilitates sometimes the dialogue through the technological side, and the digital side of which is now methodologically incorporated in science. […] we expand it very often with other disciplines, and also, we assume, and we often do it, we assume a practice of having both projects that, even at the EU level, assume alliances of knowledge as a principle, so where we work with partners from civil society, and we try to go produce some knowledge to see what are the goals of research that also serve civil society"*.

Where is there...?

We find that Unite! research teams implement interdisciplinary research practice by:

Utilising the connectivity and interoperability of digital infrastructures such as the team's website, discipline-specific repositories, institutional repositories, GitHub or GitLab, or Zenodo, as clarified by Evelyn Gius, team leader of the fortext lab at TU-Da: *" […] I think we seriously started to do this a year ago […] to build a lab structure somehow. […] it's knowledge, not a high-performance completion or something we're doing, you don't have any machines, but more or less, make us work together, but it's more shared knowledge. What we do is that we try to organise our research workflow in a transparent manner, but also for people who keep coming as new people. We now have a structure in which we store our data, which has a folder structure to it. Of course, we have different channels in this Mattermost thing where we also, for example, have an expert channel where we talk about more technical issues where people ask this, and we have a lab channel where it's more general research for the lab and so on. I think all these things speed up basically research. It's two things. I think it speeds up research because you don't have to look everywhere to find a file or to whatever, you can quickly or more quick[ly] access knowledge. The other thing is that I think it also encourages people to collaborate again"*.

Utilising open physical infrastructures such as open labs, co-creation platforms, public heritage, open libraries, or open university campuses, as revealed by Thomas Lebarbé, team leader of the Transversality of Digital Humanities research group at UGA: *"You've got 22 in France – 22 Maisons des Sciences de l'Homme, which have different names, different ways of working, but they're here to promote interdisciplinarity. We had support from them"*.

3.2.2 Transdisciplinary research practice (TRP) with emerging academics

What is...about?

We define this research practice as the mode of co-producing scientific knowledge among collaborative networks of academics, bachelor's and master's students – emerging academics – and other users of scientific knowledge, across all stages of the research process, and by the means of interoperable digital infrastructures and open physical infrastructures.

We identify that this novel type of TRP is **expanding the rationales of education and research at universities. Academics are recognising, acknowledging, and including as inflows of knowledge a new typology of users of scientific knowledge. Lecturers, consolidated researchers, postdoctoral researchers, and doctoral candidates are collaborating with bachelor's and master's students in the process of science production**, together with other stakeholders, as illustrated by Antti Ahlava, team leader of the Group X at Aalto: *"the important thing here is also the, in a way, openness in education. For us, it has been really important to use these master-level courses as a test ground for research hypotheses […] in this kind of cross-disciplinary and multi-stakeholder architectural and urban design". He continued: "we have been pioneers at the department of architecture in cross-disciplinary courses. We recently had one study course, which was called People-Driven City, where we had students from ten different degree programmes, including all schools in Aalto".*

Why...?

We encounter that Unite! research teams adopt TRP with emerging academics with the aim of:

Allowing integration of students' views and perspectives in co-developing and applying scientific knowledge to address complex societal challenges, as highlighted by Participant 12 at KTH: *"one of the aims of the project is to also have diplomats meeting scientists in a way. Scientists might also think that diplomacy is not what it is, and the other way around. So one of the aims has been to also offer a platform for discussion". Participant A12 continued, "you could say three aims. It's to produce knowledge, it's to produce teaching material and teach young people, and to bring together those who are interested in science diplomacy on a policy or diplomatic or scientific level".*

Fostering students' learning and entrepreneurial mindset to innovatively address complex problems, as reflected by Harri Koivusalo, team leader of the Water and Environmental Engineering research group at Aalto: *"this was a Hackathon, so it didn't end up – It was more like getting, forming the idea and going as far as can be gone within a few days. […] And they were learning at the same time about programming, about spatial data, about environmental data […] we are using these kinds of MC, multi-criteria decision analyses and these types of qualitative methods which are, by definition, based on these participatory approaches, but it varies from project to project, but there is some multitude of methods that we are using, and some of them are kind of close to this category of [these] open practices".*

When is there...?

We identify that Unite! research teams carry out TRP with emerging academics in different stages of the research process:

Conceptualisation and design, as pointed out by İdil Gaziulusoy , team leader of the NODUS Sustainable Design research group at Aalto: *"basically, it's a student-led initiative, and in this particular area, students are testing their ideas, sustainable design ideas, and they learn from being actually, doing the experiments themselves, they're master students"*.

Data gathering, as exposed by Pirjo Kääriäinen, team leader of the CHEMARTS group at Aalto: *"that's one way to try to take more and more people to get them involved [in] this bio art, there is this, different kinds of labs and hubs and so on where anybody basically is supposed to be able to come and work, hack things. Kind of this maker culture which comes from the field of, more from the field of digital, what is [the] right word, maybe this robotics and so on. And of course that's kind of sparing also on the field of materials now more"*.

Data analysis, as explained by Evelyn Gius, team leader of the fortext lab at TU-Da: *"this is an online annotation tool so different people can use it for annotating text. You can upload your text in one of the compatible formats, and then you can mark the text, highlight specific passages, and annotate or tag or code them, so that's different kinds of words for something. This is used for different purposes. It's text analysis basically that is typically done with that. We do that in a manual environment having, for example, people in a classroom annotating the same text and comparing what's the outcome of that, but you also use it when working towards [automation]"*.

Dissemination, as exemplified by Roger Joan Sauquet Llonch, team leader of the Centre for Research and Services for the Local Administration at UPC: *"with the methodology of the master. Our master starts in a territory. Every time is a different territory, every course. […] We work with rivers, parts of rivers, and industrial patrimony theme on the river. The methodology of knowledge for developing projects in this territory is also during a semester. Free workshops with corporations. We do a few workshops. The first one is [to] ask the population, what are the problems or the opportunities of the territory? The second workshop is sharing the first impressions or the first ideas of the students with the population. The third […] is explaining the conclusion of the course, the first course in the master, with the population, and also political staff, and others". He continued: "there is data that the projects and the student's project, in that case, that it's like news for the population'.This historical data that the students discover, or as researchers we discover, we can share with the population this kind of news, of small discoveries, but with the group of [the] population that we share more data [with] is with the technical staff of the municipalities"*.

Where is there...?

We find that Unite! research teams implement TRP with emerging academics by:

Utilising the connectivity and interoperability of digital infrastructures such as the team's website, discipline-specific repositories, institutional repositories, GitHub or GitLab, or Zenodo, as emphasised by Mikael Lindström, senior researcher of the Wood Chemistry and Pulp Technology research group at KTH: *"for example, looking at different protein expressions in different kind[s] of images, and one has taken the gamers to [help with] that, so that is a way, also, to get more people involved in science"*.

