Implementing interdisciplinarity in research-intensive universities: good practices and challenges

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About LERU

LERU was formed in 2002 as an association of research-intensive universities sharing the values of high-quality teaching in an environment of internationally competitive research. The League is committed to: education through awareness of the frontiers of human understanding; the creation of new knowledge through basic research, which is the ultimate source of innovation in society; the promotion of research across a broad front, which creates a unique capacity to reconfigure activities in response to new opportunities and problems. The purpose of the League is to advocate these values, to influence policy in Europe and to develop best practice through mutual exchange of experience.

Executive Summary

The 2016 LERU position paper "Interdisciplinarity and the 21st century research-intensive university" addressed definitional and epistemological issues related to interdisciplinarity. It laid out an ambitious agenda for the implementation of interdisciplinarity in research-intensive universities.

The current paper takes stock of the progress made by LERU universities in the implementation of the vision of a virtuous circle between disciplinarity and interdisciplinarity as a fundamental condition for the progression of knowledge.

While noting that both scientific and societal drivers continue to emphasise the critical importance of inter- and transdisciplinarity, the report acknowledges the considerable progress made and identifies the remaining challenges in terms of education, research, careers, and governance:

- In education, there is a rapid expansion of inter- and transdisciplinary programmes and opportunities. LERU stresses the need for further efforts to move from programmes that are multidisciplinary towards integrating knowledge from different disciplines in interdisciplinary programmes and towards working with stakeholders (which is defined as transdisciplinarity).

- In research, there is a very high level of interest among researchers, funders, and national agencies in multi-, inter-, and transdisciplinarity. This is reflected in the development of new avenues for collaborative research that address many of the most important global challenges. However, there is still room for improvement regarding the evaluation and the valorisation of inter- and transdisciplinary research. Efforts should be made to heighten engagement with existing literature on inter- and transdisciplinary research.

- Despite notable progress, career development remains a challenge for reaching the true potential of inter- and transdisciplinary research. Given the level of control of disciplinary structures in many universities on appointments and tenure, scholars who pursue a predominantly inter- and transdisciplinary approach, are faced with disproportionate obstacles.

- In terms of governance, the report welcomes the creation of new interdisciplinary structures, but also points out that the institutionalisation of inter- and transdiciplinarity poses challenges. While recognising that there is no one-size-fits-all approach, LERU stresses that it is important to reconsider the way decision-making power and resources are allocated between disciplinary and interdisciplinary modes of knowledge.

The development of inter- and transdiscplinarity in research-intensive universities is part of the transformation of knowledge systems which supports the broader societal drive towards addressing the sustainable developments goals.

Introduction

Humanity is faced by unprecedented challenges of sustainability. Addressing those challenges requires building intellectual and social capacities across societies. The COVID-19 pandemic has further emphasised the contribution of universities in building resilient societies at a time of growing vulnerability and uncertainty. Research-intensive universities have a critical role to play in the current transformation, while also being transformed as the result of wider societal processes. The complexity of both global challenges and questions in fundamental research stresses the importance of collaboration within and across the Natural Sciences, Life Sciences, Social Sciences, Arts, and Humanities. Over the past 10 years, interdisciplinary and transdisciplinary education and research have gained importance in national, European, and international research policies.[1]

Dedicated to pushing the frontiers of innovative research, the League of European Research Universities (LERU) has strived to foster excellence in research while developing guidance on numerous issues of research policy over the past 20 years. Inter- and transdisciplinarity are important topics for LERU. In 2016, LERU adopted a position paper entitled "Interdisciplinarity and the 21st century research-intensive university" (LERU 2016). Based on the recognition that interdisciplinary research is vital to produce and mobilise new knowledge, this paper not only addresses the epistemological foundations of interdisciplinarity but also delineated an ambitious agenda to foster a culture of successful interdisciplinarity in both research and education in research-intensive universities. Since then, LERU has frequently addressed interdisciplinarity in its main policy groups as well as at the Rectors' Assembly. Today, LERU considers interdisciplinarity as an integral part of the wider transformation of our knowledge systems that is necessary to support a broader societal transformation to inclusive and equitable sustainability.

Six years have passed since the publication of the position paper, and inter- and transdisciplinarity have received increased attention in the literature, with a broad recognition that it is vital to both fundamental and applied research. While the initial 2016 position paper focused on interdisciplinarity, i.e., collaboration across academic disciplines, LERU recognises that trans-disciplinarity – the collaboration of scholars from different academic disciplines with many actors across societies – is equally important. The substantial existing body of scholarship around the conduct of inter- and transdisciplinary research should guide any effort to move the agenda forward. The EU-funded SHAPE-ID project has synthesised extensive academic and policy literature findings on interdisciplinarity, including factors of success and failure. Today, the key issue is not lack of knowledge about the importance nor processes and practices of inter- and transdisciplinarity, but rather with the diffusion and implementation of that knowledge within the knowledge systems. To address this, SHAPE-ID recently provided a toolkit supporting pathways to interdisciplinary and transdisciplinary research for researchers, research organisations, funders, policy-makers, and societal partners, all of whom must play a part in advancing and enabling a culture of inter- and transdisciplinarity. LERU continues to "*see vision, strategy, and planning as playing a critical role in the development of an institutional environment conducive to interdisciplinary activities*" (LERU 2016).

As underlined in the 2016 LERU position paper, "*the vision of LERU universities is to support both disciplinarity and inter-disciplinarity as equally important to solve intractable scientific problems and to address unprecedented challenges faced by human societies*" (LERU 2016). LERU notes that the implementation, embedding and institutionalisation of inter- and transdisciplinarity continues to raise critical questions for universities that have been primarily organised along disciplinary lines. While LERU considers inter- and transdisciplinarity as core modes of knowledge production, it recognises that many universities still have a long way to go in terms of their institutionalisation. The disciplinary organisation of knowledge has created a path-dependency of increasing specialisation, which, in turn, results in pervasive obstacles to inter- and transdisciplinarity in the long run. The goal of this LERU paper is therefore to take stock of the progress made in implementing inter- and transdisciplinarity in LERU universities since the adoption of the 2016 position paper.

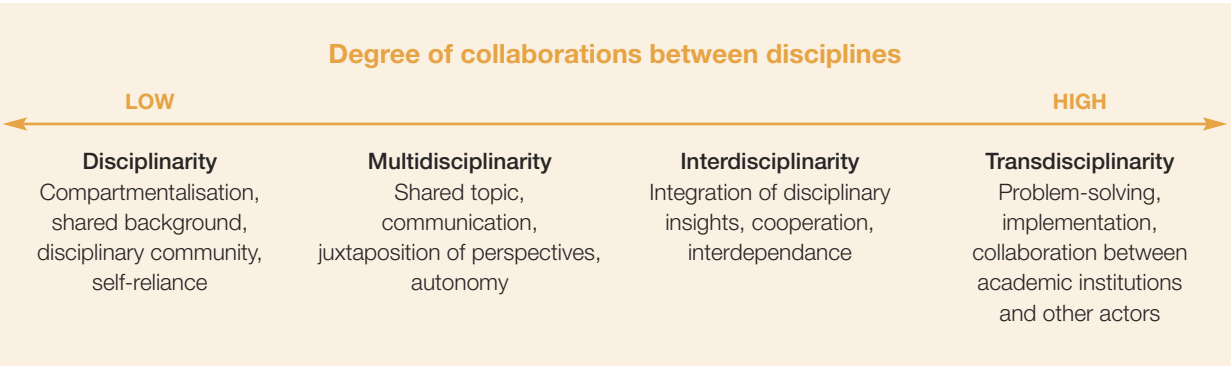
This paper, which is part of a wider reflection on the transformation of our knowledge systems,[3] is based on the analysis of responses from LERU members to a questionnaire circulated in the autumn of 2021. The questionnaire focuses on progress made in implementing the recommendations of the 2016 LERU paper. Further comments were provided on the draft report by several LERU groups and key members of the SHAPE-ID team. Progress towards implementation is analysed in five areas: 1) position within the university mandate; 2) education; 3) research; 4) career paths; 5) governance. Each of these sections starts with a summary of the main considerations from the 2016 paper.

1 LERU recognises the difference between interdisciplinarity as an epistemological issue, and as an organisational matter. The former is not possible without addressing the latter and getting scholars to work together across organisational or institutional boundaries.
2 https://www.shapeidtoolkit.eu/
3 https://www.leru.org/news/universities-stand-ready-for-present-and-future-challenges

This is followed by the results of the survey and the discussion within the context of the current literature on inter- and transdisciplinarity. Each section finishes with a set of further recommendations for the implementation of inter- and transdisciplinarity in research-intensive universities.

To avoid confusion, the definition from the 2016 LERU position paper is used. "*Multidisciplinarity refers mainly to a sequential analysis of a problem by disciplinary experts with few interactions between them. Growing interactions and efforts to integrate disciplinary insights lead to interdisciplinarity, with a scientific added value for the involved disciplines. Finally, in transdisciplinarity, interactions are extended outside academia to solve problems of societal importance through integration of knowledge from different actors*" (LERU 2016). Finally, the word 'science' is used to include all disciplines.

Figure 1. Key concepts for collaborative research between disciplines (interdisciplinarity). From LERU 2016, Inspired by (Klein 2014).



1 Place of interdisciplinarity within the core mandate of universities

2016

Many important areas of research are interdisciplinary in nature. Collaboration across disciplines is essential for answering complex questions that are beyond the realm of any single discipline. The growing interest of stakeholders (e.g., governments, business, NGOs) to address complex global challenges through engagement in complex research questions demonstrates that collaboration should not only be between disciplines but also across sectors. Inter- and transdisciplinarity are relevant because they address the multidimensionality and unknowns posed by such problems in a better way than a mono-disciplinary approach does: "In a highly competitive environment, academic institutions that are able to further capitalise on interdisciplinary research and teaching will reap a major share of the scientific benefits of its transformative potential" (LERU 2016).

Currently a majority of researchers work together with colleagues from other disciplines and research fields on interdisciplinary research questions or combine different disciplines in their own methods. In other words, most researchers are aware that many of the big questions of our time do not neatly follow the lines of scientific disciplines.[4] While the unique skillset of disciplinary academic experts in all fields is vital for responding to pressing global challenges, the COVID-19 pandemic has illustrated the need for collaboration across disciplines (LERU 2021). The 2016 report made clear that disciplines are themselves evolving, incorporating knowledge from others. In recent years, for example, it has become obvious that Computer Technologies are having a major influence on many different fields. Computer Technologies are not only facilitating access to information and data but are also supporting some aspects of inter- and transdisciplinary collaboration by providing platforms and data (e.g., collaborative tools/spaces).

Bringing together research, education, and service to society, universities play an important role in addressing societal challenges by identifying questions that can be addressed from a scientific perspective, shaping productive exchanges and generating evidence for action. LERU refers to universities "*as places that support improvement in the life of many through our primary mandate in education, research, and transfer to society*" (LERU 2021). It also reasserts the importance of inter- and trans-disciplinary collaboration in applied and basic research as both are key to the transformation towards sustainable and resilient societies.

1.1 From recognition to becoming a key part of the strategy

2016

In 2016, LERU recommended establishing interdisciplinarity as a core business of the university. To achieve this, the university is advised to *"include interdisciplinarity in the strategy of the university, explicitly recognise the importance of interdisciplinary research, and position the university as a place where interdisciplinary research is valued and proactively encouraged"* (LERU 2016). An explicit approach was meant to be a critical element to create a culture of interdisciplinarity and ensure its sustainability in a disciplinary-based environment. While the 2016 paper did not focus on it, transdisciplinarity was briefly addressed by recommending that universities "*10) Develop partner-ships and programmes in priority areas with other actors such as governments, the private sector, or non-governmental organisations to promote translational activities*" (LERU 2016).

Today, all LERU universities recognise that both inter- and transdisciplinarity are current topics of interest and debate. For some universities, they have become part of how to realise the goals of the university itself, while others have developed specific strategies for inter- and transdisciplinarity with clear objectives regarding both research and education (cf. table 1 below).

4 As several philosophers and sociologists of the sciences have pointed out, there are very few strict 'disciplines' in academia. Within one 'discipline', scholars may totally disagree on core issues and rarely attend the same conferences or read the same journals. The reverse is also true: Scholars may easily move from one discipline (i.e., department or chair) to another.

For those universities that did not, inter- and transdisciplinarity have been embedded to various degrees in their wider strategy and goals. For some, inter- and transdisciplinarity is part of a strategy to make the university more challenge-driven, for instance through the European University Alliances.[5] In addition to university-wide efforts, some subdivisions within universities also emphasise inter- and transdisciplinarity.[6] Nonetheless, there is a growing sense that efforts that depend heavily on academic champions and that are not institutionalised in the broader processes and structures of the university are lost in the long-term.

Recommendations

- LERU recommends that academic institutions include explicit commitments to advancing inter- and transdisciplinarity in their strategic plans and follow through with concrete objectives and aims to make them a key part of the long-term strategy of the university (see section 6 on governance). This entails various strategies to institutionalise inter- and transdisciplinarity at all levels of the university and across all disciplines while recognising the fundamental principle that they result from an emergent process (see section 1.2 below).
- Critical objectives should include promoting a culture of interdisciplinarity and addressing pervasive but not insurmountable obstacles to interdisciplinary research and education.
- The human capacity and financial means to realise these strategies should be commensurate with the importance of inter- and transdisciplinarity in both the production of fundamental knowledge and in addressing broader societal goals.
- The strategy should consider the design, implementation, and evaluation of proper actions and mechanisms devoted to supporting interdisciplinarity.

Table 1. The place of inter- and transdisciplinarity within the university' strategy

University of Amsterdam	In its new strategic plan (2021-2026), the University of Amsterdam emphasised the importance of interdisciplinary knowledge and skills for students.
University of Barcelona	The development of interdisciplinary activities is one of the priorities of the University of Barcelona at different levels: interdisciplinary teaching programmes, interdisciplinary subjects, or interdisciplinary activities within individual subjects.
University of Cambridge	The University of Cambridge recognises the strategic importance of interdisciplinarity and has established a series of interdisciplinary initiatives and networks (Strategic Research Initiatives & Networks).
University of Copenhagen	Interdisciplinarity has been adopted as a core element of the University of Copenhagen's strategy.
Trinity College Dublin	Trinity College Dublin's Living Research Excellence Strategy (Principle 4) commits the university to "*Harness[ing] our collective expertise for the greater good" setting a goal of being "bold in defining and taking the lead in multidisciplinary initiatives… that leverage our expertise, for the long-term benefit of humanity*". Furthermore, goal 4 of the strategic plan (2020-5) notes that "*Our five Trinity Research Institutes and nineteen collaborative Research Themes have a special role within our research eco-system, advancing interdisciplinary and collaborative research, attracting and housing externally funded large scale projects, contributing to addressing the great challenges of our time and articulating the value and reach of our research to academic and non-academic audiences*."

