

C.9

Integrating GDE into research

1. Why & how to align your research with Global Dimension priorities
2. Research methods for GDE
3. Engineering education research, with a focus on engineering for development
4. Funding routes
5. Collaboration



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EDITED BY

Global Dimension in Engineering Education

COORDINATED BY

Agustí Pérez-Foguet and **Enric Velo** (*Universitat Politècnica de Catalunya*)
Manuel Sierra (*Universidad Politécnica de Madrid*)
Alejandra Boni and **Jordi Peris** (*Universitat Politècnica de València*)
Guido Zolezzi (*Università degli Studi di Trento*)
Rhoda Trimingham (*Loughborough University*)

WITH GRATEFUL THANKS TO

Boris Lazzarini (*Universitat Politècnica de Catalunya*)
Xosé Ramil and **Sara Romero** (*Universidad Politécnica de Madrid*)
Jadicha Sow Paino (*Universitat Politècnica de València*)
Angela Cordeiro and **Gabriella Trombino** (*Università degli Studi di Trento*)
Emily Mattiussi, **Sylvia Roberge** and **Katie Cresswell-Maynard** (*Engineers Without Borders - UK*)

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PHOTO: Why students are capable of running development projects. A. Elias

CHAPTER

1

Why & how to align your research with Global Dimension priorities

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1

WHY & HOW TO ALIGN YOUR RESEARCH WITH GLOBAL DIMENSION PRIORITIES

Guido Zolezzi and Gabriella Trombino, UNESCO Chair in Engineering for Human and Sustainable Development, University of Trento

EXECUTIVE SUMMARY

In this chapter we address the relationship between academic research and the Global Dimension.

With special reference to engineering fields of study, we show that aligning research priorities with the Global Dimension is both relevant and feasible in a wide range of engineering disciplines. A series of examples are taken from several discipline areas. These are used to illustrate the practical relevance of such strategic research choices that an academic might make. The implications of boosting the Global Dimension within engineering academic research are examined, from the perspective of a single discipline and from a cross-cutting perspective.

Depending on the researcher's background and career stage, choosing to integrate or to strengthen the Global Dimension within research may demand that they face certain challenges. These may be within the working environment at research, teaching and institutional levels; but they may also be personal, professional or motivational issues too. We conclude the chapter by discussing such challenges, while attempting to compare them with the benefits that such research choices may have at individual, institutional and societal level – both in the short-term, and in the long-term.

LEARNING OUTCOMES

After you actively engage in the learning experiences provided in this module, you should be able to:

- Understand that multiple opportunities exist for researchers in many different engineering disciplines to align their research priorities with Global Dimension priorities.
- Understand how to develop practical ideas and to develop action plans to start aligning your own research priorities with Global Dimension priorities.

KEY CONCEPTS

These concepts will help you better understand the content in this session:

- How research can support the implementation and delivery of Global Dimension in Engineering Education programmes
- How academics can get started with research on Global Dimension priorities by aligning key areas of Global Dimension programming with their research

GUIDING QUESTIONS

Develop your answers to the following guiding questions while completing the readings and working through the session:

- How can sustainable research programmes be developed in different areas of engineering so that outcomes support policy making, programme design or project implementation on the global challenges of human development?
- How can the Global Dimension feed fundamental research questions?

INTRODUCTION

Academic engineering research has traditionally developed with clear discipline boundaries, and has embraced both ‘basic engineering sciences’ (such as fluid and solid mechanics, thermodynamics, semiconductor theory, materials science) and ‘applied engineering’ (such as water resources management, earthquake engineering, bioreactors, micro-electronic devices). Researchers from the basic engineering sciences most often tackle quite fundamental scientific research that has a close connection with the physical, mathematical and chemical sciences. Researchers from applied engineering disciplines primarily orientate their research towards the development of product, process and design innovations in engineering practice.

Traditionally, the academic and research systems of many industrialised countries recruit academics to research and/or teach on only one or a small number of specialisations (usually either in the basic or applied fields, occasionally both).

These traditional approaches have incentivised engineering researchers to align their own research priorities within the boundaries of their disciplines; research across discipline boundaries has traditionally been much more risky. The demand for cutting-edge research in particular specialisations – a demand driven by government research funding systems – has focused much engineering research expertise on advancing advanced technologies and on developing ‘high technology’ solutions.

In recent decades, however, several factors have encouraged researchers to begin to break with these traditional approaches to academic engineering research. These factors include the unprecedented developments in information and communication technologies, global socio-economic and political changes, the increased complexity and scale of the problems being tackled, the demand for innovation and new funding strategies that prioritise social impact. In applied engineering, research partnerships with major engineering companies are a main driver of inter-disciplinary research because, quite simply, the new innovations they demand often require co-operation among researchers with different backgrounds. More recently, new factors are being considered, such as the international agendas on sustainability, combating climate change and global development. These global challenges have an intrinsic multi-dimensionality, so addressing them effectively requires inter-disciplinary effort – which is being encouraged by new types of funding. In some cases, even ‘low-tech’ innovations are being celebrated, if only because they can more clearly demonstrate the social responsibility and impact of universities.

Whilst there has been progress, evidence from many engineering-related research fields shows that engineering research relevant to Global Dimension priorities is either: (i) already developed but seldom properly applied; (ii) lacking in novel approaches based on

appropriate solutions that address fundamental developmental challenges; (iii) lacking in the novel research questions that need to be posed to provide academic rigour to decision making in real-world policies, programmes and projects.

Throughout this chapter we are going to explore the relevance (why?) and feasibility (how?) of current and future generations of engineering researchers aligning their research with the Global Dimension. This will be done through a series of illustrative, though non-exhaustive, examples from different engineering disciplines and by discussing the value, the stimuli and the challenges associated with them.

THE RELEVANCE OF ENGINEERING RESEARCH FOR THE GLOBAL DIMENSION (AND VICE-VERSA)

The Global Dimension and academic research in various fields of engineering has a strong mutual relationship. Since technology choices determine the paths of development that are available to society, engineering research provides invaluable inputs to overcoming global challenges in terms of human and sustainable development. Meanwhile, global challenges themselves are a key stimulus for the direction and priorities of engineering research. The examples below, taken from several discipline areas of engineering, demonstrate this mutual relationship.

It must be noted that these examples have been chosen with the aim of demonstrating the range of engineering fields that can relate to the Global Dimension. There remains in many quarters a tendency to think that some engineering fields are more relevant to the Global Dimension than others; this is not necessarily the case – it is more likely that the relevance of the Global Dimension has in fact not been fully understood. Many further examples can be drawn from other engineering fields – as, indeed, will be requested within the practical activity suggested at the end of the chapter.

Energy Engineering

The proposed global Sustainable Development Goal to “*ensure access to affordable, reliable, sustainable and modern energy for all*” (goal 7) makes explicitly relevant the need for access to safe and sustainable energy for everyone. In 2015, it is estimated that about one-fifth of the global population lacks electric lighting in their homes (Lim et al., 2013) and that household air pollution caused by burning traditional cooking fuels is responsible for the death of roughly four million people each year (Modi et al., 2006). Such a critical situation becomes particularly challenging in sub-Saharan Africa, where most countries face serious issues on energy development because of the multiple dimensions of human development.

Engineering research has huge potential to support for decision-making on access to sustainable energy for all at different scales, from policies to programmes to projects.

At the policy level, the recent review by Mandelli et al (2014) is an interesting example of a continental-scale analysis of the present energy situation in Africa. Mandelli et al (2014) perform an integrated analysis of the most up-to-date data of primary energy supply, consumption and electricity generation with a set of energy indicators for sustainable development (covering household energy, energy intensities, emission and pollution, deforestation, household energy affordability and health issues). The outcome of such assessment is coupled with an energy policy overview of several African regions, and challenges for sustainable energy development are presented.

At smaller scales, the paper of Johnson and Bryden (2012) shows the relevance of village-scale analysis of energy consumption and supply, because it supports improvement in projects aimed at increasing domestic access to energy in the rural areas of Africa.

Communities of researchers already exist around research on energy in developing countries, and on how developed countries can learn from developing country solutions in order to become more sustainable. Many (>10, or in some cases, >100) scientific papers are returned in bibliographic searches in the *ISI Web of Knowledge* database of indexed international peer-reviewed literature using search terms like 'energy developing countries' or 'energy access Africa'. Major companies in developing countries are investing in research in this area. Together with the above mentioned examples, these are strong indicators of how aligning a research agenda with the Global Dimension is, on one hand, needed by policy-makers and development practitioners and, on the other hand, may become fruitful career choices for researchers in energy engineering.

Water Science and Engineering

Many branches of water-related science and engineering have strong implications for human development. Sustainable access to basic water supply and sanitation services is a fundamental prerequisite for socio-economic development, for poverty eradication and for better social equity. Yet, despite multi-decade-long global attempts to address fundamental water service issues, more than two billion people still lack sustainable access to safe sanitation services and nearly one billion lack even basic potable water supply.

Advancing research in many of these fields is a key priority that can have enormous developmental impacts, such as through the more efficient use of available resources or by better understanding past, present and future patterns of availability and consumption. Long- and medium-term coping strategies and water and sanitation (and hygiene) programmes all rely on the availability of research data for effective planning for action. The availability of such data in developing countries is, however, often scarce, fragmented and results from differing collection frameworks and methodologies. This is a consequence of the relatively little attention that is paid to research on water issues in developing countries. Good research is emerging, and indeed there are now growing centres of excellence in water research around the world. Innovation in this field is also increasing. For example, the work of Gine et al (2013), Jimenez and Perez-Foguet (2012) and Gine and Perez-Foguet (2011) represents a tangible and creative example of how rigorous statistics, spatial analysis and approaches taken from sustainability science can be integrated to develop improved and cost-effective approaches to data collection, policy making and water poverty assessments at local, basin and national levels – thus opening new perspectives in addressing fundamentally unsolved global issues of water poverty.

Research in water science has also created novel and important paradigms to understand global scale socio-economic processes, with huge implications for water and food security.

For example, the concept of ‘water grabbing’ has been recently proposed by Rulli et al. (2012) to address the implications of land grabbing on the global redistribution of water resources. Their work, encompassing human rights governance issues, is the first to propose, develop and quantify the process of global water grabbing (i.e.: the process of water resources appropriation associated with the well-known phenomena of land-grabbing) and has opened new research paths on one of the most severe challenges posed by the Global Dimension.

Information and Communication Technologies (ICT)

ICT provides many examples of the direct impact that research can have on poverty and socio-economic development, whilst also being a highly productive research field in itself. ICT is recognised as a strategic resource for economic growth, social services improvements and governance reforms (Avgerou, 2008). While ICT research is often still most relevant to developed country contexts (Roztocki and Weistroffer, 2008) it is apparent how ICT is spreading at unprecedented pace in developing countries.

In their editorial for a special issue of the journal *Information Technologies for Development*, Ponelis and Holmner (2014) call for a deeper and more comprehensive understanding of the opportunities and challenges related to the adoption and use of ICT in Africa (particularly in relation to ICT capabilities that ultimately benefit people’s wellbeing). Research is particularly needed to better understand the multiple linkages between ICT and the empowerment of marginalised communities, however most attention in the ‘ICT4D’ (ICT for Development) sector has focused on cultural implications and local adaptation (Brown and Grant, 2010). The rise of the open data movement, the growth of big data analytics and the increasingly advanced ICT infrastructures in developing countries are all very strong platforms to further develop Global Dimension research in ICT.

Mechanical Engineering Design

Mechanical engineers are normally well-trained in mechanical design, optimisation and manufacturing techniques. These skills are needed to develop sound product solutions, but are not fully sufficient when considering the Global Dimension. While product design principles have routinely been applied in areas of civil engineering, water and sanitation and basic infrastructure services, only very recently has research emerged on product engineering for high market potential in developing contexts (e.g. Morrise et al., 2011, Wood et al., 2012). This has been spurred on by recent business interest in micro-finance and ‘bottom of the pyramid’ solutions. Mattson and Wood (2014) have developed a comprehensive review of product design principles for developing countries, based on an extensive review of the findings of many engineering researchers and practitioners. Their article, published in the *Journal of Mechanical Design* illustrates with practical examples nine basic principles for sustainable appropriate engineering design. These principles refer to the design of a wide variety of products for local markets, covering medical, mobile

communication, livelihood and educational devices. Application, improvement and the impact of product design criteria in developing countries is part of a promising research field with relevance to the Global Dimension.

Research on engineering research aligned with the Global Dimension

In summer 2014, the United Kingdom Collaborative on Development Sciences published a report mapping engineering ‘research for development’ in the country (UKCDS). This found that there had been a three-fold increase since 2000 in UK international aid funding for engineering research – up to an estimated £45million a year. This is about 15% of the total aid budget spent on research. The report also found that this was accompanied by “*a shift towards larger, more multi-disciplinary projects which integrate engineering with the physical, natural and social sciences*”.

The mapping itself found that “*the UK engineering for development research base appears relatively small and fragmented, with a diverse range of individuals, consultancies and academic institutions undertaking infrastructure research*” but that “*many of the foremost in engineering research for development are world leading institutions... have expertise in specific facets of development-relevant engineering research*”.

CHALLENGES FOR THE GLOBAL DIMENSION IN ENGINEERING RESEARCH

The engineering researcher will likely face a range of challenges across different levels when seeking to align their research priorities with the Global Dimension.

The nature of research funding is often at the core of many of the challenges facing the researcher. For example, the academic community has been facing an unprecedented push for researchers to publish papers in peer-reviewed, indexed international scientific journals. This is due in many cases to the relationship between the number of published papers and the funding received by universities. Whilst peer-reviewed publishing is important in safeguarding research quality, there is evidence that the pressure to publish biases research priorities. It may also simply be that no appropriate 'traditional' research funding is available. Or, further, that a traditional research funder demands an indication of benefit to the domestic national economy of the researcher (as opposed to the economies of developing countries) which can become very problematic when building a case for, say, research into appropriate technologies like solar ovens.

It may be difficult to identify appropriate and reliable research partner organisations, and relevant fora or networks to engage with; to do so could require engagement with the development sector more generally which, given its international nature, can demand travel time and expenses that are not readily available within university departments.

If aligning research priorities with the Global Dimension also implies opening a new line of research, the researcher must be aware of some particular challenges. These can include:

- The possibility of poor recognition from colleagues within the same discipline areas.
- Colleagues who are sceptical of research areas which intersect with other disciplines rather than being squarely within one traditional discipline.
- Scepticism over the nature of the research itself and its academic rigour – particularly in cases where, say, a technology is not seen as 'cutting edge' or 'high technology'.
- Diminished personal motivations as a result of the above.
- The time needed to achieve a stable scientific productivity in a newly opened research area, which is typically about 4-5 years from the start of a new research line.

Established researchers may be safer from such challenges (in relation to the benefits for their academic career), though since they are often more time-constrained they could actually be less able to tackle them.

OPPORTUNITIES FOR THE GLOBAL DIMENSION IN ENGINEERING RESEARCH

Significant and exciting opportunities can emerge for engineering researchers working with the Global Dimension – both in terms of professional and personal development.

The high potential to make a valuable and real impact through research can be a powerful motivator for an engineering researcher, and for those supporting them. The opportunities to achieve this in developing countries are – in some ways, and for many reasons – greater than in developed countries. Putting globally-relevant engineering research activity into practice can create a sense of rejuvenation and innovation in the personal and professional experience of the researcher. It can also raise scientific visibility, since ‘global’ studies are increasingly welcomed by leading scientific journals – as well as visibility with the university institution itself, as universities continue to look for ‘good news’ stories.

A shift in research priorities towards the Global Dimension affords the researcher the opportunity to interact with practitioners, leaders and researchers from different cultural backgrounds. Such diverse perspectives – when coupled with an open-minded curiosity about issues relevant to the research topic – can quickly motivate the researcher towards the leading edges of their main discipline. While some areas of engineering may favour these conditions slightly more than others, creativity and innovation can flourish anywhere.

Depending on the topics and issues being considered by the research, there may also be the opportunity for increased professional and personal agency as a result of considering the Global Dimension. For example, engineering researchers have become involved in discussions at governmental, political and international levels as advisors on infrastructure climate risk, participatory governance systems or renewable energy targets.

Finally, as has been discussed in the previous chapter, there are also significant opportunities to improve teaching. A clear example of the relationship between engineering research aligned with the Global Dimension and GDEE is the ‘vertically integrated’ programme or curriculum (refer to Course 8 Chapters 2 and 4). Here, undergraduate students can study engineering through the lens of an active research partnership with a developing country institution or can even support current research through dissertation project activities.

CONCLUSION

This Chapter has attempted to show the relevance (why?) and feasibility (how?) of aligning the research priorities in several areas of engineering with the Global Dimension.

The illustrative examples provided in this chapter offer clear indications that an engineering researcher who intends to align, at least partially, their research interests with the Global Dimension will be able to find opportunities whatever their field of engineering. They also show the relevance and importance of such research to global development, especially if conducted by teams of researchers rather than isolated individuals.

The feasibility of aligning research priorities with the Global Dimension was explored through a summary of both the challenge and opportunities that an engineering researcher may face. Whilst there may be difficult challenges to overcome, the professional and personal opportunities that can emerge are manifold. Opportunities also exist to tie such research back into engineering education.

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PHOTO: Closed Stoves Are Appreciated by Animals and Humans Alike - Arnakot Deurali, Western Nepal. D. Narayanan

CHAPTER

2

Research methods for GDE

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COORDINATED BY

Agustí Pérez-Foguet and Enric Velo (*Universitat Politècnica de Catalunya*)

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2

RESEARCH METHODS FOR THE GLOBAL DIMENSION IN ENGINEERING

Elisabet Roca Bosch, Laboratory of Social Studies of Civil Engineering, Department of Transport Infrastructure and Territory, Universitat Politècnica de Catalunya

EXECUTIVE SUMMARY

Understanding our complex society as we head towards an uncertain future – and challenged by the principles of sustainability and social justice – calls for new modes of research. Alternative approaches based on the participatory, collaborative co-creation of scientifically and socially relevant knowledge are needed as the boundaries between theory and practice blur.