Utilising open physical infrastructures such as open labs, co-creation platforms, public heritage, open libraries, or open university campuses, as shared by Pirjo Kääriäinen, team leader of the CHEMARTS group at Aalto: *"what is happening [is] that there are more and more efforts for example to include, you have these open labs, there was just, BioGarage was just opened last week in a design factory now by four of us, for some genetic engineering stuff and so on […]."many of the [kinds of] openness and sharing, it can't be designed beforehand that okay, now we sit here and share something, it doesn't always happen that way, There [need] to be open places where things can happen, unpredicted things can happen. And uncontrolled meetings or confrontations, [where] you meet people, unaccepted things can happen. So I think that's why it can't be totally, it's more about offering or creating, enabling things to happen so that you have some kind of physical or digital space".*

3.2.3 Transdisciplinary research practice (TRP) with citizens

What is?

We define this research practice as the mode of co-producing scientific knowledge among collaborative networks of academics – lecturers, consolidated researchers, postdoctoral researchers, and doctoral candidates – and citizen users of scientific knowledge, across all stages of the research process, and by the means of interoperable digital infrastructures and open physical infrastructures.

We identify that TRP with citizens is **expanding the rationales of traditional research dissemination and societal outreach in universities by engaging and collaborating with citizens in science production along all stages of the research process**, as illustrated by Cristina Máguas, team leader of the Environmental Stress and Functional Ecology research group at Ulisboa: *"It's not just to communicate, [it] is to involve the citizen in the way that you produce science. It's a different way, but also you expect to produce science with this"*.

Why...?

We encounter that Unite! research teams adopt TRP with citizens with the aim of:

Offering insightful ways to tackle the complex challenges that are faced by societies today. This helps engage people not only in defining the research problems, but also in identifying potential solutions, and places them as key actors in research dissemination, as highlighted by Juanjo Galán, former team leader of AaltoLAND group at Aalto: *"Basically we are trying to provide or to generate something which is useful for the society. So the co-creation is essential because basically you need to be in a kind of dialogue with the society or with the people. The question is, co-creation probably applies a higher level of engagement of the society in contrast to, let's say, the more classical or [linear] process, basically you ask the people what they need, you produce one product and then you test if the product works. In the co-creation process, the people out of the research team are not only providing information but also contributing to the definition of the solution. That is the case in some types of research. Basically, I will say that if your research is about planning processes, for instance now we are working in this project […]. And there we are dealing with the adaptation of European landscapes to climate change. So basically, we are not trying to define solutions basically, we are trying to solve together the problem with local groups, with local networks. Instead of following a more classical top-down approach, we assumed people more or less are well-informed on what climate change is, but maybe they haven't done the exercise of trying to think of how climate change can affect their daily lives or their interaction with the landscape, for instance, farmers or people living from tourism. We are just trying to open a discussion with them to see how they can participate in the co-creation of potential solutions. And basically, we are co-creating with them the problem that we want to investigate or the problem that we want to solve afterwards through some solutions. The co-creation usually implies that people with different perceptions and different types of knowledge sit down together to try to co-define a solution for a complex problem in which, basically, there might be some conflicts or there might be different perceptions of the same reality. This is extremely important because this is the consequence of living in society"*.

Building trust in science, as reflected by Jorge Malheiros, team leader of the Urban and Regional Change and Policies research group at ULisboa: *"constructing data, constructing the instruments to collect data, data collection, yes […] One thing about these techniques of engaging the stakeholders, there is something which I was not talking about and I think is relevant for geographers, which is fieldwork, which means that there is an effort to be [in] the places or to go to the places. Not to develop the work just in offices or in meeting spaces, but also to engage with the communities in the community spaces so that we try to do when we implement these things […] Definitely it helps to build trust. It helps to make the contact network stronger. I think at the end of the day, it makes the research, I know it's more viable, at least, the research that better understands the needs and the demands of the groups, which we are working with, let's say"*.

Fostering reusability and creating a deep societal research impact, as pointed out by Piero Boccardo, team leader of the SDG11 Lab at Polito: *"So it's something that is really typical to geomatics and to what we are doing. What is also helping is the fact that we are strongly believing that there should be an involvement from the citizen. For example, citizen science and so on and forth. For example, when we are acquiring data or when we are using data, we are trying to involve the, let's say, the population or the citizen, just in using some crowdsourcing approach, involving people to, for example, to survey, to acquire data, and to teach them in a very simple way how they can process the data. They can profit [from] data, and they make this data available to everybody, and just to have some, an approach that is embedding also the citizen in this process, because otherwise, when we are using this data, the citizen is not really involved, is not thinking that this data is your, I mean, is of themselves, and so they need to be involved in this [practice] So, it's something that is, let's say, embedded in our work, because when we are trying to make this data and this research available to the people, we need to have them involved fully since the beginning. So for example, #name is organising mapping party experiences, where there are people that [are] coming to acquire data, and that [are] taught to acquire this data, to use this data, because this is an experience that is by the people, and in the future they can use the way"*.

When is there...?

We identify that Unite! research teams carry out TRP with citizens in several stages of the research process:

Conceptualisation and design, as exposed by Monica Truninger, team leader of the Environment, Territory and Society Research Group at ULisboa: *"conducting focus groups and designing the research with the community in this place in Lisbon. There [were] some focus groups that he conducted with the people and building the research design also with the community in there. It's something [that] many of our researchers do"*. She continued: *"there are some projects that we involved since the conceptualisation phase. […] It's a real collaboration. Since the beginning, we are working with them on designing the interview schedule, even selecting the cases for study. They are in the meetings with us. Actually, they are part of the team"*.

Data gathering, as explained by Joaquín del Río Fernández, team leader of the Remote Acquisition and Data Processing Systems in Marine Environment research group at UPC: *"we have different actions with citizens. We started years ago [a] citizen science project that is open [on] our website. That is using the real-time underwater camera, and we will open these images, let*

people help us to identify species. You can access the website, and you can see the real-time data, you can see a fish, you can capture the image, and then you can give us feedback".

Data analysis, as exemplified by Marketta Kytta, team leader of the Spatial Planning and Transportation Engineering research group at Aalto: *"to co-analyse these datasets, but we have done that sometimes, for example, in this Helsinki City Masterplan project that I was showing to you, there were some kind of focus group events organised with the idea that, like, groups of people would help us [deepen] the data, like here's the big picture, like data given by thousands of people, but let's see, in your area, what does this actually mean, if we get these and these kind[s] of results. So we have done something like this. Also in relation to [the] Helsinki City plan[ning] process, a hackathon event was arranged".*

Report writing, as emphasised by Piero Boccardo, team leader of the SDG11 Lab at Polito: *"because in the citizen science, what is really important is just to have also for them new idea publication, and if they are, this idea (-) and that can be applied, we are working to try to apply this new concept of new publication".*

Dissemination together with citizens, as shared by Josef Wiemeyer, team leader of the Computer Science in Sport, Sport Medicine, and Training Science research group at Tu-Da: *"I'm responsible for Sport Forum […] Then we have four or five sessions on Monday evening, and we invite all the people from the sports clubs and so on to come to us. Depending on the topic, sometimes more than a hundred people come and discuss current issues of learning and training and so on".*

Where is there...?

