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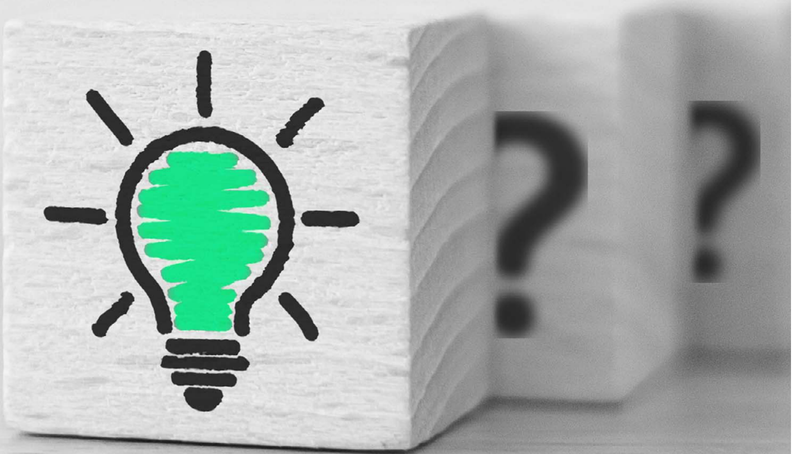

KNE INSIGHTS
TRAINING & CONSULTING

INTERDISCIPLINARY AND TRANSDISCIPLINARY HIGHER EDUCATION & RESEARCH

TRANSFORM KNOWLEDGE INTO WISDOM: STRENGTHEN ACADEMIC & RESEARCH EXCELLENCE

The *KnE Insights* series explores theories, methods, concepts, and implementation strategies that illuminate new approaches to achieving academic and research excellence.

These insights are based on Knowledge E's international expertise and experience supporting researchers, educators, universities, and governments in advancing their abilities to compete and thrive in the global knowledge economy.

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INTERDISCIPLINARY AND TRANSDISCIPLINARY HIGHER EDUCATION & RESEARCH

Skills and Mindsets for Developing Knowledge Economies and Achieving Sustainable Development Goals

Developing strong **knowledge economies** and achieving **sustainable development goals** (SDGs) are the most urgent priorities of many countries in the second decade of the 21st century.

Global competitiveness in the information age is essential to **prosperity**, but only if it can be achieved **sustainably** and **equitably** for individuals, societies, and the natural environment that supports them.

These are **complex challenges** with many interconnected opportunities and problems that involve all sectors of society and build on virtually all human and scientific disciplines of knowledge.

Strategies addressing these priorities require mindsets and skills for integrating scientific knowledge from different disciplines (**interdisciplinary**) with practical, political, and local society knowledge (**transdisciplinary**).

The National Academies of Science 2005 report, "Facilitating interdisciplinary research", identifies four **major drivers of interdisciplinary research**: complexity of nature & society, research problems at the interface of disciplines, the need to solve societal problems, and the changes caused by innovative technology (see facing page).

DRIVERS OF INTERDISCIPLINARY RESEARCH

Excerpts from "Facilitating interdisciplinary research", National Academies of Science, 2005

In 2003, the National Academies of Science established the Committee on Facilitating Interdisciplinary Research, whose members were drawn from government, academe, and industry. The committee was charged with developing findings, conclusions, and recommendations regarding the current state of interdisciplinary research and the factors that encourage (or discourage) it in academic, industry, and federal laboratory settings. The 2005 report from the committee identified four drivers of interdisciplinary research.

The inherent complexity of nature and society

"It is not possible to study the earth's climate, for example, without considering the oceans, rivers, sea ice, atmospheric constituents, solar radiation, transport processes, land use, land-cover, and other anthropogenic practices and the feedback mechanisms that link this "system of subsystems" across scales of space and time. ... If science and engineering deal with extremely complex systems, the same is true for studies of human society. How human societies evolve, make decisions, interact, and solve problems are all matters that call for diverse insights ... [which require] collaboration across the natural sciences, social sciences, and humanities."

The stimulus of generative technology

"Generative technologies are those whose novelty and power not only find applications of great value but also have the capacity to transform existing disciplines and generate new ones."

The drive to explore basic research problems at the interface of disciplines

"Some of the most interesting scientific questions are found at the interfaces between disciplines and in the white spaces on organizational charts. Exploring such interfaces and interstices leads investigators beyond their own disciplines to invite the participation of researchers in adjacent or complementary fields."

The need to solve societal problems

"Human society depends more than ever on sound science for sound decision making. The fabric of modern life—its food, water, security, jobs, energy, and transportation—is held together largely by techniques and tools of science and technology. But the application of technologies to enhance the quality of life can itself create problems that require technological solutions."

National Academies (U.S.)., Committee on Science, Engineering, and Public Policy (U.S.), National Academy of Sciences (U.S.), National Academy of Engineering., & Institute of Medicine (U.S.). (2005). Facilitating interdisciplinary research. Washington, D.C: The National Academies Press. Available from: https://www.nap.edu/catalog/11153/facilitating-interdisciplinary-research

Higher education and research institutions are key contributors to the evidence-based public policy and innovation-driven economic development at the heart of knowledge economies and sustainable development. In many countries, universities are the largest providers of the skilled workforce and the research & development needed for both economic growth and healthy governance.

In recent decades, top universities and research institutions around the world have been dedicating more resources to building interdisciplinary and transdisciplinary (ITD) competency in **faculty, researchers, students, and institutional leadership**.

Building ITD competency involves innovative approaches to research and educational design. It also involves visionary leadership to reform university infrastructure that has been historically organised by disciplines.

"The potential power of IDR [interdisciplinary research] to produce novel and even revolutionary insights is generally accepted. Ultimately, however, the value of IDR to the scientific enterprise depends on the extent to which individual researchers are free to engage in it. **IDR must be not only possible but also attractive for students, postdoctoral fellows, and faculty members**." (NAS, 2005, p. 39) [emphasis added]

This issue of *KnE Insights* introduces fundamental ITD concepts and describes key elements of building local and national **ITD competency** through higher education and research institutions.

DRIVERS OF 21ST CENTURY SOCIETIES

Developing Knowledge Economies and Achieving Sustainable Development Goals

Transformations in technology and the increasing global prioritisation of sustainability over the past 50 years have shifted the focus of advanced and developing countries alike.

KNOWLEDGE ECONOMIES

Technology development, especially computing, has shifted the primary "resources" of economic growth from natural resources to data, information, and knowledge. This transformation is often referred to as a new era or "age" in human history: the Information Age. The increased focus on leveraging intellectual capital for industry and governance innovations has led to the birth of "knowledge economies".

There are many components that contribute to the development of a successful knowledge economy. The Global Knowledge Index (GKI) tracks the knowledge performance of countries in seven areas to enable a more scientific and evidence-based exploration of knowledge policies related to different sectors and to highlight the linkage between development and knowledge. Since 2017, the GKI reports annually on seven performance measures that guide assessment of the general enabling environment for a knowledge economy:

1. Pre-university education,
2. Technical and vocational education and training,
3. Higher education,
4. Research,
5. Development and innovation,
6. Information and communications technology, and
7. The economy.

The diversity of these measures and their interconnections indicate the complexity of developing successful knowledge economies.