5 20 LERU universities are active in six European University alliances: CHARM-EU, 4EU+ alliance, UNA Europa; EUGLOH, EPICUR and NeurotechEU.
6 For example, the third pillar of Trinity College Dublin's School of Medicine Research Strategy 2021-2026 embeds the objective to "*Extend the School's translational and multidisciplinary innovative research environments through engagement across several international and European-funded research networks*".

University of Edinburgh	Interdisciplinarity is well represented in the strategy 2030 of the University of Edinburgh. "*We will strive to make our research even more interdisciplinary and international, to address social and global challenges including the United Nations Sustainable Development Goals.*"
University of Freiburg	As a comprehensive university with a broad spectrum of disciplines, the University of Freiburg is committed to fostering research collaborations across different research areas. In its strategic plan 2019-2023, the university identifies the further development and strengthening of its interdisciplinary research profile fields as a central strategic goal.
University of Geneva	Objective 1 of the University of Geneva's strategic plan (2015-2025) is to "*Ensure the long-term development of the University's constituent disciplines and foster the emergence of inter-disciplinary and multidisciplinary fields*."
University of Helsinki	As reflected in the new strategic plan 2021-2030, interdisciplinarity is a key crosscutting priority of the University of Helsinki. Within the plan, the university has chosen four themes (a meaningful life, wellbeing and a healthy environment; a humane and fair world; a sustainable and viable future for our globe; a universe of ideas and opportunities) to inspire and spur collaboration between fields and disciplines and renew research and learning.
Leiden University	The new strategic plan of Leiden University (2022-2027) 'Innovating and Connecting' includes "Pioneering interdisciplinary research and teaching" and "More value through strategic collaboration" as two of the university's six ambitions for the coming years, which demonstrate the strategic commitment to both inter- and transdisciplinary collaboration, while also maintaining strong disciplines.
KU Leuven	In the 2017-2021 Strategy "On crossroads, for a sustainable society", strengthening inter- and transdisciplinarity was the main pillar, with a focus on developing interdisciplinary institutes, research funding schemes, PhDs and teaching programmes. The 2021-2025 policy plan focuses on consolidating these choices.
Imperial College London	Transdisciplinarity is one of the four foundations embedded within the Imperial College London' strategy 2020-2025. "We will be transdisciplinary. Only by bringing together expertise from different disciplines can we solve today's global challenges."
University College London	"To Cross Boundaries to Increase Engagement" is a key part of the strategy of University College London.
Lund University	One of six priority areas in Lund University's strategic plan 2017-26 is "*Stimulating active collaboration to solve societal challenges*." Within this area, the following objective is stated: "*[…] Boundary-crossing and interdisciplinary collaborations within Lund University and with other higher education institutions shall be encouraged and new collaborations developed. Obstacles to collaboration shall be identified and removed*."
Université Paris-Saclay	"Encourage interdisciplinary work between all teams at Université Paris-Saclay" is one of the six main objectives of its research policy.
Sorbonne University	Sorbonne University is committed to a fruitful dialogue between scientific fields and follows an interdisciplinary approach to benefit society.
Utrecht University	In Utrecht University's Strategic Plan 2025 multi-, inter-, and trans-disciplinarity are mentioned as one of five guiding principles for both research and education.
University of Zurich	The first strategic principle on research and innovation of the University of Zurich (UZH) states that "*UZH is committed to embracing diverse and equal research cultures, inter- and transdisciplinarity, independent and free research as well as close national and international cooperation*."

1.2 Interdisciplinarity as emergent processes in a complex network

2016

LERU recognised the conceptualisation of interdisciplinarity as an important precondition for favouring meaningful interactions between disciplines. While disciplines have been the foundation of the contemporary scientific knowledge system, LERU rejected the notion of epistemic hierarchies and inter- and transdisciplinary as being something 'else'. LERU noted that "disciplinary knowledge is constitutive of the interdisciplinary research process as, without sharp disciplinary knowledge, it would not be possible to conduct interdisciplinary research in the first place" (LERU 2016). However, "as the constant tensioning of ideas is central to the creation of knowledge, collaboration between disciplines is a way of questioning the potential, limits, and margin of progression of the disciplines" (LERU 2016). In other words, interdisciplinarity is not against the disciplines but a driver of progress in the creation of knowledge by combining disciplinary and other types of knowledge creatively. When successful, the interactions between disciplinary and interdisciplinary modes of knowledge creation generate a virtuous circle making universities, and the knowledge they create, more than the sum of their disciplines.

LERU continues to consider interdisciplinarity as an essential component of the evolution and ongoing reconfiguration of the disciplines. Furthermore, LERU sees transdisciplinarity not only as a way of diffusing scientific thinking beyond academia, but fundamentally as co-designing research and education for important issues. This is in contrast to the classical model, which seeks to transfer knowledge to other parts of society only once the production process is completed. This co-designing model is growing in importance at policy level. Inter- and trans-disciplinarity are closely linked, as answering questions from partners from other societal sectors, or co-producing knowledge with them, often requires interdisciplinary approaches. Science, in the broadest sense, is a complex, self-organising network of new knowledge and ideas, scholars, projects, study, experiments and observations in constant co-evolution with society. Inter- and transdisciplinarity are thus part of an emergent process primarily driven by the interest of researchers and educators, but also influenced by policy priorities, societal needs, and the broader context. This means that inter- and transdisciplinarity often result from a bottom-up approach to knowledge formation.

The conceptualisation of science as a complex network emphasises academic freedom as the core principle guiding the self-organisation of universities. Academic freedom is, however, necessary but not sufficient, especially given the "*widespread disadvantages faced by under-represented groups in academia*" (LERU 2019). This in turn influences the research questions that get addressed. Put simply, both academic freedom and a diversity of people increase our capacity to address global challenges. Many universities, as well as public and private funding agencies, complement this bottom-up approach with targeted initiatives for high strategic priority areas. This includes, for example, the Irish Research Council New Foundations awards, in which research challenges are co-designed with policy departments in the national government and charitable organisations[7]. Furthermore, a few universities have taken a more proactive approach towards cultivating inter- or transdisciplinary dynamics. As part of the European University Alliance, CHARM-EU, the University of Barcelona, Trinity College Dublin, and Utrecht University are hosting a Master in Global Challenges for Sustainability[8].

Our growing understanding of the science of 'science' (in the inclusive sense) suggests that interdisciplinarity is not something that happens spontaneously in multidisciplinary research teams nor among students. Serendipity can always play a role, but inter- and transdisciplinarity are more likely to be fruitful when the scientific and pedagogical methods are consciously chosen, developed, and implemented.

Recommendations

- LERU recommends that universities are considered and managed as complex networks of people, ideas, and structure whereby diversity of thinking, culture, disciplines, and methods support the constant evolution of new scientific knowledge. This means that the role of university policy is primarily to create an incentive structure in research policy and education, not to control every process, let alone individual projects.
- Both culture and targeted actions can play a vital role in creating the ecosystem that is necessary to nurture the virtuous cycle between disciplinarity and inter- and transdisciplinarity. The focus on the right incentive structure should not prevent the support of emergent fields of research that are considered as priority areas.
- Developing an explicit strategy can help foster productive interactions within and between disciplines. Because the problem is not a lack of knowledge of inter- and transdisciplinarity, but rather institutional barriers, such strategy should include actions focusing on the dissemination and implementation of a university's vision.

7 See more at https://research.ie/funding/new-foundations/
8 See https://www.charm-eu.eu/masters/globalchallenges for more.

1.3 Diversity of inter- and transdisciplinary forms and practice

2016

Interdisciplinarity can take different forms depending on several parameters of researchers, institutions, and scientific context. This was recently also summarised by the SHAPE-ID consortium (Vienni Baptista, Maryl et al. 2020). For example, interdisciplinarity can take place both within closely related disciplines (so-called 'narrow' inter-disciplinarity) and disciplines that are more detached from one another (so-called 'broad' interdisciplinarity). It can be instrumentally or critically oriented or both. LERU further distinguished between 'bottom-up' interdisciplinarity, which focuses on academically oriented basic research, and 'top-down' interdisciplinarity, which aims to respond to societal challenges[9]. This distinction was meant to recognise that different kinds of knowledge dynamics co-exist in research-intensive universities.

Collaboration can take place at different levels that do not always follow the simple categories mentioned above. For example, LERU accepts that interdisciplinarity is a topic of interest in many disciplines that usually consider themselves inherently 'interdisciplinary'. This is the case not only in the Humanities (e.g., classics or cultural Studies) but also in Engineering & Technology, Biomedical Sciences, Medicine, Environmental Sciences, and Natural Sciences, where interactions between fields and disciplines have been common for a long time. Furthermore, practice among LERU members shows the development and growing importance of fields that combine disciplines usually considered as "further removed". Of note is the rapid expansion of computational approaches in Social Sciences and Humanities whereby these tools allow for the provision of a huge amount of data that was previously not available for quantitative analysis. Overall, LERU stresses that inter- and transdisciplinarity are ways both to develop a broader understanding of a research topic and/or to engage with societal problem solving. These different purposes require different research approaches.

Recommendations

- Noting the current variety of interdisciplinarity forms, practices and expressions by its members, LERU recommends that proper consideration is given to different kinds of interdisciplinarity within research-intensive universities.
- Universities could be more specific about what they want to achieve with inter- and transdisciplinarity in a specific field or topic. This will not only limit the risk that inter- and transdisciplinarity becomes just an end in itself, but it will also help identify incentives and mechanisms that respond to the specificities of research topics and associated needs. For instance, in some cases access to research infrastructure is a problem, while in other cases, the recognition of the activities or outputs of inter- and transdisciplinary research is the main issue.
- Because of its significant research potential and societal relevance, LERU emphasises the need for a better integration of the Arts, Humanities, and Social Sciences (AHSS) with Science, Technology, Engineering, and Mathematics (STEM) and the Biomedical and Natural Sciences, as equal partners, not just followers. The SHAPE-ID project has identified many important ways AHSS contributes to a broader understanding of contemporary challenges (SHAPE-ID 2021).
- Provide or upskill professional research development staff with expertise in inter- and transdisciplinary research/integration.

9 These terms are defined in table 1 of the LERU position paper on Interdisciplinarity and the 21st century research-intensive university (LERU 2016). Another way to look at this term is to refer to research undertaken for advancing knowledge without a focus on applications (bottom-up) and research motivated by pressing societal questions (top-down).

1.4 The role of interdisciplinarity within the creation of scientific knowledge

2016

LERU stated that: "When interdisciplinary research is successful, it can yield important benefits in terms of problem solving and research insights" (LERU 2016). In academically oriented basic research, LERU sees the appropriation of the produced content by disciplines as a primary source of success and further noted that "highly successful interdisciplinary collaboration can result in the creation of a new discipline" (a so-called 'inter-' or 'neo-discipline') as this has been the case with Biochemistry and Neurosciences in the past. The 2016 position paper further noted that several areas of science are integrative by nature. This is often the case in problem/challenge-focused applied research such as in global health or sustainability science. Rather than developing as fully fledged new disciplines, they become crossroads for researchers from the Natural Sciences, Life Sciences & Medicine, Engineering & Technology, the Social Sciences, and Arts and Humanities. For the most important challenges, researchers are hosted in interfaculty centres working on thematic problems with other researchers from a vast array of disciplines (cf. section 4 on fostering inter- and transdisciplinary research). When successful, these 'inter- and trans-disciplines' usually have strong links with other actors and influence public policies.

Recent years have seen a further rapid development of new fields driven by both scientific and societal needs. Several of these fields, such as Sustainability, Public Administration, Global Health, and Area Studies, have been recognised given that the importance of global challenges such as climate change, the risks associated with the emergence of new zoonosis, or the importance of regional dynamics between polities are better understood. These fields are intrinsically inter- and transdisciplinary, meaning that they are not primarily built around a discipline and that expertise also comes from people outside academia.

LERU is convinced that diversified ways of organising scientific knowledge in research-intensive universities offers strong scientific and societal benefits, especially when a culture of excellence is promoted. Since the publication of the 2016 paper, scientific literature has shown that collaborative research attracts generally more citations than individually conducted publications (Wuchty, Jones et al. 2007). The literature has identified various conditions that support successful collaboration (Fortunato, Bergstrom et al. 2018). The main issue is that the most commonly used form of institutionalisation in universities supports the creation of a new discipline. This siloed approach not only perpetuates the primacy of the disciplines, but it also reduces the benefits from building a field as an inter- or neo-discipline in the first place.

Recommendations

- Research-intensive universities should further recognise the critical importance of the creation of new areas of research and fields at a time of societal transformation. This means reflecting on how university leadership can best support emerging fields of research and address the institutional obstacles that result from a disciplinary-based organisation (some of these obstacles are further discussed in the sections below).
- Given the importance of other actors in the production of new knowledge, universities should also reflect on the collaboration with experts, practitioners and people beyond academia to co-produce joint knowledge.
- Universities should consider more agile and flexible ways to support the inclusion of complex global challenges in research and education. One way of doing this is by organising the university around grand challenges.[10]

10 For example, University College London has convened cross-disciplinary collaborations to explore interconnected solutions to a range of societal issues: https://www.ucl.ac.uk/grand-challenges/.

1.5 Research on interdisciplinarity

2016

LERU recognised the professionalisation of inter-disciplinarity in its 2016 position paper. This means that interdisciplinarity is a field of research and education with its own community of practice and scholarship. The third section of that paper was dedicated to taking stock of the state of interdisciplinary science. The section identified progress in the theorisation and development of interdisciplinarity with the emergence of an overarching interdisciplinary research process. It also identifies some common epistemic challenges and strategies for approaching them.

Since the publication of the 2016 paper, inter- and trans-disciplinarity have continued to develop, where these developments and research outputs could meet the criteria of academic excellence. The recent literature has further stressed the need for heterogeneity of understanding in inter- and transdisciplinarity (Vienni-Baptista B., Fletcher et al. Forthcoming). There are currently several organisations, some based in Europe, that support a broader reflection on the design, implementation, and evaluation of interdisciplinarity by organising conferences, hosting blogs, and developing online toolkits and other relevant material.[11] However, there is a lack of expertise in integrating interdisciplinarity across universities (Bammer, O'Rourke et al. 2020). Since 2016, some LERU universities, such as the University of Edinburgh and the University of Amsterdam, have further developed their expertise in interdisciplinarity and analogues, including team science, science of science, and transdisciplinarity (Menken and Keestra 2016). In 2019, KU Leuven launched its Institute for the Future, an incubator for transdisciplinary research. The Institute intends to design and implement research methods based on complexity and transdisciplinarity to co-create and develop new insights, and unfold potential actions to move society towards a sustainable future. Trinity College Dublin has established a dedicated interdisciplinary team to support inter- and transdisciplinary funding acquisition in climate and sustainability, health, and AHSS integration. The team raises awareness on opportunities and good practices on inter- and transdisciplinarity, produces resources, offers training, organises events, acts as a matchmaker, and helps researchers develop proposals, leading to successful transdisciplinary teams with effective working relationships. Efforts have been made not only to facilitate engagement with the methodologies of inter-and trans-disciplinarity but also to reflect on their institutionalisation.[12]

Recommendations

- Incorporating diverse disciplinary and stakeholder perspectives in research design and implementation can increase research excellence as well as impact. However, there is often a sense that 'excellence' must exclude these boundary-spanning practices. LERU emphasises the need to support research in inter- and transdisciplinarity, recognising that new approaches are needed in terms of the synthesis of knowledge from different disciplines.
- While stating that a strong foundation for inter-disciplinarity rests on knowledge of the philosophy of science, LERU encourages universities to support activities that build literacy in interdisciplinary and transdisciplinary theories and methods.
- LERU recommends that universities identify and reward expertise in inter- and transdisciplinarity more actively as it often exists in a fragmentary and unrecognised form.
- Universities should also play a more active role in organisations focusing on inter- and transdisciplinarity and make use of the resources and support they provide.
- As the rapid development of Computer Technologies is allowing the growing integration of methods and datasets, LERU further recommends supporting the digital transformation of universities in both education and research as a key enabler of collaboration across disciplines. For example, this could involve acknowledging the work researchers do to create and integrate methods and datasets.[13]

11 Global Alliance for Inter- and Transdisciplinarity, the Association for Interdisciplinary Studies, the Network for Transdisciplinary Studies, The Science of Team Science INSciTS, Integration and Implementation insights. Several LERU universities are members of these organisations.
12 Cf. the SHAPE-ID toolkit
13 See results from the SHAPE-ID workshop on evaluation frameworks for digital humanities research: (p.97-98).

