Integrating the Global Dimension in Engineering Education: Experiences from a Collaborative Project

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Abstract

The '*Global Dimension in Engineering Education*' (GDEE) network is an initiative that aims to increase the awareness, critical understanding and attitudinal values of undergraduates and postgraduates students in technical universities across Europe related to Sustainable Human Development (SHD) and its relationship with technology. This is being dealt with by integrating SHD as a cross-cutting issue in teaching activities by improving the competences of academics and through engaging both staff and students in initiatives related to SHD. The GDEE started as a collaborative project between a consortium of European Universities and NGOs. The chapter presents a

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common understanding of how best to establish effective education for global development, and presents a pedagogical approach to facilitate the connection between theoretical knowledge (lecturers and students from universities) with practice (through NGOs). It discusses this approach through the analysis of case studies of best practice from those already working in this area within higher education across Europe. It concludes with the presentation of a continued professional development (CPD) approach for academics that uses a series of online training courses, with support from a series of contextual case studies written by NGOs to support teaching human development within engineering courses.

Keywords
Global development · Pedagogy · Academic training

1 Introduction: Global Development and Higher Education

It can be argued that the knowledge and skills required for engineers are the same all over the world, and it is often expected that an engineer will work in a range of countries and cultures during their career (Bourn 2014). The effect of this increasingly global profession has changed the nature of learning. This change naturally has consequences on the Higher Education (HE) Engineering curriculum, with many universities reconsidering the nature and content, covered in courses. The need for this is not new, it has long been realised that there is a need for a new kind of engineer; one who is equipped with the skills to deal with the societal aspects of technologies (De Graaf and Ravesteijn 2001, cited in Segalàs et al. 2010). Indeed, in the 70s Schumacher states that for education to impact on sustainability, it would have to be 'education of a different kind: an education that takes us into the depth of things' (1973, preface). Sterling (2005) agrees stating the need for a fundamental shift in education to address the nature of sustainability. Concurrently, our world is in a constant state of change in which we face new challenges that require new solutions. Engineering must respond to these changes, with education being at the heart of the response (Gathercole 2014).

One proposed method is to incorporate a Global Dimension as an integral part of engineering education. A Global Dimension is one which encourages students to think of themselves as global citizens and thus promote a sense of global social responsibility (Bourn 2014). In particular, the focus is on the incorporation and understanding of international development, human rights, along with equality issues, and the environment. This does not stand alone within engineering education as there are already relationships with other agendas, such as; sustainability, humanitarian engineering and ethics (Gathercole 2014). However the benefits of including a global dimension is that it can help students make links to the real

world, and enable engineers to play a role in poverty reduction, human rights issues, and conflict resolution (Gathercole 2014).

Previously, the traditional response from engineering academics has been that through the use of technology we can find solutions to society's problems. This assumes that a solution can always be found, and does not necessarily account for the views of people and the cultures it effects (Bourn 2014). Some universities have already begun to recognise the impact that engineering has on; societies, ethics and ones' individual value-base. An example of this is current recognition of, and the accepted role of Sustainable Development (World Commission on Environment and Development 1987). This definition is still widely used today, by different groups and has ultimately led to the proposal of the Sustainable Development Goals, a successor to the Millennium Development Goals. Target 4.7 states that by 2030 all learners should a have acquired knowledge and skills to promote sustainable development (United Nations 2012). Abundant literature has already substantially improved scientific contribution on sustainable development teaching strategies in higher education, specifically in engineering studies (Mulder et al. 2012; Holmberg et al. 2008; Segalàs et al. 2010; Watson et al. 2013; Lozano et al. 2014). Furthermore, universities have begun to recognise the impact of globalisation pedagogy, typically under the heading of 'internationalisation'. Although some previous work was done with a humanitarian and human development focus (Boni and Pérez-Foguet 2008), the drive for the globalization of higher education has increased momentum in this direction. In recent years there has been a growing debate about the implications of such policies and practices, which has resulted in academics investigating the process of learning. One manifestation of this can be seen in the sharing of knowledge, which has increased due to the willingness to learn from other nations and the increased mobility of staff and students. As a result, there is a growing demand from students to re-think the content and form of engineering degree courses.