SUSTAINABLE DEVELOPMENT GOALS

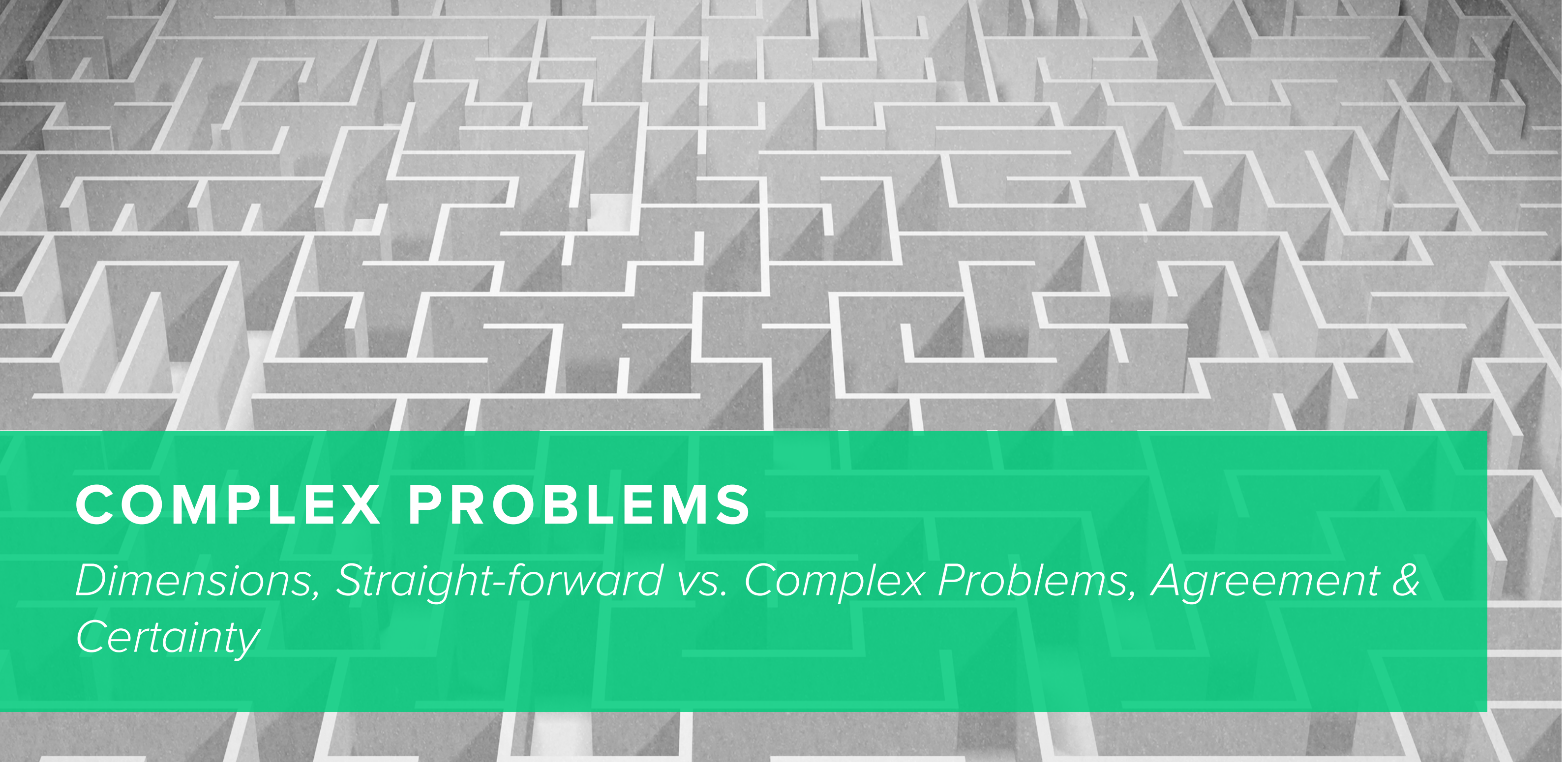
As the global knowledge economy was overtaking the "industrial" economy as the driver of prosperity and development, concerns were also growing about how to ensure that development is sustainable – conducted in conditions where economic and social improvements do not undermine the integrity and stability of the natural environment and resources upon which societies depend.

Formal global attention to sustainable development can be traced back to the 1972 UN Conference on the Human Environment. The principles and goals discussed at that conference have been revisited and updated roughly every ten years, mostly recently reflected in the 2030 Agenda for Sustainable Development of 2015, which outlines 17 Sustainable Development Goals (SDGs). The SDGs, which many countries have used to develop customised development plans, "recognize that ending poverty and other deprivations must go hand-in-hand with strategies that improve health and education, reduce inequality, and spur economic growth – all while tackling climate change and working to preserve our oceans and forests." (SDGs, United Nations)

The SDGs and the goals of building strong knowledge economies cannot be achieved in isolation. The goals all connect with each other. The individual opportunities and problems of each goal are deeply interdependent – changes in one area affect others. To design and implement strategies for addressing these challenges it is important to understand what makes a problem or goal complex.

DISCOVER MORE

- Global Knowledge Index 2020, United Nations Development Program: https://www.undp.org/publications/global-knowledge-index-2020
- Sustainable Development Goals (SDGs), Department of Economic and Social Affairs, United Nations: https://sdgs.un.org/goals
- See also Resources & Communities below.



COMPLEX PROBLEMS

Dimensions, Straight-forward vs. Complex Problems, Agreement & Certainty

Some problems are straight-forward, even if they may be complicated. Developing a vaccine for a virus, for example, is a complicated but basically straight-forward problem. There are relatively clear laws of biomedicine that direct the process, and development proceeds in linear steps until reaching a successful result. The problem of a pandemic, however, is complex. There are many interconnected and diverse social, economic, and environmental problems that are constantly shifting and “co-evolving” in non-linear ways with often unpredictable effects. These interconnected problems require much more comprehensive approaches that consider all relevant knowledge and can usually only focus on strategies and tactics for reducing the scope or severity of the problems over time rather than finding a complete and permanent “solution”.

DIMENSIONS OF COMPLEXITY

Identifying the type of a problem is a critical first step in addressing it. A useful way of distinguishing straight-forward (simple or complicated) from complex problems is to explore them by asking questions in five dimensions: definitions, boundaries, context, unknowns, and solutions.

DIMENSION	SAMPLE QUESTIONS	SAMPLE STRATEGIES *(easy for simple problems, hard for complex problems)*
DEFINITIONS	Is the problem easy to define? Does everyone agree on what the problem is?	Problem framing
BOUNDARIES	Is it clear what is part of the problem and what is not?	Boundary setting
CONTEXT	Does context matter? Do any of the following domains affect what the boundaries of the problem are, what research is needed, what solutions are possible? Can changes in a domain enable or constrain research, deliberation, or the implementation of solutions? • Time • Location • Public policy, industry • Politics (local, national, global) • Current events • Stakeholders (people affected by problem or decision makers) • Financial resources	Stakeholder engagement
UNKNOWNS	Will the problem remain predictable? Are all the relevant facts and context known or knowable?	Managing unknowns
SOLUTIONS	Can clear and final solutions be determined, or will any solution be only temporary or partial?	Designing for adaptive change Managing expectations

Table 1. Dimensions for identifying complex problems

Thoughtful consideration of questions like the above can help determine whether a problem is simple, complicated, or complex.

STRAIGHT-FORWARD (SIMPLE, COMPLICATED) VS. COMPLEX PROBLEMS

Simple problems have clear or narrow definitions that everyone agrees on. It is clear what is part of the problem and what isn't. Context (time, location, politics, etc.) rarely matters. The future is reasonably predictable if actions based on known facts are adequately executed. The final solution or result is complete (within the clear problem statement) and lasting. For example, baking a cake is simple. There are clear known chemical processes that govern the interaction between known ingredients over a known time period and in a known environment. The ingredients, time, and environment can be modified slightly, but if the basic recipe is followed, the same result can be achieved by anyone, anytime, anywhere.

Complicated problems require many more facts (processes, ingredients, etc.) and much more precise steps. If the extensive facts or steps are not followed precisely, the results/ solutions will not be achieved. For example, launching a rocket into space is much more complicated than baking a cake, but basically there is a recipe that works. The "recipe" for launching a rocket has exponentially many more "ingredients" and "processes" and "steps" which are much less flexible than those for a cake. But if done correctly, the result is predictable and repeatable.

Both simple and complicated problems can be considered "straight-forward" regardless of how difficult it is to assemble the facts and components or execute the processes.

Complex problems are not straight-forward, and their "solutions" are rarely complete, permanent, or useful for other problems. For example, success in raising one child is not a reliable indicator of success in raising another. There are so many variables and unknowns with each child and parent, their individual environments, their aging, and current events. Any "solutions" are only temporary and partial and need to be constantly adjusted throughout the life of the child. In addition, there is rarely complete agreement, even between parents, about the definition of "success" when it comes to children.

AGREEMENT & CERTAINTY

The degree of complexity of a societal problem can also be understood by the amount of agreement and certainty about the various dimensions of the problem (see Figure 1).

For example, drug addiction may be viewed as a crime problem by police, a mental health problem by psychologists, and a public health problem by government officials. People may disagree about the definition or threshold for "addiction" or "crime". Complex problems and the efforts to solve them do not have clear boundaries. For example, should we include drug addicts themselves in our research? Why? How? How do we decide? Who decides?