2 Supporting interdisciplinary education

2016

LERU stressed the importance of interdisciplinary education noting that "the evolution of society towards more collaboration between sectors, professions, and activities requires training the next generation of students to develop early on the basic skills needed for inter-disciplinary practice and research." The report also noted that "rising interdisciplinary literacy and building capacity requires teaching and training students early on in the curriculum, while making sure that they retain sufficient disciplinary depth" (LERU 2016). It recommended several actions to move interdisciplinarity education forward at the bachelor, master, and doctorate levels.

Since 2016, inter- and transdisciplinarity is increasingly taught at the bachelor, master, doctoral and postgraduate levels as exemplified by the diversity of education programmes offered by LERU universities in all areas of sciences. In addition to reforming existing programmes, members of LERU have launched numerous new interdisciplinary study programmes that combine disciplines to prepare graduates to address global challenges (cf. table 2). It is now common that students are able to follow an interdisciplinary track from bachelor to Master levels. Many ongoing efforts can be related to both societal demand and popularity among students. This also relates to the core function of education to prepare students to become engaged citizens who can look beyond boundaries, including between disciplines. For some universities, most master programmes are considered multi- or interdisciplinary. Most LERU universities have also implemented postgraduate education programmes with a strong emphasis on inter- and transdisciplinarity.

Developing interdisciplinary education also means creating joint programmes between institutions with complementary expertise. While these kinds of collaborations come with challenges with regards to governance, resources, and management, the participation of LERU universities in various forms of partnerships and alliances can help address these challenges. Furthermore, several LERU members promote student engagement in innovation. Examples of the above can be found in table 2.

As there is often no mechanism or platform to determine the distribution of student income or of teaching for shared modules, courses or programmes, there are challenges with regards to allocation of resources between participating entities of the university. Several universities have addressed this problem by monitoring the number of interdisciplinary study programmes and the number of students and graduates in those programmes. This is, for instance, the case at the University of Geneva, the University of Helsinki and Trinity College Dublin.[14]

Recommendations

- To support further progress in the implementation of interdisciplinarity in education, LERU is still convinced that "*an important principle is to develop flexible but coherent educational programmes that allow students to shape their curricula*" (LERU 2016).
- LERU recommends creating a supporting environment at the university level that facilitates the development of inter- and transdisciplinary education.
- Furthermore, better links need to be established between inter- and transdisciplinary research and education. More specific developments and recommendations are discussed in the sections below.
- Disciplinary-focused programmes should enable students to embed a minor within their curriculum as this can broaden or deepen their study.

14 Trinity College Dublin has implemented an electronic platform to review, determine and distribute income at a modular and student FTE level across all their courses. This is a powerful tool to enable and provide a foundation for interdisciplinarity. The implementation of BPI at PhD level, however, is less than ideal as to date PhD students can only be registered at one school.

Table 2. Examples of recently created interdisciplinary education initiatives by LERU members

Existing and new inter- and transdisciplinary bachelor and master programmes	
University of Amsterdam	Since 2016, the University of Amsterdam has developed several new interdisciplinary degree programmes: the BSc Cognition, Language and Communication (started in 2017), the Research Master's Programme in Business Data Science (started in 2020) and the BSc Computational Social Science (started in 2021).
University of Barcelona	The University of Barcelona offers 16 programmes that combine two different disciplines[15].
University of Copenhagen	In 2019, the University of Copenhagen launched a BSc programme in Computer Science-Economics (in Danish). An MSc in Social Data Science started in 2020, and a BSc in Cognitive Data Science will be launched in 2023.
Trinity College Dublin	Trinity College Dublin has developed a range of interdisciplinary-taught postgraduate programmes, including in Engineering for Climate Action, Smart and Sustainable Cities and Sustainable Development for Business.
University of Freiburg	The University of Freiburg has introduced several new interdisciplinary degree programmes, such as: Charity Studies and Ethics, Classical Cultures, Medieval and Renaissance Studies, Molecular Medicine (2022), and Pharmaceutical Sciences.
Leiden University	Leiden University launched several interdisciplinary programmes, including the BA Urban Studies (2018), the MSc Governance of Sustainability (2019), the MSc Law and Society: Governance and Global Development (2020), and the MSc Population Health Management (2021).
KU Leuven	Together with the partners of Una Europa, its European University Alliance, KU Leuven has launched a new joint bachelor's degree in European Studies with input from a wide range of disciplines and faculties. Interdisciplinary programmes are also growing in the field of sustainability, both at master's level (e.g. Master of Sustainable Development) and in executive education (e.g. Sustainability Leadership Programme).
University College London	UCL's Arts and Sciences programmes allow students to custom design their own programme, incorporating both Arts and Sciences.
University of Milan	In recent years, the University of Milan has launched several new interdisciplinary programmes such as the BA in Artificial Intelligence (since 2019), the MA in Law and Sustainable Development (2020), the MA in Environmental and Food Economics (2020) and the Master Course in Global Health (2020).
Université Paris-Saclay	Université Paris-Saclay offers 14 inter- and transdisciplinary degrees allowing for a double diploma. While basic training is provided on each of the two major disciplines taught, the student approaches the interdisciplinary aspects between them, which opens the way to better training during Master's studies. In addition, the university offers several inter- and transdisciplinary programmes. The overarching objective of MSc CLUES (Climate land use and ecosystem services) is to provide students with the scientific knowledge and skills necessary to understand the functioning of terrestrial ecosystems. The ARTEQ program focuses on Quantum Technologies.
Sorbonne University	Eight thematic transdisciplinary study programmes at Bachelor level combine Science and Humanities, sometimes also Engineering and Medicine.
Utrecht University	Utrecht University offers several interdisciplinary programmes. One example at the BA-level is Care, health, and society. An example on the MA-level is Medical Humanities.

15 History plus Art History, History plus Archaeology, Audio-visual Communication plus Digital Information plus Documentation Management, Business Administration and Management plus Chemistry, Business Administration and Management plus Sociology, Business Administration and Management plus Law, Business Administration and Management plus Mathematics, Law plus Public Management and Administration, Law plus Criminology, Law plus Industrial Relations, Law plus Political and Administrative Sciences, Economics plus Statistics, Mathematics plus Computer Engineering, Mathematics plus Physics, Pharmacy plus Human Nutrition and Dietetics, Teacher in Early Childhood Education plus Teacher in Primary Education.

Joint programmes between institutions with complementary expertise	
Leiden University	A joint programme is offered by Leiden University in cooperation with Delft University of Technology and Erasmus University Rotterdam. The joint programme consists of a range of multidisciplinary minor programmes including three new minors offered in 2022.
University of Milan	The University of Milan recently launched a Master in Bioinformatics for computational genomics jointly with Milan Politecnico and a Bachelor of Arts in Artificial Intelligence with the University of Pavia and the University of Milan-Bicocca.
Université Paris-Saclay	Through the EUGLOH Alliance, Université Paris-Saclay and partners provide joint curricula in global health.
University-wide education	
University of Barcelona	At the University of Barcelona, there is a well-established programme to potentiate interdisciplinarity among learning programmes. For example, in the area of the Sustainable Development Goals, the university has designed transversal subjects shared among different bachelor programmes, including: Bioethics; Creativity, Innovation and Entrepreneurship; and Gender, Science and Technology.
University of Copenhagen	The University of Copenhagen (UCPH) wants to encourage students to get curricular experiences with interdisciplinary work and to follow courses from other study programmes and faculties. UCPH students can use a course catalogue to identify relevant courses on sustainability offered at other departments and faculties within the entire university. The interdisciplinary Sustainability Science Center also offers an online course (Mooc) about the Sustainable Developments Goals.
University of Freiburg	Since 2022, the University of Freiburg offers a campus-wide certificate programme in Sustainability Studies.
University of Geneva	The University of Geneva offers a growing range of transversal courses, which aim to bring together students from different faculties around common issues. Several of these courses have problem-based components.
University of Helsinki	The University of Helsinki offers a multidisciplinary sustainability course for all its students.
Leiden University	Leiden University has an elective course at master level offered to students of Arts and Sciences 'Art, Science & Technology (Art, Science & Technology: Transdisciplinary Connections). In 2021, the Leiden-Delft-Erasmus Centre for Sustainability offered its first round of Interdisciplinary Thesis Labs, open to master students of all backgrounds. In these interdisciplinary labs, students work together on each of their individual theses and follow a half year lab programme centered around a sustainability challenge set by an external organisation.
KU Leuven	KU Leuven developed the Beyond Boundaries-platform, inviting students interested in other fields of science to broaden their curriculum or to engage in interdisciplinary course threads.
Imperial College London	The Imperial College's i-explore modules offer undergraduate students the opportunity to work across interdisciplinary teams to expand knowledge areas and allow students to share their expertise for the benefit of society.
Lund University	Lund University offers 'Digitalisation and AI', gathering courses from the faculties of Engineering, Arts, Science, Economics, and Management and The Aesthetics of Crisis: Societal Crisis in Moving Pictures, engaging the faculties of Humanities, Arts, Medicine, and Law. The Massive Open Online Course (Mooc) Elements of AI has reached over 750,000 students in 170 countries.
Université Paris-Saclay	Université Paris-Saclay has a mandatory short programme (mainly online) for undergraduate students (all disciplines) on the basics of ecological transition.

Sorbonne University	A new interdisciplinary teaching module introduces the challenges and perspectives of sustainability and prepares for the Sulitest.
University of Zurich	In 2021, the University of Zurich established the School for Transdisciplinary Studies as a hub for inter- and transdisciplinary courses as well as future skills courses that address students of all faculties and study levels. The School for Transdisciplinary Studies supports providers and initiatives in the development and implementation of their study offers.
Focus on transdisciplinarity innovation and real-life challenges	
University of Barcelona	The University of Barcelona has a strategy plan to promote the employability of students, including internships and training on entrepreneurship and knowledge transfer. In most bachelor and master programmes, academic training includes temporary placement in a company or institution. This experience makes it easier for students to complete their training in inter- and transdisciplinary environments, working alongside professionals from different sectors. The university offers learning and education experiences that not only provide students with knowledge and skills but also promote their development as active citizens committed to society. The university offers service-learning activities within a variety of study programmes.
University of Cambridge	The University of Cambridge partners with local research institutes and with other universities and for many courses encourages students to undertake internships in industry, government or the third sector as part of their studies. The Cambridge Grand Challenges framework supports such collaborations in Social Sciences.
University of Copenhagen	The University of Copenhagen set up a SCIENCE Innovation hub and encourages the student to found a start-up or take part in an academic internship at an external start-up.
Trinity College Dublin	Trinity College Dublin's Ideas Workspace Tangent provides innovation opportunities and education to undergraduate and postgraduate taught and research students, as well as professional education for staff and extensive engagement with external stakeholders.
Leiden University	Leiden University's supports the PLNT Centre for innovation and entrepreneurship in Leiden and The Hague as an example of promoting students' engagement in innovation.
KU Leuven	KU Leuven developed an incubator for entrepreneurial students with KU Leuven Kick. The platform brings students from different disciplines together in new start-ups and supports them with Product Innovation Projects (interdisciplinary teams working for a year on the solution of a challenge) and an interdisciplinary Kick Academy, among other things. KU Leuven Engage is a similar initiative that has currently developed 35 Service-learning pathways.
Imperial College London	Imperial College's Enterprise Lab is a space for students to take a concept/idea through to creation, commercialisation and beyond. The Forum aims to connect researchers to policymakers to discover new thinking on global challenges.
University of Zurich	The University of Zurich's Innovation Hub offers multiple trainings and courses that allow students to work on real-life challenges from industry partners or the public sector.
Postgraduate inter- and transdisciplinary education	
University of Cambridge	At the University of Cambridge, several postgraduate taught research courses are hosted within the University's Strategic Research Initiatives and Networks offering students the opportunity to experience interdisciplinary research in several different departments. The university has several doctoral training programmes that cross school and departmental boundaries, offering students experience in different research areas and environments.
Trinity College Dublin	Trinity College Dublin has launched two funding schemes specifically targeting transdisciplinary PhD research focused on global challenges: the Kinsella E3 Awards and the Prendergast Challenge-Based Awards.

Leiden University	At Leiden University, doctoral candidates can work under the supervision of professors affiliated to different faculties, or through cotutelles and joint doctoral programmes, at universities in different countries, enabling interdisciplinary doctoral trajectories.
KU Leuven	The Doctoral School for the Humanities and Social Sciences at KU Leuven sponsors interdisciplinary initiatives proposed by young researchers. The three doctoral schools (HSS, Biomedical, and Science & Technology) sponsor IdeaLabs that offer financial support to innovative scientific collaborations not yet ready for conventional financing. Young researchers who want to explore an original scientific idea or hypothesis in a multidisciplinary context can apply for start-up funding for a maximum of three years.
Imperial College London	The Graduate School at Imperial College London offers all doctoral students the opportunity to engage with its Research Impact Programme. The Graduate School also recently accredited the Enterprise Lab's Idea Challenge so that doctoral students who participate in this Challenge can use it towards Graduate School course attendance credit for their PhD milestones. Also available to doctoral students is the Global Fellows Programme, which brings together students from Imperial and partner institutions abroad to work in multidisciplinary teams.
Lund University	Lund University established the Agenda 2030 Graduate School in 2018 as an interdisciplinary research school.
Université Paris-Saclay	At Université Paris-Saclay, some of the programmes at PhD level are strongly interdisciplinary, for example on 'agriculture and food', or on 'therapeutic innovation'. It allows exchanges on methods and knowledge among students from different disciplinary backgrounds.
Sorbonne University	Interdisciplinary doctoral programs aim to develop and support research areas that go beyond the disciplinary boundaries, and to provide an appropriate response to societal issues.