In order to address this, in 2012, academics came together in a collaborative consortium known as Global Dimension in Engineering Education (GDEE), which aims to increase the awareness, critical understanding and attitudinal values of undergraduates and postgraduate students related to Sustainable Human Development (SHD). Roots of the thematic and methodological approaches followed by the project are found in Pérez-Foguet et al. (2005), Boni and Pérez-Foguet (2008), Pérez-Foguet and Cruz (2011). The consortium comprised of five technical universities and four NGOs from three EU countries: United Kingdom, Spain and Italy.

During the two year initiative the consortium has established an understanding of best practice for effectively integrating global dimensions into the engineering curriculum. Consequently, this paper presents the pedagogical theory which underpins this understanding. It discusses this approach through a discussion of pedagogical theory derived from prior art plus a review of best practice from those already working in this area within higher education across Europe. It concludes with the presentation of a CPD approach for academics that uses a series of online training courses, with support from a series of contextual case studies written by

NGOs to support teaching human development within engineering courses. It argues for integrated active learning pedagogies and for Universities to actively seek engagement with experts in the field.

2 Goals, Competences and Pedagogical Approach

Referring to curriculum design, Sterling points out that if engineers are to contribute truly to Sustainable Development, then sustainability must become part of their everyday thinking. This can only be achieved if Sustainable Development becomes an integral part of engineering education programmes, not a mere 'add on' to the 'core' parts of the curriculum (Sterling 2005).

In 2008, 'The Global Engineer' report laid out a conceptual methodology to incorporate the competences of a 'Global Engineer' onto the professional accreditation standards (in the UK), comprising 5 sequential stages (Bourne and Neal 2008). However, this list has grown to 10, as others have been added to reflect new understandings of effective education for global development. The additions have come from the outcomes of a review of papers which reflect on best practice submitted during the course of the GDEE project (Trimingham 2014, see also below). It also embeds learning from a recent publication on Internationalising Higher Education from the Higher Education Academy (2014). The 10 key objectives are:

1. Develop a faculty wide philosophy and base of knowledge and understanding
2. Identify areas within the curriculum where global development can enhance current teaching
3. Introduce students to global development
4. Integrate the idea of systems thinking in relation to global development
5. Convey an appreciation of the commercial, institutional, legislative and social motivations for implementing global development
6. Demonstrate knowledge and understanding of the concepts of global development and how it exists within discipline specific contexts
7. Advance practical understanding of the pressures facing industry in terms of integrating global development
8. Acquaint students with the current range of tools and resources available for integrating global development and understand how to use some of the most common
9. Allow students to generate solutions through active learning.
10. Develop a view of future directions for global development engineering (Trimingham 2014).

Such an approach would enable greater integration of Global Development criteria into the curriculum. It promotes learning outcomes that enable graduates to establish a clear connection between engineering and Global Development and helps them in practising sustainable engineering.

But within this methodology a reorientation on pedagogy and learning processes is essential to achieve effective Education for Global Development. The Barcelona declaration states: "*teaching strategies in the classroom and teaching and learning techniques must be reviewed*" (Barcelona declaration 2004). But what is needed to achieve an effective Education for Sustainable Development (ESD) in higher education, and specifically in engineering education? What pedagogy is especially good for Sustainable Development?

The level of adaption required by engineers to enable them to produce globally appropriate outcomes is large, therefore engineering students (and academics!) need to be made more aware of the issues and given the skills with which to deal with such change. Best practice approaches all follow the same pattern. They begin by building momentum within their HE establishment, then they introducing concepts of global development and build global development knowledge, they then move to supporting learners who are expected to be working on live projects. This approach promotes learning that emphasises independence of mind and the ability to make sense of, rather than reproduce information (Khan 1995). Engineering for global development must involve the key characteristics of a transformative educational approach (where the learning constructs meaning, Sterling 2001). It involves creative, solutions-focussed learning; self-directed team work; learning by doing (commonly 'live' projects); iterative refinement and reflection; and drawing from a range of disciplines to inform outputs. Since the introduction of the concept of Education for Sustainable Development there has been wide ranging discussion regarding the knowledge, skills and values needed to contribute to SD, and what competencies should be obtained in Universities (Segalàs et al. 2010; Svanstrom et al. 2008; Mulder et al. 2012). Effective Education for Global Development should promote the development of the following competencies (see Table 1).