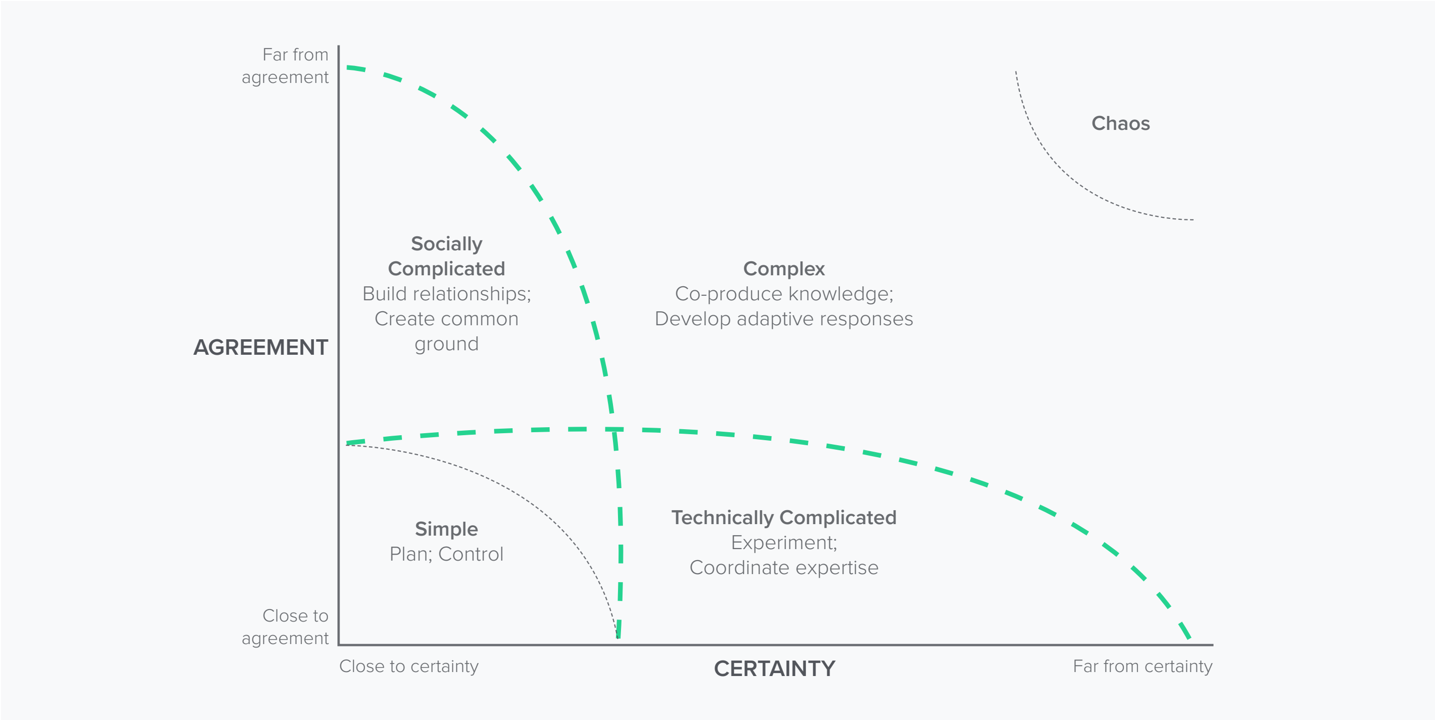


Figure 1. Problem types by agreement and uncertainty

Image based on Cheuy S., Fawcett L., Hutchinson K., Robertson T. (2017) A Citizen-Led approach to enhancing community well-being. In: Phillips R., Wong C. (Eds.). Handbook of community well-being research. *International Handbooks of Quality-of-Life*. Springer, Dordrecht. https://doi.org/10.1007/978-94-024-0878-2_8; and Stacey R.D. (2002). *Strategic management and organisational dynamics: The challenge of complexity* (3rd ed.). Harlow: Prentice Hall.

In complex problems, context always matters and affects how research is designed, how evidence-based solutions are determined, and how those solutions are implemented. For example, one city might be willing to fund drug addiction research because they've had a lot of recent drug-related deaths. Another city might be unable to conduct research on drug treatment programmes because the police view drug addiction as a crime problem and have power in local government that enables them to divert funds from treatment-related solutions to law & order solutions instead.

There are many unknowns in complex problems, due to the many variables at work in the contexts of a given problem. These unknowns affect how approaches to problems are researched and designed as well as how solutions or strategies are implemented. Even a comprehensive understanding of a specific context and problem at one time in one place will not guarantee that the same facts and steps will be relevant in a different time or place. These varying contexts and changing circumstances are a large reason why solutions for complex problems can only ever be partial and temporary.

Knowledge from specific disciplines is essential for understanding and addressing many aspects of complex problems, but problem-based research requires alternative approaches that are more comprehensive and transcend disciplines.

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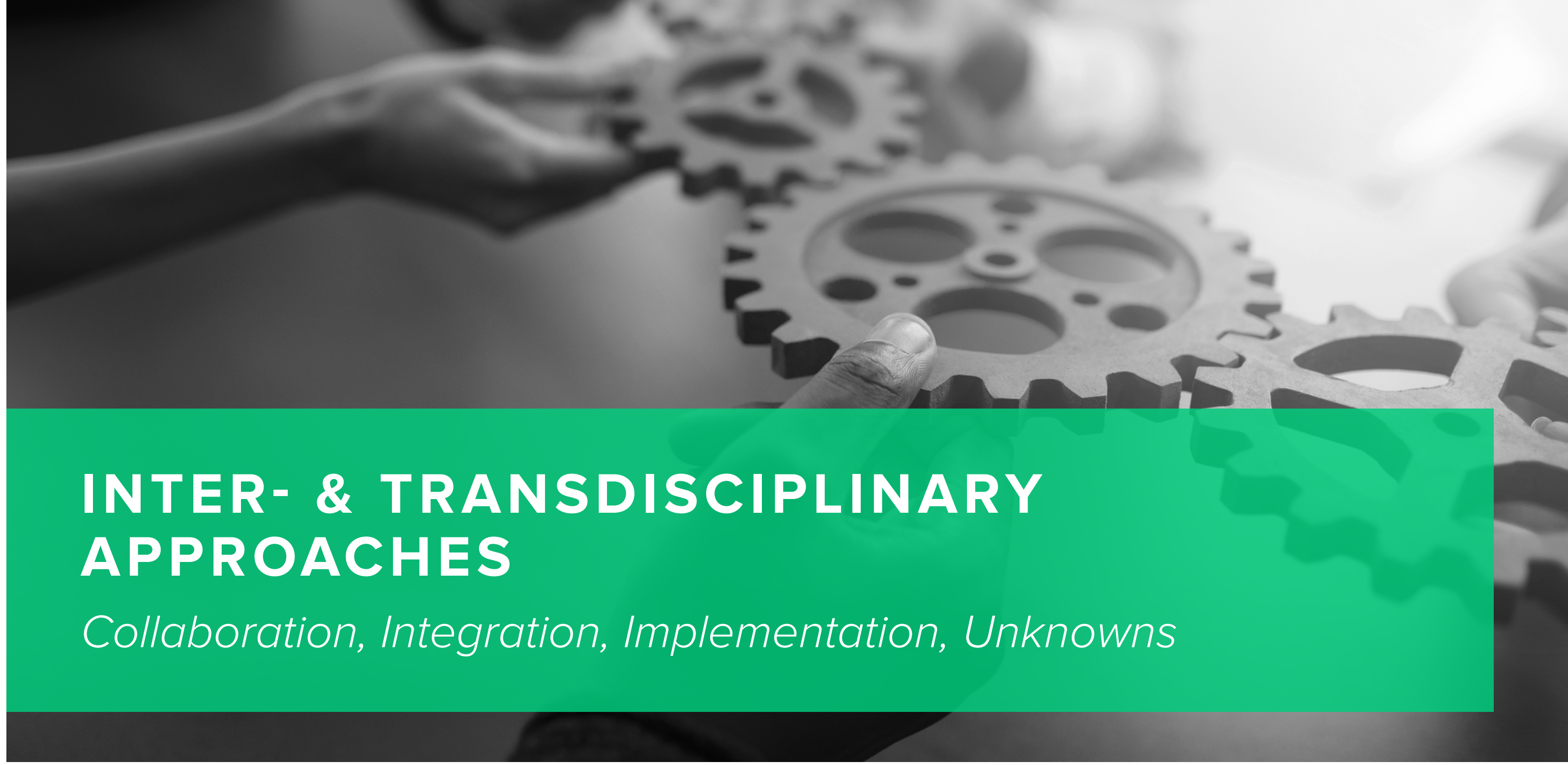
- Stacey R.D. (2002). *Strategic management and organisational dynamics: The challenge of complexity* (3rd ed.). Harlow: Prentice Hall.
- See also Resources & Communities below.