2.1 Fostering innovation in teaching and education

2016

LERU advocated innovation in teaching and education regarding interdisciplinarity. It noted that at bachelor and master levels, "*the goal of LERU universities is for students to develop core disciplinary knowledge, competencies, and skills*". It recognised the multidisciplinary nature of many educational programmes but stressed the need for increasing interdisciplinary literacy. LERU recommended including some elements that contribute to developing a broader understanding of science in the curriculum. These included the need to train students to develop their own epistemological position, to cultivate critical thinking, and to be open to a multiplicity of ways of knowing things (epistemological pluralism).

LERU universities are strongly involved in innovation in education in both disciplinary and inter- and transdisciplinarity. Formats that favour interactions between students and/or instructors are of particular importance for inter- and transdisciplinary education. Several universities have implemented co-teaching, problem-based, and challenge-based learning with students from several educational programmes. Problem-based and challenge-based learning are particularly useful for developing teamwork capacities. Several universities have also further developed transversal courses that are open to students from different faculties or sometimes offered as Massive Open Online Courses (MOOCs). Other developments cover core academic topics and skills, such as an introduction to academic studies, writing, and methods in different disciplines. Some universities have implemented policies that promote incentivisation on an individual and college-wide basis which include the recognition of interdisciplinary teaching or specific funding (cf. table 3).

LERU recognises the challenges of implementing inter- and transdisciplinary education within monodisciplinary structures (Lindvig, Lyall et al. 2019). Implementing interdisciplinary teaching activities can be time consuming. Investments in time and energy are a major deterrent for many academics who show an interest in interdisciplinarity. Reward and proper incentive mechanisms should be reinforced (cf. section 5 on career). Some topics, such as digitalisation, computational skills, or critical thinking, are particularly relevant for students enrolled in different programmes to mix and work together in a productive manner.

Recommendations

- While the focus of education is on promoting individuals and not groups, LERU recommends that universities make the ability to work and perform in groups a larger part of training and assessment.
- To foster a bottom-up dynamic, universities should develop calls for projects on interdisciplinary teaching, including co-teaching, the use of e-learning in complement to ex-cathedra course, and problem-based and service-learning.
- It is important to reinforce proper reward and incentive mechanisms. Incentives for teachers include teaching release, teaching assistance, and pedagogical support for good practice.
- For a long-term vision of education, it is useful to encourage the creation of interdisciplinary courses and diplomas to make students at the undergraduate level aware of dual (or multi) expertise approaches, for instance in order to prepare them for inter- and transdisciplinarity at the master and PhD level.
- Universities should further develop a life-long learning approach to inter- and transdisciplinarity.

Table 3. Examples of initiatives and mechanisms to foster innovation in teaching and education

University of Barcelona	The University of Barcelona organises regular meetings to share teaching experiences in a multidisciplinary environment. Likewise, the university boosts inter- and transdisciplinarity by promoting transversal subjects, taught by teachers from different disciplines, who work together to design consistent programmes.
Trinity College Dublin	Teaching innovation is a specific ask in the evaluation of all academic staff seeking promotion at Trinity College Dublin. Innovation in many cases has involved co-teaching and/or teaching across disciplines. Moreover, each faculty funds several teaching awards, and Trinity College Dublin has approximately five Provost's teaching awards per annum as well as PhD postgraduate teaching awards.
University of Freiburg	In order to foster interdisciplinary research, the University of Freiburg has introduced internal funding programmes which aim at strengthening the University's research profile fields. Funding is provided for networking activities within the profile fields, international collaboration and innovative interdisciplinary research projects. These measures also increase the visibility of interdisciplinary research conducted at the university.
Heidelberg University	In the context of Marsilius Kolleg, the Marsilius Study Programme offers interdisciplinary seminars conducted by at least two lecturers from different academic backgrounds. The programme is rounded out by an interdisciplinary colloquium in which students present their final projects for discussion.
Leiden University	The MSc Governance of Sustainability at Leiden University (offered since 2019) starts its programme with a compulsory course on transdisciplinary skills (6 ECTS) related to reflecting, debating, and consideration of different sources of knowledge.
KU Leuven	The Transdisciplinary Insights (TDI) Honours Programme is a university-wide, one-year course that allows second- and third-year Bachelor students, Master students, and PhD students from different disciplines to work together with stakeholders (from government, industry, university, society) to address complex problems in a transdisciplinary manner. Every year, TDI launches several challenges to solicit commitment from students in helping to tackle these complex problems together with researchers and societal partners. Each team is supported by coaches who have expertise in the complexity of the problem or in the process of approaching a complex problem with a transdisciplinary team. TDI selects students from different disciplines to work on the challenges, usually a team of five to eight students per challenge.
Imperial College London	Imperial College London offers doctoral students professional skills workshops in: Introduction to Philosophy – Knowledge, Truth and Science.

Lund University	Lund University has setup an 'Introduction to academic studies', gathering the philosophy, academic writing, scientific methods in different disciplines, and lectures by distinguished researchers from every faculty.
Université Paris-Saclay	The Climate Action University Diploma at Université Paris-Saclay will enable students to master the foundations and challenges of climate and ecological transitions to complement and put into perspective their initial training, whether in Science and Engineering, Life Sciences, or Human and Social Sciences. The aim of the course is to combine the knowledge of engineers and academics to accelerate the climate transition. It differs from traditional training courses by focusing learning on a collective project combining the disciplinary expertise of the learners. The objective is to acquire systemic analysis methods and know-how at the crossroads of Techniques, Sciences, and Humanities. The DU Acting for the Climate offers master level learners a holistic vision of the challenges of transitions, coupled with a practical component and sharing of knowledge.
Sorbonne University	All freshman students at the Faculty of Science and Engineering are participating in an interdisciplinary workshop animated by two supervisors from different disciplines. All combinations of disciplines apply.
Utrecht University	Utrecht University has a fund specifically for interdisciplinary education (courses, minors/tracks, programmes).
University of Zurich	The recently implemented UZH Teaching Fund at the University of Zurich focuses on trans-disciplinary innovation. In 2022 the University of Zurich launched the initiative Future of Teaching at UZH to create structures and frameworks that foster teaching and learning innovations in a strategic and sustainable manner. One of the activities of the initiative is the implementation of the UZH Curriculum, which with inter- and transdisciplinary education one of its principal components.

2.2 Moving from multi- to inter- and transdisciplinary education

2016

The 2016 paper considered the need for explicit inter-disciplinary education that helps students to question, seek, and recognise the disciplinary provenance/origin of knowledge. It noted that "*a specific course or seminar in interdisciplinarity and systems thinking might be highly beneficial for all programmes in interdisciplinary areas so that students grasp 1) current scientific challenges and 2) the diversity of views and disciplinary perspectives*". The report identified concrete elements that should be part of a course, including core concepts in the history and philosophy of science and an understanding of different methodologies.

Within LERU universities it is increasingly common that students from a disciplinary programme must take courses outside their faculty.[16] This is an important requirement to favour an exchange of ideas between students. Nonetheless, LERU notes that there is still frequent confusion between multi- and inter- and transdisciplinary education. In contrast with multidisciplinarity, which simply juxtaposes disciplinary insights, interdisciplinarity makes the issue of integration between disciplinary insights explicit, as well as the use of methods to understand how knowledge differs or is conflicting. It also requires strategies for integration. In other words, there is a fine line between allowing students to shape their curricula and leaving them to do all the integrative work. The introduction of courses on interdisciplinarity methodology in several universities is an important development, as these courses provide concepts in and methods for understanding the diversity of ways to produce such knowledge.[17]

16 For example, Utrecht University aimed to ensure that by 2022 every bachelor's student chooses at least two courses outside the field of their own major and every bachelor's student chooses at least one interdisciplinary course. This quantitative approach has now been exchanged for a qualitative approach that, by 2025, makes sure it has been entirely self-evident for students to take interdisciplinary courses as part of their degree programme. In 2018, Utrecht University also organised an 'educational parade' with the theme *Interdisciplinarity: Building Bridges*. At Sorbonne University, bachelor students can choose in their second and third year a minor discipline, outside of the discipline where they graduate, that amounts 42/180 ECTS.

17 For example, the University of Geneva has introduced a course on interdisciplinary methodology in the Bachelor of International relations. The same goes for Utrecht University, which encourages departments offering interdisciplinary courses, minors/tracks and programmes to develop a core module centred around a selected interdisciplinary methodology or that teaches a selection of such methods.

Recommendations

- LERU emphasises the diversity of viewpoints and modes of knowledge production of which students should be aware, which will help prevent future misunderstandings and biases between AHSS and STEM disciplines. Not all courses should be interdisciplinary, but each degree programme should explicitly encourage students to confront the knowledge acquired through courses in different disciplines. These courses should use formative assessment strategies to test the capacities of students to analyse a problem from different disciplinary perspectives.
- LERU further recommends the use of the growing literature on inter- and transdisciplinarity teaching in the design, implementation, and evaluation of interdisciplinary education. It provides a strong foundation to build programmes that are specific to each institution's context yet ensure that best practices are used across those contexts (cf. the reference list at the end of this report).

2.3 Supporting the development of expertise in interdisciplinary education

2016

There are organisational and pedagogical challenges associated with interdisciplinary programmes. LERU recommended "*establishing a committee for interdisciplinary education to elaborate an institutional strategy*" as an important step towards favouring the sharing of experience. It advised "*developing support from pedagogical units to overcome problems in interdisciplinary teaching*" (LERU 2016). Finally, the report underlined the need to "*enhanc[e] the status of interdisciplinary teaching to reward investments in building interdisciplinary courses or curricula*" (LERU 2016).

Some universities have developed specific expertise in interdisciplinary education and teaching. Such in-house expertise is also useful for providing advice on the development of new interdisciplinary curricula. Some offer workshops for teachers that are involved or interested in interdisciplinary education, on topics such as working methods and meaningful assessment in an interdisciplinary context. Good examples include the University of Amsterdam's Institute for Interdisciplinary Studies, Utrecht University's first edition of a teacher professionalisation course on interdisciplinary teaching and learning from all over the university and its medical centre in 2021, and Lund University's Teaching and Learning Conference in 2019 that focused on the overall theme of "Interdisciplinary pedagogy in higher education". In some cases, relevant and accessible literature on interdisciplinary teaching and assessment has also been developed (de Greef, Post et al. 2017, Boor, Gerritsen et al. 2021). These activities show that entities of the university such as interdisciplinary research centres can play a critical role in developing inter- and transdisciplinary educational programmes[18], facilitate the necessary administrative arrangements to host these programmes, and foster new career pathways (see section 5 about careers).

Recommendations

- While many interdisciplinary educational programmes have been launched thanks to initial support from the university or other funding sources, LERU stresses that a priority now is to guarantee the sustainability of these programmes by making those that are successful a core offer of the university. This relates to the appointment of staff with an interest in teaching interdisciplinary courses while maintaining undergraduate teaching capacities regarding the core discipline. Currently this most likely means hiring people who also study, research, or practice inter- or transdisciplinarity (cf. section 5 on career below).
- Further efforts to harmonise regulations across universities can help support the development and sustainability of interdisciplinary educational programmes.
- Finally, LERU recommends that interdisciplinarity is a recognised topic in national funding and accreditation frameworks[19] and that better measurements for assessment of inter- and transdisciplinarity are developed.

18 For example, the 13 Interfaculty Centres at the University of Geneva enrolled around 14% of the students at the university in 2021-2022.
19 While this is a huge task, when submitting to the recent UK research excellence framework, REF 2021, universities had the option to flag research outputs as interdisciplinary.

3 Fostering interdisciplinary research

2016

LERU in 2016 recognised the importance of inter-disciplinary research as a mode of knowledge production. It stressed that a multipronged strategy that involves universities, funding agencies, publishers, and institutions responsible for science policy is needed for inter-disciplinary research to reach its full potential. At the university level, the position paper emphasised the need to 1) support priority ideas, 2) create the next generation of interdisciplinary researchers, and 3) promote a culture of interdisciplinarity. LERU noted an important gap in the evaluation and funding of interdisciplinary research and recommended funding agencies to improve funding and consolidate evaluation. Lastly, LERU recommended improvement in terms of valorisation and publication of interdisciplinary research.

Inter- and transdisciplinary research is high on the research policy agenda and will continue to be for the foreseeable future, owing to both scientific drivers and the need to address societal challenges. LERU notes improvements at both the national and European levels. A growing number of research calls and funding opportunities features inter- and transdisciplinarity. Because of this rapid development of funding opportunities and societal drive toward collaborative research, the entrance costs to inter- and transdisciplinary research are gradually diminishing. This is also matched by a growing interest from researchers in applying for inter- and transdisciplinary research funding. In most LERU member universities, the majority of researchers are aware of or engaged in an interdisciplinary unit.

For interdisciplinary research to advance further, it is key that the research practices of the disciplines involved are considered and aligned where necessary. Especially in research-intensive universities, an important stimulus for interdisciplinary work is the sharing of research infrastructures between disciplines. LERU also recognises that there are still critical gaps concerning the implementation of good practice regarding the evaluation and valorisation of interdisciplinary research, since a substantial part of the research labelled as inter- and transdisciplinary lacks substance (see point 3.3).

Recommendations

- LERU recommends that universities continue to support and invest in both disciplinary and interdisciplinary research as part of the wider transformation of universities. It is impossible to have strong inter-disciplinarity without significant and sustained investment in all disciplines across all career stages. So interdisciplinarity should not be an excuse for not funding a wide range of disciplines.
- In supporting inter- and transdisciplinary research, a fine balance should be found between top-down and bottom-up approaches to interdisciplinarity.[20] LERU vigorously defends academic freedom as the basic principle for the organisation of research. It re-emphasises the fact that academic freedom has been conducive to the tremendous success of research-intensive universities.

Given its fundamental commitment to academic freedom, LERU further identifies three key areas for the development of interdisciplinary research, which are discussed below.

20 David Budtz Pedersen (2016) found in a survey of Danish humanities researchers that most interdisciplinary research was bottom-up, or curiosity-led.

3.1 Activities and institutional arrangements to support inter- and transdisciplinary project collaboration

2016

LERU recognised enduring obstacles to interdisciplinarity and promoted a proactive approach to fostering inter-disciplinarity research. LERU called for the development and implementation of a variety of actions at the project, career, and structural levels to support interdisciplinary research. LERU noted that the kind of actions to be implemented depended on both the specific stage of development of interdisciplinary collaboration and the broader institutional context.

At the project level, a variety of activities and mechanisms have been implemented to support inter- and transdisciplinary collaboration both within and across schools and faculties. For instance, some universities have supported collaboration in what they identify as priority areas. These areas are often linked to global challenges such as sustainability, global health, or migration. Support can also take the form of 'clusters of excellence' i.e., loose network on large thematic/challenges to specific development of interdisciplinary research structures andinitiatives (interdisciplinary research centres are further discussed below). Some of these priority areas have been defined across universities, for instance in European University Alliances.[21] The opportunity of acquiring funding for interdisciplinary projects helps making inter- and transdisciplinarity initiatives more visible. Ultimately, this promotes a culture of inter- and transdisciplinarity, encouraging ongoing discussions within and between units.