In relation to teaching engineering for global development most authors do not opt for one specific learning technique, but for using a wide range of pedagogical tools and strategies. Important aspects of pedagogy include encouraging students to explore issues within contexts relevant to them and their communities. This involves student-centred and interactive enquiry-based approaches to teaching and learning. There are pedagogical approaches that promote dialogue and community, higher-order critical thinking and problem-solving. Some strategies to facilitate integrative teaching and learning are as follows:

- Team-teaching and team planning
- Collaborative learning and learning communities
- Clustered and linked courses
- Core seminars at introductory and capstone levels
- Theme or problem focus in courses
- Proactive attention to integration and synthesis
- Models of interdisciplinary and integrative process
- Theories and methods from interdisciplinary fields

Table 1 GDEE competencies (GDEE 2015, adapted from CSCT 2008; Wiek et al. 2011; Segalàs et al. 2010; Svanstrom et al. 2008; Mulder et al. 2012)

Competence	Description
Systemic thinking	Ability to recognize and analyse the complexity of development issues across different domains (society, environment, economy, etc.) and across different scales (local to global). Ability to identify locally and globally relevant SHD issues and to connect the local and global aspects. Ability to analyse and explain the role of technology and engineering in a globalized context connecting local and global aspects
Knowledge acquisition	Ability to acquire relevant knowledge about SHD challenges and issues. Ability to select educational goals for SHD, taking into account the prior knowledge of students, and the diversity within the group of learners. Ability to find partners outside the school community and to co-operate with organizations which promote SHD
Ethics and values	Ability to include and embed in teaching SD Ethic and values, principles and goals. Ability to encourage students to question their beliefs and assumptions on SD values such as justice, solidarity, dignity, participation, etc. in order to clarify their thinking. Ability to work with students on contradictory beliefs, assumptions and values, as well as moral dilemmas, specifically about the role of technology and engineering in sustainable development issues
Action	Ability to introduce SHD as cross-cutting issues in teaching (introductory courses). Ability to advice students who are actively participating in the resolution of sustainable development issues. This could be through field-work or other extension activities during B.Sc. projects or M.Sc. thesis, typically within a formalized International Cooperation Project (mid-level courses). Ability to design and implement a subject in the field of SHD (advanced courses)
Emotion	Ability to motivate students towards Sustainable Development issues through Leadership and Empathy. Motivate and facilitate participative problem solving and Teamwork. Build capacity to understand diversity across cultures, social groups, communities

- Projects and case studies
- Dyads, triads, and small groups for discussion
- Game and role playing
- Inquiry- and discovery-based learning
- Learning portfolios
- Case studies
- Active participation
- Total immersion (for example managing a site)
- Balancing the far and near (making content relevant)
- Experiential- and service-learning, internships, and fieldwork
- Residential living-learning experiences (developed from Segalàs 2014; Wals and Corcoran 2005).

As well as integrating global development into HE, there is also a need to place it within an industrial context and to highlight the importance of business, innovation and enterprise skills. Teaching techniques in order to accomplish this include work placements, brought in speakers/tutors and strong links with industry, NGO's and community organisations (Trimingham 2014).

Finally it is important to understand the future direction of Global Development in Higher Education. This is important for both academics and students as it helps to guide current activity through a lens of future possibilities. From an academic perspective this includes becoming involved in research related to Global Development and keeping up to date with current thinking within the GDEE agenda. New principles and understanding, as well as new tools and techniques can then be integrated into teaching via regular curriculum reviews.

3 Overview of an Initiative to Engage Engineering Academics with Global Development: The GDEE Project

Roots of the methodological approach on which this initiative is based can be found in the previous works of project partners (Boni et al. 2004; Pérez-Foguet et al. 2005; Boni and Pérez-Foguet 2008; Pérez-Foguet and Cruz 2011). Diverse initiatives for improving SHD teaching have been separately promoted among project partners at a local and national level in Italy and Spain such as: case studies (Oliete-Josa and Pérez-Foguet 2005, 2008), faculty empowerment (Archetti et al. 2007), networking and awarding best practices (Cabrera et al. 2006). In the UK, it is worth mentioning a namesake initiative *The Global Dimension of Engineering Education* project coordinated by the NGO Engineers Against Poverty, alongside Engineers Without Borders, a project partner on the current initiative.