INTER- & TRANSDISCIPLINARY APPROACHES

Collaboration, Integration, Implementation, Unknowns

Interdisciplinary and transdisciplinary (ITD) approaches can be described in a philosophical way as forms of reasoning – mindsets and ways of thinking more comprehensively about the nature of reality and how to interact with that reality to achieve societal and environmental goals. ITD approaches to generating knowledge and addressing complex societal problems are often said to be concerned with systems (like forests) more than solely with individual components (like timber, soil, hectares). To understand systems it is necessary to understand the components of those systems (disciplines), how those components interact with each other (interdisciplinary), and how they effect and are affected by their surrounding environments and contexts (transdisciplinary). Figure 2 provides a simplified visualisation of the interaction between science and practice in transdisciplinary projects – what each contributes to the process and what each receives from the process.

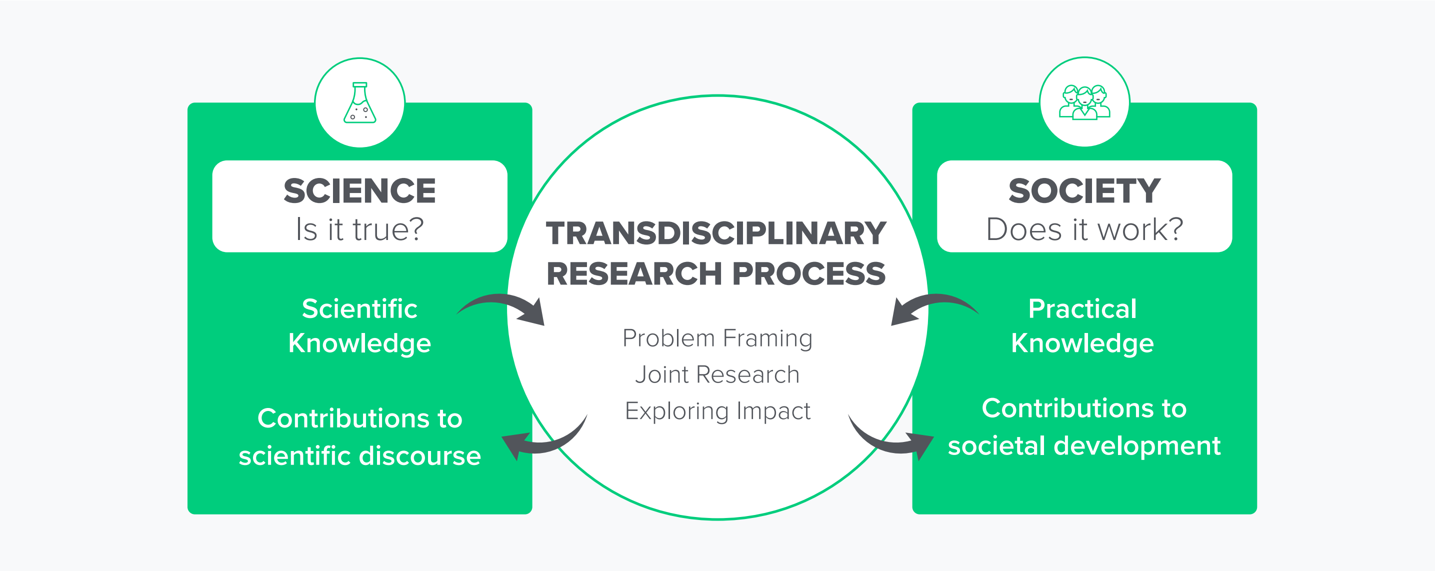


Figure 2. Collaboration of science and society in transdisciplinary research processes

Based on Partnering for change – Link research to societal challenges [online course], Network for Transdisciplinary Research; and Pohl, C., Krütli, P. & Stauffacher, M. (2017). Ten reflective steps for rendering research societally relevant. *GAIA – Ecological Perspectives for Science and Society,* 26(1), 43-51.

BACKGROUND

The term "disciplines" usually refers to academic branches or sub-sets of knowledge taught and researched at the university level. Basic or "pure" research in disciplines is focused on expanding the boundaries of the branch of knowledge and is not necessarily concerned with the application of that knowledge to any specific problem or challenge. This specialised focus of narrow disciplines is necessary for developing deep knowledge and understanding parts of our physical, intellectual, and social world.

Since at least the 17th century, the scientific method of rigorous observation and testing has been the foundation for generating valid, reliable, and predictable evidence about the nature of reality. In very simplistic terms, the scientific revolution produced new knowledge by breaking "reality" down into its component parts to facilitate the observation of each isolated piece to understand how it worked. This "basic" knowledge of the functioning of parts of reality (e.g., disciplines like physics, chemistry, biology) eventually led to applied research, which used the scientific method to attain practical goals – in effect recombining knowledge of these parts of reality in new, interdisciplinary ways (e.g., engineering, medicine). These innovations drove the industrial revolution of the 18th and 19th centuries and the advancement of key domains. In many ways, the interdisciplinary integration of scientific knowledge still drives the technological revolution of the 20th and 21st centuries.

In the 20th century, it began to be clear that innovations and economic development based on the fruits of the scientific method were having negative effects on society and the environment. These effects threatened the sustainability of economic progress and the entire human experience. Many aspects of society and the environment have been amenable to scientific investigation, and the 20th century saw the evolution of the social and environmental sciences. Environmental sciences, in particular, are highly interdisciplinary and have also gained recognition as new "disciplines" within universities, similar to engineering and medicine in previous eras.

Despite this scientific advancement, complex practical problems in society and the environment still exist, as evidenced by nearly 50 years of international agendas related to sustainable development. Transdisciplinary research emerged with a focus on applied research specifically for complex problems, often called "problem-based research". The Handbook of Transdisciplinary Research (Hirsch Hadorn et al., 2008) indicates that "Transdisciplinary research, therefore, aims at identifying, structuring, analyzing and handling issues in problem fields with the aspiration

a. To grasp the relevant complexity of a problem,
b. To take into account the diversity of live-world and scientific perceptions of problems,
c. To link abstract and case-specific knowledge, and
d. To develop knowledge and practices that promote what is perceived to be the common good."

"Despite this scientific advancement, complex practical problems in society and the environment still exist, as evidenced by nearly 50 years of international agendas related to sustainable development. Transdisciplinary research emerged with a focus on applied research specifically for complex problems, often called "problem-based research"."

PROBLEM-BASED MINDSETS AND PARADIGMS

Researchers raised in the historical disciplinary environment are often instructed that research must remain separate from the real world and from policy making to be objective and rigorous. While this is true in many cases, problem-based applied research is usually more relevant and successful when researchers understand how and why their research is used (or ignored). For many researchers, this is a radical and uncomfortable shift in mindset.

Problem-based research is a paradigm that focuses as much on understanding the "messy" political systems of power and influence within which any new knowledge may be implemented as it does on the precision of facts and data. It requires skills in facilitating collaboration amoung individuals and groups with very diverse views of the world and ways of operating. It also requires skills for integrating a range of types of knowledge, from scientific data to the tacit knowledge and interests of actors in the problem space.