A relevant action is to encourage researchers embarking on inter- and transdisciplinary research to organise events on topics that cross disciplinary lines and favour formats that allow for the mixing of diverse researchers. Some LERU members have developed guidance on interdisciplinary research. Some universities support collaborative proposal writing and organise events and training to increase visibility of inter- and transdisciplinarity and build capacity among researchers.[22] Multi-stakeholder initiatives on specific areas can also support the establishment of new inter- or transdisciplinary collaboration.[23] In some cases the networks deal with interdisciplinarity research through a reflexive approach. LERU also recognises that building and maintaining semi-permanent or standing networks across many scientific fields within one university is both time- and resource-consuming.

Recommendations

- Striking a balance between top-down and bottom-up approaches to interdisciplinarity also means supporting specific areas and initiatives while striving for a culture of interdisciplinarity that encourages and supports collaboration at all levels. This in turn reflects the plurality of forms of interdisciplinarity, from interdisciplinarity within a discipline (e.g., Classics or Medicine) or within a school, and interdisciplinarity between the Natural/Life Sciences and Social Sciences/Humanities, and transdisciplinarity with collaboration between stakeholders external to the university.
- LERU strongly believes that all these interactions are crucial but that some forms of collaboration between disparate disciplines, typically between the Natural/Life Sciences and Social Sciences/Humanities, require specific incentives and dedicated efforts.[24]

Table 4. Examples of activities and institutional arrangements to support inter- and transdisciplinary project collaboration at LERU universities

Initiatives to support priority areas regarding inter- and transdisciplinarity research	
University of Amsterdam	Since 2018, the Research Priority Areas at the University of Amsterdam are all interfaculty initiatives, which are identified through an open call for new interfaculty research lines.
University of Copenhagen	As part of the launch of the Green Solution Centre, a university-wide call was launched among all researchers on topics, which led to the identification of 28 topic areas. Some of these areas received seed money to develop more thorough project descriptions.

21 TORCH, the research arm of the CHARM university alliance – which includes three LERU members (the University of Barcelona, Trinity College Dublin, and Utrecht University) – has designated water, food and health as the main global sustainability challenges.
22 For example, the University of Amsterdam's Institute for Interdisciplinary Studies
23 For example, the Cambridge Grand Challenges is a framework for collaboration between industry, government, and academia, designed to help deliver the UK's Industrial and Innovation Strategy.
24 In this context it might be worth reinforcing the need for special efforts to build capacity for AHSS. SHAPE-ID made recommendations to this effect (Section 4.2 of this report), which synthesised findings from the literature review, survey and six stakeholder workshops, and developed a Toolkit of resources to support capacity-building.

	In addition, as part of the 2023-strategy, the university has launched 27 projects where interdisciplinary PhD-students and postdocs are co-funded. All 27 projects use methods and tools from Data Science applied to the domain specific research topic (e.g. from law, history, biology, or cancer research). The funding of younger scientists is part of a larger Data Science initiative, where all UCPH scientists from all departments have access to guidance regarding use of Data Science methods.
Trinity College Dublin	A STEM-driven philanthropic donation was used to catalyse interdisciplinarity research at PhD level (the Kinsella E3 Awards). A funding call was designed to create teams of Principal Investigators representing more than one faculty to co-supervise four to five PhD students in challenge-based research projects. An example is SUMMIT- Sustainable Mobility Models for a Just Transition, which rethinks models of mobility with a view to achieving universal and equitable access to a sustainable transportation system. Using philanthropic support, Trinity College offered The Prendergast Challenge-based Multi-disciplinary Project Awards in 2022. The awards recognise that global challenges are complex and driven by multiple and often overlapping phenomena that are best addressed by exploiting the collaborative expertise of multiple disciplines. This exciting initiative aims to foster innovative cross-disciplinary research inspired by the cluster areas in the EU Horizon Europe's Global Challenges and Industrial Competitiveness pillar.
University of Edinburgh	The University of Edinburgh supports five areas of excellence that sees researchers tackling big questions and forging new paths through innovation.
University of Freiburg	At the University of Freiburg, interdisciplinary research is most visibly conducted at the numerous scientific centers, the clusters of excellence, and the Freiburg Institute for Advanced Studies, among others.
Heidelberg University	Four profile-forming Fields of Focus (FoF) were implemented at Heidelberg University to address the complexity and demanding challenges of a rapidly changing world in the Life Sciences, the Natural Sciences, the Humanities, and the Social and Behavioural Sciences. In order to cross-link its four profile-forming FoFs, the university is building new bridges across disciplinary borders in the Excellence Strategy with two flagship Initiatives. Both address emerging and paradigm-changing research fields of high societal relevance. Engineering Molecular Systems (FI EMS) acts as a pioneer for Nanoscale Engineering, while Transforming Cultural Heritage (FI TCH) will redefine cultural heritage as a result of dynamically changing social and political negotiations. It brings together the disciplinary and region-specific expertise of universities in the research and management of cultural heritage.
University of Helsinki	In recent years, the University of Helsinki has made a significant effort to advance interdisciplinarity via the establishment of new cross-faculty initiatives (research communities) that have the strategic aim of doing high quality multi- and interdisciplinary research. Taking advantage of the national competitive funding available for universities to strengthening their research profiles, the university has strategically chosen to put forward (as profiling areas) initiatives that are highly interdisciplinary, successfully securing €92 million since 2015. As an example, a new profiling initiative named Interdisciplinary Research for Health and Wellbeing (involving seven of the 11 faculties) was launched in 2021, with €9.1 million in funding over the next six years. Furthermore, the university has created an internal competitive process for selecting and funding new interdisciplinary research initiatives and actions.
Leiden University	Leiden University has set up eight university-wide interdisciplinary programmes. They focus on intensifying interdisciplinary collaboration throughout the university and respond to issues affecting the world today and agendas such as the UN Sustainable Development Goals. The programmes will receive funding from the university's Board of Directors for a period of four years. The eight programmes are Society Artificial Intelligence and Life Sciences; Museums, Collections and Society; Social Resilience and Security; Citizenship and Global Transformations; Population Health; Drug Discovery and Development; Regenerative Medicine; Liveable Planet – Sustainable Futures.

KU Leuven	The internal funding scheme for Interdisciplinary Networks (ID-N) at KU Leuven represents interdisciplinary and/or transdisciplinary top research that is challenging and inspiring and that has a high, possibly disruptive novelty value. The project which can fall under either "high risk, high gain" or "high societal impact" is made possible by the unique combination and interaction of knowledge and expertise from various disciplines. The annual budget for this initiative is some €5 million; each year five to eight projects are awarded funding. In addition, KU Leuven and the four other Flemish universities commit resources to funding interuniversity research projects with a strong interdisciplinary angle (the so-called iBOF scheme, €35 million, three-year call).
Lund University	Lund University's Strategic Research Areas 2020-2030 states that the strategic research areas are central to realising the university's vision for understanding, explaining and improving the world. The strategy's goals involve further developing research in the interdisciplinary research areas. There is dedicated university funding for common activities among the Lund University Strategic Research Areas to support implementation of the strategy (about SEK 6.7 million yearly). The university has opened several calls for seed funding of emerging research topics to stimulate collaborative projects among the Lund University Strategic Research Areas.
University of Milan	In 2019, the University of Milan launched an internal call for proposals (SEED) to fund bottom-up, innovative, multi- and interdisciplinary research projects with seed grants. The rules of the €1 million budget call required researchers from different disciplinary areas and departments to team up, with a particular focus on early career researchers (this would ensure that researchers would experiment with the "code" of interdisciplinarity at the beginning of their careers). Of the 151 submitted proposals, 42 were funded. Through a Seal of Excellence (SoE) mechanism, the university funded a further 38 projects.
Université Paris-Saclay	At Paris-Saclay, 20 interdisciplinary programmes were selected in 2021 and 2022 through a call that stressed that projectsshould address strong societal challenges, involve multiple graduate schools, and includeresearch, education and innovation. This was preceded until 2020 by a general call for interdisciplinary PhD positions (30 each year).
Sorbonne University	The SOUND project (Sorbonne University for a New Deal) aims to strengthen the contributions to 3 major societal transitions: One Health, One Earth, One Humanity. It was built bottom-up by the scientific community and is awarded 30 Mio € over 10 years.
University of Zurich	The University of Zurich (UZH) fosters interdisciplinarity in research with various modes of funding. With its University Research Priority Programs (Digital Religions, Dynamics of Healthy Aging, Human Reproduction, and Language and Space, "Equality of Opportunity"), UZH facilitates and fosters excellent interdisciplinary research in areas of strategic importance and high societal impact. These programmes get funding for a 12-year period. In addition, the Executive Board of the University provides financial incentives for new interdisciplinary networks (UZH Competence Centers) and organisational units (TRANSFORM - To Reach a A New Structure For Optimal Research and Methods).
Diffusion of ideas and public engagement initiatives linked to inter- and transdisciplinary research	
KU Leuven	KU Leuven founded the Metaforum in 2008 to make the university's wealth of scientific and scholarly expertise on pressing societal issues available to policymakers and the general public. It publishes debate and position papers on interdisciplinary issues with high societal relevance. Two years ago, a Leuven Institute of Advanced Study was also established in the lap of Metaforum, which attracts international fellows from different disciplines around thematic programmes with a similar aim.
Université Paris-Saclay	The Centre d'Alembert at Université Paris-Saclay organises events open to academics and students on interdisciplinary subjects related to the evolution of ideas, sciences, and technologies.
University of Zurich	The University of Zurich organises "Ringvorlesungen", public lectures for a wide audience that are generally interdisciplinary in nature.

Support and guidance for inter- and transdisciplinary research

University of Edinburgh

The Institute for Academic Development at the University of Edinburgh has developed an online resource guide on interdisciplinary research specifically tailored for early career researchers. The Edinburgh Research Office (ERO) also provides an interdisciplinary research toolkit that includes advice and guidance for those new to interdisciplinary research, support for interdisciplinary academics developing and managing bids, and strategic guidance for research leaders heading interdisciplinary research units. There are also links to successful interdisciplinary applications and case studies of Edinburgh academics who have made a career of interdisciplinary research.

Initiatives targeting young researchers

Leiden University

The Young Academy of Leiden University (YAL) actively promotes interdisciplinarity among early career researchers. YAL initiated the series Seasons of Interdisciplinarity for early career researchers to highlight existing and emerging themes and initiatives with interdisciplinary potential and to foster collaboration. Seasons of Interdisciplinarity offers Interdisciplinary Activity Grants and organises lunches for young faculty to encourage networking and collaborations (see: Young Faculty and Interfaculty Lunches - Leiden University).

3.2 The role of interdisciplinary research centres and other initiatives

2016

The 2016 paper recognised the importance of interfaculty centres *"working on thematic problems with other researchers from a vast array of disciplines."* (LERU 2016) As part of its recommendation to build a flexible organisational environment, it advocated the creation of centres, institutes, or joint laboratories for the most dynamic areas of research and education and promoted a matrix affiliation system where scholars formally participate in interdisciplinary structures while retaining their department affiliation. In general, interdisciplinary research centres are created to address specific issues. They can involve two primary disciplines or several depending on the topic at hand. Acknowledging that their growing importance can be a source of conflict over resources in disciplinary-organised institutions, LERU stressed the need to recognise and value the contribution of schools and departments to interdisciplinary structures for educational and research activities.

Universities have developed and are hosting interdisciplinary research centres in key areas. These centres serve several functions: exchange of ideas, education, collaborative research, and engagement with other stakeholders. Some of them are set up in partnership with other public and private organisations, favouring transdisciplinarity[25].

For several universities, these interdisciplinary research centres are a primary locus of innovation (cf. table 5 below). A few of them are exceptionally large in terms of the number of researchers involved. For example, the Cancer Research UK Cambridge Institute, based at the University of Cambridge, is home to more than 1,100 researchers, drawn from 34 departments, institutes and units across all six schools and affiliated NHS Trust Hospitals.

In the most ambitious form, these interdisciplinary research structures have their own governance mechanism, award doctorates, and can appoint their own academic staff, including at the professorship level. Other inter- and transdisciplinarity research centres are institutionalised to various degrees. Recent years have also seen the emergence of platforms that support interdisciplinary collaboration more generally. Usually, these platforms are intended to support interdisciplinary collaboration in several domains.

Finally, several challenges have also been identified at the management level of interdisciplinary research centres. These include the distribution of research funding, of which schools and departments might retain the overhead received for successful research grant applications, and finding suitable successors for academics with leading roles in such centres.

25 For example, in 2022 Université Paris-Saclay and the Institut Polytechnique de Paris jointly launched the Paris Saclay Cancer Cluster.

Recommendations

- LERU recommends providing inter- and transdisciplinary research centres with sufficient autonomy that allow them to manage their human, financial and administrative resources.
- As researchers frequently have both a faculty affiliation and an affiliation to an interdisciplinary research centre, LERU recommends that, as a general guideline, external research funding is placed in the faculty when the funded project is disciplinary and in the interdisciplinary research centres when the project is interdisciplinary. However, LERU recognises that in some cases this decision may rely on other factors, such as availability of staff in a given unit to provide support for the funded initiative.
- Given the rapid development of inter- and transdisciplinary, it would make sense that interdisciplinary platforms become part of the already established networks and conferences and make use of the toolkits and resources already available.
- LERU recommends that universities further define processes regarding the long-term viability of interdisciplinary research centres (cf. section 5 on career below).

Table 5. Examples of inter- and transdisciplinary research centres/initiatives

University of Amsterdam	Since 2016, the University of Amsterdam's Institute for Advanced Study has been active in developing innovative methodologies for interdisciplinary research and sharing them across the university.
University of Cambridge	In 2010, the University of Cambridge established the programmes Strategic Research Initiatives and Networks and Interdisciplinary Research Centres. These initiatives built on areas of existing research strengths by bringing together a critical mass of expertise from across the six academic schools. These programmes are initiated and developed within the academic community, reviewed in a competitive internal peer review process, and finally approved by the university's Research Policy Committee. The current portfolio includes 12 Interdisciplinary Research Centres, six Strategic Research Initiatives and three Strategic Research Networks in areas as diverse as Language Sciences, Engineering Biology, Reproduction, Conservation and Digital Humanities.
University of Copenhagen	Launched in February 2022, the Crown Princess Mary Center at the University of Copenhagen aims to foster interdisciplinary collaborations between researchers and practitioners to identify and solve societal problems. The centre creates new knowledge in close interaction with organisations in the public sector, businesses, and civil society. The centre is a joint project of four faculties: Humanities, Social Sciences, Theology, and Law. SODAS (Copenhagen Centre for Social Data Science) is an interdisciplinary Social Science centre based at the Faculty of Social Sciences, UCPH, combining the entire range of classic Social Science methods, from econometrics to ethnography, with new Data Science techniques, including machine learning and natural language processing. SODAS aspires to do cutting-edge and creative interdisciplinary research, teaching, and impact at the fertile crossroads between the Social Sciences and Data Science.
Trinity College Dublin	Trinity College Dublin's Faculty and School structures are complemented by several large-scale interdisciplinary research centres, including the Trinity Long Room Hub Arts and Humanities Research Institute, the Biomedical Sciences Institute, and the Institute of Neuroscience, as well as a range of inter-institutional research centres that specifically harness interdisciplinary collaborations to tackle global challenges. These include Trinity Research in Childhood Centre (TRiCC), which covers all aspects of childhood and children's biological, psychological, cognitive, and socio-emotional development and well-being. Trinity Centre for Global Health aims to ensure that every individual has access to quality healthcare. Trinity EngAGE, the Centre for Research in Ageing, provides formal leadership for the coordination of ageing research across disciplines and coordinates the efforts of hundreds of Principal Investigators from around the world.