The concerns of the Global Dimension of Engineering include addressing real-life problems, environmental impacts and social inequalities. These concerns are also at the core of alternatives to traditional research approaches, such as Action Research (Lewin 1946), Sustainability Science (Kates et al. 2001), Mode-2 Science (Gibbons et al. 1994), Post-Normal Science (Funtowicz et Ravetz, 1992). These approaches aim to simultaneously enable both social change and scientific progress.

This chapter provides an overview of these approaches, and introduces and reflects on their values and usefulness in the context of the Global Dimension of Engineering. It gives a brief introduction to Participatory Action Research (PAR), including its key issues. This is followed by other more contemporary approaches that have emerged in the face of new, non-linear and complex global challenges.

LEARNING OUTCOMES

After you actively engage in the learning experiences provided in this module, you should be able to:

- Acknowledge and discuss the need of a more collaborative production of knowledge to deal with sustainability challenges.
- Distinguish Participatory Action Research and other approaches as alternatives to cope with complex problems and environmental risks.
- Describe the key issues that characterise each of the approaches presented.

KEY CONCEPTS

These concepts will help you better understand the content in this session:

- Positivist Science
- Participatory Action Research
- Post-normal Science
- Mode-II Science

GUIDING QUESTIONS

Develop your answers to the following guiding questions while completing the readings and working through the session:

- Why is Positivist Science not adequate to address current societal challenges?
- What is Participatory Action Research and its key issues?
- What are Post-Normal Science and Mode-II Science?
- How do these approaches deal with environmental risks?

INTRODUCTION

To consider new perspectives that might help engineering researchers tackle Global Dimension priorities, it is instructive to ask: what is the role of science in today's society? This chapter reflects on the relationship between science and society and introduces alternatives to the positivist science that has been the dominant paradigm of the last century.

The conventional forms of knowledge production are the discipline-focused specialisations that are managed by hierarchical organisations, which frequently compete for funding within the framework of a market economy. Science is therefore conditioned by industrial and commercial interests and is subject to power dynamics that prioritise projects and areas of research. Moreover, conventional research institutions have an internal logic – informed by 'management science' approaches – that finds expression in their methods and results, but can limit access to technological research even by affected stakeholders (who may have little power). Asymmetries and inequalities in the control of knowledge production and research funding mean that certain issues and groups receive more attention than others. For this reason, new approaches and mechanisms are used to allow other voices to be considered in the research process – or, recognising the problem, are at least claimed to be used (Gaveta and Cornwall, 2001).

Over the last few decades there has been an increasing awareness and growing commitment to research that can challenge traditional restrictions on knowledge production, and that can bridge research and social change. As a consequence, this has intensified the need to engage in collaborative community building for meaningful pedagogy, policy and practice towards social transformations (Abraham and Purkayastha, 2012). New epistemological and methodological paradigms have emerged. These paradigms converge by proposing a new mode of producing knowledge and managing science, which is both closer to and under the control of the society. Direct participation of stakeholders in science should help to direct scientific and technological advances towards public demands for sustainability and social justice – or, more generally, in favour of the public interest rather than vested interests. Thus, the critics agree on a vision of science as a dynamic system that depends not only on the internal logic of hierarchical organisations and the scientific method, but is also concerned by contextual determinants of social or political nature. In effect, this is the application of Global Dimension principles to the production of knowledge.

There are various labels applied to such participatory and contextually-sensitive research, which include 'action research', 'action-oriented research', 'community-based participatory research', 'collaborative action research', 'feminist participatory research', 'feminist action research' and some forms of 'public sociology' – among others.

These complementary methods to conventional science are also driven by: potential risks to health and the environment caused by some of the technological advances of our post-industrial society (or the so-called 'risk society' of Ulrich Beck); reactions to certain uses of technological innovations (such as for the arms industry) and; inequalities in the distribution of the benefits of research. Finally there is the wider recognition and understanding of the development of complexity science and 'systems thinking'; acceptance of this is driven not only by more powerful analytical tools but also by the realisation that the complex dynamics of global change makes linear models (which are so typical of positivist science) unsuitable for understanding future impacts.

Other integrative paradigms have also been developed during the last two decades to overcome the limitations of traditional approaches and to explicitly support policy making. These are in many ways similar to Participatory Action Research, but with a specific focus on socio-environmental conflicts. These integrative paradigms have received many names but in general their purpose is also to complement traditional methodologies or 'normal science' to deal with urgent and complex environmental problems – because of the inherent uncertainties, diversity of knowledge and value judgments involved. They include: the Science of Surprise (Holling, 1986); Post-normal Science (Funtowicz et al., 1992); Civic Science (Lee, 1993); Mode-II Science (Gibbons et al., 1994; Nowotny et al., 2003) and; Sustainability Science (Kasemir et al., 2003; Kates et al. 2001).

In this chapter, the Participatory Action Research approach is explained before briefly describing Post-Normal Science and Mode-II Science. The chapter attempts to illustrate the potential of these methods for considering the Global Dimension in engineering research.

WHAT IS PARTICIPATORY ACTION RESEARCH (PAR)?

The origins and chronology of the linking of research and action are complex; they cannot be attributed to any single discipline or any part of the world (Reason and Bradbury, 2001). But while there is no definitive history to the origins of ‘action research’, many writers do attribute it to Kurt Lewin who coined the term. Lewin first elaborated on the model of action research in his article on ‘action research and minority problems’ to address inter-group relations in some American communities (Lewin, 1946). With its emphasis on combining theory and practice, his work influenced the fields of action research and community-based research.

Participatory Action Research (PAR) flows from different traditions such as political economy, pragmatic philosophy, community development and education rather than any particular discipline. In past decades, PAR was mostly applied in the fields of social work, education, community development, work studies and health – both in developed and developing countries (Fals-Borda & Mora-Osejo, 2003). However, it was more recently proposed that action research skills should and could be brought into environmental issues in order to open communicative spaces for the most pressing concerns of the public agenda – such as climate change, biodiversity loss and sustainability. PAR seems particularly relevant in sustainability contexts since discourses on environment have explicitly politicised issues of ecology and enacted them through social justice and participatory democratic politics (Bodorkos et al. 2009). Several definitions of PAR read as follow:

“A way of working in the field, of utilising multiple research techniques aimed at enhancing change and generating data for scientific knowledge production. Action Research rests on processes of collaborative knowledge development and action design involving local stakeholders as full partners in mutual learning processes.” (Greenwood and Levin, 2007:1)

“A participatory, democratic process concerned with developing practical knowing in the pursuit of worthwhile human purposes, grounded in a participatory worldview which we believe is emerging at this historical moment. It seeks to bring together action and reflection, theory and practice, in participation with others, in the pursuit of practical solutions to issues of pressing concern to people, and more generally the flourishing of individual persons and their communities.” (Reason and Bradbury, 2001:1)

“What is empowering about participatory research is the extent to which it is able to link the three, to create more democratic forms of knowledge, through action and mobilisation of relatively powerless groups on their own affairs, in a way that also involves their own critical reflection and learning.” (Gaventa and Cornwall, 2001:76)

These definitions are each describing the three important aspects:

- action (or practice, change and improvement);
- research (or theory, understanding and knowledge);
- participation (or partnership, democracy, mobilisation and empowerment).

The concept of research is therefore not simply of a theory, and its linear application, alone. Rather, PAR is a flexible, open and iterative spiral process with stakeholders that allows action and research to be achieved at the same time (see Figure 1). The understanding allows more informed change whilst, at the same time, is also informed by that change. People affected by the change are usually those engaged in the action research. This allows the understanding to be widely shared and the change to be pursued with commitment.

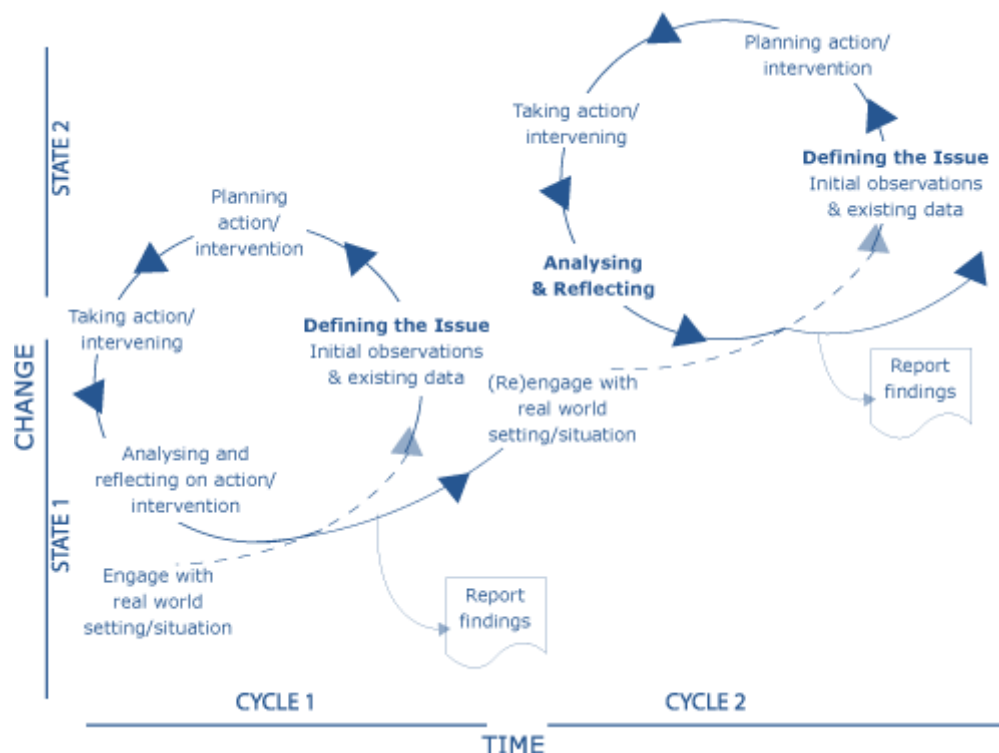


Figure 1 Participatory Action Research model (Lewin, 1943)

PAR aims to articulate knowledge production and transformative action and assumes interdependence between action and research (Lewin, 1946). The knowledge produced should therefore be meaningful and relevant both to the people participating in the research and to the contexts in which it is produced. Participation is a key principle (aligned with the emancipation and empowerment goals of action research) whereby the purpose of research is not only for producing knowledge but for promoting practical insights that can contribute to issues of social justice, or “*strengthening the capacity of the individual to play the role of actor in his or her own life*” (Miller & Rose, 2008). More than just a methodology, PAR is an attitude to the role of science, a way of thinking about the scientific method and a bridge to integrated knowledge and practice with a commitment to social justice.

Aspects that characterise PAR:

- **It is context-bound and focuses real-life problems:**

A primary purpose of PAR is to produce practical knowledge that is useful to people in their everyday lives, increasing their well-being and promoting equity and sustainability. The information gathered is not assumed to be independent of the time, place and people in context; the objective is to address specific situations instead of generalising across cases and contexts (Abraham and Purkayastha, 2012). Therefore, action-oriented research has challenged positivistic epistemologies which hold that the way we conduct research and produce knowledge must be objective and value-free to be credible. Solutions seek to address specific problems of social interests which, at the same time, necessitates continuous negotiation with non-academic stakeholders.

- **It is participative:**

PAR has strong democratic aspirations as it is only made possible by involving all stakeholders both in the questioning and 'sense-making' that informs the research, and in the action which is its focus (Reason and Bradbury, 2001). Since the 1990s the discourse of participation has been introduced into the decision-making processes as one of the characteristics of sustainable development. Its inclusion in sustainability assessments is justified on many grounds. While, a priori, PAR can be stated that it strengthens the democratisation of the production of knowledge, a relevant key feature is that it can contribute to creating more socially robust knowledge for its context of application (Gibbons et al. 1994). Van den Hove (2006) argues that public participation ensures holistic thinking about the environment as complex environmental problems often cannot be solved through technology or scientific expertise alone. Ensuring that a wide variety of viewpoints are considered when defining the problem may assist decision-makers in understanding complexities and fit-in solutions. Lynam et al. (2007) suggest that a participatory tool must: support communication and learning between its users; be adaptable for implementation in different contexts and; produce data and information that are useful and valid for decision-making. Furthermore participation enhances transparency since conflicting claims and views become clearer, which can increase public trust in the final outcome. Finally, participation contributes to building an active civil society (Richards et al., 2007). PAR can promote higher levels of public acceptance of the decisions adopted, entailing the legitimacy of public policy; it can contribute to better communication of uncertainties and it can enhance processes of social learning and institutional change. Public participation acts as a quality control of established knowledge which is more socially robust.

More specifically, in research processes, participation assures that the perspectives and interests of those immediately affected are considered and not filtered through an outsider's preconceptions (Reason and Bradbury, 2001). Involving new participants enhances the definition of the problem addressed and the issues framed in the research.

- **Trans-disciplinarity:**

The bridging of different disciplines – be they in natural sciences and/or social sciences – is particularly useful in research on sustainability issues. Nowadays there is a need to understand the systemic nature of our eco-systems, and the complex relationships between nature and society to tackle dynamic problems such as climate change or the risks associated to new technologies. Trans-disciplinarity highlights the importance of extended peer-communities to quality control the output of the research process. It also requires researchers to have higher levels of flexibility in adapting their approaches and methodological practices, operating in hybrid zones or intersections between disciplines – this may require becoming a specialist in areas beyond the researcher's background.

- **Reflexive:**

PAR sees research as a process of reflection, learning and the development of critical consciousness. Assessing the success of a PAR project in meeting its empowerment goals – or in making some form of transformative impact – requires a reflexive and cyclical standpoint that links action and reflection, theory and practice. PAR is then a process that pursues action (e.g.: policy change) and research (e.g.: understanding of policy processes) and at the same time 'learning by doing' (e.g.: participatory natural resources management).

PAR includes several iterative and complementary processes such as: bottom-up community learning and experimentation; horizontal experience sharing between communities; vertical policy dialogue; learning events at the local level and; stakeholders' workshops and feedback (Reason & Bradbury, 2001).

- **Collaborative process where the researcher is a participant:**

In the traditional research, scientists can and have claimed privileged knowledge; they are experts and have the mindsets of experts. In the traditional application of research, such experts are usually outsiders who come in to a particular context to try to use their knowledge to affect a change.

However in PAR, the researcher is considered a participant with a particular set of skills and information, within a wider knowledge. So, the researcher is required to move from the position of an outside expert to a position of an involved participant (Greenwood & Levin, 2007). This transforms the research into a collaborative process between the researchers and stakeholders in the context. Upon invitation into a context, the outsider researcher's role is to implement methods in such a manner as to produce a mutually agreeable outcome for all participants, with the process being maintained by them afterwards. To accomplish this, the researcher may need to: break down borders between themselves and the stakeholders; to demonstrate humility and free themselves of the mindset that they are the expert; to manage expectations and; to adopt many different roles at various stages of the process (such as those of planner, facilitator, teacher, designer, listener, observer, reporter... and expert). Their main role, however, is

to take the time to facilitate dialogue, to foster reflective analysis and to nurture local leaders to the point where they can take responsibility for the process. This point is reached when they understand the methods and are able to carry on after the researcher leaves. This process is strongly analogous to the role of, say, an international development engineer undertaking participatory development work in a rural community.

- **Power relationships:**

PAR critiques the connection between power and knowledge and the ways that structural relationships of power are maintained by monopolies of knowledge. Conventional science is used to declare that the knowledge of some groups is more valid than others; ‘experts’ over ‘lay people’ (Gaventa et Cornwall, 2001). Positivist methods increase the distance and barriers between those who study reality (the expert) from those who experience it through their own experience (the lay people). Thus, PAR recognises that those who are directly affected by the research problem possess different forms of knowing – such as feeling, intuition and experience – which are considered as important as rationality or cognition in the knowledge creation process.

Finally, PAR seeks to change power relationships, allowing people to say something in the decisions that affect them. And what is more – through a more open and democratic process – other forms of knowledge are framed and given voice. In the end, it is desired to empower local communities and the underprivileged through the construction of their own knowledge in a process of action and reflection or awareness. Note that feminists also remind us that gender is embedded in power relations.

- **Tools and methods:**

Participatory Action Research is a holistic (whole-system) and contextual approach to problem-solving that aspires to certain principles including participation, collaboration, trans-disciplinarity, equity and transformation. It is more than a single tool or method for collecting and analysing data – it is an approach that requires a different kind of mindset. Preferring a very loosely structured, inductive research approach over a pre-structured methodology has usually proved to be one of the first crucial steps in moving to this mindset. Responsiveness and flexible research design are considered to be of rigour for improving the validity and credibility of the research (Abraham and Purkayastha, 2012).

PAR allows for several different research tools to be used as the research is conducted (see Figure 2). These various methods, which are generally common to the qualitative research paradigm, include: keeping a research journal; document collection and analysis; participant observation recordings; questionnaire surveys; structured and unstructured interviews and; case studies. (For more information on social science methods see for example Babbie, 2007). Scientific rigour can be enriched by combining quantitative measures with relevant qualitative or ethnographic information. Apart from the inductive and deductive examination of results, empathetic involvement and local judgement might play a role in the validation of the results.