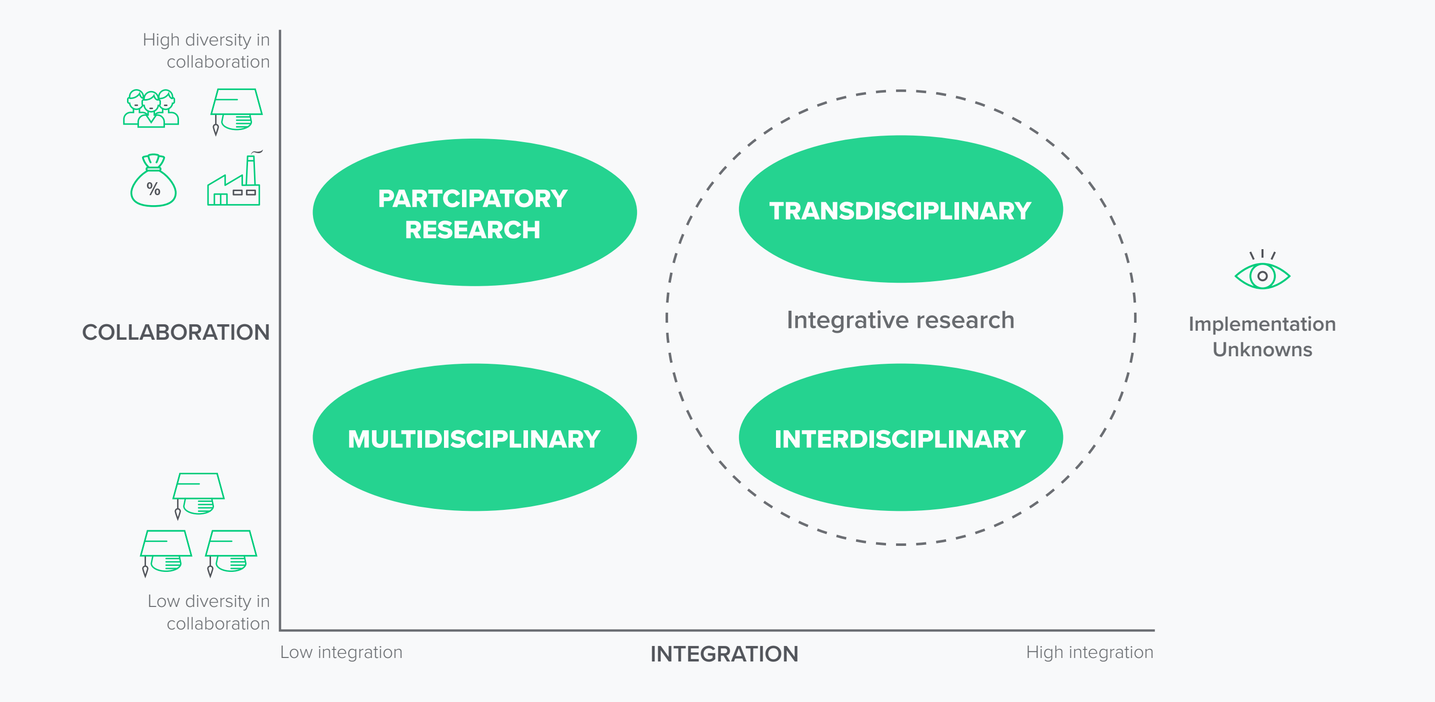


Figure 3. Types of research by collaboration and integration

Image based on Tress, G., Tress, B. & Fry, G. (2005). Clarifying integrative research concepts in landscape ecology. *Landscape Ecology*, 20, 479–493. https://doi.org/10.1007/s10980-004-3290-4

TERMINOLOGY

Figure 3 provides a very general characterisation of types of research based on the degree of integration and the diversity of actors included in collaborative processes. The terms presented in the figure are often used interchangeably, which can create confusion. Although strict definitions can be helpful (see box), the labels should be viewed as ways to roughly group different approaches rather than to describe clear boundaries between unique activities. The concept of "participatory research", for example, usually represents processes where stakeholder knowledge is collected but is not necessarily intentionally or systematically integrated with other stakeholder views or with scientific knowledge. "Transdisciplinary research" is more often used to describe research which solicits stakeholder knowledge and actively engages stakeholders in the integration process itself.

When collaboration with a diversity of stakeholders is not involved, "multidisciplinary research" usually describes research that provides co-located sets of knowledge generated by individual disciplines, requiring the end-user of that knowledge to make the choices of what or how to integrate the knowledge for their purposes. "Interdisciplinary research" is more likely to describe the integration of knowledge from relevant disciplines during the research process so that the result of the research is, in many ways, "ready-to-use" for problem solvers.

TERMS

The terms multi-disciplinary, inter-disciplinary, and trans-disciplinary are often used interchangeably. Generally accepted technical distinctions between these terms are described below, but it is usually more important to focus on the specific goals of research rather than to debate which term to use.

- **Multi-disciplinary** – The juxtaposition or collation of knowledge created independently in distinct disciplinary areas. Example: Edited book with chapters by authors from different disciplines.
- **Inter-disciplinary** – The intentional integration and synthesis of knowledge from different disciplinary areas during research design and execution. Example: Researchers from three disciplines design and conduct research together and present integrated results.
- **Trans-disciplinary** – The intentional integration and synthesis of knowledge from different disciplines AND knowledge from stakeholders, based on a systems or sustainability orientation. Example: Researchers from academic disciplines design and execute research with one or more representatives from communities affected by the problem.

The sections that follow briefly outline three key domains of the unique mindset and skills necessary for interdisciplinary and transdisciplinary research: implementation, collaboration, and integration. These sections are followed by an overview of the strategic orientation necessary for higher education institutions to build their inter- and transdisciplinary research capacity.

DISCOVER MORE

- Hirsch Hadorn, G., Hoffmann-Riem, H., Biber-Klemm, S., Grossenbacher-Mansuy, W., Joye, D., Pohl, C., Wiesmann, U., Zemp, E. (Eds.). (2008). *Handbook of transdisciplinary research*. Springer.
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- Pohl, C., Krütli, P. & Stauffacher, M. (2017). Ten reflective steps for rendering research societally relevant. *GAIA – Ecological Perspectives for Science and Society, 26*(1), 43-51.
- See also Resources & Communities below.

IMPLEMENTATION, IMPACT & UNKNOWNS

Domains of Influence, Communication, Unknowns

Understanding how change happens in different domains enables researchers to design investigations that are scientifically rigorous, while simultaneously generating valid, relevant, and useful knowledge that can be more successfully implemented for greater impact.

DOMAINS OF IMPLEMENTATION AND IMPACT

Societal change involves changes in policy (laws, regulations, guidelines) or practice (actions/behaviours) in government, private sector/industry, or civil society. Most complex social and environmental challenges involve all three domains. Each domain is influenced by different factors and responds to different types of knowledge and methods of engagement and communication.

Inter- and transdisciplinary (ITD) research can have an impact on these domains by informing, triggering, or driving agendas. It is important to understand what motivates the individuals and organisations in each domain. For some issues, targeted communication to key players can be effective. For example, if the new knowledge includes economic analyses and results that are easy to commercialise, industries may be quick to adopt new practices that put pressure on governments to adjust policies or may directly influence consumer behaviours (e.g., mobile technology). In other cases, broad communication of significant and powerful results to the general population through media can influence civil behaviours and put pressure on government and industry to change policies (e.g., environment, human rights). Some transdisciplinary projects generate evidence that addresses specific government policies. Providing the knowledge directly to key government personnel can result in policy change which cascades through industry and society (e.g., tobacco taxes, smoking prohibition in public spaces).