University of Edinburgh	The University of Edinburgh has formally established pan-university interdisciplinary institutes that coordinate activities in earth sciences, neuroscience, infectious diseases, data sciences, justice, health, food security, etc. These report within one of the 3 Colleges rather than one of the 22 discipline-based schools.
University of Geneva	The University of Geneva hosts 13 interfaculty centres.
Heidelberg University	More than 20 interdisciplinary inter-faculty research centres are part of the scientific framework of Heidelberg University. For example, the Marsilius Kolleg brings together scholars from all disciplines of the university as well as from the surrounding non-university research institutions. The Heidelberg Centre for the Environment (HCE) is a cross-disciplinary institution for environmental research. Based on disciplinary expertise, it connects research competences, e.g., in water research, geo-engineering or in global health research, and puts them into formats that make it possible to translate new knowledge to society. The Interdisciplinary Centre for Scientific Computing (IWR) promotes mathematical and computational methods in Science, Engineering and the Humanities. Currently it comprises more than 50 research teams from various faculties.
University of Helsinki	Four of the recently launched interdisciplinary initiatives have been incorporated into the organisational structure of the University of Helsinki as new joint units (the Helsinki Institute of Life Science, the Helsinki Institute of Sustainability Science, the Helsinki Institute for Social Sciences and Humanities, and the Institute for Atmospheric and Earth System Research), becoming clear referents for the university in terms of interdisciplinary work.
Leiden University	The NIAS-Lorentz programme, set up in 2006 by the Lorentz Center and the Netherlands Centre for Advanced Study in Humanities and Social Sciences (NIAS) and supported by Leiden University, promotes cutting-edge interdisciplinary research that brings together perspectives from the Humanities and/or Social Sciences with the Natural and/or Technological Sciences through fellowships, theme groups, workshops and public lectures. The Leiden Institute for Brain and Cognition (LIBC), and on a smaller scale, the Centre for Dutch Politics and Governance (see: Centrum voor Nederlandse Politiek en Bestuur), offer examples of interdisciplinary centres within Leiden University initiated by researchers affiliated to different faculties and institutes working on related topics. Furthermore, established in partnership with Delft University of Technology and Erasmus University Rotterdam, Leiden University partakes in six interdisciplinary and inter-university LDE Centres and three LDE Programmes. Many of the research institutes at the Faculty of Humanities are interdisciplinary, like the Leiden Institute for Area Studies, in which historians, anthropologists, and linguists work together to better understand Asia and the Near and Middle East, from antiquity to the present time, in a comparative and interdisciplinary perspective. Also, the Leiden University Centre for Arts in Society is dedicated to ground-breaking research that explores the multifaceted relationships between the arts and society.
KU Leuven	At KU Leuven, the newly created interdisciplinary structures – KU Leuven Institutes – are officially included in the university's organisational chart. This is important for their recognition and visibility. It also puts them in a position to develop their own scientific planning, which demands a close collaboration among its different partners. Some of the 15 Institutes have since grown into sizeable interdisciplinary platforms that are the main locus of innovation. For example, the KU Leuven Brain Institute today has 620 researchers from the various disciplines, with, in addition, a strong anchoring from the Flemish Institute of Biotechnology and Imec. The KU Leuven Cancer Institute and the KU Leuven Institute for Artificial Intelligence are also examples of solid structures.
Imperial College London	Imperial College London leads the MedTech SuperConnector programme, which supports ECRs in developing impactful medtech solutions from research from a wide variety of institutions, including the Royal College of Art and Royal College of Music.
University College London	University College London Grand Challenges convenes cross-disciplinary collaborations to explore interconnected solutions to a range of societal issues. UCL Grand Challenges are part of the strategy of UCL. UCL also has an Institute of Advanced Studies.

Lund University	The Pufendorf Institute for Advanced Studies is an interdisciplinary institute at Lund University. Inaugurated in 2009, it is a place where researchers from all faculties at Lund – from Science and Medicine to the Humanities and Arts – are invited to work together.
University of Milan	In 2018, the University of Milan launched four UNITECH technological platforms, which provide high-level technical services and assistance inside and outside the university, and which promote innovation as well as multi- and interdisciplinarity through the cooperation of researchers from different areas.
LMU Munich	There are many cross-disciplinary centres at LMU Munich, for example, the Clusters of Excellence funded through the Excellence Strategy of the Federal Government and the Länder are interdisciplinary to a large extent. Furthermore, LMU hosts a number of Collaborative Research Centers (Sonderforschungsbereiche) funded by the German Research Foundation that are interdisciplinary in nature. LMU's Centre for Advanced Studies supports interdisciplinary initiatives. It is a forum for intensive interdisciplinary academic exchanges which promote cooperation between outstanding researchers from various LMU departments and foster participation of visiting scholars in research and academic life at LMU Munich.
Université Paris-Saclay	Besides its interdisciplinary programmes, Université Paris-Saclay has two long-term interdisciplinary institutes, one on Land use and climate change, and one on Data Science and Artificial Intelligence. Université Paris-Saclay has also launched two interdisciplinary initiatives with specific missions. The Institut Pascal (Ipa) is an international scientific hub, dedicated to the exchange of knowledge and the development of new ideas. The spirit of the IPa initiative is to host programmes of long durations, allowing researchers to devote the necessary time and energy to particularly important challenges. Institut Pascal encourages programmes that dedicate large slots of time to interactions of small to medium-size groups of researchers. The Maison des Sciences de l'Homme Paris-Saclay sustains research in Humanities in their interactions with other disciplines.
Sorbonne University	Multidisciplinary institutes and initiatives created by Sorbonne University Alliance are intended to bring together several disciplines, overcoming the traditional divisions, and thus giving researchers from different backgrounds the opportunity to compare their knowledge and experience.
University of Zurich	The University of Zurich has several Centres of Competence, such as the Centre for Ethics (Medicine, Law, Theology, Philosophy) and the Kompetenzzentrum Zürcher Mediävistik (Philologies, History, Law, Theology, Asian Studies), with an interdisciplinary MA in Medieval Studies. The university is one of three supporting institutions of the Collegium Helveticum, the Institute of Advanced Studies jointly run by ETH Zurich, the University of Zurich and Zurich University of the Arts. The Collegium Helveticum acts as a forum for dialogue among the Humanities, Social Sciences, Physical Sciences, Engineering, Medicine, and the Arts. This transdisciplinary approach makes the Collegium an ideal setting for innovative academic and artistic projects, with a three-way partnership among a university of Science and Technology, a university of the Arts and a full university providing a unique environment unlike any other IAS worldwide.

3.3 Evaluation of interdisciplinary research

2016

The LERU paper noted that an important challenge for the development of interdisciplinary research was to build a system that can evaluate interdisciplinary research both ex ante (before award) and ex post (at the end of an award) for its integrative nature and/or transformative potential rather than its disciplinary one. It noted that evaluation is often a conservative process that discourages interdisciplinary research. The paper recommended that "*continuous efforts need to be made to strengthen different aspects of research policy including funding and evaluation*" (LERU 2016). These recommendations mainly applied to funding agencies, which play a key role in shaping research priorities.

LERU acknowledges that progress has been made in the evaluation of research projects funded by different instruments at the university, national, and international levels. However, there is still work to be done, both within as well as outside universities, to further develop high-quality evaluation of interdisciplinary research. This requires additional effort, training and new measurable criteria compared to a more traditional, mono-discipline evaluation. Especially the degree to which a research proposal is truly interdisciplinary is still often insufficiently evaluated. In addition, the number of reviewers trained in interdisciplinary research remains inadequate. Because criteria to assess integration of disciplinary insights are not used or applied correctly, many funded projects labelled as interdisciplinary are in fact multidisciplinary. Ex post, the outputs of that research (e.g., papers) are not always well assessed in reviewing processes (e.g., reviewers are experts in specific fields and do not fully appreciate the work that has been done).

Recommendations

- LERU recommends that the literature on inter- and transdisciplinary research evaluation is used in evaluation mechanisms regarding ex-ante and post evaluation. This will help ensure that funding is effectively allocated to inter- and transdisciplinary research projects (as recommended by LERU in 2016).
- Better incorporation of good practices regarding the evaluation of interdisciplinary research is needed. A combination of qualitative evaluation with the development of clear and measurable criteria is the most fruitful approach to evaluate inter- and trans-disciplinarity research.[26]

26 For example, the SHAPE-ID project has created and curated significant resources on this subject.

4 Forging career paths for interdisciplinarity

2016

The 2016 paper emphasised that the career path of those engaged in interdisciplinary research raises important issues in a disciplinary-dominated university. It noted that "*LERU has been a strong advocate for the view that a powerful and internationally competitive research base, essential to the present and future vitality of Europe, depends fundamentally on a strong cohort of highly creative researchers, and therefore on Europe's capacity to attract and retain some of the best minds in each generation in attractive research careers (LERU, 2010a)*". As further noted in the literature, an academic career is one of the major issues regarding the implementation of interdisciplinarity in academic institutions that retain an essentially disciplinary structure. In 2016, the LERU position paper on interdisciplinarity recognised the evaluation of academic careers as an important issue in supporting interdisciplinarity.

LERU notes that some universities have been engaged in a reflection regarding inter- and transdisciplinary careers (cf. table 6 for example of initiatives). The development of T-shaped careers, which combine disciplinary depth with diverse perspectives, has been adopted as a solution but comes with challenges such as time pressures. These tensions between developing excellence in a single discipline and in cross-disciplinary working (which requires more time and training in itself) are the most extreme in time-limited systems such as tenure-track. Moreover, there is still a significant gap when it comes to opportunity. Dual appointments are used at several universities, mostly on an ad hoc basis. These dual appointments can be between two faculties or between a faculty and an interdisciplinary research centre. Some universities have noted 'belonging issues' regarding dual appointments. Some LERU members have launched wider university initiatives to foster dual appointment positions. The University of Amsterdam, the University of Geneva, the University of Helsinki, Heidelberg University, KU Leuven, Lund University, and LMU Munich, for instance, frequently open dual positions. In some cases, dual appointments are considered within inter-university alliance. However, there are still limited concrete mechanisms for career development as appointments are primarily done within the disciplines.

Recommendations

- Obstacles associated with an interdisciplinary research career remain an important challenge, with current frameworks insufficiently rewarding inter-disciplinary approaches.
- Universities should advertise some positions as interdisciplinary, planning for how these researchers will be recruited, how interviewers will be trained, how the appointee's teaching will be distributed, and providing clarity on the mechanisms and expectations so the researcher hired does not end up with more work than disciplinary counterparts.
- LERU believes that institutional appointment practices should be flexible to support both academic and academic-related staffing categories for interdisciplinary research.
- LERU emphasises the need for more reflections on the integration of researchers moving between sectors and gaining valuable insights by working with stakeholders to formulate new research questions.
- LERU recognises that evaluating inter- and trans-disciplinary careers requires further effort based on a multidimensional approach. (LERU 2022)

Overall, this will contribute to making interdisciplinary careers less risky than is the case today. The sections below identify the doctorate level, the postdoctoral level, and tenure as key steps in the process.

Table 6. Examples of forging career paths for interdisciplinarity

University of Geneva	The University of Geneva notes that some joint appointments for interdisciplinary profiles are being considered at the biggest centres, such as the Global Studies Institute, with the associated procedure under reflection at the office of the Rector.
Heidelberg University	Since 2007, Heidelberg University has created about 35 bridge professorships.
University of Helsinki	The University of Helsinki has launched dozens of positions over recent years where interdisciplinarity has been prominent both in the title and description of the position, which consequently brings the issue of interdisciplinarity into focus during the evaluation of candidates. Examples of such positions include tenure track positions in e.g. Pharmaceutical Nanotechnology, Ecological Data Science, and Algorithmic Data Science, with a special focus on Humanities and Social Sciences applications. Many such positions are shared between two units, with some dual appointments also established with outside organisations.
Leiden University	Leiden University strives for dual appointments for professors in the context of its alliance with Delft University and Erasmus University Rotterdam.
KU Leuven	A few years ago, the Group of Science and Technology at KU Leuven took the initiative to open more than 10 professor positions that have a dual appointment at two departments. Dual or joint appointments also play an important role today in connecting Biomedical Sciences with Engineering Sciences and Data Sciences in general.
Université Paris-Saclay	An inter-transdisciplinary recruitment process at Université Paris-Saclay is guaranteed by a committee, which is itself inter- transdisciplinary, in order to cover the broad skills of the profile of the competition, which can concern up to 30 candidates. Each year, Université Paris-Saclay offers three to six lecturer or professor jobs defined by at least two major scientific disciplines.

4.1 Doctorate level

2016

The 2016 paper recognised the lack of opportunities of interdisciplinary doctorates as one of the two main bottlenecks regarding career. It noted: "*A first bottleneck is at the doctoral level where there are too few programmes that explicitly value interdisciplinary work. The creation of interdisciplinary doctorates or the reform of existing ones to offer more interdisciplinary exposure is important for developing long-term research capacities*" (LERU 2016). The report further noted that while there were more opportunities and innovations, most of them were accomplished in an ad hoc manner, which may present difficulties for supervisors, evaluators, and, above all, for doctoral researchers.

Some progress has been made regarding the recognition of interdisciplinarity at the doctorate level. Some universities have set up and recognised inter- and transdisciplinary doctorates. However, there is still a need for more consistency between sets of regulations across faculties. At University College London, one set of regulations for all doctorates across faculties is stimulating interdisciplinary PhDs. In some cases, inter- and transdisciplinary doctorates are supported by doctoral schools that explicitly cover inter- and transdisciplinary theories and methods (cf. table 2 for relevant examples). PhD students supervised across different faculties often experience difficulties with both university regulations and 'customary practice'. Navigating these differences is emotionally draining and time-consuming for both students and their supervisors.

Recommendations

Given the persistence of several obstacles, LERU still recommends actively supporting inter- and trans-disciplinary PhDs:

- LERU stresses the need for more consistency between sets of regulations across faculties.
- Quality criteria and clear rules that best suit individual candidates should be developed.
- The development of doctoral schools on inter- and transdisciplinarity can help doctoral candidates understand methodological challenges. The design of doctoral schools can be informed by the integration of the findings of research in this area.
- Given the importance of collaboration for both inter- and transdisciplinary research, LERU believes that research evaluation at the doctoral level should also address the ability to work in groups and accept joint output (e.g., papers) as a form of achievement (and not as something that can be separated into individual contributions).
- Interdisciplinary approaches should be discussed in examiner training sessions, and examiners for inter-disciplinary work should be carefully selected to include those more experienced with or sympathetic to it.