We find that Unite! research teams implement TRP with citizens by:

Utilising the connectivity and interoperability of digital infrastructures such as the team's website, discipline-specific repositories, institutional repositories, GitHub or GitLab, or Zenodo, as mentioned by Cristina Máguas, team leader of the Environmental Stress and Functional Ecology research group at Ulisboa: *"we have one of the few FCT grants just for citizen science. […] she has been develop[ing] a digital platform about biodiversity. She has a longer history and experience [with] biodiversity. This is the case of several other researchers that are involved, or in not only [the] dissemination but even the building up of digital platforms. In this case, is biodiversity for all […] all the data that we do with our students, we put in this platform. There is a big enthusiasm about these platforms, and we ask for people, for students, for normal citizens to be involved [in] this".*

Utilising open physical infrastructures such as open labs, co-creation platforms, public heritage, open libraries, or open university campuses, as clarified by Xavier Gamisans Noguera, team leader of the Biological Treatment of Gaseous Pollutants and Odours research group at UPC: *"our commitment is to place there a fab lab for this kind of open prototyping or to have more feedback and more collaboration with outside. There's a lot of people who have knowledge that could be useful for us to develop whatever".*

3.2.4 Transdisciplinary research practice (TRP) with professionals

What is...about?

We define this research practice as the mode of co-producing scientific knowledge among collaborative networks of academics – lecturers, consolidated researchers, postdocs, and PhD candidates – and professional users of scientific knowledge, from private and public organisations – businesses and political actors – across all stages of the research process, and by means of interoperable digital infrastructures and open physical infrastructures.

We identify that TRP with professionals is **evolving the traditional collaboration model of scientific knowledge production with actors outside academia, moving from on-demand production for stakeholders to co-production together with professional experts**, as illustrated by Tiago Domingos, team leader of the Marine Environment and Technology Centre at ULisboa: *"It's not just bringing them into a room for a meeting. For two hours, 'Oh, tell us what we would like us [to] research.' That doesn't go anywhere. In fact, they have now a name for it, which they call 'stakeholders fatigue' […].* Tiago Domingos, continued: *"It's much more interesting, much more relevant and useful to have these ongoing relationships that you build across decades"*.

Why...?

We encounter that Unite! research teams adopt TRP with professionals with the aim of:

Drawing on crucial external knowledge from various areas of expertise to unlock complex problems, as highlighted by Gorän Finnveden, senior researcher of the Sustainability Assessment and Management research group at KTH: *"in a sense, through research, the knowledge is co-produced with the stakeholders, because they have insights and knowledge that we don't have"*.

Building long-standing, trust-based, and cooperative relationships, as reflected by Antti Ahlava, team leader of the Group X at Aalto: *"[…] professional people are crucial in projects because they are better [at] anticipating possible futures and alternatives […] it's important to combine this kind of local knowledge of the people with the professional knowledge […] this openness means that we should also include those people who have financial input in the project"*.

Getting access to significant research infrastructures, as pointed out by Bruno Raffin, team leader of the Datamove research group at UGA: *"we work with companies […] that are capable of high-performance computing […] [which] is very expensive and requires a lot of expertise. It's reserved [for a] large company often. We are working with them"*.

When is there...?

We identify that Unite! research teams carry out TRP with professionals across several stages of the research process:

Conceptualisation and design, as exposed by Tiago Domingos, team leader of the Marine Environment and Technology Centre at ULisboa: *"we have also a lot of work with companies, with economic agents out there, mostly farmers in some cases, but also other companies to whom we provide technical assistance. Or solve technical problems or develop joint research problems to solve their technical problems. We also have a lot of experience, this is also, obviously, [in] open science and in what you could call co-creation, and this is especially in the areas of terrestrial ecosystems. In agriculture, where the solutions that we develop, well, they are co-created. They are developed together with farmers and farmers' organisations"*.

Data gathering, as explained by Participant 12 at KTH: *"one of the aims of the project is to also have diplomats meet scientists in a way. Scientists might also think that diplomacy is not what it is, and the other way around. So one of the aims has been to also offer a platform for discussion"*. Participant 12 continued: *"three aims. It's to produce knowledge, it's to produce teaching material and also teach young people, and to bring together those who are interested in science diplomacy on a policy or diplomatic or scientific level"*.

Data analysis, as exemplified by Tiago Domingos, team leader of the Marine Environment and Technology Centre at ULisboa: *"especially the co-analysis of the data is particularly relevant when we reach the stage at which we say, 'Well, now what would be the policy recommendations, or what would be the technical solution to your problem?' That grabs their interest in the co-analysis"*.

Where is there...?

We find that Unite! research teams implement TRP with professionals by:

Utilising the connectivity and interoperability of digital infrastructures such as the team's website, discipline-specific repositories, institutional repositories, GitHub or GitLab, or Zenodo, as illustrated by Bruno Raffin, team leader of the Datamove research group at UGA: *"Often they agree to work on open-source codes, so things are being openly published on both sides"*.

Utilising open physical infrastructures such as open labs, co-creation platforms, public heritage, open libraries, or open university campuses, as clarified by Antti Ahlava, team leader of the Group X at Aalto: *"So we have built a Lego model of the campus […] So if you made changes in the Lego model, it shows changes in biodiversity, CO2 emissions, innovation capacity, and those kinds of things. But it's very important that the interface is user-friendly and open because anybody can play with Lego blocks. And they don't have to know anything about it […] It's also good that it's an attraction for people to gather there, and we can play with politicians and city officials"*.

3.2.5 Recombining open science outputs

What is...about?

We define this research practice as the mode of co-producing scientific knowledge by recombining open science outputs from collaborative networks of participants in research available in interoperable digital infrastructures as transparent and accessible inflows of knowledge across several stages of the research process.

We recognise that Unite! research teams are **recombining open data and databases, recombining open-source software, and recombining research results published openly**, as illustrated by Viktor Stein, team leader of the Protein Engineering research group at TU-Da: *"Open data in a sense that yes, we use publicly available databases in biology all the time. We use databases, structural databases for protein structures, sequence databases, and publications, of course, too"*. Viktor Stein, continued: *"Information retrieving. As a biologist, you frequently query DNA protein sequences, looking at protein structures"*.

Why...?

We encounter that Unite! research teams recombine open science outputs with the aim of:

Accelerating scientific knowledge production and reducing its costs, as illustrated by Sanna Syri, team leader of the Energy Efficiency and Systems research group at Aalto: *"So the basic raw material data is extremely useful for us [...] So meteorological data, solar radiation, wind speed, outdoor temperatures, that's the input for our modelling. And it has been great progress that – that is freely available on the internet; we can choose any location on the globe and get good data on that. So it really speeds up the work, and everything is free"*.

Increasing the relevance of their research by combining access to key sources of knowledge, as highlighted by Mats Magnusson, senior researcher of the Integrated Product Development and Design research group at KTH: *"we have used much more open data. For instance, we've looked into, we've used MIT sites where they have [...] environmental, sustainability innovations, so we have actually collected a lot of data from there and used that in our analysis"*.

When is there...?

We identify that Unite! research teams recombine open science outputs along several stages of the research process:

Conceptualisation and design, as pointed out by Patrizia Semeraro, senior researcher of the Probability and Applications research group at Polito: *"we often make some theoretical, methodological work, and then apply it to open data that we found [in] journals, on public repositories"*.