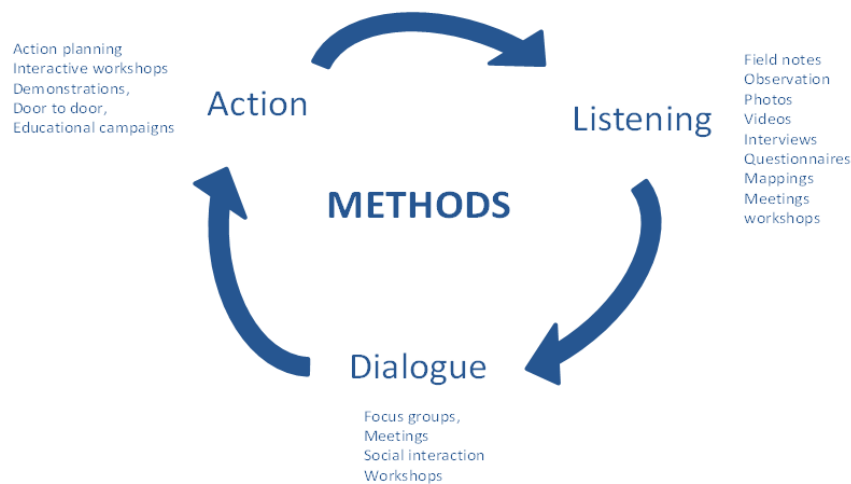


Figure 2 Methods employed in a PAR process (adapted from www.cparn.org)

A central issue is to assess the extent to which empowerment has been achieved – both during and after the research process (in the reflexive loop) – through analysis of the research produced, its impact on the individuals and groups involved and its effectiveness for social action. A variety of methodological devices and methods can be used here, such as participant observation, questionnaires or workshops. Therefore, knowledge of a range of methods and techniques for implementing and evaluating the process is highly desirable.

- **Ethical issues:**

Since PAR is carried out in real-world contexts and involves close and open communication with stakeholders, researchers must pay close attention to the ethical considerations of their work. The following is adapted from Richard Winter (1996):

- Make sure that the relevant persons, committees and authorities have been consulted and that the principles guiding the work are accepted in advance by all.
- All participants must be allowed equal access to information generated by the process and to influence the work, and the wishes of those who do not wish to participate must be respected.
- Development of the work must stay visible and open to suggestions from others.
- Permission must be obtained before making observations or examining documents that were produced for other purposes.
- Descriptions of others' work and points of view must be negotiated with those concerned before being published.
- The researcher must accept responsibility for maintaining confidentiality.
- Researchers are explicit about the nature of the research process from the beginning, including all personal biases and interests.
- The outside researcher and the initial design team must create a process that maximises the opportunities for involvement of all participants. Decisions made about the direction of the research and the probable outcomes are collective.

OTHER ALTERNATIVES TO TRADITIONAL SCIENCE

Mode-II Science:

In reaction to the conventional ‘Mode-I’ production of knowledge or positivist research, Gibbons et al. (1994) introduce the need for alternative ‘Mode-II’ scientific approaches (see Table 1). This paradigm has much in common with PAR because the basic principles are contextualisation, social utility, trans-disciplinarity, heterogeneity, reflexivity and participation.

Social use and applicability are prioritised and disciplinary boundaries are overcome. Non-hierarchical groups are created ad-hoc to specifically respond to social demands. It is a method for the production of knowledge that is oriented to its application context and for its social acceptance. High social value is given to science since it provides useful knowledge for daily life.

This new way of producing knowledge is no longer exclusively located in universities and research centres, but rather other environments outside of conventional institutions are potential generators of knowledge. Thus, heterogeneity and diversity characterise new organizational forms of work.

	Conventional approaches	Alternative approaches
Who generates knowledge	Academia: researchers	Different social actors
Scope	Single-dimension; Partial; Fragmented	Integrative/holistic; Interdisciplinary; Transdisciplinary
Methods	Model orientated; Scientific and technical methods	Participatory approaches; Several methodologies
Process	Linear; Predictive	Cyclical; Exploratory
Where produced the knowledge?	In the research centres	In direct contact with social actors
How the work is structured?	Hierarchical; Vertically in academic structures	Heterogeneous; non-hierarchical
Quality control	Scientific criteria; Academic peer review	Social, economic, environmental impact
Treatment of uncertainties	Only facts and certainties	Acknowledgement of uncertainty

Table 1: Summary table comparing conventional with alternative approaches to research methods (adapted from Gibbons et al (1994) and Weaver et al (2006)).

Post-normal Science:

Knowledge about human development is characterised by uncertainty, multiple inter-related dependencies and imperfect understanding. Technological development often demands that decisions are taken before scientific evidence is available about impacts, even when the potential impacts of such decisions could be very large. In the face of this paradox, Funtowicz and Ravetz (1992) proposed a shift to what they called Post-normal Science. This would help to cope with high-uncertainty, high-stakes risks and disputed values in response to the challenges of policy issues and risks. The starting point for Post-normal Science is then the recognition that uncertainty is inherent in complex systems and conventional, positivist science is not well suited for addressing contemporary technological, environmental and health concerns. Where disciplinary science meets its limits in dealing with societal trans-disciplinary issues (such as trans-national or trans-generational environmental problems) Post-normal Science offers a framework for approaching them. This particularly means at times when uncertainties are of an epistemological or ethical kind, or when decision stakes reflect conflicting purposes among stakeholders.

“The intimate connection between uncertainties in knowledge and in ethics is well illustrated by the problems of extinction of species, either singly or on a global scale. It is impossible to produce a simple rationale for adjudicating between the rights of people who would benefit from some development, and those of a species of animal or plant which would be harmed. However, the ethical uncertainties should not deter us from searching for solutions; nor can decision makers overlook the political force of those humans who have a passionate concern for those who cannot plead or vote. Only a dialogue between all sides, in which scientific expertise takes its place at the table with local and environmental concerns, can achieve creative solutions to such problems, which can then be implemented and enforced.” (Funtowicz et Ravetz, 1993: 751)

Post-Normal Science can be located in relation to the more conventional complementary strategies by means of Figure 3 where there are two axes: ‘systems uncertainties’ and ‘decision stakes’. When both are small, we are in the realm of ‘normal’, safe science where expertise is fully effective. When either is medium, then the application of routine techniques is not sufficient; skill, judgement and sometimes even courage are required. We might call this ‘professional consultancy’ (with the examples of the surgeon or the senior engineer in mind). In recent years, we have learned that even the skills of professionals are not always adequate for the solution of science-related policy issues. When risks cannot be quantified, or when possible damage is irreversible, then we are beyond the range of competence of conventional sorts of expertise and traditional problem-solving methodologies. This situation is represented on the diagram as the outer band – the domain of Post-Normal Science.

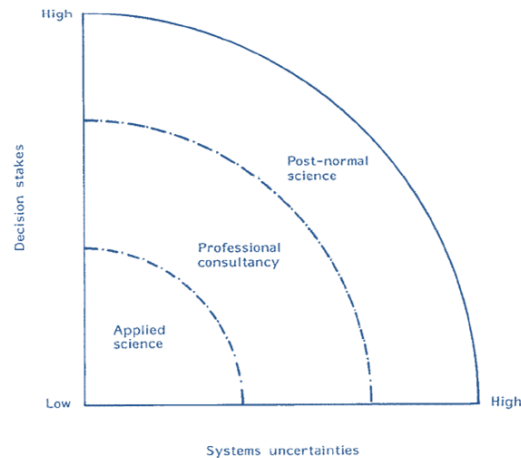


Figure 3 Classification of science proposed by Funtowicz and Ravetz (1992)

The treatment of subjectivity and peer-review is also considered by Post-normal Science. In the face of some environmental conflicts, one has to choose the scientific strategy to best solve the problem at hand although a simple methodology often does not work. For instance the use of models, scenarios or integrated evaluation methods (i.e.: multi-criteria analysis, cost benefit analysis) predominates. However, it should be acknowledged that many hidden value judgements are associated with the way one approaches a problem. Values affect, say, the indicators used and the assumptions made (van der Sluijs, 2007).

In order to deal with subjectivity and values, Post-normal Science proposes extending peer communities beyond those for core science. There are currently many initiatives to incorporate social groups into decision-making and in subsequent implementation. However, in Post-normal Science, the involvement of the affected groups is not only associated with a democratic participation but also involves the inclusion of a growing number of 'legitimate stakeholders' to ensure the quality of scientific inputs...

Those who are directly affected by an environmental problem will have a deeper awareness of symptoms and a more compelling interest than those who are not directly concerned – so they can provide another type of knowledge and data that is more related to their own experiences and life trajectories. They will also have 'extended facts', including anecdotes, informal surveys and official information published by unofficial means. It may be argued that affected people lack theoretical knowledge and are biased by self-interest; but it can equally well be argued that the experts lack practical knowledge and have their own forms of bias.

Thus, the approach of Funtowicz and Ravetz (1993) is that the quality of decisions depends on a broad dialogue between those affected beyond those with institutional accreditation. This is why the dynamic of resolution of a policy issue in Post-normal Science involves the inclusion of an ever-growing set of legitimate participants – and broader societal and cultural institutions or movements – in the process of quality assurance of the scientific inputs.

CONCLUSION

This chapter has discussed alternative research methods to complement conventional research methods in order to progress research that considers the Global Dimension.

Moving beyond conventional positivist science has been suggested through approaches such as PAR, Mode-II Science and Post-normal Science. Other approaches exist that have not been explored in this chapter.

According to these alternative approaches, the production of knowledge should be subjected to several principles:

1. The production of knowledge is accountable to society since research is increasingly oriented towards social, economic and political issues.
2. The production of knowledge takes place in a specific context, with particular utility for certain stakeholders.
3. The monopoly over the production of knowledge by universities and research centres is overcome by participation from new actors and research networks designed to respond to specific problems.
4. Heterogeneous research teams should move towards inter- and trans-disciplinary skillsets and mindsets to overcome the disciplinary division of knowledge.
5. Quality control of research incorporates external (social, political and economic) criteria and it is not limited to internal control through peer-review.

The involvement of social actors in research processes breaks with the traditional model of science, but aligns well with the objectives of the Global Dimension.

Practical recommendations to undertake such alternative research include: personal skills and attitudes; taking time to go slow; linking to social movements and local capacity; creating vertical alliances and networks and; monitoring for quality and accountability. In particular, skilled action research teams are required in order to encourage and facilitate communities to participate in such research processes.

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FURTHER READING AND SUGGESTED MATERIAL:

- Book: Chevalier, J.M. Buckles, D.J. 2008. SAS2 A Guide to Collaborative Inquiry and Social Engagement. IDRC. Available online at: www.idrc.ca/EN/Resources/Publications/Pages/IDRCBookDetails.aspx?PublicationID=108
- Website: SAS2 Participatory Action Research, Evaluation and Planning. www.participatoryactionresearch.net/
- Website: NUSAP - The Management of Uncertainty and Quality in Quantitative Information. www.nusap.net
- Website: Participatory Action Research and Organisational Change. <http://participaction.wordpress.com/>
- Website on action research tools: www.web.net/robrien/papers/arfinal.html#_Toc26184667
- Video on Participatory action Research. E. Alana James. www.youtube.com/watch?v=s-SAJPF5xiA



PHOTO: Sustainable development, combining techniques. Senegal. M.M. García Alcaraz

3

CHAPTER

Engineering education research, with a focus on engineering for development

C.9

Integrating GDE into research

3

CHAPTER 3. Engineering education research, with a focus on engineering for development

EDITED BY

Global Dimension in Engineering Education

COORDINATED BY

Agustí Pérez-Foguet and Enric Velo (*Universitat Politècnica de Catalunya*)

Manuel Sierra (*Universidad Politécnica de Madrid*)

Alejandra Boni and Jordi Peris (*Universitat Politècnica de València*)

Guido Zolezzi (*Università degli Studi di Trento*)

Rhoda Trimingham (*Loughborough University*)

WITH GRATEFUL THANKS TO

Boris Lazzarini (*Universitat Politècnica de Catalunya*)

Xosé Ramil and Sara Romero (*Universidad Politécnica de Madrid*)

Jadicha Sow Paino (*Universitat Politècnica de València*)

Angela Cordeiro and Gabriella Trombino (*Università degli Studi di Trento*)

Emily Mattiussi, Sylvia Roberge and Katie Cresswell-Maynard (*Engineers Without Borders - UK*)

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3

ENGINEERING EDUCATION RESEARCH (WITH A FOCUS ON ENGINEERING FOR DEVELOPMENT)

Elizabeth Hauke, Senior Teaching Fellow, Imperial College London

EXECUTIVE SUMMARY

This chapter will introduce an extended case study, written from a personal perspective, as an example of the integration of Sustainable Human Development and the Global Dimension in engineering into science and engineering undergraduate education.

It will offer a non-engineering perspective on issues of complexity and mastery, as informed by the author's work with both engineering and non-engineering students over the last three years.

The chapter will conclude with some ideas about evaluation and educational research that could better inform work on the Global Dimension in Engineering Education.

A brief background into Engineering Education Research is provided for context before the chapter begins.

LEARNING OUTCOMES

After you actively engage in the learning experiences provided in this module, you should be able to:

- Understand the connections between research and teaching
- Understanding the role of education research in improving teaching and learning of the Global Dimension in Engineering Education.

KEY CONCEPTS

These concepts will help you better understand the content in this session:

- Team design projects, particularly the Engineers Without Borders Challenge
- Traditional engineering education assessment methods
- How non-traditional engineering education assessment methods resonate with the values of the Global Dimension

GUIDING QUESTIONS

Develop your answers to the following guiding questions while completing the readings and working through the session:

- How can we know if engineering teaching should be improved?
- How can the student's experience and response to engineering education inform teaching?
- How can researching the effectiveness Global Dimension in Engineering Education help to inform changes to engineering education in general?

BACKGROUND: ENGINEERING EDUCATION RESEARCH

Engineering Education Research brings together a relatively small community of academics, many of whom are also actively involved in delivering engineering education. Focusing on Engineering for Development within this, we find a very new and even smaller community, many of whom are – in addition – also active in international development work as well. Most of these researchers have a background in engineering rather than, say, the social sciences.

This community is growing in influence as the need for pedagogic change is increasingly recognised, as engineering employers increasingly demand ‘global skills’ and as the advocacy and support from civil society organisations grows (particularly from the ‘Engineers Without Borders’ movement, which engages many engineering undergraduates, and also the ‘Big Beacon’ movement). To date, most of the research on Engineering for Development within engineering education consists of case studies and student evaluations by those within this community; it is still too new a field to find published longer-term research conducted by social scientists or educationalists.

Engineering Education Research is associated with the wider Engineering Studies field. Engineering Studies emerged in the 1980s, has roots in Virginia Tech and the Colorado School of Mines in the USA and focuses on the inter-disciplinary study of engineers, engineering and (in some cases) the formation of engineers. There are a number of regional and international networks such as ‘The International Network for Engineering Studies (INES)’, the ‘Research in Engineering Education Network (REEN)’, the ‘International Federation of Engineering Education Societies (IFEES)’ or the ‘European Society for Engineering Education (SEFI)’ which published the European Journal of Engineering Education. New publications are emerging, such as the 2014 ‘Cambridge Handbook of Engineering Education Research’, and books such as ‘A Whole New Engineer’ and ‘The Case for Working With Your Hands’. There a range of conferences, such as the annual ‘World Engineering Education Forum’ and the international ‘Engineering Education Conference’ series in Europe (the fifth of which was held in Coventry, UK in 2012 on ‘Innovation, Practice and Research in Engineering Education’ and included a session on the Global Dimension in Engineering Education). There are also a number of relevant centres, such as these in the UK:

- Aston Engineering Education Research Group
- Manchester Science and Engineering Education Research and Innovation Hub
- Kings College London Centre for Research in Education in STEM
- Engineering Subject Centre’s Education Research Special Interest Group
- University College London Centre for Engineering Education

However, engineering education research centres tend to focus on Science, Technology, Engineering and Mathematics (STEM) at the primary and secondary educational levels or on, say, the evaluation of Problem Based Learning. No centre has yet focused major research on Engineering for Development in engineering education or on the Global Dimension in Engineering Education.

UNESCO plays an important role in supporting Engineering Education Research. Through its UNITWIN / UNESCO Chairs Programme, there are chairs in: Continuing Engineering Education (Beijing); Co-operation between Higher Education and Industries (Beijing); Problem-Based Learning in Engineering Education (Aalborg); Peace, Human Rights and Democracy at an Academy for Engineering Educational Research (Pune); Engineering Education (Tehran); Science, Technology and Engineering Education (Krakow); Distance Education in Engineering (St. Petersburg). These are alongside the UNITWIN network in Humanitarian Engineering (Coventry) and chairs in Sustainable Engineering in Developing Communities (Haifa) and Engineering for Human and Sustainable Development (Trento). In addition, the UNESCO Engineering Report published in 2010 included sections on Engineering Education Research and strongly advocated for the development of Engineering Studies and the growth of Engineering for Development in engineering education. Indeed, the report recommends solving the problems of engineering education by using Engineering for Development, in order to help solve the problems of the engineering profession and the world.

INTRODUCTION

Over the last three years, I have developed a cross-faculty programme of study called 'Global Challenges' at Imperial College London (the university's full name is The Imperial College of Science, Technology and Medicine). This programme comprises eight undergraduate courses that can be studied as ancillary modules or as co-curricular options. These options form part of our wider 'Imperial Horizons' programme, which also offers languages, humanities and business options. The courses cover a wide range of Sustainable Human Development and Engineering for Development topics and form a coherent curriculum with an emphasis on independent learning, enquiry skills and interdisciplinary approaches to real-world problems. The case study used in this chapter is our 'Engineers Without Borders (EWB) Challenge' course (other chapters in these GDEE courses have also used this case study).