COMMUNICATION FOR IMPACT

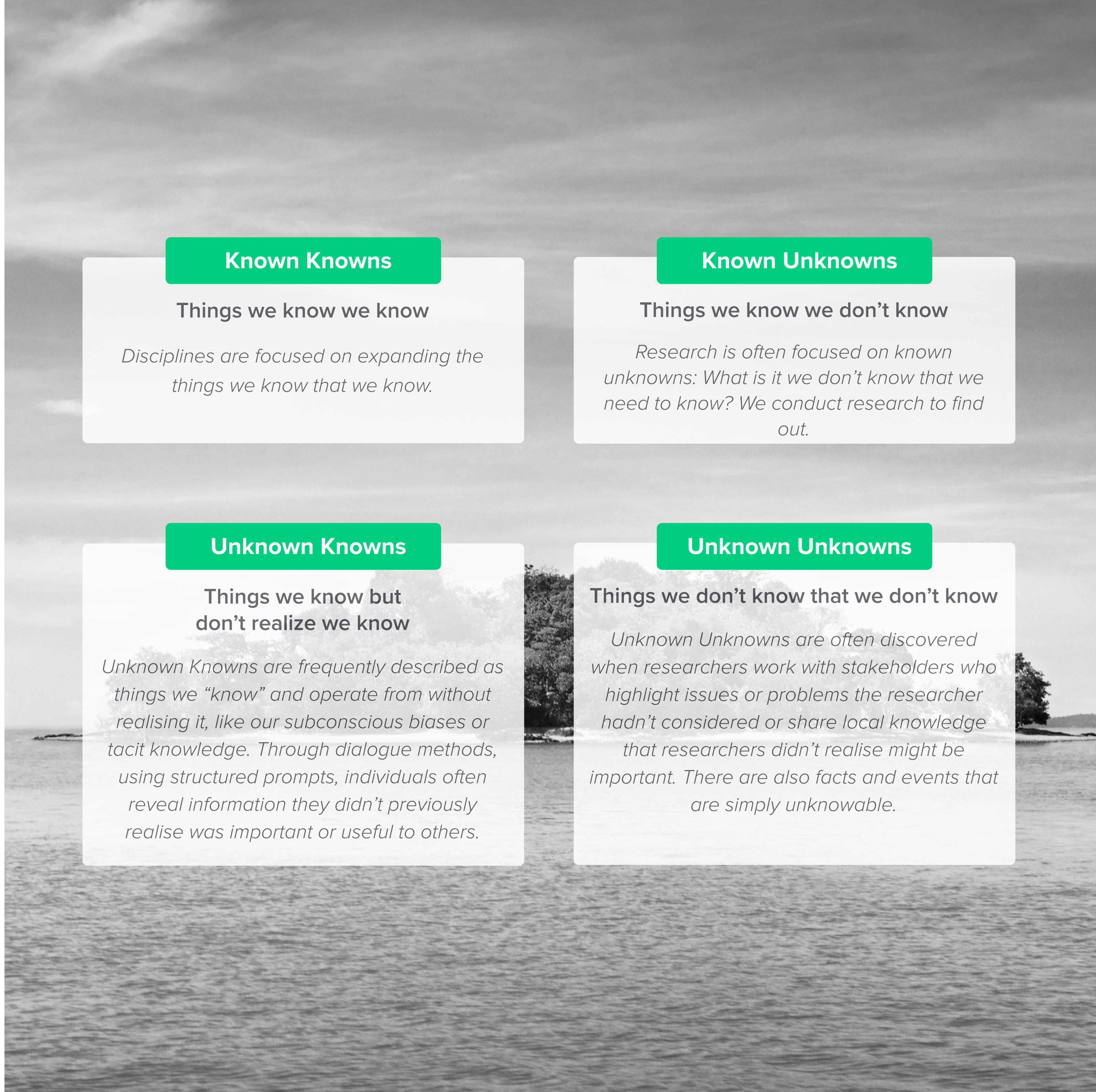
In the academic community, “impact” is often measured by citations (the number of other authors who have referred to your work in their publications). However, for academic research to impact the real world, non-academics need to be able to easily understand and use new knowledge. It is an old joke that researchers work for years to publish results that only a few other academics read. Funders of problem-based research have begun demanding tangible outcomes beyond just scholarly publication of results. Researchers need to learn how to communicate their research to the media, to policymakers, to private sector/industry, and to the general public.

UNKNOWNS

Identifying diverse ways of thinking about uncertainty and unknowns can encourage the development of adaptive strategies for managing the unpredictable, both in the production of integrated knowledge and in plans for implementing that knowledge in solutions or strategies. Even if we struggle with how to manage unknowns, it is important to acknowledge their presence and potential effects.

If we think of knowledge as an island in an infinite sea of unknowns, we can consider the shoreline to be our awareness of unknowns. The larger the island of our knowledge grows, the longer the shoreline becomes and our awareness of what we don’t know expands.

The Known-Unknown matrix is a common way of thinking about the diversity of “unknowns” that influence individuals, organisations, projects, and societies.



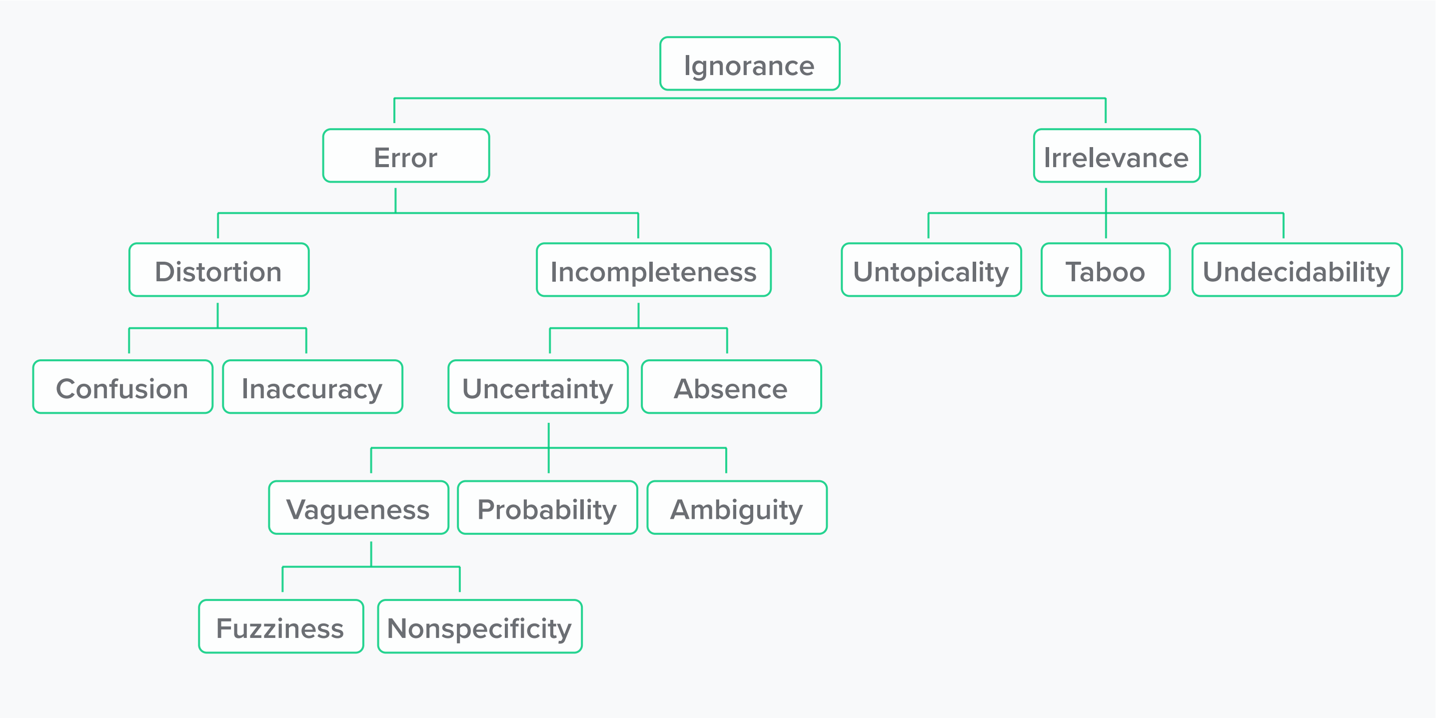


Figure 4. Typology of ignorance

Smithson, M. (1989). Ignorance and uncertainty: Emerging paradigms. *Cognitive Science Series.* New York: Springer Verlag.

The most common approaches to managing unknowns tend to be statistical analyses of risk and probability. But as Mike Smithson outlines in his typology of ignorance (see Figure 4), there is a diversity of types of unknowns. Considering what types of unknowns are relevant for a particular challenge can help with developing plans for reducing the amount of unknowns or adapting to the persistence of ongoing unknowns.

Thoughtful consideration of the roles of disciplines and stakeholders in collaboration and integration processes, with attention to implementation contexts and unknowns, is essential to problem-based research. Successful ITD research requires competency in these unique ITD mindsets and skills.

> Understanding how change happens in different domains enables researchers to design investigations that are scientifically rigorous, while simultaneously generating valid, relevant, and useful knowledge that can be more successfully implemented for greater impact.

DISCOVER MORE

- Blog posts with key insights and references:
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- See also Resources & Communities below.

COLLABORATION & CO-PRODUCTION OF KNOWLEDGE

Types of Knowledge, Stakeholders

Collaboration is a key dynamic of interdisciplinary and transdisciplinary (ITD) research aimed at complex problems. The need for collaboration is based on a recognition that different types of relevant knowledge come from a variety of sources.

Transdisciplinary research is often referred to as "co-production" of knowledge because it actively engages stakeholders from outside the academic disciplines to substantially contribute their unique perspective in the generation of new knowledge. Successful transdisciplinary co-production involves thoughtful decisions about how to structure interaction and engagement among disciplinary experts and stakeholders to incorporate all relevant knowledge.

TYPES OF KNOWLEDGE

"The concept of 'three types of knowledge' is helpful for structuring project goals, formulating research questions and developing action plans. The concept first appeared in the 1990s and has developed into a core underpinning of transdisciplinary research. It highlights the co-production of knowledge among scientists, decision-makers, and those affected by the problem and by any solution." (Tobias Buser & Flurina Schneider, 2021, Three Types of Knowledge, Integration & Implementation Insights [blog]; see Figure 5)

Not all transdisciplinary research projects address or include all types of knowledge, but it is useful to recognise that **systems knowledge** (facts generated by scientists about the systems involved in the problem) is less valuable when it is not accompanied by **transformation knowledge** about how to use the systems knowledge (agency in practice/actions in the real world) to generate desired change (**target knowledge** reflecting the values of society and political will).