4.2 Institutional affiliation of early career researchers

2016

LERU stated that "*the difficulties associated with an interdisciplinary career path are particularly stringent in the early stages of the research career, with current system for promotion and tenure preventing interdisciplinary researchers to gain recognition*" (LERU 2016). It also emphasised that "*the ideal approach to an interdisciplinary career path may be for researchers to start early on to cultivate both their own discipline and an interest and expertise in inter- and transdisciplinarity*" (LERU 2016). In this regard, LERU recommended "*to identify and support early career interdisciplinary researchers that have potential for developing leadership, for example through fellowship, advice, and mentoring*" (LERU 2016).

The practice regarding employment varies across universities. While universities traditionally employ academic staff through departments, several LERU universities directly employ researchers in interdisciplinary structures, such as interdisciplinary researcher centres. LERU universities note that, increasingly, young researchers pursue a career within interdisciplinary research structures with, in some cases, limited or no affiliation to a disciplinary department. After a few years of research, the profile of these researchers does not fit within the established disciplines. Nonetheless, their work is important within their interdisciplinary research centre and, more importantly, recognised within their field. Careers in interdisciplinary research centres are usually possible at early-stage, but there are often limited opportunities for permanent appointments as a professor. Another problem arises when disciplinary departments and schools have their own centres that span several disciplines.In this case, the primarily disciplinary structure is less likely to hire researchers from a different discipline. For example, an economist working in global health can be an asset for an interdisciplinary research centre on global health. However, s/he has limited chance to be tenured if the institute of global health is situated within a Faculty of Medicine.

Recommendations

- Universities should continue to expand possibilities/ opportunities for young researchers to pursue an interdisciplinary research career based on scientific excellence and their broader contribution to society (LERU 2022).
- LERU recommends that university leadership works with faculties' leadership to create a system that allows its researchers to progress independently from their affiliation.
- As previously noted in the literature, the lack of inter- and transdisciplinary teaching positions is also contributing to the problem. If inter- and trans-disciplinary education were better formalised, such lectureships would provide a tenure route for post-docs (Lyall 2019).

4.3 Appointment and tenure

2016

LERU recognised that "*the second bottleneck is at the tenure level where disciplinary criteria in the faculties/ departments generally penalise interdisciplinary researchers*" (LERU 2016). While noting the enduring view that interdisciplinary research is reserved for tenure-track professors who master their discipline, the 2016 report noted that "*Developing criteria to evaluate performance [of interdisciplinary researchers] that include the impact on society and tailoring research positions for interdisciplinary research are two related avenues that can fundamentally change the story*" (LERU 2016).

In 2022, most LERU universities have limited central policies that facilitate the career of interdisciplinary researchers. Primary appointments are usually done by the faculties or within disciplinary departments. Several LERU universities report that interdisciplinarity is not always considered as a criterion for appointment. Renewal and promotion are also the responsibility of the disciplinary department. As criteria for renewal and promotion are usually disciplinary, this can create tension regarding the level of investment within the interdisciplinary research centre and the disciplinary department. This is especially visible when people work part-time in an interdisciplinary research centre. Appointment within the disciplines remains the main practice, but progress can be noted in a few areas. Some universities consider interdisciplinarity as a criterion within the wider process of recruitment/appointment. For example, Trinity College Dublin has developed guidelines to evaluate interdisciplinary research outputs as part of the promotion/progression procedures. Furthermore, all Dutch universities participate in the national initiative for a new approach to Recognition and Reward in academic scholarships. For Leiden University, this will lead to new quality criteria for assessing interdisciplinary collaboration at the team level and individual level.

It is now generally accepted that the development of research activities within an interdisciplinary context is more challenging and asks for specific skills and efforts than do research activities in traditional monodisciplinary topics. In addition, interdisciplinary careers have a disadvantage when evaluated in light of the impact they have on the scholarly community. Discipline-specific impact is most easily achieved for disciplinary, rather than interdisciplinary, researchers. The interdisciplinary researcher may have had a smaller impact across multiple disciplines (perhaps equal in the total amount of impact), but as a result won't have garnered the same recognition from any one of those communities as someone working exclusively within the discipline.

At the same time, the community of primarily interdisciplinary researchers will likely be smaller (and itself more diverse) than the disciplinary communities. This means the interdisciplinary career has a smaller 'support base' to feedback to the institution that the researcher is making important contributions.

Trying to overcome some of these hurdles, dual appointments have been implemented in several universities. Sometimes dedicated financial means are foreseen by the central administration for this kind of arrangements. In some cases, LERU members also have set up joint appointments between different universities/institutions that collaborate through inter-disciplinary research and education programmes (cf. also table 6 for other relevant examples). Some universities, including KU Leuven, have specific, although limited, financial support for incentivising the development of those positions. A multiplicative effect is the main expected positive outcome of these appointment.

A few universities, like the University of Amsterdam and the University of Geneva, consider appointments within interdisciplinary research centres (cf. section 4 on ID research) and recognise that this topic should be part of a broader discussion about recognition and rewards, which may lead to new policies aimed at interdisciplinary research and education. Some universities, including Trinity College Dublin, have developed strategies for appointment and promotion, while others have relied on guidelines to evaluate progression in the academic career. Finally, some universities have created positions of 'professor of practice' that are key to developing networks between the university and the professional world, bringing topical information and problem-based approaches that are used in teaching and research. This is the case, for instance, in the University of Helsinki. When hiring fulfils a teaching need, the interdisciplinary researcher may be prejudiced if the teaching need is not itself interdisciplinary. Unless teaching programmes are interdisciplinary, disciplinary researchers will likely be favoured.

Recommendations

- LERU underlines that inter- and transdisciplinarity should be a criterion, among others, in the appointment of professors. The importance of this criterion should be based on the position advertised. For positions that are strongly disciplinary, experience in interdisciplinary collaboration is an advantage. By contrast, experience and success in interdisciplinary collaboration should be a central criterion for positions that are strongly inter- and transdisciplinary. The evaluation of this criterion should certainly include authored publications and successful grant applications in inter- and transdisciplinary areas, on the condition that sufficient external funding opportunities are available.
- LERU recommends considering leadership in development of inter- and transdisciplinary research as an important criterion. Such leadership can be expressed in different ways, such as a lead applicant on a collaborative research grant or as a lead or senior author of collaborative work.
- Another criterion that should be considered for evaluation of inter- and transdisciplinary research careers is a proven capacity to work with others, including relevant stakeholders. As in disciplinary research, the added value in the long term and the sustainability/viability of the internal inter- and transdisciplinary collaboration should be considered.
- LERU further recommends using guidelines and other material developed for the evaluation of inter- and transdisciplinary research careers. Research support systems that centralise information about funding and publication output can help evaluators assess whether key performance indicators have been met. Funding and publication metrics, when used, may need to be adjusted to reflect collaborative work (e.g., different roles people play) and diverse outputs of interdisciplinary work (beyond academic publication).

4.4 Dual appointment and the issue of double academic/administrative load

2016

The 2016 paper stated: "*LERU however recognise that often interdisciplinary researchers face a double load of teaching, administrative and committee duties, particularly when reporting lines are unclear. This situation may result in considerably decreased time available for research*" (LERU 2016). LERU further acknowledges that due to "*current financial and administrative systems in place, shared positions do entail an additional administrative burden with university administrators often trying to discourage such shared arrangements*" (LERU 2016).

It is clear from the section above that dual appointments are becoming more common in academia. For example, Leiden University has a longstanding practice of joint professorial appointments, including Medical Delta professors bridging Technology and Medical Sciences. Also in its new strategic plan (2022-2027) 'Innovating and Connecting' the university announces that, as part of the strategic ambition on Pioneering interdisciplinary research and teaching, it will explore the possibilities for academic staff to work in multiple institutes or faculties with a view to further integrating interdisciplinarity within the organisation. This may lead in the future to more interdisciplinary remit for vacant professorial positions.

The increase of dual appointments reinforces an academic culture where scholars must be both excellent in a discipline and excellent in inter- and transdisciplinarity, which creates some important challenges, like the time pressure mentioned in point 4. The literature has reported on other difficulties arising from double administrative and teaching loads and expectations. Some universities have sought to address these double loads by providing mechanisms for alleviating the burden associated with an interdisciplinary career. For example, some schools at Trinity College Dublin provide teaching relief or sabbatical leave to researchers participating in large interdisciplinary research projects or proposals. The University of Amsterdam has set up a policy to try to minimise the hurdles that can be present when working across faculties, consisting of: i) collecting and sharing best practices in interfaculty collaborations, and ii) actively collecting those hurdles and how they have been overcome.

Recommendations

- While many dual appointments were recently created, there is a current knowledge gap regarding the challenges associated with dual appointments. To address this gap, reflections on the topic are needed. These should include an in-depth assessment of the issues faced by those in a dual appointment position.
- LERU further suggests finding flexible way to alleviate double administrative/teaching load. This may include recognising a primary affiliation and a secondary affiliation.
- Dual appointments are possible but not necessarily the best way to advance inter-and transdisciplinarity. LERU recommends that some positions should be labelled as interdisciplinary and located in the university structure that is the most relevant for the topic.
- In general, universities should strive to ensure the continuity of appointment and the rights of freedom of research, independently from any structures.

5 Governing interdisciplinarity in disciplinary-based institutions

2016

LERU identified university governance as a key area for improving support for interdisciplinarity. It noted that university leadership with the support of researchers at all career levels can drive change in the academic system. Building a culture of interdisciplinarity requires investment in different areas of the university.

In most cases university governance recognises the importance of interdisciplinarity and their role in supporting interdisciplinary research. Initiatives or actions implemented by university leadership to promote the wider institutionalisation of interdisciplinarity have sometimes generated tensions as the disciplines strive to preserve control over career paths and resources. Dealing with this requires leadership and long-term commitment. Managing a university as a complex network of interactions between disciplines requires fostering adaptation and agility and thus addressing the lack of flexibility of the current academic system organised along disciplines.

Recommendations

- The vision of science as a complex and self-organising network of scholars, projects and ideas should guide actions implemented by universities.
- Universities should strive to become more flexible and adaptive structures, enabling researchers to be less connected to a specific department, institute, or centre, while providing a supportive environment to their academic and administrative staff.
- Based on the core idea of academic freedom, universities should privilege incentives over regulations when it comes to influencing the directions of research within their institutions.

5.1 Interdisciplinarity in the governing structure of the university

2016

LERU recommended that universities incorporate inter-disciplinarity in their governing structures and suggested several ways forward, from setting up a reflection group or task force within the Rector's office to supporting inter-disciplinary research at the institutional research policy level. Furthermore, LERU identified the following actions: "*1) Entrust the Vice-Rectors for Research and/or Education with the responsibility to move interdisciplinarity forward. While creating a Vice-Rector position for interdisciplinary research is one option, LERU believes that interdisciplinarity should rather be part of the core business of Vice-Rectors for Research or Education; 2) Fill the main positions with senior and/or leading academics with strong experience in interdisciplinary research and an awareness of the institutional obstacles associated with interdisciplinary practice; 3) Set up an advisory committee composed of successful interdisciplinary researchers, for example, to identify local institutional barriers, suggest relevant activities according to local context, review proposals and monitor projects*" (LERU 2016).

A large variety of practice exists regarding the place of interdisciplinarity within university leadership. At an early stage, a taskforce might help raise awareness of the importance of inter- and transdisciplinarity and make key recommendations to move it forward. To further embed inter- and transdisciplinary in university governance, some universities have created specific leadership positions for inter- and transdisciplinarity. Further, some universities have created specific mechanisms to manage priority areas. At an operational level, some universities are promoting new roles, such as an 'integration expert', who leads, administers, manages, monitors, assesses, accompanies, and/or advises others on integration within [inter- and transdisciplinary] projects or programmes (Hoffmann, Deutsch et al. 2022). These positions have been useful for the allocation of specific responsibilities and the follow-up of different projects. In most cases, the responsibility for interdisciplinarity has laid with the Vice-Rector for research or the Vice-Rector for education.

Given the broad responsibilities associated with those positions, LERU notes that progress is more likely when these positions are filled with people championing interdisciplinarity.[27] Overall, this underlines the importance of leadership for cultivating inter- and transdisciplinarity when it comes to implementing the university's vision.

Recommendations

- In terms of governance, representation of inter- and transdisciplinarity in the decision-making bodies of the university is also a critical issue. For example, section 2.1 of this report recommended further defining objectives regarding inter- and transdisciplinarity in the university strategy. For these objectives to be effective, inter- and transdisciplinarity centres should be represented in main university bodies, which usually gather the Deans of the faculties and the Rector's office. This would create better visibility for cross faculty interdisciplinarity.
- LERU also recommends the explicit inclusion of interdisciplinarity within the university administration.[28] The identification of proper lines of responsibility, the adoption of measurable objectives and targets, and the allocation of specific funding are the main ingredients to creating a strong mandate for interdisciplinarity. Given the self-organising nature of research, it is vital to create incentives and support for researchers to engage in interdisciplinary research and teaching. For instance, research project and programme officers may help with interdisciplinary funding applications or integration experts to lead projects and initiatives requiring integration. Knowledge transfer experts, public policy, and public engagement officers can also strengthen capacities in transdisciplinary projects. LERU believe that investments in personnel and human capacity can underpin the leadership commitment.

Table 7. Examples of interdisciplinarity in the governing structure of the university

University of Geneva	The University of Geneva created a Director of interdisciplinarity at the Rectors' office, who is leading the discussion about the place and role of interdisciplinary research centres within the university. In 2020 a mapping of the 13 Interfaculty Centres was done (teaching, research, link with the city, administrative, and main difficulties faced).
Heidelberg University	At Heidelberg University, four Fields of Focus (FoF) are the key instruments that define and advance the university's research profile (see also table 3). Each FoF is coordinated by a Research Council (RC), composed of university members and extra-university research partners. Central tasks of the RCs are to identify emerging research areas, to combine complementary expertise to address new research topics, to trigger innovative projects with seed money, to initiate applications responding to calls of various funding agencies, and to monitor the decision-making and evaluation processes for young researchers' careers. Moreover, the RCs plan the establishment, evaluation and potential discontinuation of joint research infrastructures and advise the Rectorate in all questions of research.
Utrecht University	In 2021, Utrecht University created the position of a university-wide Dean for interdisciplinary education who aims to improve the recognition of interdisciplinary teaching both in terms of reward systems and in pragmatic terms (staffing, finances, logistics) during a four-year term.
Université Paris-Saclay	Since 2020, Université Paris-Saclay has appointed a Vice-President for interdisciplinary education programmes and a Vice-President for Art-Culture-Science-Society relationships.
Sorbonne University	The Vice-President for Arts, Science, Culture and Society is responsible for the University's policy of openness and commitment to the community. He works to bring together the Arts, Sciences and Humanities.