Data gathering, as exposed by Joaquín del Río Fernández, team leader of the Remote Acquisition and Data Processing Systems in Marine Environment research group at UPC: *"Yes, we are doing the same. For example, we are merging sometimes our data with MeteoCat, the Catalonian service of [meteorology]. When we need data – we are producing marine data, but if we*

need meteorological data that we are not producing, we are accessing data from other repositories".

Data analysis, as explained by Marc Pfetsch, team leader of the Optimisation research group at TU-Da: *"In the area, there are several such benchmark data. The most common one is called MidLib. It's a collection of instances for mixed integer optimisation. This is continuously developed every five to seven years. It's updated. We test our algorithms on that".*

Where is there...?

We find that Unite! research teams recombine open science outputs by **utilising the connectivity and interoperability of digital infrastructures such as the team's website, discipline-specific repositories, institutional repositories, GitHub or GitLab, or Zenodo**, as mentioned by João Gonçaves, team leader of the Molecular Microbiology and Biotechnology Research Group at ULisboa: *"It's so easy now to have access to data from COVID research, [which] we don't see in other areas now. I see, for example, in orphan diseases or in oncology, there are many databases now of open science [so] that you can really have data. Of course, here, one of the things that we want also to explore here at our institute is the use of bioinformatic tools, really to extract data from the open science databases".*

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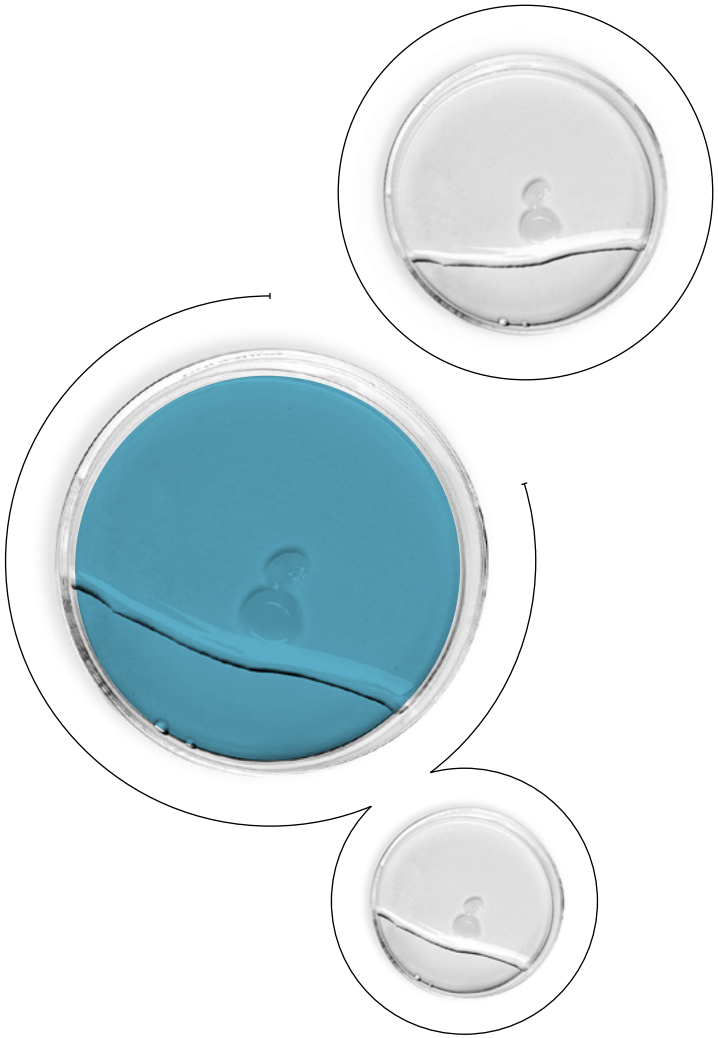
3.3

Novel open innovation practices

We identify that Unite! research teams' adoption of open science practices, principles, and goals to share and produce knowledge is expanding the rationales of knowledge valorisation, transfer, and IP at universities. Open science practices are expanding the open innovation approaches to the exploitation and exploration of scientific knowledge (Dahlander and Gann, 2010; Evald et al., 2021; European Commission, 2022).[1] We encounter two novel inbound and outbound approaches which can be considered two novel open innovation practices: open inbound exploration and open outbound exploration.



1 Dahlander, L., Gann, D. M. (2010). How open is innovation? Research Policy 39, 699–709
Evald, M. R., Clarke, A. H., Boyd, B. (2021). An open innovation project typology of exploration and exploitation: Managerial implications and empirical applications. Journal of the Knowledge Economy 12, 740–755
European Commission, Directorate-General for Research and Innovation, by de la Cueva, J. and Mendez (2022) Open science and intellectual property rights: How can they better interact? State of the art and reflections, Report of study. Publications Office of the European Union

3.3.1 Inbound open exploration

What is...about?

We define inbound open exploration as the novel inbound open innovation practice of purposely – sourcing – using open science outputs and working with collaborative networks of participants in research, available in interoperable digital infrastructures and open physical infrastructures as transparent and accessible inflows of knowledge, to accelerate internal responsible product and service innovation in research teams.

We encounter different distinguishable manifestations:

Purposely using open data and databases, open-source research software, and research results published openly as inflows of knowledge to accelerate internal responsible product and service innovation in research teams, as illustrated by Giuseppe Giorgi, team leader of the Marine Offshore Renewable Energy research group at Polito: *"From the generation of new knowledge, we are mostly taking advantage of the open data available. For example, we use a lot the data from Copernicus […], a lot of data available outside from the European initiatives and also from other European projects that [have shared] their own data. Our interaction with the open science is mostly [in] taking the data as an input and ourselves, delivering our data and our models as output. Also, there [is] different software that [has] been developed, and we're using [the software] that [is] in the open-access or open-source approach. In the generation of innovation for the specific work that we are doing, it's [very] relevant I'd say because we are really a hard engineering research group that has an impact: our results or our technologies are going to be installed and going to produce energy for the citizen at large".*

Purposely working with collaborative networks of academics, professionals, and citizen users of scientific knowledge, as inflows of knowledge to accelerate internal responsible product and service innovation in research teams, as highlighted by Luís Tinoca, team leader of the Education Research and Development Group at ULisboa: *"We are trying to implement transformative interventions. The way we are doing it, we are challenging the participant, all the research team, including the teachers from the schools or the students, to think about this issue and to think about what can we do to transform, and then we cyclically re-evaluate the implementations, the interventions that we are developing. Because we are doing this in cycles we can adjust, okay, this didn't work so well, we'll do it slightly different[ly] this time or completely different[ly]. This way we are promoting innovation".*

Why...?

We encounter that Unite! research teams adopt inbound open exploration, the novel inbound open innovation practice, with the aim of **developing targeted responsible product and service innovations that solve complex driven-agenda cultural, economic, environmental, societal, and technological challenges**, as reflected by Harri Koivusalo, team leader of the Water and Environmental Engineering research group at Aalto: *"we for instance had this kind of Hackathon some time ago. And that was very interesting. There were students coming from Aalto, from our research group, knowing about water, from computer sciences knowing about programming, and from GI's group, which is this geo-informatics group, [with] knowledge about spatial data, and then there was the CGI company, who are basically making spatial data tools for customers. And then there was the Finnish Environmental Institute, who had […] spatial data about water resources in Finland. So there was this Hackathon to do a product for mobile phone[s] that uses environmental spatial data and makes something [innovative] […] for the general public".*

When is there...?