The EWB Challenge is a student-focused design-based competition to encourage students to consider the Global Dimension while problem solving for a real developing community. The EWB Challenge is delivered to mixed discipline second year undergraduates, which allows students to work in multi-disciplinary teams involving engineering, science and medical students. The inherent diversity in approaches and experience within the teams provides a fertile base for the students to explore their collective skillset and define their own axis of engagement with the project. The course shares elements of core theory and methodology with the other second year courses, which focus on poverty, communication in development and local sustainability – and there is the opportunity for further cross-fertilisation of ideas between the courses.

Over the three years that the EWB Challenge course has been running, it has been evolved to privilege the practice of process, rather than a pre-occupation with product. We explicitly introduce the students to methodologies from disciplines such as the social sciences, art and design and business studies to better enable them to grapple with the complexity of the real world – and to move them away from the linear thinking common to their core degree studies. This is also an opportunity to offer a complementary approach, rather than replicating work they have already completed.

The EWB Challenge course, though still relatively new, provides an instructive example of the need for research into engineering education itself. The chapter will show that evaluations of the EWB Challenge course have taken an action research approach (as discussed in the previous chapter) because attempts to apply only conventional, linear assessment and evaluation methodologies would diminish the embrace of the complexity of the real world that is emphasised by the course. More research into this type of engineering education is needed to help such educational approaches become better understood and more mainstream – and so this chapter will suggest some lines of research for the future, based on the experience of the EWB Challenge course.

ROLLING OUT THE EWB CHALLENGE

The EWB Challenge course has now been delivered to five cohorts of students, and has markedly developed from our initial pilot. When I began developing the course, the aim was to create a course that ‘fit’ the core aims and values of our wider Global Challenges programme, and that offered something different to the work any of the students would come across in their main courses of study – whether they were from an engineering discipline or, for example, from maths, biology or medicine.

I also think that course design and effective teaching and learning requires that we listen and learn from the students. This is the only way that we can determine how they are interacting and engaging with the world and wider issues of human development and what they need as learners and future professionals in order to make meaningful choices for themselves and be effective and active in work and in life. I therefore purposely designed a very open pilot that would allow me to observe the students existing values and working practices, and to target areas for further development.

The EWB Challenge is an engineering design challenge that is built around the problems faced by a real community in a developing country. The organisation Engineers Without Borders UK provides us with a detailed design brief and some contextual information about the community. The students need to focus their efforts on one particular aspect of the design brief, identify a specific problem, write a design question and design a solution. For example, they might choose to look at the energy aspect and the problem of indoor smoke from cooking, and then develop a design question that leads to a solution such as an establishing an improved cookstove social enterprise. They must consider the Global Dimension of engineering to ensure that their solution is culturally, socially and economically appropriate, and that it is sustainable – both environmentally and for the community to maintain and operate.

The course was designed to facilitate the students to plan and complete their own design project, with ten structured steps to work through during the ten weeks of the course (see Figure 1). The students were given support as they asked for it, but were not required to work in any one particular way or follow any specific methodology (although we did introduce the use of a binary dominance matrix / decision matrix / Pugh method for step 4).

1. **Meeting the team and tackling the design brief** – students were encouraged to explore the expertise and experience of their team members, and to read the design brief
2. **Allocation of design areas** – students pitched for the area of the design brief that they wanted to focus on in their teams, and explored this area in more depth
3. **Writing the design question** – students were required to focus their work with the design brief and write a design question to guide their work
4. **Identifying the factors for success** – students were asked to think about what be required for their design to be considered successful, and how this could be evaluated and measured
5. **Working through potential solutions** – the students were encouraged to document as many potential design ideas as possible and relate them back to the design question and success factors
6. **Pitch and submit** – the students pitched their ideas to their colleague to obtain feedback and submitted their ideas to their tutors for further feedback
7. **Revision and technical specification** – the students were required to demonstrate incorporation of the feedback and to start fleshing out their design with technical detail
8. **Problem solving** – the students were challenged to identify potential problems with their design and solve them
9. **Documentation of the design process and solution** – the students had to document their design process and relate it to the initial brief, their design question and factors for success
10. **Presentation of the final design** – the students were required to make a formal presentation of their final design, with consideration of the community for whom the design was targeted

Figure 1. *The ten step design process for the EWB Challenge course*

Each week the students had to complete a ‘Progress Goal’ which was a short answer question that demonstrated whether the students understood the step of the process that they were completing and allowed them to comment on their own approach. In addition, the students were informally interviewed about the process during the course.

Designing the course in this way allowed us to gain a really good understanding of how our students were working and thinking. Admittedly, we were working with a small sample of students, in a very specific institutional context, and we were not following any rigorous research methodology. At the end of this chapter there will be some discussion of research methodology that ideally would be implemented to give validity to any observations or findings. The development of this course has been based on empirical observation of the students and reflection on the quality of work produced (participatory action research).

Initial observations

The most striking and frustrating observation is that our students seem to be incredibly goal-focused. In both this early pilot and further iterations of the course, we have a large number of students who design a water filter in the first session, without even reading the design brief. Exploration of this with the students reveals that many students believe that engineering is about designing the ‘perfect’ solution, and then adapting the situation to make use of the solution. This way of thinking doesn’t just come from the engineering students – I recently had a physics undergraduate who stated *“this course is wasting my time. I could have come up with the solution in the first week, then spent the rest of the course perfecting it”*. I then asked how the student would know what problem he was attempting to solve if he didn’t read the brief, and how he would know whether his solution would work in the real world if he didn’t engage with the community. He responded *“it doesn’t matter. I know clean water is an issue for poor people and my solution will be perfect, so they will want to use it”*. I challenged him further and asked exactly what or who the solution would be perfect for, and he replied *“the solution itself will be perfect”*.

This example highlights the first issue that I have been attempting to address with developments of the course:

**My students find it hard to engage with the real world
and to maintain realistic expectations of their interaction with the world;
they are pre-occupied with achieving a goal;
they believe they can achieve ‘perfection’**

In a way, this leads on to the next issue that has arisen. In many ways, our students do not have a very developed sense of identity – whether professionally speaking or in terms of their skills and strengths. This is something that we work hard to develop during all the Global Challenges courses.

We focus on deconstructing what the students think when they begin a course, and letting them reconstruct this in the light of the experiences they have with us and the work they do. However, what they believe they know about themselves and their potential as scientists or engineers is very tied to the concept of mastery.

Sometimes this can manifest as an arrogant sensibility, and their projects sometimes demonstrate a strongly paternalistic approach to engaging with others or offering solutions in a development context. At other times, mastery manifests in a very bounded approach to the world. The students are however unwilling to recognise their borders and the simplistic / reductionist lens that they use to make the real world ‘fit’ their approach, and to make their solution ‘successful’.

So this issue might be summarised as:

**my students have a strong sense of disciplinary identity –
that their role in the world is to use their specialisation
to ‘master’ nature and problematic situations;
in order to maintain an ability to be successful and achieve mastery,
they fail to engage with the real world, and work within
un-acknowledged boundaries that over-simplify the context**

For me, as a non-engineer, I see:

- Students who struggle to make an empathic connection with the real world, or with the people they are trying to help;
- Students who possess limited self-awareness about their approach;
- Students who have a strong sense of how they should achieve their goals, which largely follows a linear thinking process established within their disciplinary study.

In order to unpack this a little, and to think about how to work more effectively with the students to increase their awareness of the Global Dimension in engineering – and to give them practical approaches to Sustainable Human Development and Engineering for Development – I have explored the existing influences on these students and tried to bring together an inter-disciplinary toolkit to give the students new approaches and insight into the issues.

THE PROBLEM WITH REAL-WORLD PROBLEMS

Words like multi-disciplinary, inter-disciplinary and trans-disciplinary are used in a post-modern context to talk about learning, research and knowledge though they have no common or agreed definitions. For the purposes of this chapter, and in my work with students, I define the terms as follows:

- **Multi-disciplinary:** bringing together distinct ideas or methods from multiple disciplines to enhance understanding of a phenomena (the disciplinary contributions remain distinct)
- **Inter-disciplinary:** synthesising new methods or approaches to a phenomena by combining disciplinary ideas or methods (the disciplinary roots of the contributions are acknowledged, but the product belongs to no discipline)
- **Trans-disciplinary:** approaching a phenomena with no disciplinary lens at all (completely independent of disciplinary boundaries)

Thinking outside of disciplinary boundaries can be incredibly helpful but we must recognise that Western education systems – and indeed Western thought – are largely adherent to a strongly disciplinary structure. Our students have been taught within this framework, and have chosen to specialise within disciplines and sometimes even sub-disciplines. Integrating ideas that step outside these boundaries must therefore begin with a recognition of why these boundaries exist in the first place, and what they mean to our students and to the wider professions.

Disciplinary contexts

Modern engineering began in the Scientific Revolution of the 1600s, emerging from a background of scientific discovery and methodological development. In the UK, engineering emerged as an apprenticeship profession (Watson, 1982). John Smeaton is first credited with establishing the practice of engineering as a discipline in England when he coined the term ‘civil engineer’ (meaning non-military engineer) (Culligan and Peña-Mora, 2010).

Shortly after this, in 1771, the first professional body representing the profession of engineering was founded. Initially a rather informal gathering of like-minded professionals, called the ‘Society of Civil Engineers’, it changed its name to the ‘Institution of Civil Engineers’ in 1818 (Institution of Civil Engineers, n.d.). When they petitioned for a Royal Charter in 1828, they defined their new discipline as “*being the art of directing the great Sources of Power in Nature for the use and convenience of man*” (Institution of Civil Engineers, 2014). This statement remains part of the latest version of the Royal Charter, first approved in 1975. So we see that the idea of ‘mastery’ has a long and established heritage within the discipline of engineering.

There are now several engineering disciplines, and many sub-disciplines. The great benefit of organising learning and research into disciplines is that it allows a division of labour and greater specialisation of knowledge (Holbrook, 2010). As we learn more and more about the natural world and our presence in it, there becomes too great a body of knowledge for each individual to know everything. In the interests of cultivating depth of knowledge, the disciplines serve us well. However, the disciplinary approach to the world becomes less useful as the disciplines become more boundaried, and approaches and methodologies become distinct across disciplines.

It might therefore be the case that Sustainable Human Development and Engineering for Development makes demands of engineering that may best be answered from a non-disciplinary standpoint.

Within the domain of Sustainable Human Development there are a number of critical tensions – possibly the most important of which being between the local and global context. Approaches to analysing problems, our valuing of knowledge and expertise and the engagement of communities and implementation of change are all part of this tension. The public discourse encourages us to value the global approach – we are told that global action is needed to combat sustainability challenges such as climate change. But is it global ‘action’ that is required, or rather global engagement with local action? Can any sustainability challenge be answered by a global or widely implemented homogenous response?

The Global Dimension in engineering and a growing awareness of Sustainable Human Development attempt to re-organise and deploy existing knowledge and expertise in novel and more effective ways. With regards to the engineering profession, the question posed seems to be do we need more engineers, new types of engineers or engineers with a new sensibility?

Complexity in the enemy of mastery

If engineering is a problem-solving discipline, and Sustainable Human Development presents a number of problems, why is a new approach needed?

The answer lies in the nature of the problem. Unlike our organisation of knowledge, research and technical processes, problems in the real world do not abide by disciplinary boundaries. This means that many problems require the expertise of more than one discipline to be effectively tackled. Hansson (1999) advocates inter-disciplinary practice for solving problems of this nature. However, he also notes that inter-disciplinarity, “*no matter how desirable, is very hard to achieve*” (Hansson 1999: p. 340).

There are two helpful approaches that might aid our understanding of why the complexity inherent in the real world presents problems to our existing disciplinary thinking.

Rittel and Weber (1973) have been very influential in their classification of problems as either being 'tame' or 'wicked'. A wicked problem might be defined as one that meets the criteria set out in Figure 2. These criteria also help us to understand why effective solutions are so hard to achieve.

1. There is no definitive formulation of the problem (the exact nature of the problem is hard to understand)
2. Wicked problems have no stopping rule (there is no ideal solution or marker that would indicate that the problem has been completely resolved)
3. Solutions to wicked problems are not true or false (they are usually good or bad, or more often better or worse)
4. There is no way to test the solution (implementing a solution will cause waves of intended and unintended effects over a limitless timescale)
5. Every attempt to solve the problem is the only attempt (by testing the solution you are changing the context and therefore creating a new problem and potential solution that is not tested)
6. Wicked problems do not have a set number of solutions (you can never know whether every solution has been considered)
7. Every wicked problem is essentially unique (when comparing even the most similar wicked problems, there will be some overriding characteristic that differs and is considered important)
8. Every wicked problem is a symptom of another problem (you cannot solve problems by tackling the symptoms alone)
9. Wicked problems can be framed in numerous equally valid ways (there is no correct explanation for a problem, or correct way to view a problem)
10. There is no immunity for unsuccessful intervention (in science, hypotheses are meant to be tested and either corroborated or falsified; whereas the solution to wicked problems needs to be right first time, there is no tolerance for mistakes)

Figure 2 *The definition of a wicked problem* (adapted from Norton, 2012)

Approaching Sustainable Human Development from an engineering and design perspective forces us to reduce complex real world problematic situations to simple, bounded design questions. This might explain why so many attempts to achieve difference and progress with Sustainable Human Development do not succeed. Recognising and acknowledging the complexity in these contexts will require us to think, work and act differently.

Complex systems are nicely defined by Snowden and Boone (2007). They involve large numbers of interacting elements that interact in a non-linear fashion; the history of the system is integrated with the present; they are dynamic and are more than the sum of their parts; and they may appear ordered and predictable when they are not.

Snowden's Cynefin Framework (2000) can further help us to see the difference in approach needed depending on the complexity of the situation. He defines four types of situation – simple, complicated, complex and chaotic. Simple and complicated situations are ordered, with obvious cause-and-effect relationships. Examination of the situation can help you to determine correct answers or actions. Complex and chaotic situations are not ordered and have no obvious cause-and-effect relationships. Correct actions or solutions cannot be pre-determined, but rather 'emerge' from the situation itself. He also goes on to describe a fifth state, 'disorder', where multiple perspectives vie for prominence, and there is much conflict. See Figure 3.

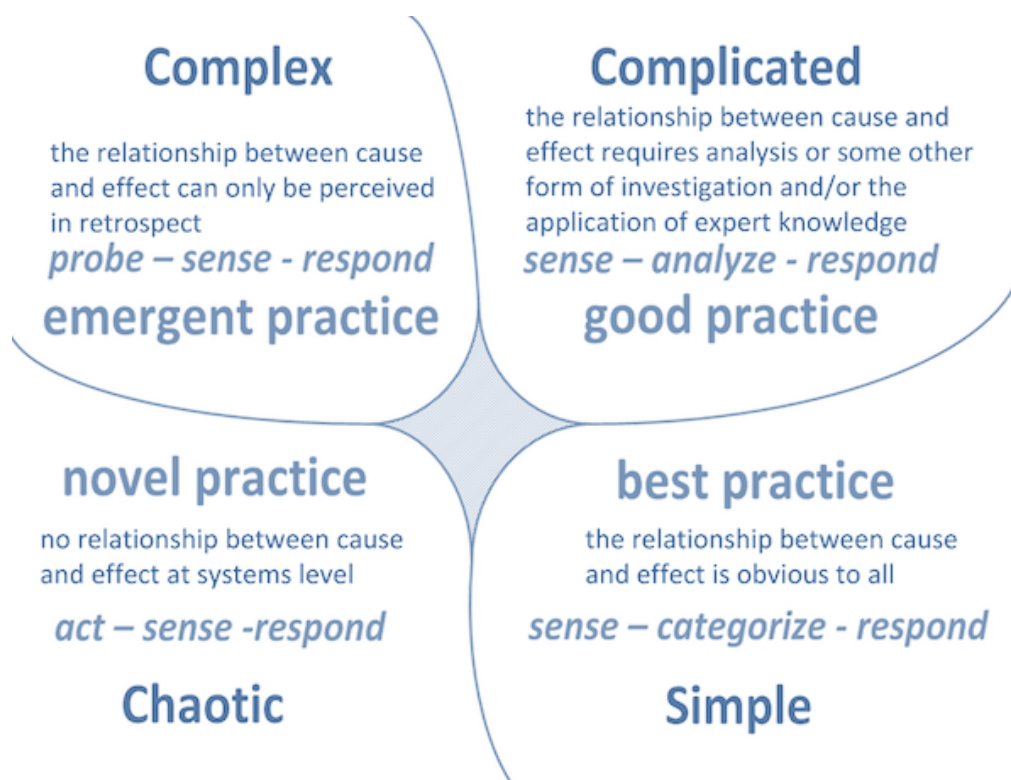


Figure 3 Cynefin Framework with central domain being 'disorder' (Snowden, 2000)

Whether we view Sustainable Human Development as a set of wicked problems, or as complex, chaotic or disordered situations, it is clear that conventional problem-solving approaches are unlikely to achieve helpful solutions.

DESIGNING THE EWB CHALLENGE COURSE FOR IMPERIAL COLLEGE STUDENTS

Returning to the EWB Challenge course, I have learned that my students are highly goal-oriented, believe that they should achieve 'perfect' solutions, have a strong sense that they should be able to 'master' any given problem or scenario and that they work in a very linear fashion with little self-awareness.

I am requiring them to tackle wicked problems, in a complex, real-world setting and want them to be able to develop inter-subjectivity in their approach and feel empowered to work outside their disciplinary experience and context. I am asking them to overcome the effects of the historical development of knowledge, education and their professions and the conventional and institutional status quo that shapes their formation, their future careers and their world view. These are big demands from an ancillary module.

The course has now been developed to cover four main areas of exploration – design brief analysis, conceptual design, technical specification and implementation planning.