The main aim of the GDEE initiative is to integrate different approaches on engineering education issues, reflected by consortium composition, in order to transcend the national level and encourage a European vision of this issue. From one side, previous approaches more focused on engineering education for SHD, mainly implemented in Spain and Italy and, from the other side, the UK approach that goes back to the concept of Global Engineer (Bourn and Neal 2008). This integrated approach is broadly reflected in different project outcomes, such as training materials and on-line courses.

In order to increase competencies among academics to engage with the global development agenda training materials alongside a set of 9 open source online courses were developed to train academics, teachers or researchers throughout Europe (and internationally as it transpired!). More than forty academics from sixteen European universities and twelve experts in the field of development (from NGOs, development training centres, and engineering organizations, among others) have closely collaborated in developing materials, and nine separate publications,

Table 2 Course outline (GDEE 2015)

Block A—the global engineer	Addressed to those academics that want to introduce cross-cutting issues in their activities; i.e., including a session related to SHD within, typically, a B.Sc. course *Course A.1*: *Making the case for a critical global engineer* *Course A.2*: *Key elements for addressing the global dimension of engineering* *Course A.3*: *The global engineer in Sustainable Human Development*
Block B—supervising BS/MS thesis with fieldwork	Addressed to those academics who want to advice students involved in field-work or other extension activities during B.Sc. projects or M.Sc. thesis, typically within or close to a formalized International Cooperation Project *Course B.4*: *Supervising Engineering Students* *Course B.5*: *Knowing the context and partners* *Course B.6*: *Knowing International Cooperation*
Block C—integrating GDE into teaching and research	Addressed to those academics (or professionals) who want to design a course relating Technology and SHD, from their own technical expertise *Course C.7*: *Integrating GDE into the academic* *Course C.8*: *Integrating GDE into Teaching: Theory and Practice* *Course C.9*: *Integrating GDE into Research*

one for each course, have been published and disseminated as Open Educational Resources (GDEE 2015; see Table 2).

To maximise participation, courses have been implemented through distance learning in the three European countries; Italy, Spain and the United Kingdom. In parallel, participants engaged with one another through collaborative tools and through discussion forums. Evaluation consisted of three types of assessment tools: (i) assessment quizzes at the end of each session; (ii) two academic activities, with the aim of putting in practice notions learnt through the sessions; (iii) a final multiple choice assessment. The open source nature of the online materials also allowed interested academics (and others) to 'dip in' without completing the courses (these materials can be found at www.gdee.eu).

4 The Impact of GDEE Academic Training

From January 2014 to January 2015 the Europe wide online web portal (GDEE 2015) saw just under 8000 visitors, with 39 % of those visitors returning more than once after their first visit. There were over 750 resources and course papers downloaded and over 42,000 page views. In total there were 295 participants across all three training centres (Spain, UK and Italy). The following discusses the impact the academic training has had in Spain.

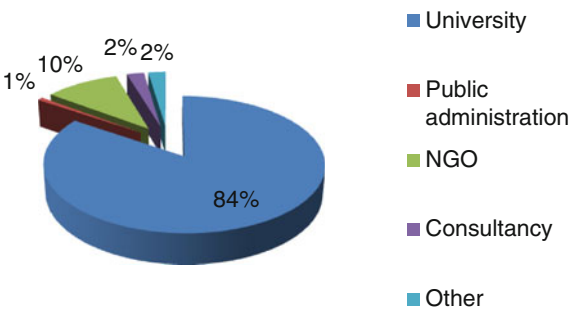

Fig. 1 Participants' affiliation

In Spain courses run from March 2014 to April 2015. Overall, a total of 129 participants enrolled, mostly to more than one course, with a median average of 70 participants per course. Females appear to be more interested, representing the 58 % of participants.

As shown in Fig. 1, the majority of participants (84 %) are linked to a University, with more than hundred participants. NGOs workers and volunteers represent the second largest group (10 %). But other categories (Public Administration, Consultancy firms, etc.) showed an interest in the GDEE training initiative. Enrolled professors come from 36 different universities: 30 Spanish, 2 Portuguese, 2 Colombian and 1 Danish.

The completion rate can be defined as the percentage of enrolled participants who satisfied the courses' criteria in order to earn a certificate. Completion rates of GDEE courses vary across different courses and thematic blocks. The highest rates of completion were seen during the introductory block (A1, A2 and A3, see Table 2). The trend indicates a decrease for courses of the mid-level block and then a slight increase for the advanced group of courses. Time availability also has to be taken into account here however, since academics have limited time for professional development training. Courses for the Mid-Level block (B4, B5, and B6, see Table 2) ran during the months of June and July; notoriously busy months for university professors. Besides, to meet the project timelines, courses were scheduled one after another with a very short break (or sometimes no break at all) between courses. This overload might have affected participants' motivation to complete all course activities.