We identify that Unite! research teams carry out inbound open exploration **simultaneously across the research process. Research and innovation intertwine and happen simultaneously**, as exemplified by Björn Laumert, team leader of the Heat and Power Technology research group at KTH: *"we also – the department, not me personally, but groups inside the department work on open-source models and open-source development online, models that are used for example in the United Nations. It's something that's called Osmosis, that is a tool that is worked on [by] several research groups when it comes to energy sourcing and energy implementation on [the] national level, on [the] regional level, and so on. So there are different levels of openness, so to say"*. Björn Laumert continued: *"It's to [develop] a platform for analysing or for bringing the right energy infrastructure depending on the existing resources in different nations and different regions. It has been used to a large extent to look at, for example, electrification of different African nations. It has also been used to analyse wind farm placement in Sweden, so it's about sourcing technology for different resources, energy technology but also water and other commodities"*.

Where is there...?

We find that Unite! research teams implement inbound open exploration by utilising:

The connectivity and interoperability of digital infrastructures such as discipline-specific repositories, institutional repositories, GitHub or GitLab, or generalist repositories such as Zenodo, and digital journals with open-access options.

Open physical infrastructures such as open labs, co-creation platforms, open libraries, cultural heritage, and open campuses.

3.3.2 Outbound open exploration

What is...about?

We define outbound open exploration of knowledge as the novel outbound open innovation practice of purposely making available – revealing – research teams' open science outputs, such as open data, open-source research software, and research results, as transparent and accessible outflows of knowledge to collaborative networks of participants in innovation, by means of interoperable digital infrastructures, to accelerate responsible external product and service innovation.

We encounter different distinguishable manifestations within general outbound open exploration:

Purposely open data and database sharing as outflows of knowledge to accelerate responsible external product and service innovation in collaborative networks of participants in innovation, as illustrated by Miina Rautiainen, team leader of the Remote Sensing research group at Aalto: *"There was one dataset, a spectral library that we released a couple of years ago which got also interest from companies. There were some companies contacting us. It was open data, so of course they were welcome to use it". She explained that this dataset is "not directly an application […] but the basis for future applications" in forest areas' sustainable management and conservation".*

Purposely open-source research software sharing as outflows of knowledge to accelerate responsible external product and service innovation in collaborative networks of participants in innovation, as highlighted by Vicent Acary, team leader of the Modeling, Simulation and Control of Nordsmooth Dynamical Systems research group at UGA: *"We can find some companies that are expert[s] in innovation from research, based on open principle[s]. We select our partners like that".* Vicent Acary continued: *"The deal is that we produce open software that can be just a prototype. If you want to sell something, you can redevelop something based on that, but I want that [my student's] publication […] has to be open, and they're [the company] able also to show this software to other people".*

Purposely sensitive research results disclosure as outflows of knowledge to accelerate responsible external product and service innovation in collaborative networks of participants in innovation, as reflected by Participant 32 at TU-Da: *"We perform, first of all, responsible disclosure of discovered vulnerabilites. The manufacturers typically fix this and we will often interact with their security team. After the vulnerabilities are fixed, there is more value in making them known so that other people do not repeat the same mistakes. That also puts a bit of pressure [on] the manufacturer if you tell [them], 'yes, we do responsible disclosure, but we will publish the vulnerability in 90 days. If they ask us for [an] extension, we give them [an] extension typically. In this case, delaying the sharing of this information has an added value, since for a certain amount of time it could be putting potentially hundreds of millions of people at risk if this is a severe vulnerability in a device such as a widely deployed smartphone".*

We identify that revealing research teams' open science outputs is **expanding the rationales of knowledge exploitation – valorisation, transfer, and IP – at universities**, as pointed out by Marc Pfetsch, team leader of the Optimisation research group at TU-Da: *"The original idea was to promote science. Nowadays it's mixed use. It's still used for science, but it's also used by commercials, solver developers".* Marc Pfetsch, continued: *"The use is mixed, but still it's public. The data is public. In principle, one can reproduce [it]".*

Why...?

We encounter that Unite! research teams adopt outbound open exploration, the novel outbound open innovation practice, with the aim of:

Fostering cultural, economic, environmental, societal, and technological value, as explained by Amélia Branco, senior researcher of the Research Centre in Economic and Social History at ULisboa: *"I think [it] is innovation, but I also think that, for instance, I'm thinking about this project that we have with companies in Portugal. We tried to preserve the archives of the companies. This is a cultural heritage that we try to preserve. This for me is also a kind of innovation"*. Amélia Branco continued: *"Yes, and try to preserve the archives that exist about these companies. Some of them still survive, other[s] [don't]. Where are these archives? Where they are? Also, this is important because sometimes I think that we don't preserve, we don't care about these things. This is also important to the community and the municipalities. For instance, this is important for municipalities because the factories or whatever are located in places. They are abandoned sometimes. We have abandoned the buildings, and still stay there some archives or something. They must create museums for instance with this kind of archives to research, to study more some sectors, some companies, or some project"*.

Protecting their research results as a way of boosting visibility and gaining recognition in their research disciplines and innovation communities, as exemplified by Vicent Acary, team leader of the Modeling, Simulation and Control of Nordsmooth Dynamical Systems research group at UGA: *"we are doing some open software and open science because it's a way also to be protected […] if you put the public licence on it, if you distribute it, you are visible and, in some way, you are protected". He continued: "we're working for all the companies that are at least in France or in Europe, perhaps in the world. We're not working for one, and we do not have to favour one company with respect to the other"*.

When is there...?

We identify that Unite! research teams carry out outbound open exploration **after the end of the research process, after an embargo period for accomplishing their research objectives in terms of dissemination and career evaluation. However, it's very probable that outbound open exploration happens simultaneously along the research process and the research and innovation processes are interlinked**, as illustrated by Helle Pedersen, team leader of the Waves and Structures research group at UGA: *"The fact that we ship 100 terabytes of data to users all over the world every year means that, of course, it contributes to innovation, but I can't tell you how. It's anonymous access. People go the user. I assume the data are useful because we get 3000 users, 100 terabytes shipped every year, 60 million data and metadata requests, so of course, it does". She also shared: "I'm not quite sure what we do, whether we are doing innovation or whether we're doing research half the time; it's a little bit of both, I think".*

Where is there...?