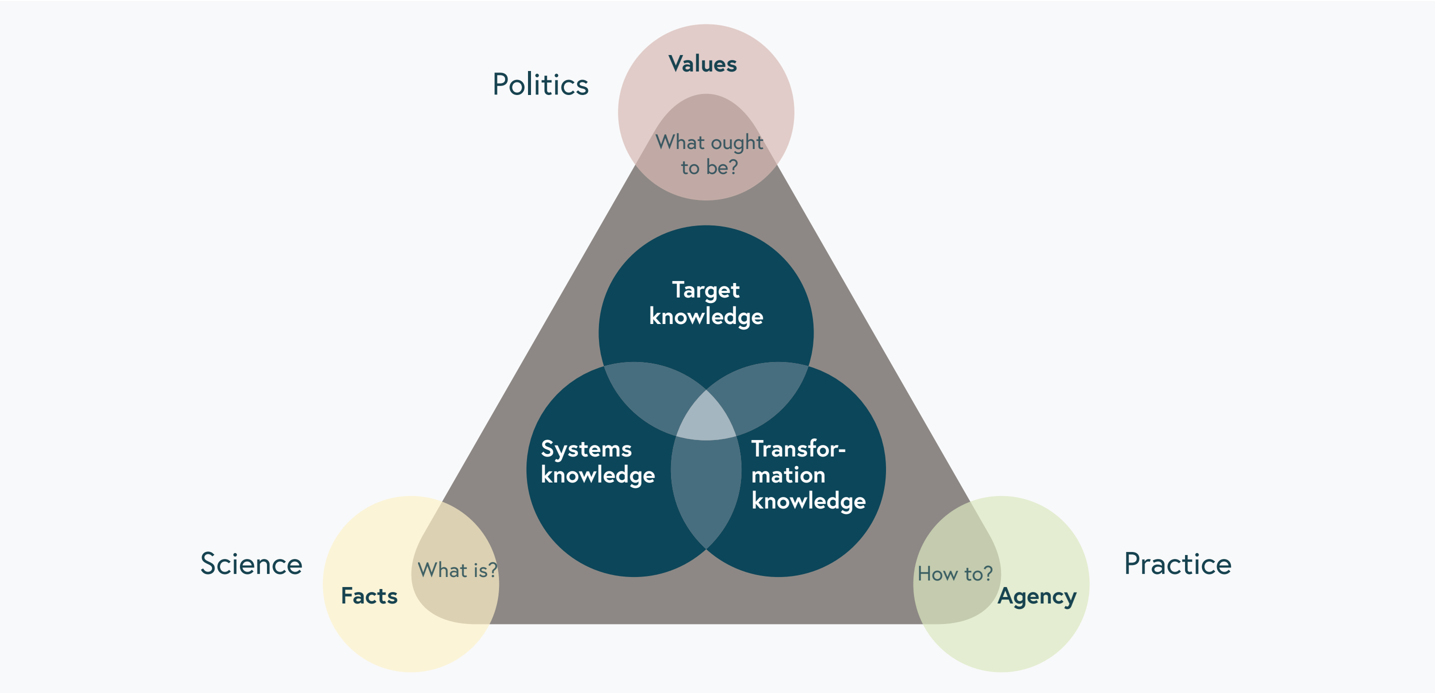

Figure 5. Three types of knowledge

Created by Flurina Schneider and University of Basel New Media Center, CC BY 4.0. Based on: ProClim- (1997). Research on sustainability and global change: Visions in science policy by Swiss researchers. ProClim-.

By aligning and integrating the facts that science can produce about fundamental systems with knowledge of the values and goals underlying the targeted change and a clear understanding of how that transformation might be executed, co-produced research can have the greatest impact.

STAKEHOLDERS

Stakeholders are individuals, groups, and organizations who have a "stake" in the outcome of research or problem-solving. They possess unique knowledge about the system in which the problem exists. Stakeholders can include the people who are trying to address the problem, the people who are impacted by the problem and any solution (personally or as representatives of impacted actors with no voice, like the environment), and the people who have the power to implement or prohibit any solution or strategy.

Stakeholder knowledge is helpful for defining and framing problems accurately and effectively, and they can help in setting boundaries for what aspects of the problem can be considered. Stakeholders are essential for ensuring that research teams understand the contexts in which the problem exists and which solutions can be implemented, including identification of unknowns and knowledge about opportunities and limitations for any solutions. New knowledge that is "co-produced" with stakeholders often has a better chance of being relevant and successfully implemented in the real world to generate positive impact.

In most transdisciplinary projects, the first step is to identify which stakeholders are relevant and important. A common approach is to identify all persons, groups, or organisations that are

> By aligning and integrating the facts that science can produce about fundamental systems with knowledge of the values and goals underlying the targeted change and a clear understanding of how that transformation might be executed, co-produced research can have the greatest impact.

- able to affect the project or problem,
- affected by the project or problem, or
- interested in the project or problem.

> Engaging stakeholders in collaboration with disciplinary experts involves a delicate balance of exploring and encouraging diverse perspectives while simultaneously neutralising or preventing conflict that can distract a project from its aim.

These stakeholders are then often categorised by their power to affect the problem or solution and their level of interest in the problem. This stakeholder analysis can guide choices about what level of engagement is necessary, appropriate, or possible for different stakeholders. Some stakeholders should be active collaborators in the design and execution of research. Some may only need to be involved in some aspects of the work or consulted periodically for feedback. Some stakeholders only need to be kept informed on progress.

Engaging stakeholders in collaboration with disciplinary experts involves a delicate balance of exploring and encouraging diverse perspectives while simultaneously neutralising or preventing conflict that can distract a project from its aim. It is important for researchers to develop skills for working with diverse stakeholders to maximise their contributions.

DISCOVER MORE

- Blog posts with key insights and references:
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- See also Resources & Communities below.

INTEGRATION

Why, Who, What, When, How

The heart of interdisciplinary and transdisciplinary (ITD) research is the integration and synthesis of diverse knowledge. Many approaches have emerged in different domains that reflect the diversity of purpose, scale, and settings of ITD projects. As an introduction to the different dimensions of integration, it is useful to think about integration using the journalistic framework of "W" questions.

WHY – REASONS FOR INTEGRATION

Most theoretical and methodological approaches to integration aim to:

- **bring together** relevant knowledge from diverse disciplines and stakeholders,
- **clarify** diverse aspects of a problem, or
- **synthesise** facts, judgments, visions, values, interests, epistemologies, time scales, geographical scales, world views, etc.

WHO – ACTORS INVOLVED IN INTEGRATION

Another question to consider is who will be involved in the integration. Different stakeholders (individuals and groups) may require different processes to enable them to contribute different knowledge at different stages. Approaches can be distinguished by whether they are designed for **common group learning, deliberation by experts, or integration by sub-groups or individuals** (Pohl, et al., 2008).

WHAT – ELEMENTS BEING INTEGRATED

In addition to gathering, integrating, and synthesising facts, Vilsmaier & Lang (2015) built on Bergmann's groupings (2012) to provide additional categories for "what" is being integrated:

- Communicative integration focuses on finding common **language** as the basis of mutual understanding (e.g., collaborative exploration of terms, meanings, and communicative practices).
- Socio-organisational integration aims to surface and integrate **interests** and **modes of operating**.
- Epistemic integration aims at clarifying **theoretical, conceptual, and methodological differences** to develop a coherent epistemic framework that allows for implementing a consistent methodology.
- Cultural integration cuts across all other dimensions of integration and supports tackling and making transparent **values, norms** and **world-views** informing research and practice.

WHEN – STAGES WHEN INTEGRATION IS RELEVANT

Determining which approaches, theories, methods, and specific tools are most appropriate, can be challenging. It is useful to consider the different stages of a project where knowledge integration can be useful. In a model of team-based research, Stokols, Hall, & Vogel (2013) named four phases, which can often be iterative processes:

- **Development** establishes conditions for collaboration by forming a team and taking steps toward a joint initiative.
- **Conceptualization** develops a framework for integrating them around research questions or hypotheses and design of the initiative.
- **Implementation** executes the research plan.
- **Translation** applies findings for an innovative solution to a problem.

HOW – METHODS AND TOOLS FOR INTEGRATION

There are many ways of classifying methods and tools. One of the most concise ways of thinking about them is in terms of dialogue methods and product-based methods (Bammer, 2006) .