27 For example, on the 447th Dies Natalis of Leiden University in 2022, interdisciplinarity was the central theme of the address by Rector Magnificus Professor Hester Bijl. On the same occasion both Dies lectures, by Professor Matthias Barz and Professor Meta Roestenberg, offered inspiring examples to the whole academic community of the value of bridging disciplinary boundaries in research.

28 New roles have been created across the Trinity College Dublin e.g., interdisciplinary-focused research programme officers in Trinity Research and Innovation. At Université Paris-Saclay, a direction has been created to help creating transdisciplinary actions between academics and the society.

5.2 Financing and distribution of funding and resources

2016

LERU recommended to "*secure an institutional budgetary line to support interdisciplinary research and education within the university with transparent rules for the allocation of resources*" (LERU 2016). It further recommended to "*Ensure that adequate management and administrative staff are provided to key areas regarding the coordination between different departments and schools of the university as interdisciplinarity requires strong support at the administrative level. This also entails properly rewarding people who support interdisciplinary collaboration as they are critical to success*;" (LERU 2016). In parallel, the 2016 paper stressed "*the need for recognis[ing] and valu[ing] the contribution of schools and departments to inter-disciplinary structures for educational and research activities" noting that contributions are usually poorly accounted for*" (LERU 2016).

Interdisciplinarity poses key challenges to the distribution of resources and decision-making power in universities. Interdisciplinary research centres are often not represented in the decision-making mechanism of the university, contrary to the discipline-oriented structures. In addition, most funding was or is traditionally assigned to the disciplines via their schools, faculties or departments. The allocation of resources to interdisciplinary programmes, centres or staff often leads to a reduction of the budget of the disciplines involved, which is, in most cases, met with little enthousiasm. Also, the allocation of resources resulting from successful grant applications can be challenging. LERU notes that the incentives structures of the university make researchers more likely to associate their research projects with their faculty than in an interdisciplinary research centre. As some centres grow in importance and develop their own educational programmes, they want to adopt their own policies regarding research and education. This can be another source of tension with the disciplines. Finally, a core element for the governance of interdisciplinarity is the allocation of proper physical resources. The importance of shared research infrastructures was already highlighted above (point 3), but also more generally, buildings can play a facilitating role in creating an inclusive and lively environment.

Recommendations

- LERU recommends that large scale interdisciplinary research centres are given sufficient autonomy when it comes to the adoption of their own policy regarding research.
- Resources need to be distributed fairly. Overhead coming from successful grant applications should be placed where the project makes most sense to be located.
- LERU recommends using an approach that includes a reflection on the architecture and design of buildings that may favour inter- and transdisciplinary research.

Table 8. Examples of financing and fair distribution of funding and resources

Trinity College Dublin	Trinity College Dublin launched the E3 learning foundry, an €80m project that has a capital element (7,000m^2 new on-site building) and a human element (staff/student growth strategy that involves the integration of financial and student targets within three STEM schools: Engineering, Natural Sciences and Computer Science). Both the building design and teaching concepts centre around multi-disciplinary teaching across these schools.
Leiden University	Leiden University is developing a building in the heart of The Hague's city centre. Many of the university's new interdisciplinary educational programmes (see table 2) will be offered here. Synergy and collaboration between disciplines and with other universities will be further stimulated as spaces within the building are let to partner universities. Leiden University also supports the continuous development of, and investments in, the Leiden Bio Science Park, where education, research, care, and business are clustered, stimulating inter- and transdisciplinary research and education in Life Sciences and health.
University of Milan	The University of Milan is currently building a new campus within the Milan Innovation District. The project of the Science for Citizens Science campus will allow researchers and students to work in more functional, innovative, and attractive premises within an ecosystem open to innovation, international collaboration and synergy between different areas.
Université Paris-Saclay	Institut Pascal at Université Paris-Saclay has its own building dedicated to international mi-duration meetings mainly on interdisciplinary topics.
Sorbonne University	Sorbonne University was awarded two multiannual grants NLSU and REAL@SU within the call of the French government PIA3 (Future Investments Programme #3) that include both an important budget to finance interdisciplinary research and education. They are targeted to bachelor, master and doctorate levels.

5.3 Collaboration with other stakeholders

2016

The 2016 paper emphasised the need for collaboration between science policy stakeholders when it comes to promoting and supporting inter- and transdisciplinary research. It recognised the importance of funding agencies and publishers to address some of the most pervasive obstacles to inter- and transdisciplinary research. The position paper identified several recommendations to strengthen evaluation of research proposals and provide more opportunities for publishing inter- and trans-disciplinary research output.

Given the challenges of mobilising existing funding for inter- and transdisciplinary activities, additional fundraising activities can play a key role in establishing interdisciplinary collaboration. At the project level, funding mechanisms can facilitate what would otherwise be very difficult to achieve in both research and education. Large endowments by private foundations and other stakeholders can support the creation of new structures working across disciplines and schools. Some universities have worked directly with public and private funding agencies to remove barriers, encourage wider participation in knowledge transfer, and amplify the potential for long-term impact. In addition to several programmes from the EU's Framework Programme for Research and Innovation, today the national funding agencies of most LERU members offer some funding for interdisciplinary research.

Recommendations

- LERU recommends that universities work with partners to create mechanisms that encourage inter- and transdisciplinarity. Those mechanisms should incorporate clear criteria for the evaluation of inter and transdisciplinary research and should be as transparent as possible regarding the criteria that will be used to assess academic excellence.
- LERU advises using the growing literature on trans-disciplinarity and co-production to facilitate interactions between different stakeholders in the production of new knowledge.

Table 9. Examples of collaboration with other stakeholders

University of Copenhagen	The University of Copenhagen takes part in the Strategic Sector Cooperation initiative where Danish public authorities cooperate with counterpart authorities in a number of emerging economies and high-income countries, achieving sustainable development around the world and generating value for Denmark and Danish companies.
Trinity College Dublin	In interdisciplinary education, the national government of Ireland, through its Higher Education Academy, launched a challenge-based, transdisciplinary funding call to which the Trinity College Dublin applied. This provides resources to deliver several new courses and new transdisciplinary challenge-based offerings e.g., M.Sc. in Sustainable Cities, postgraduate diploma in Sustainable Development for Business, postgraduate diploma in Engineering for Climate Action. These are targeted at different markets e.g., professional up-skilling, graduate training, micro-credentialling.
University of Edinburgh	The Edinburgh Futures Institute at the University of Edinburgh, which will open in 2023, has had an investment of £140m.
University of Helsinki	Thanks to a major research funding initiative from a private foundation, a new multidisciplinary research centre for coastal ecosystem and climate research is being established at the University of Helsinki. The centre brings together, for the first time in the Baltic Sea region, expertise in the fields of marine ecology, biogeochemistry and atmospheric research in order to develop more integrated knowledge about how different marine processes and the Baltic Sea coastal environments interact with atmospheric processes, and what this means for the climate.
Imperial College London	The Forum at Imperial College London is an example of collaboration between science policy stakeholders and researchers.

5.4 Evaluation of performance

2016

The 2016 position paper on interdisciplinarity recognised the importance of evaluation in the context of inter-disciplinarity. Emphasis was placed on the evaluation of research projects and careers (as discussed in the respective sections above). The proactive approach taken by LERU also emphasises the need for proper evaluation of the commitment and impact of different actions implemented at the university level.

Several universities recognise that interdisciplinarity should not only be evaluated at the level of the university but also in all schools and other types of structures, such as interdisciplinary research centres. In some universities, inter- and transdisciplinary initiatives are given freedom to develop their own vision and strategies and report periodically to the most senior university bodies.[29] Some universities have developed quantitative evaluation of interdisciplinarity. LERU notes that despite this progress, few specific mechanisms have been implemented (cf. table 10 for examples). In other words, interdisciplinarity is dominantly evaluated within wider mechanisms for evaluation of universities performance. It remains challenging to find appropriate metrics for the evaluation of interdisciplinarity. An obstacle remaining in this regard is the challenge of properly defining and assessing (within and across institutions) when a publication (or a project) can be considered inter- and transdisciplinary. Evaluation of progress is usually assessed by success in national and international competitions.

Recommendations

- LERU stresses the need for proper evaluation of inter- and transdisciplinarity. Evaluation is a way to raise the quality of inter- and transdisciplinary contributions but also to ensure equity in important processes within the university. Evaluation is also the basis for improvements and adaptation in a rapidly changing environment.
- LERU recommends that evaluation of inter-disciplinarity become better integrated within the universities. Evaluation should be conducted under the lead of the entity devoted to inter- and transdisciplinarity at university leadership or by the Vice-Rector research and the Vice-Rector education, depending on how the governance of inter- and transdisciplinarity is organised.
- A priority should be to develop metrics of inter-disciplinarity within the broader framework for quality evaluation. Bibliometric analysis provides a strong foundation for the evaluation of inter- and trans-disciplinary research (Leydesdorff and Ivanova 2021).

29 This is the case at the University of Cambridge for example.

Table 10. Examples of evaluation of performance

University of Amsterdam	The University of Amsterdam conducts an annual analysis of research output (articles) with authors from two or more faculties (plus authors from other universities) to monitor progress regarding interdisciplinary collaborations within the university.
University of Edinburgh	The Edinburgh Research Office at the University of Edinburgh provides an interdisciplinary research strategy paper as a key example of quantitative evaluation of interdisciplinary connections. It provides a baseline and a mechanism for tracking interdisciplinary funding and research outputs at university, college and school levels.
Leiden University	Leiden University is currently engaged in a self-evaluation of its eight university-wide interdisciplinary programmes. The programmes are asked to reflect on: The original ambitions regarding its interdisciplinary contribution to science, the collaboration in and between faculties and disciplines, as well as with external public and private partners; the resulting networks, consortia, joint publications and joint doctoral trajectories; its connection to subsidy- and research programmes at national and European level and possibilities for acquisition of funding for both large-scale projects and young talent; demonstrable impact on education and on society. Furthermore, the programmes are asked to present their results, including activities undertaken, the results achieved, the programme's (inter)national standing, and a reflection on factors stimulating or hindering the interdisciplinary programmes's success.
KU Leuven	KU Leuven plans to evaluate the newly established KU Leuven Institutes and the ongoing ID-N-projects to provide a realistic indication of the level of interdisciplinarity as well as the remaining obstacles.
Lund University	The major research quality evaluation at Lund University praised the university's success in attracting external funding for interdisciplinary research areas, but at the same time pointed out that there is potential to further enhance interdisciplinary research and make better use of the combination of strong faculties and the strong research areas at Lund University. The university-wide Research Board has an action point in its business plan to develop indicators to follow research at Lund University, including the use of quantitative measures and taking advantage of the Lund University Current Research Information System.

Conclusion

This paper focusing on the implementation of the 2016 LERU position paper on interdisciplinarity demonstrates that the members of LERU have been active regarding the implementation of the vision of a virtuous circle between disciplinarity and interdisciplinarity as a fundamental condition for the progression of knowledge. LERU reiterates its stance that for comprehensive research-intensive universities to be more than the sum of their parts, it is essential to cultivate both disciplinarity and interdisciplinarity, within a scientific culture of excellence. A core conclusion of this report is that there is no single way to organise and facilitate inter- and transdisciplinarity.

The place of inter- and transdisciplinary within the core mandate of universities has increased. Few people will dispute that inter- and transdisciplinary are important modes of knowledge production. And many will agree that fostering inter- and transdisciplinarity is a key part of the transformation of our knowledge system that will in turn support the transformation to sustainability. Yet interdisciplinarity is not always readily accepted and accommodated by a knowledge system organised around delimited disciplines. Many obstacles remain regarding the implementation of interdisciplinary education and research in predominantly disciplinary-based institutions.

Good progress has been made in education where the offering of new programmes reflects a strong demand from students. However, a gap exists between programme ambitions and the inter- and transdisciplinary knowledge and skills of people involved in teaching and managing these programmes. This means many programmes are multidisciplinary rather than inter- and transdisciplinary, as there is limited space devoted to the integration of knowledge from different disciplines and stakeholders. Good progress can also be noted in terms of inter- and transdisciplinary research. Encouragement of collaboration in thematic areas has led to the establishment of some successful research programmes supported by an increasing number of funding opportunities. Interdisciplinary and transdisciplinary research continue to grow.

This paper focused on how universities can advance interdisciplinarity but there are other stakeholders that can play an important facilitating or hindering role in this development, for instance, research funders, degree-regulating bodies or quality assurance agencies. Many of the challenges universities are still facing in relation to strengthening interdisciplinarity are also challenges for the funders and agencies with which they work.

LERU noted more limited progress in the key issue of career and evaluation of research where there is fierce competition for resources. There is currently a discrepancy between the discourse and the implementation. A very important challenge is the appointment/tenure of successful scholars who pursued a predominantly inter- and transdisciplinary research career. These scholars are usually less central to any single discipline. Given the control of appointment and tenure by disciplinary structures in many universities, these scholars are faced with disproportionate obstacles that in turn impede the advancement of inter- and transdisciplinarity as valuable modes of knowledge creation.

The embedding and institutionalisation of inter- and trans-disciplinarity remain an important challenge in universities primarily organised along disciplinary lines. LERU recognises that institutionalisation can take different forms as there are large contextual differences. While many universities have implemented limited actions, some universities use an upfront and proactive strategy that is generally championed by an academic with a leadership position in collaboration with people at different levels of their academic career. LERU sees the usefulness of implementation of different action within a broader reflection to institutionalisation of inter- and transdisciplinarity. This entails discussion about the distribution of money and positions.

Finally, the limited use of the growing literature on inter- and transdisciplinarity is still a major issue. This literature, some of which has been referenced in this report, can guide an evidence-based approach to the implementation of interdisciplinary. It is critical to make universities aware of and encourage them to use guidelines and other forms of evidence to implement an evidence-based policy.

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About LERU

The League of European Research Universities (LERU) is an association of twenty-three leading research-intensive universities that share the values of high-quality teaching within an environment of internationally competitive research.

Founded in 2002, LERU advocates:

- education through an awareness of the frontiers of human understanding;
- the creation of new knowledge through basic research, which is the ultimate source of innovation in society;
- and the promotion of research across a broad front in partnership with industry and society at large.

The purpose of the League is to advocate these values, to influence policy in Europe and to develop best practice through mutual exchange of experience.

Facts and figures

- Collectively LERU universities represent more than **750,000 students**
- Each year about **16,000 doctoral degrees** are awarded at LERU universities
- Across the LERU members there are an estimated **1200 start-up and spin-out** companies across Europe
- In 2016 the LERU universities received **1.1 billion euro** in contract and collaborative research income
- LERU universities contribute approximately **1.3 million jobs** and **99.8 billion Gross Value Added** to the European economy
- On average more than **20% of ERC grants** are awarded to researchers at LERU universities
- Over **230 Nobel Prize** and **Field Medal winners** have studied or worked at LERU universities
- **Hundreds of LERU university members** are active in more than **30 LERU groups** to help shape EU research and innovation policies and exchange best practices


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