We find that Unite! research teams implement outbound open exploration by **utilising the connectivity and interoperability of digital infrastructures such as discipline-specific repositories, institutional repositories, GitHub or GitLab, or Zenodo, and by publishing in digital journals with open-access options.**

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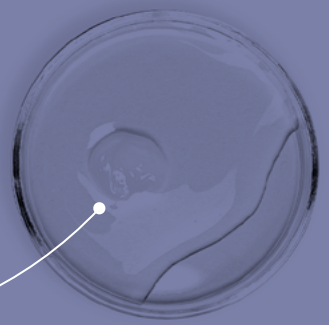
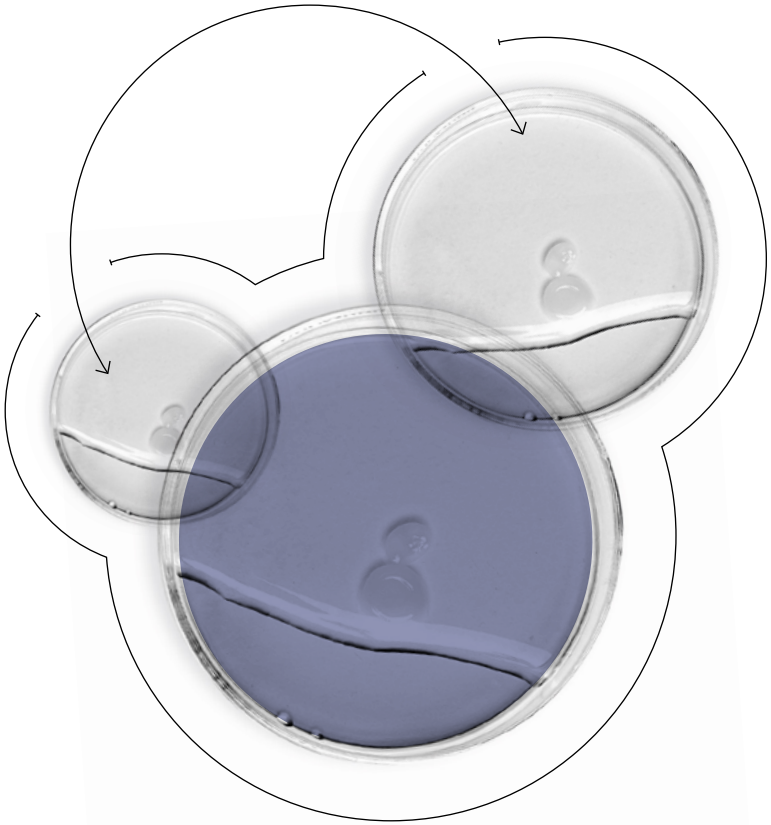
Recommendations
How

Unite! guidelines for ready-to-adopt open science and innovation practices



04

In this section, based on the primary analysis of Unite! research teams' best open science and innovation practices, together with the analysis of university guidelines and policies, national policies, and EU reports, we outline practical guidelines for supporting Unite! researchers in the adoption of open sharing practices, open collaborative practices, and novel open innovation practices.



4.1

Ready-to-adopt open sharing practices

General recommendations for all open sharing practices

- When possible, apply the Creative Commons CC BY 4.0 license to clearly define the permissions for making your open science outputs available. Other licensing options may apply, in which case the choice of license is influenced by the research objectives, funders' requirements, and data policy requirements. But please kindly keep in mind that the chosen license needs to promote the reuse, adaptation, and redistribution of your open science outputs, with the aim of fostering research collaboration and innovation.
- Make sure that the collaborative networks you are engaged in recognise, credit, and reward your efforts which benefit the community. Track and monitor the usage and impact of your open science output by monitoring citations, downloads, or usage stats. This helps the evaluation of the effectiveness of open science practices and provides valuable insights for future research efforts.
- Remember to communicate your experience with open sharing practices in your CV and all grant applications.
- Evaluate, re-adapt, and improve these practices continuously based on feedback, experiences, and evolving best practices.

How to do…open protocol sharing?

- Prior to starting your data gathering, pre-register your study's research design with a dedicated service, such as osf.io, or in your field-specific repository.
- Or if you prefer, submit a registered report – your research design, including an introduction, methods, and the analysis plan, before starting data gathering – for peer review to a scientific journal that has adopted this editorial procedure.

How to do…open data sharing?

- The intricacies, restrictions and workflows of open data are field-specific. Familiarise yourself with the data stewardship services of your university. Data stewards collect and disseminate the field-specific best practices.
- Aim for full reproduction packages and supplement open data with software and documentation. Ensure that others can reuse your research to as large an extent as possible. Data must be FAIR (findable, accessible, interoperable, and reusable).
- Plan to avoid needing to invent a time machine. Write a data management plan (DMP) at the beginning stage of research and update the plan regularly with the help of data stewards or other research data management specialists.
- The repository solutions for open data are case-specific and may include field-specific repositories, general-purpose repositories such as Zenodo and GitHub, and institutional repositories. When choosing a repository, pay attention to, e.g., whether unique identifiers (such as DOIs) are provided and how the repository is connected with other services.
- Data stewards can help you to choose a suitable repository for your project.

How to do…open-source research software sharing?

- Plan open-source research software sharing from the start: source-code/ research prototypes developed by a single or few authors to illustrate a concept or to evaluate the feasibility of an idea vs. large community software to achieve a wider and deeper impact.
- Developing open-source research software requires not only technical skills but also community-building and communication skills. Be ready with training in software development/management.[1]
- Make your open-source research software available on platforms such as GitHub and Zenodo.
- Make sure that your software collaborative networks recognise, credit, and reward your efforts which benefit the community (Alliez et al., 2019).[2]

How to do…open access publishing?

- Talk to your local library about open access funding opportunities and services for publishing preprint manuscripts, peer reviews, research papers, books, and doctoral dissertations.
- Check if OA journals are available or if your preferred journal has an OA publishing offering.
- Always keep in mind that OA publications are more broadly available and more cited than non-open publications. If two journals with similar quality are available, choose the OA version to be more visible (this is especially interesting for early-career researchers or new research groups).
- Still don't forget to check OA journals for quality, integrity, and reputation aspects – avoiding predatory journals – libraries can help here, too.
- Check if your journal also allows preprint publishing, or if national regulations allow publishing a preprint with open access, e.g., at your university repository.
- Check if the journal also suggests open peer review options.
- If you are working on a doctoral dissertation, please make it accessible in your university's repository.
- When working on the creation of a new journal – talk to your library about Diamond OA services. Some libraries are also offering support for publishing books in open access or can help you look for funding.

1 https://software-carpentry.org/
2 Alliez, P., Di Cosmo, R., Guedj, B., Girault, A., Hacid, M. S., Legrand, A., & Rougier, N. (2019) Attributing and referencing (research) software: Best practices and outlook from Inria. Computing in Science & Engineering 22(1), 39–52. doi: 10.1109/MCSE.2019.2949413

How to do…open multimedia sharing?

- Talk to your local communications specialist about guidelines and services for producing podcasts and videos, participating in exhibitions, and publishing social media scientific posts.
- Select your digital infrastructure – such as your research team's website or multimedia-, image-, or video-based social media platforms – and/or open physical infrastructure – open university campuses, open libraries, or public heritage – for making your open multimedia output available, considering where your collaborative network of participants in research engage.

4.2

Ready-to-adopt open collaborative practices

General recommendations for all open collaborative practices

- Make sure that the collaborative network of academics, citizens, professionals, and emerging academics you work with is recognised, credited, and rewarded when producing your research.
- Remember to communicate your experience with open collaborative practices in your CV and all grant applications.
- Evaluate, re-adapt, and improve this practice continuously based on feedback, experiences, and evolving best practices.