Dialogue methods target communication processes and are a foundation of many other methods and approaches. These methods bring people together in structured dialogue to gather relevant knowledge, clarify problems, and surface key issues. They are best for gaining broad understanding or focusing on a particular aspect of a problem.

Product-based methods use a "product" (model, technical device, regulation, etc.) as the focal point for integrating knowledge. These types of methods are good for synthesizing specific knowledge in very practical ways. For example, the construction of a common metric (e.g., carbon footprint, disability-adjusted life years) is a highly quantitative way to integrate knowledge. The creation of a systems dynamics model provides a structure for synthesising knowledge of various actors (characteristics, priorities, behaviours) and events (anticipated, triggered, unexpected) and the corresponding effects on other actors. The development of a technical device or the drafting of a regulation or position statement also provides a structured and directed way of integrating knowledge by focusing on a practical output.

This binary classification is a limited introduction. Readers are encouraged to investigate online repositories which describe and organise resources that are useful for ITD research (Klein, 2016, September 6).

- I2S (Integration and Implementation Sciences) - Hosted by the Australian National University, "Resources" link presents tools, cases, and approaches along with information about pertinent journals, professional associations and networks, and conferences.
- Interdisciplinary Research Short Guides – This set of wiki-based guides for interdisciplinary research provides digests for developing and reviewing proposals, building and managing research teams, managing challenges, plus topics of leadership, evaluation, and funding.
- Td–net (Network for Transdisciplinary Research) – The td-net toolbox on "Co-producing Knowledge" provides links to pertinent methods, practical experiences, criteria, and related toolboxes, as well as guidelines for selecting appropriate tools.
- Team Science Toolkit – The US-based National Cancer Institute's Team Science Toolkit includes methods and measures contributed by users and supported by an annotated bibliography along with Editor's Picks.

DISCOVER MORE

- Blog posts with key insights and references:
  - Klein, J.T. (2016, August 30). Integration – Part 1: The "what". *Integration & Implementation Insights*. https://i2insights.org/2016/08/30/what-is-integration/
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- See also Resources & Communities below.

> "The heart of interdisciplinary and transdisciplinary (ITD) research is the integration and synthesis of diverse knowledge."

ITD IN HIGHER EDUCATION & RESEARCH

Strategic, Administrative, Practical Institutionalisation for Research and Education

Higher education and research institutions are key drivers of national and local societies by preparing a skilled workforce and conducting research. As such, they can make a significant impact on developing inter- and transdisciplinary (ITD) mindsets and skills for addressing today's complex societal challenges. Universities that want to build ITD competencies will find it useful to consider three dimensions related to research and general education: strategy, administration, and practice.

Institutional ITD capacity building needs to begin with a clear strategy, to establish administrative infrastructure that can adequately support the goals, and to design robust and flexible practical activities that generate measurable outcomes for all participants and the institution.

STRATEGY, ADMINISTRATION AND PRACTICE

There are an infinite number of creative approaches to ITD capacity building. Table 2 provides a very brief sampling of issues institutions may need to consider when embarking on a journey to strengthen ITD competency in research and graduates.

	RESEARCH *(skills, funds, projects)*	**EDUCATION** *(curricula, pedagogy, projects)*
STRATEGIC	• International and regional collaboration • Partnerships with government, industry, and civil society • ITD research/science communication (e.g., communicating institutional research achievements impacting SDGs)	• Target audience decisions (undergraduate, graduate, post-graduate, faculty) • Goals, outcomes for ITD activities and audiences
ADMINISTRATIVE	• Administrative units (cross-university departments, institutes) • Cross-faculty collaboration policies • Tenure and promotion incentives for ITD research • Funding strategies to support ITD research	• Administrative units (cross-university teaching & learning departments, centers) • Supervision of ITD higher degrees
PRACTICAL	• Researcher ITD skills development, including reasoning/mindset, integration, stakeholder engagement, implementation, research design, project management • Proposal writing & publication support	• Curriculum development • Teaching methods • Problem-based learning/project opportunities

Table 2. Sampling of issues to consider when building ITD competency in higher education

Building 21st century competencies in ITD mindsets and skills will enable higher education and research institutions to lead the way in developing knowledge economies and achieving sustainable development goals, both nationally and globally.

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- See also Resources & Communities below.

RESOURCES & COMMUNITIES

Discover, Connect, Collaborate

This *KnE Insight* is only a brief introduction to the forces driving the need for inter- and transdisciplinary competency and a few fundamental concepts. Below are selected resources to continue exploring this increasingly important global priority for higher education and research.

REPOSITORIES, WEBSITES & BLOGS

- AIS (Association for Interdisciplinary Studies) – The "About Interdisciplinarity" at the "Resources" link on the AIS website covers definitions, philosophy, history, and best practices spanning communication, teaching, research, administration, and public policy analysis. It also provides links to other online resources.
- I2S (Integration and Implementation Sciences) – Hosted by the Australian National University, this website is part of a global network initiative to improve research on complex real-world problems. The "Resources" link presents tools, cases, and approaches along with information about pertinent journals, professional associations and networks, and conferences.
- Integration & Implementation Insights – This is a community blog providing research resources for

understanding and acting on complex real-world problems. It contains many short posts on a range of topics covering aspects of inter- and transdisciplinary research, with references.

- Interdisciplinary Research Short Guides – This set of wiki-based guides for interdisciplinary research provides digests for developing and reviewing proposals, building and managing research teams, managing challenges, plus topics of leadership, evaluation, and funding. Related guidelines also appear in Lyall, Bruce, Tait, and Meagher's 2011 book on practical strategies.
- Td–net (Network for Transdisciplinary Research) – The td-net toolbox on "Co-producing Knowledge" focuses on solving complex problems in collaboration with stakeholders in society. It provides a wide international audience with links to pertinent methods, practical experiences, criteria, and related toolboxes, while guiding choice of options and their applicability.
- Team Science Toolkit – The US-based National Cancer Institute's Team Science Toolkit is a user-generated searchable repository of resources on team science, which is often interdisciplinary in nature. The primary categories of resources are methods and measures, supported by an annotated bibliography along with Editor's Picks.

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Integration

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ACKNOWLEDGEMENTS

This brief introduction to inter- and transdisciplinary competencies for higher education and research emerges from an innovative, national-level ***Interdisciplinary Excellence*** programme in higher education to build interdisciplinary research and teaching skills in faculty and universities across Egypt.

The programme was developed by Knowledge E in collaboration with the Egyptian Knowledge Bank and the Egyptian Ministry of Higher Education and Research. Following a 2020 pilot, the programme was expanded in 2021 to include over 100 university leaders from 20 institutions. Delivered by Knowledge E, and led by global experts from Australia, Europe, and North America, including leaders of the Integration & Implementation Sciences (i2S) team at the Australian National University and the Global Alliance for Inter- and Transdisciplinarity (ITD Alliance), the 2021 ***Interdisciplinary Excellence*** programme was designed to:

- Prepare researchers in the foundations of effective interdisciplinary research for addressing complex societal and environmental problems, including the achievement of Egypt's Vision 2030 goals.
- Develop educational design strategies to incorporate the teaching of interdisciplinary research skills in higher education throughout Egypt.
- Increase the impact of interdisciplinary research expertise in Egypt through advanced training and collaborative research projects.

The introductory overview outlined in this *KnE Insight* was prepared by Caryn Anderson, Training & Strategy Expert at Knowledge E and one of the programme course leaders. It is informed by and indebted to the deep knowledge and extensive international experience contributed to the ***Interdisciplinary Excellence*** programme by the expert course leaders:

- **Gabriele Bammer** – Professor, The Australian National University and leader of the Integration and Implementation Sciences (i2S) team and the Integration and Implementation Insights global network and blog;
- **Tobias Buser** – Executive Secretary, Global Alliance for Inter- and Transdisciplinarity (ITD Alliance) and former Project Leader for the Network for Transdisciplinary Research (td-net) of the Swiss Academies of Arts and Sciences;
- **Dena Fam** – Associate Professor, University of Technology Sydney, Australia and Leadership Board member of the Global Alliance for Inter- and Transdisciplinarity (ITD Alliance); and
- **Ulli Vilsmaier** – Apl. Professor, Leuphana University Luneburg, Germany and Co-Founder and Leadership Board member of the Global Alliance for Inter- and Transdisciplinarity (ITD Alliance).

For further information about the ***Interdisciplinary Excellence*** programme,
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