- **Design Brief Analysis:**

In this stage the students work to understand the context of Sustainable Human Development and Engineering for Development. They are introduced to boundary critique (Ulrich, 2002) as a way to manage the complexity of the community situation they are working with. This allows them to generate deeper understanding of specific aspects of the situation without denying the complexity. To assist with this exploration we introduce the students to an adapted version of soft systems methodology (Checkland, P and Poulter, J., 2006). This allows them to quickly create dynamic visualisations of complex systems (such as the community they are studying) and identify areas that could be targeted for directed problem solving and therefore are ideal opportunities for their design projects. In addition we encourage the students to develop their inter-subjectivity by using the soft systems methodology to explore different stakeholder perspectives of the scenario, and to use 'empathy maps' as developed by Alexander Osterwalder (2010).

The use of these social science methodologies helps us to push the students further in two ways. Firstly, it helps to slow the students down. Having to learn an unfamiliar methodology from a foreign discipline is challenging and forces the students to take a methodical approach to examining the design brief. Secondly, the unfamiliarity and distance from their disciplinary experience, means that the students are less likely to unconsciously revert to using their 'usual' approach to their work. We found in the pilot that some students went through the motions of following the process that we outlined, but created their design solution using a completely different process.

During this period, the students are also conducting background research to further their understanding of the local and national context of the community they are studying.

- **Conceptual Design:**

The students should now have a good understanding of the community that they will be designing for, and of the design brief. At this point the students begin to develop design questions that they refine in groups. They are given sketch books and have a number of sessions to gather design inspiration and develop a series of sketches of potential design solutions to their design question (see Figure 4). We encourage the students to design freely, without considering technical practicality at this point. We also ask that the students make as many sketches or diagrams as possible. They are also able to collage illustrations and photos from multiple sources.

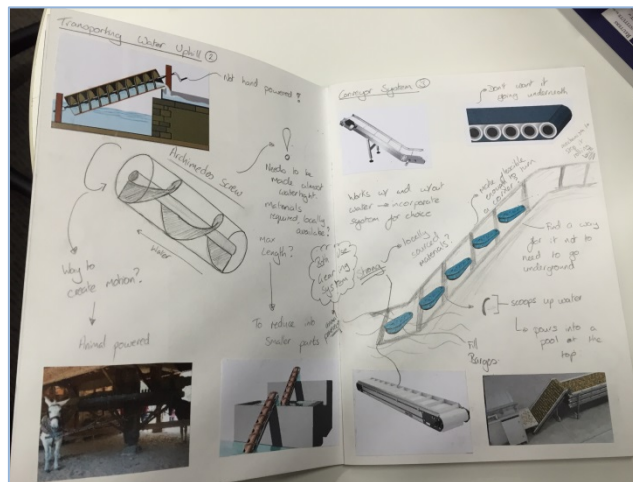


Figure 4 Photograph of a sample of a student's sketchbook

- **Technical Specification:**

The students vote on which conceptual designs they want to take forward to technical specification and form their final teams. Up until this point they have been working in informal teams to help them share as much experience and expertise with as many other students as possible. They now start to specify materials, dimensions and functionality of their designs. They need to discard the impractical or impossible and focus on bringing the best ideas together into a workable design. They must also consider the economic practicality, environmental sustainability and sociocultural appropriateness of their ideas.

- **Implementation Planning:**

Using the knowledge gained about the community in the first phase of the course, the students now work to create a multimedia package that will act to both communicate their design, and facilitate local implementation. They must consider whether there are initial set-up requirements (time, funding, labour, expertise) and how their idea will be maintained and further developed in collaboration with the community. The students are also asked to reflect on the quality and type of communication they have been able to establish with the community and the impact that this might have had on their final work.

PEDAGOGIC CONSIDERATIONS

Since one of the core aims of all our Global Challenges courses is to develop independent learning skills with the students, none of our courses employ subject experts as tutors. We work with junior researchers from around Imperial College who offer excellent support for the students in terms of enquiry skills, critical thinking and independent learning. With respect to the content of the project, the tutors and students 'learn together'.

Our curricula follow a 'process-oriented' approach (Kelly, 2004), where we mark the students equally for the demonstration of their use of processes such as soft systems methodology, as well as for the product or design that they end up with. We allow the students a lot of freedom to determine the exact areas within the scenarios that they work on, and expect them to take responsibility for their own working practice.

We are working towards an emancipated classroom, where the students and tutors are co-learners (Grundy, 1987 and Rancière, 2010). In fact, Rancière's idea of the idea of the ignorant schoolmaster (Rancière, 2010) helps us to understand how this approach actually greatly benefits our students. It also means that as a group, we are emancipated from any implicit ideals that arise from disciplinary specialisation – namely the mastery that is so tied to science and engineering.

CONCLUSION

I have not yet had a chance to complete any formal or structured research into the efficacy of these approaches and they are merely presented here as an example. However, I would claim that I am working in the right direction with my course development based on the feedback from students, the quality of the work produced, and the fact that the students are following up work started on the course with external partners.

Planning formal educational research requires attention to several elements beyond the methodology of the research itself.

Firstly there is ethical approval to consider. Next there is the required expertise to make sure that the research methodology (whatever that might be) is correctly employed to retain the validity of any findings or results. There is the time required to administer and analyse the research. Finally, there is student recruitment or identification to consider. It is also critical to develop a robust research question, which can effectively be answered by the planned research.

For most practising lecturers with minimal experience of educational research, action research is the best starting point (as presented in the previous chapter). Its very flexible approach enables the study of a range of areas such as teaching methods, learning strategies, evaluation and the thinking processes and value systems of the students (Cohen, Manion and Morrison, 2011). For me, this encompasses all the aspects that I am most interested in.

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PHOTO: Bamboo Bike. S. McPhillips

4

CHAPTER

Funding routes

4

CHAPTER 4. Funding routes

EDITED BY

Global Dimension in Engineering Education

COORDINATED BY

Agustí Pérez-Foguet and Enric Velo (*Universitat Politècnica de Catalunya*)

Manuel Sierra (*Universidad Politécnica de Madrid*)

Alejandra Boni and Jordi Peris (*Universitat Politècnica de València*)

Guido Zolezzi (*Università degli Studi di Trento*)

Rhoda Trimingham (*Loughborough University*)

WITH GRATEFUL THANKS TO

Boris Lazzarini (*Universitat Politècnica de Catalunya*)

Xosé Ramil and Sara Romero (*Universidad Politécnica de Madrid*)

Jadicha Sow Paino (*Universitat Politècnica de València*)

Angela Cordeiro and Gabriella Trombino (*Università degli Studi di Trento*)

Emily Mattiussi, Sylvia Roberge and Katie Cresswell-Maynard (*Engineers Without Borders - UK*)

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4 FUNDING ROUTES

Soraya Hidalgo Hidalgo, Research & Innovation Advisor and Project Manager, European Projects Office, Universitat Politècnica de Catalunya

EXECUTIVE SUMMARY

This chapter provides the reader with a comprehensive, up-to-date overview of the instruments and programmes of research funding in Global Dimension related areas (as at the time of writing). By adopting a very practical approach and presenting the tools needed, the reader can remain up-to-date with the most relevant sources of funding.

‘Framework Programmes for Research and Innovation’ and more precisely the current ‘Horizon2020’ fund has been introduced in detail in this chapter, since it represents the largest and most internationally open funding instrument for research on global challenges. Guiding references, concepts to keep in mind, tools to choose the different instruments and useful tips will be provided.

EuropeAid funds have been considered in this chapter due to their relevance in funding global challenges in engineering. However, EuropeAid is not funding research as such – rather implementation and technology transfer. Thus EuropeAid instruments will be explained in enough detail so that the reader can have an understanding of this type of funding mechanisms.

By considering these important funding routes, which encourage international co-operation, the chapter illustrates the processes of securing research funding in a more general sense; the approaches are applicable to many other research donors. A list of other European funding opportunities and supporting tools for civil society organisations is provided.

LEARNING OUTCOMES

After you actively engage in the learning experiences provided in this module, you should be able to:

- Understand where to find sources of funding for GDEE-related topics.
- Understand the process of writing a proposal.
- Know the evaluation mechanisms you will require after applying for funds.
- Know what skills and knowledge are needed to write funding applications.

KEY CONCEPTS

These concepts will help you better understand the content in this session:

- The importance of international co-operation on research and innovation
- Writing funding grants in Global Dimension related disciplines
- Supporting tools while applying for funds

GUIDING QUESTIONS

Develop your answers to the following guiding questions while completing the readings and working through the session:

- What is the most appropriate instrument to fund our research?
- Do we meet with the minimum selection and award criteria?
- Where can I find support to prepare my proposal? Or the reference documents?
- What are the required skills?

INTRODUCTION

International co-operation is vital in research that considers the Global Dimension. Societal challenges that have a Global Dimension cannot normally be tackled from a single-country perspective, but they demand multi-country and multi-stakeholder perspectives. With this in mind, finding the most appropriate approaches to these challenges often calls for international research collaboration; there is a need to join forces across the world to tackle global challenges.

Examples of the existing initiatives supporting international research collaboration include the European and Developing Countries Clinical Trials Partnership (EDCTP) and GÉANT, the high bandwidth pan-European research and education backbone that interconnects National Research and Education Networks (NRENs) across Europe and provides worldwide connectivity through links with other regional networks.

The global financial crisis has seriously affected the funds available for research, including research funds allocated in international development. However, policy makers – aware that research into Global Dimension issues is an influential driver of change – remain clear about the need to make resources available to non-state actors, local authorities, civil society organisations and the research community to tackle global challenges together and in an integrated manner.

This chapter presents two major funds for Global Dimension related research: Horizon2020 and EuropeAid. The chapter aims to improve awareness of available European Union funds, the policies behind them, but also of the need to establish multi-disciplinary collaborations to succeed in a research project proposal. The chosen examples are large and important funds, and their scale and status is such that describing them will shed light on how other research funding might work. The detail of these funds will change every few years or so but they are useful examples for understanding international research funds.

Implicit in the need for research collaboration into global societal challenges is the need to create networks of scientific collaboration to improve international relations. These concepts will also be described in the chapter.

HORIZON2020: THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION OF THE EUROPEAN UNION

The main instrument to fund research in Europe, including on Global Dimension areas, is the Framework Programme for Research and Innovation of the European Commission. The current programme is called 'Horizon2020' (H2020) and it covers the period 2014 to 2020. H2020 will be considered in depth in this chapter simply because it is the largest instrument that can fund research and innovation for the Global Dimension. The total fund is €80billion.

Coupling research and innovation in H2020 puts emphasis in excellent science, industrial leadership and tackling real societal challenges. These are the three main pillars of H2020, as shown in Figure 1.

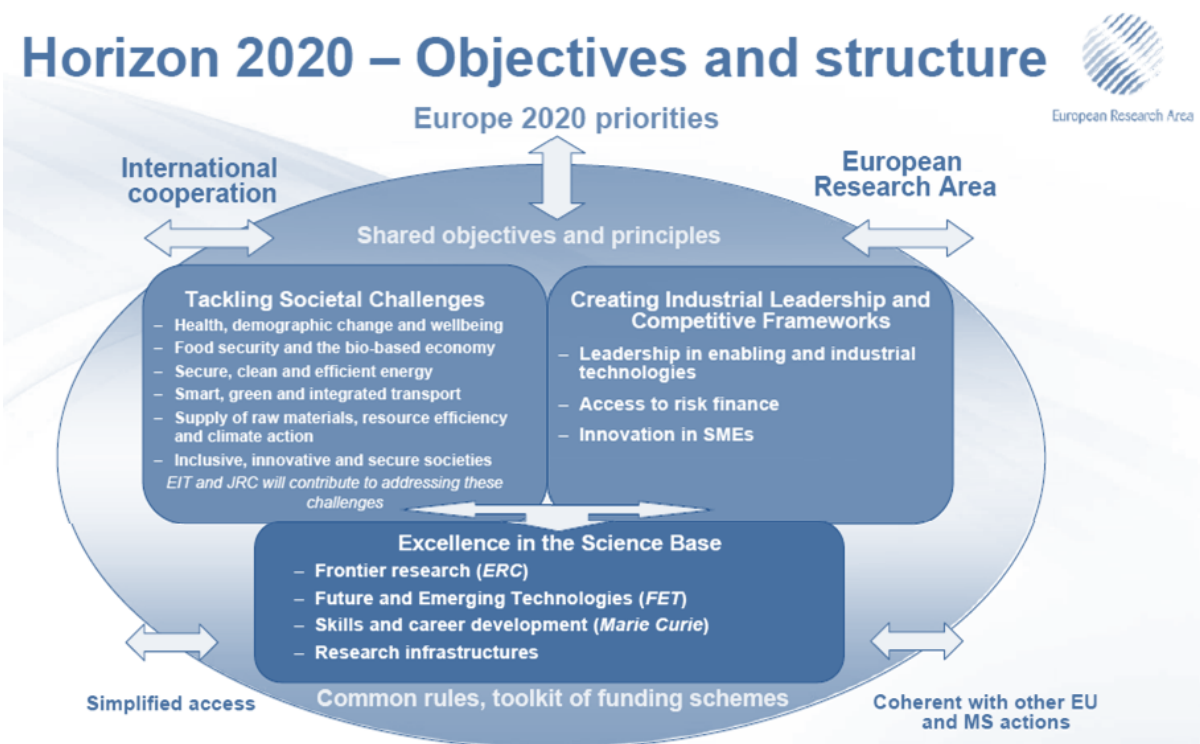


Figure 1 H2020 Structure (taken from www.upc.edu/euresearch)

Key to any application to H2020 is a clear understanding the objectives behind each pillar, which are outlined below. Crucially for research related to the Global Dimension, the Societal Challenges and Industrial Leadership pillars offer opportunities with required or preferential 'third country' participation (a country that is not a European Union Member State, Candidate Country or H2020 Associated Country).

Pillar 1: Excellent Science

The drivers for this pillar are:

- World-class science is the foundation of tomorrow's technologies, jobs and wellbeing.
- Europe needs to develop, attract and retain new talent.
- Researchers need access to the best Research Infrastructures.

Horizon 2020 will raise the level of excellence in Europe's science base and ensure a steady stream of world-class research to secure Europe's long-term competitiveness. It will support the best ideas, develop talent within Europe, provide researchers with access to priority research infrastructure, and make Europe an attractive location for the world's best researchers.

Horizon 2020 will...

- European Research Council: Support the most talented and creative individuals and their teams to carry out frontier research of the highest quality by building on the success of the European Research Council ([ERC](#));
- Future & Emerging Technologies: Fund collaborative research to open up new and promising fields of research and innovation through support for Future and Emerging Technologies ([FET](#))
- Marie Skłodowska Curie Actions: Provide researchers with excellent training and career development opportunities through the [Marie Curie Actions](#);
- Research Infrastructures: Ensure Europe has world-class [research infrastructures](#) (including e-infrastructures) accessible to all researchers in Europe and beyond

Pillar 2: Industrial leadership and competitive frameworks

The drivers for this pillar are:

- Strategic investments in key technologies underpin innovation across existing and emerging sectors.
- Europe needs to attract more private investment in Research and Innovation.
- Europe needs more innovative SMEs to create growth and jobs.

The pillar has two objectives on Competitive Industries and Leadership in Enabling and Industrial Technologies:

The Competitive Industries objective aims at making Europe a more attractive location to invest in research and innovation, by promoting activities where businesses set the agenda. It will provide major investment in key industrial technologies, maximise the growth potential of European companies by providing them with adequate levels of finance and help innovative SMEs to grow into world-leading companies. The Leadership in Enabling and Industrial Technologies objective will support the development of technologies underpinning innovation across a range of sectors, including ICT and space. Horizon 2020 will have a strong focus on developing European industrial capabilities in Key Enabling Technologies. These include: Micro- and nano-electronics; photonics; Nanotechnologies; Advanced materials; Biotechnology; Advanced manufacturing and processing. Development of these technologies requires a multi-disciplinary, knowledge and capital-intensive approach.

Horizon 2020 will...

- Build leadership in enabling and industrial technologies, with dedicated support for ICT, nanotechnologies, advanced materials, biotechnology, advanced manufacturing and processing, and space, while also providing support for cross-cutting actions to capture the accumulated benefits from combining several Key Enabling Technologies;
- Facilitate access to risk finance;
- Provide Union-wide support for innovation in SMEs.

Pillar 3: Tackling Societal Challenges

The drivers for this pillar are:

- Concerns of citizens and society/EU policy objectives (climate, environment, energy, transport etc.) cannot be achieved without innovation and collaborative research.
- Breakthrough solutions come from multi-disciplinary collaborations, including social sciences and humanities.
- Promising solutions need to be tested, demonstrated and scaled up.

Horizon 2020 reflects the policy priorities of the [Europe 2020](#) strategy and addresses major concerns shared by citizens in Europe and elsewhere. A challenge-based approach will bring together resources and knowledge across different fields, technologies and disciplines, including social sciences and the humanities. This will cover activities from research to market with a new focus on innovation-related activities, such as piloting, demonstration, test-beds, and support for public procurement and market uptake. It will include establishing links with the activities of the European Innovation Partnerships (EIP).

Horizon 2020 will fund research focussed on the following challenges...

- Health, demographic change and wellbeing;
- Food security, sustainable agriculture, marine/maritime research and bio-economy;
- Secure, clean and efficient energy;
- Smart, green and integrated transport;
- Inclusive, innovative and secure societies;
- Climate action, resource efficiency and raw materials.

International Co-operation on research and innovation in Horizon2020

International co-operation on research and innovation is key to tackling societal challenges. Researching issues in engineering with a Global Dimension can hardly be conceived without a multi-disciplinary and international approach. With this in mind, H2020 (as with its predecessors) sets out a particular strategy to address international co-operation.