How to do…interdisciplinarity research practice and TRP with citizens, professionals, and emerging academics?

- Understand the differences between collaborative and contract research prior to entering interdisciplinary and TRP collaborations. Liaise with university staff who work with strategic partnerships and can provide guidance.
- Identify the complex societal problem you want to tackle with the help of academics (interdisciplinarity) and/or citizens, professionals, and/or emerging academic users of scientific knowledge (TRP).
- Acknowledge that citizens, professionals, and emerging academics have key expertise, and treat and collaborate with them as experts.
- Invite academics and/or citizens, professionals, and emerging academic users of scientific knowledge to jointly explore the problem, jointly develop research ideas, and explore their level of engagement and co-creation along the different stages of the research process.
- Be clear on key principles in the collaboration. Bring your university's legal services in and draw contractual agreements about the most important things. Who will own the data? How will the data be co-analysed? How will the research results be disseminated?
- Be mindful of the value different kinds of expertise can bring these experts in co-creative research processes, from conceptualisation and design to dissemination.
- Foster cross-fertilisation of knowledge among the collaborative network of participants in the research by developing your own emerging research discipline knowledge, integrating expertise, concepts, and research frameworks to ensure a mutual understanding.
- Long-standing partnerships require trust, and trust takes time to build. Do not underestimate the "soft skills" in communication and cultivating interpersonal relationships that are necessary for establishing these kinds of partnerships.

How to…recombine open science outputs?

- Identify the complex societal problem you want to tackle with the support of open science outputs from the collaborative networks of your research area.
- Liaise with university staff who work on open science support services and can provide guidance on digital infrastructures to find high-quality and reproducible open science outputs for your research.
- Explore the terms of reuse, adaptation, and redistribution of the license used to make available the open science output you want to recombine.

4.3

Ready-to-adopt novel open innovation practices

General recommendations for both open exploration practices

- Remember to communicate your experience with open exploration practices in your CV and all grant applications.
- Evaluate, re-adapt, and improve this practice continuously based on feedback, experiences, and evolving best practices.

How to do…open inbound exploration?

- Sourcing with open science outputs
- Identify the complex societal problem you want to tackle by fostering responsible innovation with the support of shared open science outputs from collaborative networks you are active in.
- Liaise with university staff who work on open science support services and can provide guidance on digital infrastructures for finding high-quality and reproducible open science outputs.
- Explore the terms of reuse, adaptation, and redistribution of the license used for the shared output you want to purposely use now for fostering responsible innovation.
- Sourcing with collaborative networks of participants in research
- Understand the differences between collaborative and contract innovation prior to entering inbound open exploration. Liaise with university staff who work with strategic partnerships and can provide guidance.
- Identify the complex societal problem you want to tackle by fostering responsible innovation with the support of citizens, professionals, and emerging academics.
- Acknowledge that citizens, professionals, and emerging academics have key expertise, and treat and collaborate with them as experts.
- Invite citizens, professionals, and emerging academic users of scientific knowledge to jointly explore the problem, jointly develop innovative ideas, and explore their level of engagement and co-creation along the different stages of the research process.
- Be clear on key principles in the collaboration. Bring your university's legal services in and draw contractual agreements about the most important things.
- Sourcing with open science outputs and/or collaborative networks of participants in research
- Make sure that the open science outputs you use and/or the collaborative network of academics, citizens, professionals, and emerging academics you work with are recognised, credited, and rewarded when producing your responsible product innovation and/or service.

How to do…open outbound exploration?

- Talk to your open science unit and university staff working with strategic partnership services available for revealing your open science outputs to foster responsible innovation.
- Prepare your open scientific outputs and ensure that they are well documented, organised, and ready for sharing. This of course includes adhering to best practices for data management, creating clear documentation, and warranting the reproducibility of their work.
- Select the most suitable channels for sharing your scientific outputs. This includes publishing research articles in open-access journals or preprint servers, depositing datasets in public repositories, sharing software code on platforms like GitHub or Zenodo, or utilising institutional repositories or project websites.
- Ensure that your shared outputs are discoverable and easily accessible, which requires providing appropriate metadata, keywords, and descriptions when submitting publications or depositing datasets. Several examples show that using standardised formats and following relevant metadata standards can enhance discoverability.
- When possible, apply the Creative Commons CC BY 4.0 license to clearly define the permissions for making your open science outputs available. Other licensing options may apply, in which case the choice of license is influenced by the research objectives, funders' requirements, and data policy requirements. But please kindly keep in mind that the chosen license needs to promote the reuse, adaptation, and redistribution of your open science outputs, with the aim of fostering responsible innovation.
- Actively promote your shared outputs to maximise visibility and impact, such as through social media, academic networks, mailing lists, or collaboration platforms; engage with relevant communities; attend conferences; and participate in discussions.
- Actively engage with users and stakeholders who access your shared outputs, among others by responding to inquiries, seeking feedback, and collaborating with other researchers or practitioners interested in utilising or building upon the research materials. Collaboration and dialogue foster innovation and can lead to new practical applications.
- Make sure that the collaborative network of your research area recognises, credits, and rewards your efforts which benefit the community. Track and monitor the usage and impact of your open science output by monitoring citations, downloads, or usage stats. This helps to evaluate the effectiveness of open exploration practices and provides valuable insights for future innovation efforts.

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Summary

Shaping a new university open science and innovation governance model

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In this section, drawing on our findings, we present a new university governance model for the management of research and innovation processes with open science and innovation practices, principles, and goals in the digital era.

We reveal the state of the art of the adoption of open science and innovation practices in Unite! Alliance

We provide a comprehensive taxonomy of the open science and innovation practices encountered in the Unite! research teams. First, we encounter emerging open sharing and collaborative practices. We identify that Unite! research teams pursue openness in the sharing of scientific knowledge by adopting open protocol sharing, open data sharing, open-access publishing, open-source research software sharing, and open multimedia sharing. We identify that openness in the production of scientific knowledge is carried out by adopting interdisciplinary research practice, transdisciplinary research practices with emerging academics, professionals, and citizens, and by recombining open science outputs. Second, we encounter that Unite! research teams' adoption of open science practices for the sharing and production of knowledge is expanding the rationales of knowledge valorisation, transfer, and IP at universities. We identify two novel inbound and outbound approaches, which can be considered two novel open innovation practices: open inbound exploration and open outbound exploration. Based on our findings, we shape a new university open science and innovation governance model. This model contributes to advancing the field of open science and innovation management in the digital era (Smart et al., 2019; Beck et al., 2020; Vicente-Saez et al., 2020).[3]

3 Smart, P., Holmes, S., Lettice, F., et al. (2019). Open science and open innovation in a socio-political context: Knowledge production for societal impact in an age of post-truth populism. R&D Management 49, 279–97
Beck, S., Bergenholtz, C., Bogers, M., et al. (2020). The open innovation in science research field: A collaborative conceptualisation approach. Industry and Innovation 29(2), 136–85
Vicente-Saez, R., Gustafsson, R., Van den Brande, L. (2020). The dawn of an open exploration era: Emergent principles and practices of open science and innovation of university research teams in a digital world. Technological Forecasting and Social Change 156, 120037