Investing in research into a global challenge is costly, especially in the transaction costs of co-ordinating international research and large projects. So openness is central to the strategy. While the research community benefits from unprecedented knowledge and resources to support their work, there remains an incentive to free-ride on existing solutions rather than to invest in the costs of solving global challenges. So thematic targeting is also part of the strategy.

The drivers for international co-operation on research and innovation are:

- The need to access knowledge from outside Europe and gain access to new markets
- The need to promote Europe and to partner for research and innovation
- The need to join forces globally to tackle global challenges

Openness: once the minimum requirements for participation has been accomplished (three member states or Associated Countries), Horizon 2020 is open to participation from across the world. However, the list of countries that receive automatic funding has been revised. The programme is implemented distinguishing among three-country grouping: Enlargement and neighbourhood countries, and EFTA, will generally be funded; Developing countries will generally be funded; Industrialised countries and emerging economies will be funded only in exceptional cases (industrialised countries are for instance US, Canada, Republic of Korea, Singapore, Australia, Taiwan, New Zealand, Macao, San Marino, Monaco, Andorra, Vatican, etc; and emerging economies are Brazil, Russia, India, China and Mexico). A factsheet provides information on [Funding of applicants from non-EU countries & international bodies](#).

Thematic targeting: targeted international co-operation activities are 1) research and innovation projects with obligatory or recommended participation of third countries or 2) joint initiatives involving the Union and international partners (co-ordinated calls, contribution of Union to third country/international organisations, ERA-Net/Art185). In addition: horizontal activities promote the strategic development of international co-operation; policy dialogues, networking activities, etc. (the former "INCO projects" now located in [Societal Challenge 6 "Europe in changing world" - inclusive, innovative and reflective societies](#)).

Another important aspect is the [bilateral Science and Technology \(S&T\) agreements](#) with third countries, which are also seen as an important instrument in the European Union's strategy international co-operation in research and innovation.

More information on the European Union Strategy for International Co-operation (the calls and topics recommended for international partners etc) can be found at <http://ec.europa.eu/research/iscp/index.cfm>.

HORIZON2020: MAKING A RESEARCH FUNDING APPLICATION

Start by starting: from the idea to the project proposal

The starting point for a research proposal to H2020 is likely to be:

- A non-solved technological need.
- The continuation of a former project.
- A proposal that has been submitted but not accepted in previous calls.

It takes a significant time investment to prepare a research proposal, and there may be unforeseen complications along the way, so starting sooner rather than later is advisable!

The typical steps involved in an application are summarised in Figure 2.

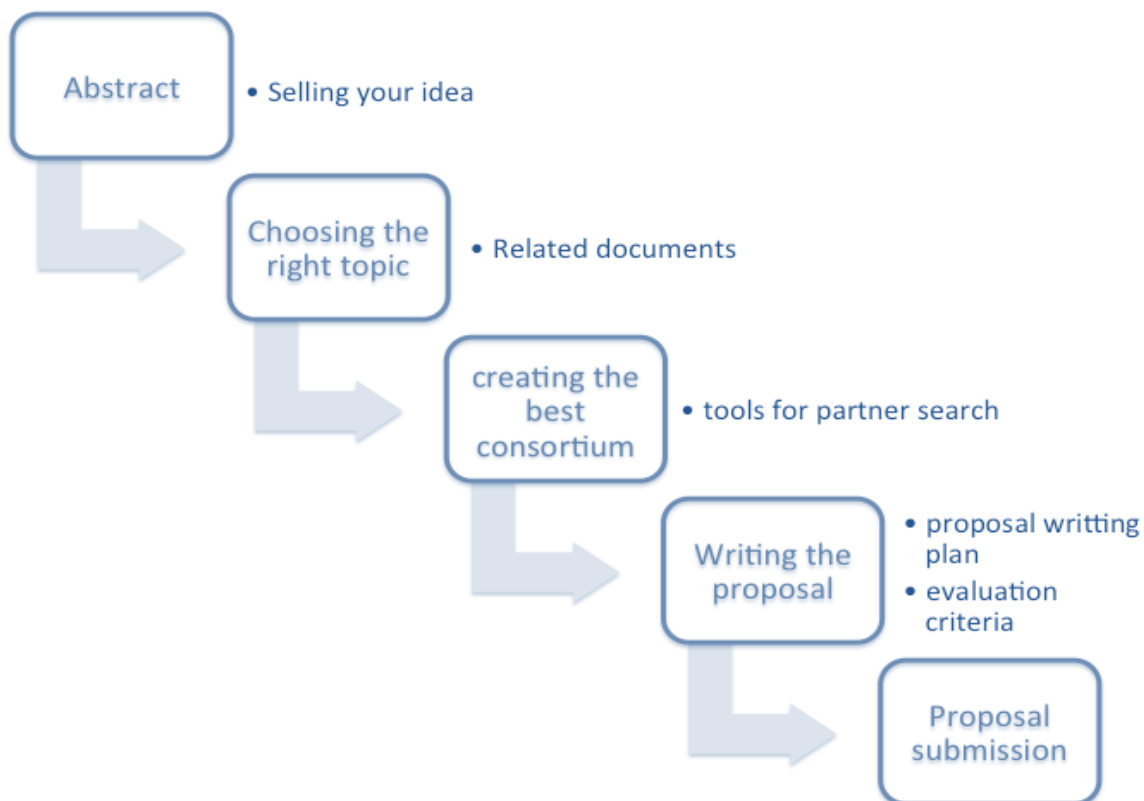


Figure 2 H2020 proposal writing steps

The abstract

The abstract could be a one-page proposal gathering your ideas on how you might achieve the objectives of your research project. The abstract should mention the initial objectives, the expected impact and a first list of partners or partner profiles you will need. The abstract could be used to invite other members to the consortia or simply to be shared with research advisors so they can check if your proposal idea fits with the call.

The topic

The calls are published in the [Participant Portal](#) and you can filter for the ones you are interested in. The topics appear in the work programme, where you will find details on the specific requirements (i.e. international co-operation). You will be more successful if you filter by 'Societal Challenges' when searching for topics that are related to the Global Dimension.

In the case of Societal Challenges, the approach is top down and the topics are well identified in responding to the European Union strategy and priorities. In contrast, under the Excellent Science pillar, the work programmes generally have a bottom-up approach where you must demonstrate its scientific excellence. In both cases, it is of utmost importance that you understand the scope of the topic, and the expected impact, otherwise the proposal has little chance of succeeding. A good tip is to consult with the 'National Contact Points' in your country for advice.

The work programme that you choose is very important as it may:

- Restrict eligibility of participants from third countries (e.g. security issues, reciprocity)
- Introduce additional eligibility criteria
- Limit number or types of participant and place of establishment
- Lay down further details for the application of the award criteria, and specify weighting and thresholds
- Specify the third countries that are eligible for funding
- Specify the funding rate for an action
- Specify the lump sums or unit costs that can be used for an action
- Identify beneficiaries for grants without a call for proposal

The consortium

Another important aspect in writing a successful research proposal is the consortium – the team that will perform the research and innovation activities throughout the life of the project. Different partners can be chosen for particular expertise and thinking, adding value to the project.

A project co-ordinator must be chosen from the consortium. The project co-ordinator takes responsibility for being the sole contact with the European Commission for the research project, and so has the role of receiving transfers and distributing payments. For this reason – and due to the complexity of the European Commission rules – it is very helpful to have a strong co-ordinator with outstanding experience in managing European Union funded projects. The project co-ordinator is not necessarily the co-ordinator of the research itself, which can be, say, the partner who had the initial idea or the partner with the best overall picture of the activities to be performed.

How can we find partners? Some suggestions include:

- Personal contacts
- An existing research community
- Partners who collaborated on previous projects
- Contacts made at ‘Infodays’ organised by the European Commission
- Suggestions from the [National Contact Points](#)
- Suggestions from national funding agencies
- Small and medium enterprises from the [Enterprise Europe Network](#)
- [Specific partner search tools](#) which are thematically based

Table 1 shows the minimum conditions of participation in H2020.

<i>Type of actions</i>	<i>Conditions</i>
1. Standard collaborative actions	At least 3 legally independent entities each established in different member states or associated countries
2. SME Instrument, ERC, MSC, programme co-fund, CSO	1 legal entity established in a member state or associated country
3. Fast Track to Innovation	Maximum of 5 participants

Table 1 Minimum conditions of participation

Writing the proposal

As for any European funded, the partner organisations must be registered in the European Commission database and have a unique Participant Identification Code (PIC) number. Most universities will already be registered and the number can be [checked](#), but some smaller civil society organisations may not be if they have not had European funding before. The [registration process](#) is quite simple and can be done through the participant portal.

All proposals are submitted through the Electronic Submission System that is integrated in the participant portal. The service is available if the call is open, and proposals can be uploaded and modified until the call closes. It is accessible under ‘my proposals’ in the participant portal. Figure 3 illustrates the procedure of submitting a proposal via the participant portal.



Figure 3 Proposal submission steps through the participant portal

The proposal is divided into two parts: Part A contains all administrative information and contact details; Part B is for the research to be outlined in three sections (science and technology excellence, impact and implementation) and additional aspects as ethical and gender issues have to be addressed here.

Proposal submission

A considerable number of proposals fail near the submission deadline, because a lot of work is left to the last minute. Common problems include: technical problems (the European Commission server collapses); panic-induced errors (uploading the wrong version of the proposal); or simply just too late in starting the proposal upload. The deadline is often 17:00 Central European Time so submit your proposal at some hours before the deadline. The submission process is continuous, which means that the project co-ordinator who sends the proposal on behalf the consortium can upload updated versions (the last one uploaded is the version that will be evaluated).

Selection criteria

Financial capacity: at the proposal stage only co-ordinators of actions equal or superior €500k completing a self-assessment on-line tool can do this. Public bodies, entities guaranteed by member states or associated countries, higher and secondary education establishments will not be required to carry out the financial capacity assessment.

Operational capacity: the applicants must have the professional competencies and qualifications required to complete the proposed action or work programme. It may be assessed on the basis of specific qualifications, professional experience and references in the field concerned.

Evaluation criteria

Peers in the research field carry out the evaluation process. Transparency, fairness and no conflicts of interest are guaranteed. Evaluators rate proposals using three standard award criteria: excellence, impact and quality/efficiency of implementation. Normally these criteria have the same weighting however they can vary depending on the type of action (which is why reviewing the work programme is essential); proposals to the European Research Council are evaluated only on excellence criteria and innovation actions have more weight for impact. Experts assess the operational capacity of applicants to carry out the work.

Note that, for some topics, evaluation is carried out in two steps: proposers submit an initial short proposal and if they are ranked highly enough they can go to the second full proposal

phase. This saves the time on both sides, and if the second stage is reached the chances of success are much greater.

Descriptions of evaluation criteria for the most common funding instruments that are relevant to the Global Dimension are summarised in Table 2.

Type of action	Excellence	Impact	Quality / efficiency of implementation
All types of actions	<p>Clarity and pertinence of the objectives.</p> <p>Credibility of the proposed approach.</p>	[The expected impacts listed in the work programme under the relevant topic.]	<p>Coherence and effectiveness of the work plan, including appropriateness of the allocation of tasks and resources.</p> <p>Complementarity of the participants within the consortium (when relevant).</p> <p>Appropriateness of the management structures and procedures, including risk and innovation management.</p>
<p>Research and innovation;</p> <p>Innovation;</p> <p>SME instrument</p>	<p>Soundness of the concept, including trans-disciplinary considerations, where relevant.</p> <p>Extent that proposed work is ambitious, has innovation potential, and is beyond the state of the art (e.g. ground-breaking objectives, novel concepts and approaches).</p>	<p>Enhancing innovation capacity and integration of new knowledge.</p> <p>Strengthening the competitiveness and growth of companies by developing innovations meeting the needs of European and global markets and, where relevant, by delivering such innovations to the markets.</p> <p>Any other environmental and socially important impacts (not already covered above).</p> <p>Effectiveness of the proposed measures to exploit and disseminate the project results (including management of IPR), to communicate the project, and to manage research data where relevant.</p>	
Co-ordination & support actions	<p>Soundness of the concept.</p> <p>Quality of the proposed co-ordination and/or support measures.</p>	Effectiveness of the proposed measures to exploit and disseminate the project results (including management of intellectual property rights), to communicate the project, and to manage research data where relevant.	

Table 2 Evaluation criteria (taken from [European Commission website](#))

Useful proposal writing tips

During the proposal writing process, it is helpful to have some tips from researchers with experience of the framework programmes:

- Don't apply to many topics just to increase your chances.
- Think about the evaluator:
 - The evaluator might not be a leading expert in the field.
 - Don't assume that the evaluator has mental powers! They will evaluate what is written down.
 - They are often working under sparse conditions.
- Be precise and concrete.
- Do not use an excessive technical English:
 - Avoid the use of conditionals, better to say 'will' to be convincing.
 - Get the attention of the evaluators from the very first pages.
 - Use a 'catchy' title or acronym
- Pay attention to the look and feel.
- Make your objectives understandable.
- Respond clearly to the evaluation criteria.
- Highlight the results, methods and deliverables in a clear manner.
- Be coherent; don't present a patchwork of different parts.
- Include charts and tables.
- Sell the consortium – that you have the best consortium.
- Highlight the consortium's existing complementarities and synergies.

EUROPEAID

International co-operation is at the core of research related to the Global Dimension. For this reason, EuropeAid is the most important European Union funding instrument. EuropeAid is the European Union's international aid donor agency and is by some measures the largest aid donor in the world. It is operated by the European Commission under [DG DEVCO/EuropeAid](#) (whereas humanitarian and emergency aid is under [DG ECHO](#)). Since EuropeAid is an aid donor, and not a research funding agency, its focus is on implementation and technology transfer.

This section covers the main EuropeAid funding instruments and gives to the reader an overview of the different opportunities available for the current Multi-annual Financial Framework (2014-2020).

How to find EuropeAid funding opportunities

Funding opportunities can be found under the [call for proposals or procurements](#) on the EuropeAid website along with specific guidelines. This information can be found also in the website of each [European Union delegation](#).

Funding Instruments

The European Union aid budget is divided into different funding instruments, which provide the legal basis for the implementation of the various programmes. There are thematic, geographic and mixed funding instruments (such as the Development Co-operation Instrument). This chapter will introduce the most relevant instruments for researchers and civil society organisations working with the Global Dimension.

There are four geographic instruments (see Table 3) whose coverage is shown in Figure 4:

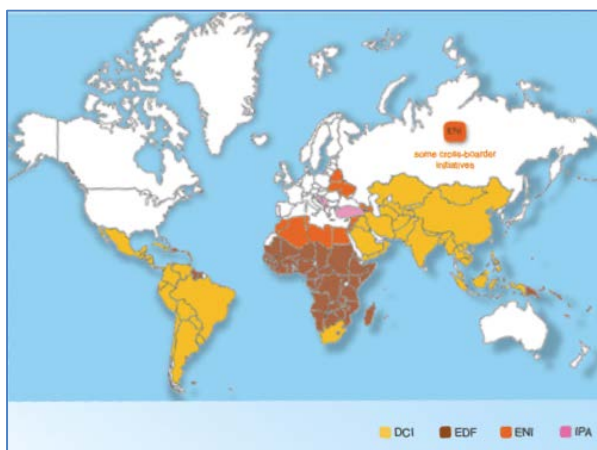


Figure 4. EuropeAid geographic instruments by country (taken from www.concordeurope.org)

	Development Co-operation Instrument (DCI)	European Development Fund (EDF)	Instrument for Pre-accession Assistance (IPA)	European Neighbourhood Instrument (ENI)
Objectives	Poverty reduction in developing countries, to achieve the internationally agreed Millennium Development Goals (MDGs) and the post-2015 agenda for sustainable development; and to consolidate and support democracy and human rights.	Reduction and eradication of poverty in ACP (Africa, Caribbean, Pacific) countries and regions. Sustainable economic, social and environmental development, and to consolidate and support democracy, the rule of law, good governance, human rights and the relevant principles of international law are topics covered by EDF funds.	To fund reforms on social, economic and legal aspects in future or potential European Union member states, including: public-sector and legal reform, sustainable economic and social development (democracy, gender, equality, and employment), agriculture and rural development.	To fund political and economic reforms in the countries belonging to the European Neighbourhood policy. Among the six ENI targets are: poverty reduction, internal economic, social and territorial cohesion, rural development, climate action and disaster resilience.
Budget	€19.5b for the period 2014-2020. Of which €11.8b to geographic programmes, the rest CSO-LA, GPGC and pan-African programmes.	Member states will contribute with €30.5b to the 11 th EDF, of which 80% are targeted to ACP countries and the rest to intra-ACP thematic action, benefiting ACP countries.	€11.7b funding country, multi-country or cross-border programmes.	€15.4b
Modalities	The aid is managed mainly through agreements between the EU and the partner countries or the EU and Regional Economic Communities for regional programmes. Aid is given to partner countries and regions as budget support or as projects.	Budget support, grants and tenders adapted to each partner country or region. New aid modalities have been introduced with the 11 th EDF enabling new resources from the private sector and investment banks.	Aid is managed by government institutions and decentralised authorities in partner countries.	Most of the funding will be made available through call for proposals.
Countries ¹	Latin America, Asia, Central Asia, the Gulf States and South Africa.	79 ACP partner countries of the Union and for the Overseas Countries and Territories of Member States.	Albania, Bosnia and Herzegovina, Kosovo, Macedonia, Montenegro, Turkey and Serbia.	Algeria, Egypt, Israel, Jordan, Lebanon, Libya, Morocco, the occupied Palestinian territory, Syria, Tunisia, and eastern neighbourhood countries: Armenia, Azerbaijan, Belarus, Georgia, Moldova and Ukraine. Russia can participate also under some cross-border actions.

Table 3 EuropeAid geographical funding instruments summary

¹ Under the Development Co-operation Instrument Upper Middle Income Countries (and 2 large Lower Middle Income Countries whose GDP is larger than 1% of global GDP) will no longer be eligible for bilateral aid. These emerging economies will be considered rather as EU partners for addressing global challenges. (Middle income: Argentina, Brazil, Chile, China, Costa Rica, Kazakhstan, Iran, Malaysia, Maldives, Mexico, Panama, Thailand, Venezuela and Uruguay, Large Lower Middle Income Countries: India and Indonesia)

There are two main thematic instruments (see Table 4):

	Civil Society Organisations and Local Authorities (CSO-LA)	Global Public Goods and Challenges (GPGC) ²
Objectives	<p>To strengthen civil society organisations and local authorities in partner countries, improving governance and accountability through inclusive policy-making by empowering citizens and populations through the voicing and structuring of their collective demands. Three main priorities:</p> <ol style="list-style-type: none"> 1. Focus on country level to enhance CSOs' and LAs' contributions to governance and development processes as: actors in governance and accountability; partners in fostering social development and providing welfare; as key stakeholders in promoting inclusive and sustainable growth (65-75% of the total budget). 2. Reinforcing regional and global CSO networks and Associations of LAs (ALAs) (5-10% of the total budget). 3. Support to Development Education and Awareness Raising in the European Union (10-15% of the total budget). 	<p>To tackle key economic, social and environmental issues adopting a cross-cutting approach, at different levels, in five key areas:</p> <ul style="list-style-type: none"> - Environment and climate change [see Box 1]; - Sustainable energy [see Box 2]; - Human, social and economic development [see Box 3]; - Food security and sustainable agriculture and fisheries [see Box 4]; - Migration and asylum.
Budget	€1.9b	€5b
Modalities	Most of the funding will be made available through call for proposals, launched by European Union delegations or headquarters.	[See Boxes 1-4 on following pages]
Countries	All countries on the ODA list of the OECD DAC, excluding those covered by the Instrument of Pre-Accession (IPA), but including European Overseas Countries and Territories. Actions for development education and awareness raising include IPA countries. Countries phased out of the DCI's geographical programmes will still be eligible under CSO-LA.	Countries on the ODA list of the OECD (except those covered by the Instrument of Pre-Accession) and including European Overseas Countries and Territories. Countries phased out of the Development Cooperation instrument's geographical programmes will still be eligible under the GPGC. The GPGC programme targets thematic issues on a multi-country or global scale, rather than at country level alone.

Table 4 *EuropeAid thematic funding instruments summary*

² Based on the concept of Public good: "[one] with benefits that are strongly universal in terms of countries (covering more than one group of countries), people (accruing to several, preferably all, population groups), and generations (extending to both current and future generations, or at least meeting the needs of current generations without foreclosing development options for future generations)" <http://web.undp.org/globalpublicgoods/globalization/glossary.html>

Environment and climate change

This key area sets four components which complement work at regional and national levels through initiatives, knowledge development and capacity building in the following areas:

1. Climate change adaptation and mitigation and support to the transition to climate resilient low-carbon societies.
2. Valuation, protection, enhancement and sustainable management of ecosystems.
3. Transformation towards an inclusive green economy and mainstreaming of environmental sustainability, climate change and disaster risk reduction.
4. International environmental and climate governance in respect of the above.

Box 1 Global Public Goods and Challenges key area priorities – environment and climate change

Sustainable energy

This key area seeks to complement bilateral programming by providing innovative tools for policy advice, project design and capacity development, particularly in the fields of renewable energy and the development and roll-out of energy-efficient technologies, as well as supporting international dialogue. Research and Education will be addressed in the programme. There are two key components establishing the objectives and scope:

1. Enabling energy stakeholders to improve the regulatory framework for sustainable energy and accelerate investment in partner countries. 1) Increased and improved access to modern, affordable, secure and sustainable energy/ Renewable energy/ Energy efficiency; including rural electrification. 2) Sustainable energy in poor urban and semi-urban communities and smart energy use.
2. Building strategic alliances to achieve sustainable energy goal.

Box 2 Global Public Goods and Challenges key area priorities – sustainable energy

Human development , including decent work, social justice and culture

This key area includes specific programmes in the fields of: health; education, knowledge and skills; gender equality, women empowerment and protection of women's and girls' rights; child well-being; employment, decent work, skills, social protection and social inclusion; growth, jobs and private sector engagement.

The programme of education, knowledge and skills will focus on strengthening global/regional initiatives and country level actions on key educational issues complementing geographical instruments giving support to the reduction of inequalities, improvement of the quality of education and promotion of inclusive education.

Box 3 Global Public Goods and Challenges key area priorities – human development

Food security and sustainable agriculture and fisheries

This key area will address global food security governance, support knowledge and capacity building with the following priorities:

1. Generating and exchanging knowledge and fostering innovation, supporting pro-poor demand driven research, technology transfer and innovation.
2. Strengthening and promoting governance and capacity at the global, continental, regional and national level, for all relevant stakeholders, strengthening and promoting governance and capacity at the global level, continental, regional and national level;
3. Supporting the poor and food and nutrition insecure to react to crises and strengthen resilience

Box 4 Global Public Goods and Challenges key area priorities – food, agriculture and fisheries

CONCLUSION

The chapter gave an overview of the major funding sources for research related to the Global Dimension that emphasise international collaboration – Horizon2020 and EuropeAid. Practical information, reference documents and useful tips have been shared.

Through these examples, the typical processes of securing research funding have been outlined, including on the formation of consortia and consideration for evaluation processes. Emphasis has been placed on the need for funding to enable Global Dimension related research to consider in diverse perspectives and stakeholders.

As this chapter has shown, securing research funding is not a quick or simple task. However the application process can greatly benefit the research itself by bringing together new partners, improving research project planning and considering the wider policy priorities of major donors. With enough time (and patience) to fully understand the aims and criteria of a particular research fund and to develop a sound proposal, the chances of success are greatly improved.

Research into Global Dimension issues is an influential driver of change, so a successful conclusion to a research funding effort really can make the world a better place.

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FURTHER/SUGGESTED MATERIALS

- 2014 CONCORD AidWatch report, 'Aid Beyond 2015: Europe's role in financing and implementing sustainable development goals post 2015:
www.concordeurope.org/publications/item/download/323_19e2c6498a632ce21442452b5931f0a2
- OECD Science, Technology and Industry outlook 2014
www.keepeek.com/Digital-Asset-Management/oecd/science-and-technology/oecd-science-technology-and-industry-outlook-2014_sti_outlook-2014-en#page1

Other European Union funding opportunities

- Humanitarian Aid and Civil Protection, DG ECHO:
<http://ec.europa.eu/echo/en>
- Programme for the Environment and Climate Action, Life, DG Environment:
<http://ec.europa.eu/environment/life/funding/life2014>
- Erasmus +, Education, Audiovisual and Culture Executive Agency (EACEA):
http://eacea.ec.europa.eu/index_en.php
- Europe for Citizens, Education, Audiovisual and Culture Executive Agency (EACEA):
http://eacea.ec.europa.eu/index_en.php

EuropeAid

- Practical Guide on EU external actions
<http://ec.europa.eu/europeaid/prag/document.do?chapterId=1.&id=221>
- Potential Applicant Data On-Line Registration (PADOR)
http://ec.europa.eu/europeaid/search/site/pador%252520onlineservice_en_en

Civil Society Organisations and Local Authorities

- Multiannual Indicative Programme for the Thematic Programme "Civil Society Organisations and Local Authorities" for the period 2014-2020, European Commission C(2014) 4865 final
https://webgate.ec.europa.eu/fpfis/mwikis/aidco/images/2/2b/CSO_LA_MIP_CSO_LA_2014_2020_EN.pdf
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<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2012:0492:FIN:EN:PDF>
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<http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013DC0280&from=EN>
- Staff working paper on DEAR
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Global Public Goods and Challenges

- Global Public Goods and Challenges 2014-2020, Multi-Annual Indicative Programme 2014-2017,
https://ec.europa.eu/europeaid/sites/devco/files/mip-gpgc-2014-2017-annex_en.pdf
- Sustainable Energy for all initiative
<http://www.se4all.org/>
- A decent life for all: Ending poverty and giving the world a sustainable future', COM(2013) 92 final, Brussels, 27.2.2013

http://ec.europa.eu/europeaid/documents/2013-02-22_communication_a_decent_life_for_all_post_2015_en.pdf

- An EU policy framework to assist developing countries in addressing food security challenges, COM(2010)127 final
<http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52010DC0127&from=EN>

Horizon2020

- Research and Innovation, International Cooperation, European Commission
<http://ec.europa.eu/research/iscp/index.cfm>
- EC REsearch and Innovation Participant Portal
<http://ec.europa.eu/research/participants/portal/desktop/en/home.html>
- ECAS account creation
<https://webgate.ec.europa.eu/cas/eim/external/register.cgi>
- FAQ on H2020 per themes
<http://ec.europa.eu/research/participants/portal/desktop/en/support/faq.html>
- Helpdesk
http://ec.europa.eu/research/participants/portal/desktop/en/support/research_enquiry_service.html
- Unique Registration Facility- User's Guide
<https://ec.europa.eu/research/participants/portal4/desktop/en/organisations/index.html>
- How to write a bad proposal (Previous Framework program, but still useful)
http://cordis.europa.eu/fp7/ict/micro-nanosystems/docs/how-to-write-a-bad-proposal_en.pdf
- Community Research and Development Information Service (CORDIS) – News and events
http://cordis.europa.eu/home_en.html



PHOTO: Transporting a Hydroelectric Power Station Transformer in Need of Maintenance, Arnakot Deurali, Western Nepal. D. Narayanan

CHAPTER

Collaboration

5

CHAPTER 5. Collaboration

EDITED BY

Global Dimension in Engineering Education

COORDINATED BY

Agustí Pérez-Foguet and Enric Velo (*Universitat Politècnica de Catalunya*)

Manuel Sierra (*Universidad Politécnica de Madrid*)

Alejandra Boni and Jordi Peris (*Universitat Politècnica de València*)

Guido Zolezzi (*Università degli Studi di Trento*)

Rhoda Trimingham (*Loughborough University*)

WITH GRATEFUL THANKS TO

Boris Lazzarini (*Universitat Politècnica de Catalunya*)

Xosé Ramil and Sara Romero (*Universidad Politécnica de Madrid*)

Jadicha Sow Paino (*Universitat Politècnica de València*)

Angela Cordeiro and Gabriella Trombino (*Università degli Studi di Trento*)

Emily Mattiussi, Sylvia Roberge and Katie Cresswell-Maynard (*Engineers Without Borders - UK*)

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5 COLLABORATION

Armela Dino, Policy Analyst, State Secretariat of Science, Development & Innovation, Ministry of Economy & Competitiveness, Spain

EXECUTIVE SUMMARY

This chapter describes and analyses the main aspects and characteristics of collaboration in research. The main benefits of collaboration are seen not only in the delivery of more efficient research projects, but also in achieving success both for the individual researchers and their teams. The chapter attempts to furnish the engineering researcher with helpful concepts and instruments for future use. Explanations of the collaborative nature of research will be given to elucidate the research activity framework.

Different collaborative situations will be outlined. The chapter will include recommendations of when a situation should be formalised and transformed with a collaboration agreement. Since written agreements are important for the stability and further success of a research partnership, the chapter shares example agreements and makes recommendations on their use (especially for competitive public funding).

Instruments that may help collaboration and factors that may hinder collaboration are then discussed before, finally, Open Science and European research funding for collaboration are introduced to help the engineering researcher with vital cross-cutting aspects.

LEARNING OUTCOMES

After you actively engage in the learning experiences provided in this module, you should be able to:

- Acknowledge the benefits of collaboration.
- Understand the relevance of collaboration to all stakeholders during the entire research process.
- Understand the use of collaboration agreements.
- Understand the open science, technology and innovation as a concept.

KEY CONCEPTS

These concepts will help you better understand the content in this session:

- The collaborative nature of research
- Collaboration agreements
- Factors that hinder and foster collaboration
- Open Science

GUIDING QUESTIONS

Develop your answers to the following guiding questions while completing the readings and working through the session:

- How can I effectively collaborate in my academic and research activities?
- What should I focus on to achieve successful collaboration?
- What types of agreement may I need when formalising my collaboration?
- How can I use Open Science platforms?

INTRODUCTION

The term 'collaboration' is traditionally used in research to refer to an equal partnership between two or more academic researchers who are pursuing aligned and mutually beneficial research. Today, however, many collaboration activities can also involve a wide range of researchers from different types of organisations from around the world. It is highly recommended that any academics and researchers who have not yet gained an appreciation for the benefits of collaboration should do so soon. Our highly globalised world and the Global Dimension agenda demand greater collaboration.

Other experts go further. They see collaboration in research as an investment strategy because it brings many benefits to both the research and the researchers (Bukvova, 2013). If collaboration is done proactively, it can optimise the returns and maximise the benefits. Fear of collaboration can hinder the success of research. Collaboration is not only about sharing; it is about being proactive on building better research and academic results together. This can be done by, say, increasing the efficiency of the work done as a team.

Some experts even compare collaboration to a personal relationship (Holgate, 2012). They suggest that this means sharing the good and the bad, the rewards, the problems or the responsibilities throughout the entire process. Others believe that with the correct procedures – and the right collaborators – collaboration can quite simply be an effective and enjoyable experience that brings sociability and diversity into engineering research.

This chapter will present different aspects of collaboration, starting with its benefits. It will review the nature of collaboration in research, its situations, the types of written agreements (and when these can be used) and what can hinder and foster it. The chapter will finish with two chapters dedicated to Open Science and European Union research funds available for collaboration.

BENEFITS OF COLLABORATION

- **Higher impact publications:**
There is a direct correlation between the number of authors and the impact of a research publication. High impact research needs the combined efforts of many good researchers.
- **Efficient learning:**
The challenges that are faced by teams of experts working towards a common goal bring extraordinary efficiency in their learning processes. Asking questions and being proactive are useful ingredients for both individual learning and informing future joint actions.
- **Wider range of techniques:**
Collaboration can bring new techniques from across the world, and hence can give more relevance to the research. This availability of problem-solving can be very helpful.
- **Easier funding for the research:**
Research funding is often easier to secure because international funding agencies, companies and foundations seek collaboration to maximise their results and efficiencies.
- **Higher number of publications:**
Bigger teams conduct deeper research and so can publish more. Also, bigger teams can share the workload of producing more publications.
- **Higher number of patents:**
The multi-faceted approaches of collaboration between researchers with industry can lead to commercial benefits and patents (and share the cost and filing for a patent).
- **Higher number of spinoffs:**
Quite simply, it is far more likely that a team of researchers from different organisations and contexts can create spinoffs from the research (compared to individual researchers).
- **Identified early adopters:**
Collaboration partners are, by definition, the early adopters for any novel approach, new technology or new hypothesis that may be developed.
- **Convincing investors:**
If the collaborators in the field accept the results, it is a very strong argument to convince future investors or funders (including national or international funding agencies).
- **Selected human capital:**
Through networking and collaboration, the team can recruit the best staff (including undergraduates, postgraduates, PhDs or Postdocs).

THE COLLABORATIVE NATURE OF RESEARCH

In the current global environment, all aspects of research show a remarkably strong collaborative nature across all stages of the process:

- **Funding sources:**

The biggest research and innovation funding programme in the world – Horizon 2020 from the European Union (detailed in the previous chapter) – dedicates most of its resources to collaborative research. National funding in European member states may still focus funds on individual research groups, but even here there is a tendency towards inter-disciplinary and multi-disciplinary research (calling for research engineers to collaborate with different disciplines or sectors). Both public and private research funding asks research groups to work with universities, government agencies, research centres, research networks, businesses, industry bodies or civil society stakeholders. Recently in Europe, private foundations are increasingly funding research groups at universities or research centres (this has a longer history in the United States). Such funding is rarely given just to a research group but, instead, to solve a particular problem or to understand a particular issue (and tackling complex problems demands collaborative approaches).

- **Complementary skills:**

Due to the trend for multi-disciplinary research, the skills of engineering researchers need to be complemented with other skills. For example, there are many collaborations between engineering researchers and medical researchers for new medical devices. During clinical trials, such researchers must check and understand the patients' needs to help recognise the usefulness and impact of a device – so they may also call upon social science researchers too. These intersections of skill sets can help everyone involved.

- **Speed:**

Evidence shows that collaboration improves the progress of research since collaboration allows researchers to ask questions they could not ask if they worked alone. For example, engineering researchers looking at road construction in developing countries can deliver research results faster if they work with local partners to understand the socio-economic dynamics of daily life in that context. Further, including partners who work on gender issues can yield innovative ideas for the needs of half the population – so research results can also have an impact more quickly on the ground.

- **Communications tools:**

New web-based technologies can support data exchange, team communication and networking or co-ordination tools. Researchers can benefit from open platforms that enable greater research input, data collection and data manipulation etc.

COLLABORATIVE SITUATIONS

Different types of research collaboration are outlined below to provide a flavour of what is possible; as there are no limits on types of collaboration in research, this list is not exhaustive.

- **Inter-disciplinary collaboration:**

Inter-disciplinary projects are when researchers from different academic disciplines are involved in a research project and can focus on a problem from different perspectives. A project may also involve a complex set of questions that fall across different disciplines.

- **Collaboration with other universities:**

In collaborative research, researchers from different universities normally work on different aspects of a project. The Horizon 2020 funding programme fosters collaboration of research institutions in a single project from at least three European Union or 'Associated' countries – and developing country universities may participate as well. In such collaborations, an agreed understanding or 'Rules and Procedures' is necessary to guide the different parties.