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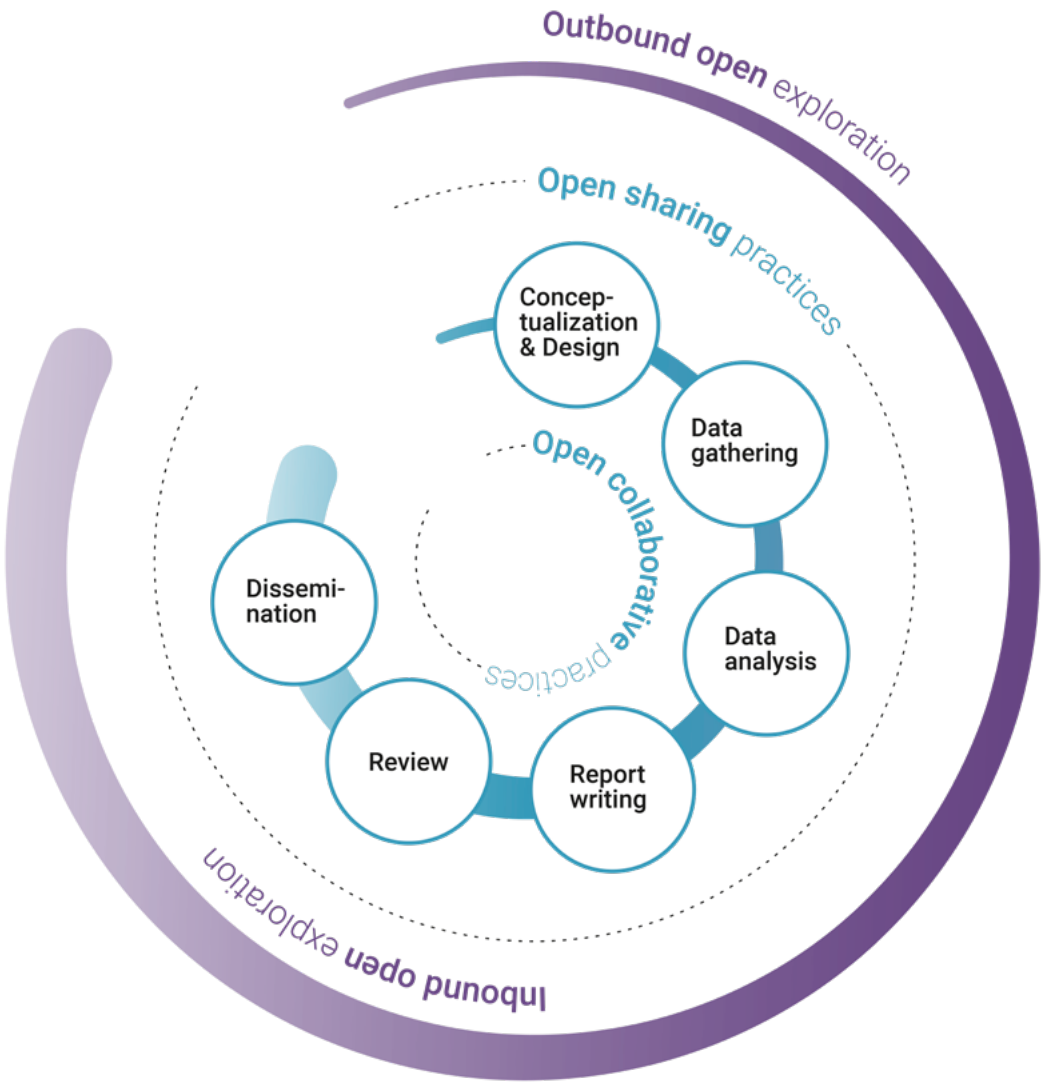
Open science practices

Novel open innovation practices



GRAPH 1: A new university open science and innovation governance model in the digital era

Open sharing practices

- Open protocol sharing
- Open data sharing
- Open source research software sharing
- Open access publishing
- Open multimedia sharing

Open collaborative practices

- Interdisciplinary research practice
- Transdisciplinary research practice with emerging academics
- Transdisciplinary research practice with citizens
- Transdisciplinary research practice with professionals
- Recombining open science outputs

This governance model is a practical tool for leading institutional transformations in universities in the digital era

First, this governance model illustrates how university researchers can administrate, organise, and conduct open science and innovation in their research teams.

Second, this model can also provide guidance on designing and setting up open science and innovation support services for the adoption of these practices at universities.

Third, this governance model can support university managers to develop university- and school-level actions, redesigns, and incentives for the effective administration of open science and innovation in universities.

To sum up, this model outlines the foundations for developing high-impact European open science and innovation universities and policies.

"The pursuit of science is confined to democracies".

Robert K. Merton

Authors' Contributions

Ruben Vicente-Saez led the conceptualisation and design of the empirical study; all data gathering at Aalto, KTH, Polito, TU-Da, ULisboa, UGA, and UPC; the data analysis; and the original draft writing and final review of the handbook. Ruben Vicente-Saez was also responsible for supervising the research and managing the project.

Jürgen Windeck participated in the conceptualisation and design of the empirical study, all data gathering at TU-Da, and the data analysis and contributed to the original draft writing and final review of the handbook.

Maria H Ribeiro participated in the conceptualisation and design of the empirical study, all data gathering at ULisboa, and the data analysis and contributed to the original draft writing and final review of the handbook.

Antti Rousi participated in the conceptualisation and design of the empirical study, supported data gathering at UPC, participated in the data analysis, and contributed to the original draft writing and final review of the handbook.

Anna Rovira Fernandez contributed to the conceptualisation and design of the empirical study, participated in all data gathering at UPC and the data analysis, and contributed to the original draft writing of the handbook.

Arnaud Legrand participated in the conceptualisation and design of the empirical study and the data analysis and contributed to the original draft writing of the handbook.

Cecilia Rodrigues participated in the data analysis and contributed to the original draft writing and final review of the handbook.

Kristin Halverson participated in the data analysis and contributed to the original draft writing of the handbook.

Federica Cappelutti participated in the conceptualisation and design of the empirical study and the data analysis and provided suggestions for the writing of the handbook.

Acknowledgements

We thank **Pernilla Looman**, **Shalini Kurapati** and **Silvia Tabotta** for participating in the conceptualization and design of the empirical study, **Rosa Lönennborg**, and **Lina Andrén** for participating in the data gathering at KTH, and the **UPC librarian team** for supporting data gathering at UPC.

Credits

Cover photography: Aleksi Poutanen, Aalto University
Design and layout: Eva Álvarez Garabito, Niugrafic

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This document derives from Deliverable 6.2 - Handbook of best practices for effective open scienceand innovation mainstreaming at universities - of the UNITE.H2020 project (GA n. 101017408) - pending EC approval.

Recommended citation: Vicente-Saez, R., Windeck, J., Ribeiro M., Rousi, A., Rovira-Fernandez, A., Legrand, A., Rodrigues, C., Halverson., K, Cappelutti., F. (2023). Unite! handbook of best practices for effective mainstreaming of open science and innovation at Universities. Unite! Alliance Publications.