- **Collaboration with companies or civil society organisations:**

Collaboration between university engineering researchers and companies is one of the most common yet potentially most problematic forms of collaboration. Issues can arise over confidentiality, non-disclosure, the ownership of intellectual property, timing, budget pressures and so on. However, they can be very effective ways of achieving impact with research. Similar issues apply to collaboration with civil society organisations.

- **Collaboration with an independent expert:**

Depending on the needs of the research, the team may find it useful to collaborate with an independent expert or consultant. Normally this is done where the expert can bring novelty, experience or broader networks and perspectives.

- **Collaboration as sharing:**

Sharing or transferring material, data or methods means collaboration that is developed between two or more stakeholders – this simple type of collaboration is usually done through written agreements (discussed below). Open collaboration can be much more difficult to achieve within standard university processes, but can be very useful in attracting interested parties to the research.

TYPES OF AGREEMENT

Experience shows that the most prudent and responsible way of facilitating collaboration in research is to make agreements in writing about the rights, responsibilities and procedures involved. Consideration needs to be given both to the people and to the institutions that participate, but written agreements are highly recommended in most cases of collaboration. In the case of funding from governments, major companies or international funding agencies, written agreements between partners can become a requirement. For example, the European Commission does not demand an internal agreement but suggests that having one demonstrates compromise and stability (and it can help should issues emerge).

Agreements do not always address all aspects of collaboration; some cover a wide array of issues and others focus on one issue or a few issues that are relevant to the team or topic. Nevertheless, agreements are mechanisms that help with the formalisation of collaboration. There are some issues that arise in most research collaborations where it is highly recommended to have prior written agreements. These issues include:

- **Intellectual Property (IP):**

Handling intellectual property rights is very complicated, especially when the inventions are discovered while performing research and so may be jointly owned. Researchers also need to understand how copyright, patents and intellectual property rights are usually handled before they sign an agreement.

- **Use of Data:**

Normally, research data are owned by the institution. In collaborations, a written agreement ensures access to data by different researchers from different institutions (and perhaps different countries or jurisdictions). There is a general interest in sharing data among institutions – indeed, sharing data is helpful for securing public funding. Agreements should cover background data as well as new data produced in the framework of the collaboration.

- **Funding allocations:**

Planning and expectations management needs an understanding of funds for each party.

In the case of smaller collaborations, researchers tend to work on the basis of unwritten agreements, such as:

- **Authorship and credit in the publication:**

Names of the authors are included (in some cases their order is significant, although normally it is in alphabetical order) and the person with final authority will be agreed and shown as the designated author for the publication.

- **Research accountability:**

Researchers decide what type of access to assign to all the members of the collaboration on the original data and on the works during the research. They may also decide when and where to discuss milestones and results of their common work.

Larger collaborations may demand specific types of agreements, such as:

- **Sub-awards or Third Parties:**

These are agreements between an institution that receives funding for a specific project or tasks and another institution or company to which it transfers a portion of the work that it cannot develop itself. The third party agreement sets the tasks and relationship with the main institution, but not the funding agency/institution/company etc. The agreement establishes in detail: the work that is to be done by the third party; budget; eligible and illegible costs; how and when payments will be made; milestones; deliverables to be submitted; and how to resolve disputes.

- **Consulting Agreement:**

Often, Consulting Agreements are not seen as proper collaboration agreements because the hired consultancy works under the direction of one of the collaborators or the collaboration team and payments are normally made upon satisfactory completion. Normally the work in a Consulting Agreement is very well detailed and specific. The consulting company has no rights over any of the work performed or over its results.

- **Teaming Agreements:**

These establish the nature of the working relationship and/or the creation of advisory bodies (for example the 'Scientific Advisory Board', 'Technological Advisory Board' or 'External Advisory Committee' etc). There are cases when such agreements can establish basic terms related to intellectual property rights and ownership.

- **Collaboration Agreements:**

These are normally agreements that are established between independent institutions if they execute research funded by institutions, foundations or companies etc. They cover the main issues of collaboration and issues discussed under any Teaming Agreements. Special emphasis is paid to intellectual property in general terms.

- **Intellectual Property Agreements:**

These are defined agreements that detail intellectual property rights in depth. Normally they are written to cover inventions, discoveries, or projects that finish in a result or product that reaches the market. They describe who owns what, and what conditions are applied to the property. They may also cover issues of copyright.

- **Data Sharing Plans:**

These are agreements that contain information on how to manage existing data among different research teams from different institutions, and how to manage the common usage and sharing of specific data that is developed under a collaboration.

- **Material Transfer Agreements:**

Similar in concept to the Data Sharing Plans, these are instead applied to the transfer of research material among different groups or institutions in the same country or across national jurisdictions. It is advisable to establish a written agreement when transferring materials, detailing any conditions.

- **Facility or Infrastructure Usage Agreements:**

These are normally agreements between institutions or companies that cover the researcher's needs when using a piece of equipment, a laboratory or the infrastructure of another institution. At the European Union level, and to accomplish the European Research Area, the sharing of regional and national infrastructures is strongly promoted (as are the European Strategy Forum on Research Infrastructures facilities). Moreover, the agreement establishes charges that may be associated with the use of facilities and equipment. Normally there needs to be a cost analysis and, for fair play, the same rates should be charged to all users (although discount fees can be applied). For public facilities and infrastructures, a market cost analysis of previous charges is recommended. Large infrastructures and e-infrastructures are difficult to access for developing countries, so researchers here can establish networks of their own infrastructures using open access for researchers, engineers and technicians worldwide.

FACTORS THAT HINDER COLLABORATION IN RESEARCH

This section outlines some of the aspects that may delay or hinder effective collaboration amongst researchers, organisations and institutions. Acknowledging these factors – and then being proactive in preventing them – can strengthen collaboration at every level.

- **Behavioural Differences:**

Behavioural or cultural differences affects the way collaborations develop, and – where mindsets and habits are deeply ingrained – can affect the results of collaboration too. A simple example might be that some academic researchers are more formal, while others are more relaxed; some researchers build collaborations on the basis of a handshake, but others need signed documents stating responsibilities etc. Normally, a written agreement is essential when there is external funding involved.

- **Disciplinary differences:**

There are fields of research where people who have not contributed substantially to the research are not named in the publications, while in other fields the convention is that everyone who has participated at any level receives authorship. In inter-disciplinary projects the differences may occur in terms of the size of data, duration of experiments, etc. Work habits vary in different disciplines. There are laboratories that operate around the clock, and others that have a more routine working day. When collaborating, these differences need to be discussed and agreements reached for optimum performance.

- **Language differences:**

Team members may all have different native languages. English is accepted as the lingua-franca of research activities worldwide, though there will remain differences in understanding and meaning. International research may demand that agreements are drafted in major global such as Spanish, French, Swahili, Hindi, Mandarin or Bahasa etc.

- **Academic vs. Industrial Research:**

Traditionally, academic research has in its nature the dissemination of its results – to expand and grow human knowledge. Industrial research mainly aims to commercialise and generate profits from its results. These two different priorities mean that academic and industry researchers must reach a common agreement with a shared interest. Acknowledging these differences is crucial for success of such agreements.

- **Ethical Considerations and Conflicts of Interest:**

Different universities in different countries may have different standards regarding the nature of disclosure of potential financial conflicts of interest. International collaborations can raise concerns about different standards of ethical treatment, especially for research in developed countries compared to developing countries. Such issues should be carefully raised and discussed as early as possible to avoid assumptions being made.

FACTORS THAT FOSTER COLLABORATION IN RESEARCH

This section makes some simple recommendations for efficient and effective collaboration:

- **Communicate:**
Communication on ideas, strategy, implementation, infrastructure and human capital is crucial for a better collaboration between researchers, teams, institutions and countries. A wide range of communications tools are now available, and can be selected according to the style preferred by the group. Adapting how you communicate is key to success.
- **Communicate in advance:**
All parties in a collaboration should define goals that may have not been possible without the collaboration. Setting goals leads to robust expectations and outcomes.
- **Authorship:**
Discuss authorship in advance, although (as mentioned above) different disciplines have varying standards for determining authorship. Collaborators need to determine how they deal with the expertise. Who will be the designated author? Who will write the first draft? Who will co-ordinate the article? Such questions should be discussed in advance.
- **Data and material:**
Talking through all the issues on data and material management is highly recommended. Expectations and common standards (including ethical requirements) should be agreed and then captured in writing for all parties to commit to.
- **Intellectual Property:**
Discussing intellectual property issues in advance is highly recommended. Many researchers or engineers want to be able to protect results that may have potential commercial application, and disclosing early results could prevent collaborators from having patents. In the case of external funding, it is important to know the policy and patent procedure guidelines of the funding agencies (particularly for public bodies).
- **Be accountable:**
All institutions have regulations, policies and established practices. Researchers working within institutions (usually) conform to these. Researchers need to inform collaborators in advance about any relevant regulations and policies to enable smooth progress when formal agreements take place. When working across countries and jurisdictions, issues of accountability need to be looked particularly carefully. Trust, sincerity and confidence – experienced in human relations – can quickly emerge where these issues are considered early on, and can become the basis of highly effective collaboration.

OPEN SCIENCE

A new movement is being pushed by researchers around the world called 'Open Science'. To date, it is supported more by individuals than by institutions. But, at its core, it defends open collaboration through sharing research resources and results. It is aligned with the wider Open Knowledge global movement, which seeks to ensure that knowledge is a common good that is accessible to everyone – and so to empower everyone (as opposed to organisations that currently retain knowledge and whose business model depends on only granting access to those who, say, can afford it).

The six pillars of Open Science are: Open Resources; Open Access; Open Peer Review; Open Methodology; Open Source, and; Open Data. The movement goes further and promotes activities (such as Citizen Science) that foster curiosity and the spirit of enquiry, as well as advocating for the results of publicly-funded research to be made open to the public.

The Open Science movement has gained momentum over the last decade, especially as new online technologies enable open repositories of scientific and technological information. The widest Open Access portal is provided by the United Nations Educational, Scientific and Cultural Organisation (UNESCO) under the name 'Global Open Access' (GOAP).

GOAP provides an overview of the status of Open Access to scientific information around the world and it includes information from nearly every country. A specific repository is dedicated to Engineering and Technology (see Box 1).

Technology (General)

- CalTech Thesis
- Cemadoc
- InfoScience
- QUT e-Prints

Computer and Information Sciences

- arXiv Computing Research Repository
- BDB Comp
- CiteSeerX
- HAL-INRIA
- Memoria digital de Canarias
- University of Texas at Austin

Engineering

- Engineering Commons

Architecture and Civil Engineering

- Eldorado
- Greater Cincinnati Memory Project
- York Digital Library
- GROW

Chemical Engineering

- Chemical Engineering Research Information Centre
- Electrical and Electronic Engineering
- ECS EPrints Repository

Mechanical Engineering

- BEACON eSpace
- Crystallography Open Database

Box 1 UNESCO's GOAP Engineering and Technology repository as at March 2015 (UNESCO).

The GOAP database might be useful for the Global Dimension in Engineering Education community. UNESCO makes registration available to everyone, anywhere in the world.

Open Science is increasingly recognised and supported at a political level. For example, as at early 2015, the President of the United States Barack Obama appointed 13 ‘Champions of Change on Open Science’, and two are interesting examples of engineering researchers from academia and industry who work with the Global Dimension (White House, 2014):

- Drew Endy, Ph.D: a bioengineer at Stanford, also a co-founder and President of BioBricks.org (a charity advancing biotechnology to benefit all people and the planet).
- Rebecca Moore: an Engineering Manager at Google where she initiated and leads the development of the Google Earth Engine (a new technology platform that puts an unprecedented amount of satellite imagery online for the first time and enables scientists to conduct global-scale monitoring and measurement of changes in the earth’s environment).

The European Commission has launched its ‘Science 2.0’ initiative, which aims to bring “*a broad change of mind-set in the way we collaborate on science in the European Union*”. In co-ordination with member states, the European Commission has committed to enhance all the dimensions of Open Science (at least politically).

Finally, it is worth noting that there is opinion amongst the international development community that Open Science will enable faster development through greater access to knowledge, as well as for enhancing community-driven approaches to create better technology solutions. However, barriers remain – not least over language, Internet access, the levels of pre-existing education that may be required, and the difficulties of sharing ‘know-how’ (as distinct from knowledge) through online platforms. Websites like ‘Appropedia’ and ‘Engineering for Change’ are trying to find ways to tackle these problems through volunteer action, but the ‘Open Know-How’ movement is yet to fully establish itself.

EUROPEAN FUNDING FOR COLLABORATION IN RESEARCH

Funding has been covered in the previous chapter so this section gives a brief revision of particular opportunities for funding collaboration in research. The three following examples are taken from the European Commission Research and Innovation Directorate:

- **Horizon2020 Framework Programme for Research and Innovation:**

Collaborative research is at the core of the Horizon2020 Programme, which requires participation from at least three member states or 'Associated Countries' (see <http://ec.europa.eu/programmes/horizon2020/>). Networking, collaboration and partnerships are promoted in each pillar of the fund, mostly under 'Industrial Leadership' (to promote collaboration with industry) and 'Societal Challenges' (to tackle the major challenges facing society in collaboration with civil society organisations etc). Unfortunately, there are limited opportunities for research on international development (which may be better tackled from the EuropeAid directorate).

- **European Co-operation in Science and Technology (COST) actions:**

This long-running European framework supports collaboration between researchers across Europe (see www.cost.eu). It aims to reduce fragmentation in research investments and to open the 'European Research Area' to global co-operation.

Through its bottom-up principle, COST funds networking actions in the following thematic and transversal science and technology fields: Biomedicine and Molecular Biosciences; Food and Agriculture; Forests, their Products and Services; Materials, Physics and Nanosciences; Chemistry and Molecular Sciences and Technologies; Earth System Science and Environmental Management; Information and Communication Technologies; Transport and Urban Development; Individuals, Societies, Cultures and Health. A 'trans-domain' domain also allows for broader, multi-disciplinary proposals.

- **European Institute of Technology:**

Set up in 2008, the European Institute of Technology and Innovation (see <http://EIT.europa.eu>) and its Knowledge and Innovation Communities (KICs) in different research fields offers great opportunities for collaboration. The EIT community is vibrant and helpfully diverse, with quite a strong focus on postgraduate education.

The following EIT communities (which sometimes change) might interest the Global Dimension in Engineering Education community: Climate KIC, addressing climate change mitigation and adaptation; EIT Health, addressing healthy living and active ageing; EIT ICT Labs, addressing future information and communication technologies; EIT Raw Materials, addressing sustainable exploration, extraction, processing, recycling and substitution; KIC InnoEnergy, addressing sustainable energy.

CONCLUSION

Collaboration in research has many benefits, but is essential for engineering research that considers the Global Dimension. The main benefits of collaboration have been set out, which aim not only at raising efficiency during the project cycle but at bringing success for the research, researchers and their teams.

There are a range of different collaborative situations that a researcher or engineer may use, and each can be formalised through written agreements. Written collaborative agreements are important for the stability and further success of a collaboration, because they help to ensure a common understanding of responsibilities, accountabilities and expectations. Most funders require a formal agreement among members of a collaboration.

Successful collaboration calls for careful consideration of possible behavioural, disciplinary and language differences. It is vital to understand the goals of collaboration to help to overcome these differences and achieve a mutual agreement. In addition, ethical standards and ways of dealing with conflicts of interest need early attention.

Tackling any differences is one way to foster collaboration, but good communication flows between people and between institutions are fundamental. Accountability and trust are foundations of success for any form of collaboration.

Collaboration in research is benefitting from a growing new phenomenon. The Open Science movement aims to make research data and results accessible to everyone. Consideration should be given to the use of Open Science platforms for further enabling, and particularly where research is focused on the Global Dimensions of engineering.

Research cannot take place without funding. Collaboration in research is however a priority for many research funders, and indeed is a requirement of the major research funds of the European Union.

Integrating the Global Dimensions of Engineering into research can best be achieved through collaboration. Indeed, given the complexity of the issues considered by the Global Dimension, it is hard to imagine research in this area being effective without collaboration! Putting more of the world's best and most highly-educated minds to work – together – in the service of the poorest and most vulnerable in global society would not only be a valuable and important change in the priorities of most engineering researchers; it is also a re-affirmation of the original purpose of research. The right team of researchers – working together effectively and aligned towards shared goals – can discover and develop results, products and impacts with a profoundly positive effect on the path and pace of human progress.

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FURTHER/SUGGESTED MATERIALS

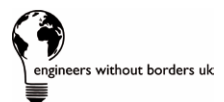
- A Recipe for Collaboration: http://sciencecareers.sciencemag.org/career_magazine/previous_issues/articles/2009_11_13/caredit.a0900140
- Studying Research Collaboration: A Literature Review: <http://sprouts.aisnet.org/826/1/ResearchCollaboration.pdf>
- Science 2.0 Initiative by the European Commission: <http://scienceintransition.eu/>
- Open Science projects funded by FP7: <https://www.openaire.eu/>; <http://www.pasteur4oa.eu/>
- Champions on Open Science: <http://www.whitehouse.gov/champions/open-science>
- Open Access Community of UNESCO: <http://www.wsis-community.org/pg/groups/world/?filter=newest>
- Collaboration: Key to scientific Success. <https://www.youtube.com/watch?v=-wz90IVQE9w>
- Engineering in the 21st Century: https://www.youtube.com/watch?v=_oalhzlpENY
- Horizon2020: <https://www.youtube.com/watch?v=CimJI88c4fE>
- What is Science 2.0? https://www.youtube.com/watch?v=Bqo46r_yIoU
- Open Science Summit Keynote 2011: <https://www.youtube.com/watch?v=sZlxzTsvWhw>



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