Since the goal of the majority of academics enrolled wasn't to earn credit (each course was worth 1 ECT), and given the varied background and the broad range of motivation of participants, completion rate may be not the right indicator to measure the impact of the courses. Nevertheless, it can still be argued that GDEE completion rates are higher than other free on-line courses. Research on MOOCs shows that the majority of courses have completion rates of less than 10 %, with a median average of 6.5 % (Jordan 2014). The GDEE courses showed completion rates between 14.86 and 40 % (see Table 3).

According to the answers of anonymous surveys launched at the end of each GDEE course the training initiative had a positive impact on participants. Specifically, a very high percentage of participants (77–100 %) agree that, as a result of

Table 3 Completion rates for online GDEE courses

	Introductory block			Mid-level block			Advanced block		
	A1	A2	A3	B4	B5	B6	C7	C8	C9
Registered	65	67	73	60	63	74	66	73	84
Completions	26	25	21	16	13	11	11	13	14
Rate (%)	40.00	37.31	28.77	26.67	20.63	14.86	16.67	17.81	16.67

taking a course, their interests in GD issues (such as Millenium Development Goals, Human Development, extreme poverty, climate change, etc.) has increased. Moreover, a high percentage of participants (69–100 %) agree that courses were useful for integrating cross-cutting issues in teaching activities. It is worth highlighting that the introductory courses, that dealt with topics in a more theoretical way, are perceived as less useful for integrating cross-cutting issues.

5 Contextual Case Studies

By 'training the trainers' (academics) in global development issues, it is hoped that there will be an increase in academic staff' competences to integrate Sustainable Human Development issues in curricular teaching. However, in addition to this there is evidence of an increasing need to tackle the shortage of adequate tools to implement effectively the acquired competences. With this in mind, another aim of the project was to provide academic staff with specific materials to be used with students. This has been done in two main steps: initially, case studies of real development projects were provided by project partners, as well as external NGOs and universities. The selection process, which led to the choice of twenty-seven case studies, was carried out using the following criteria; geographic context; technology area affected by the project; and subject into which the final material could be used by academics. Finally, each case study was assigned to a specific academic who developed the teaching material following a standardised template.

Following previous experiences of Pérez-Foguet et al. (2005), each case study combines practical/contextual information on the specific project from which it is drawn (the context) with more academic-oriented content specifically designed to be used in class and during self-directed study (activities). The combination of practice and theory in the available materials allows lecturers to overcome the distance between traditional academic teaching and the evidence in the field. As part of a "standard" academic subject, students are also provided with a set of information, both technical and socio-economic, which allows them to understand the multiple variables present in a specific context (as well as practice critical thinking skills!). On the basis of this information a set of activities is provided, designed to provide students with technical problems related to the context. The

case studies, which are published under a Creative Common Licence, can be adapted by each academic to suit their own teaching agenda. This process has involved more than 50 authors, from 14 universities.

6 Best Practice

An additional role of the GDEE project was to recognise best practice within Higher Education on the integration of sustainable human development into technology education through 2 editions of a 'best practice award'. The motivation for the best practice awards was two-fold; firstly it allowed the project team to reflect on, and learn from existing academic engagement with the global development agenda (reported on at the beginning of this chapter); and secondly it allowed the project team to motivate and reward activities that stemmed from the training initiative.

The award was presented through two different calls, the first one in 2013 and the second one in 2015. It focused on University academics and awarded the best examples of teaching that contributes to extend the education Global Development through technical courses within European Universities. Submissions, that could be either theoretical or applied, had to focus on:

- Innovative methods for integrated SHD into the curriculum.
- Converting existing experiences in development education into technology/engineering studies.
- Making materials for the integration of SHD available to the Academic Community.
- Innovative methods for the support and supervision of a Ph.D. Thesis, Master Thesis, Bachelor Thesis, or equivalent (GDEE 2015).

Submissions were evaluated through a competition panel. The panel was composed of both Academics and NGO's. Each submission was evaluated against the following criteria:

- Innovation of the work, including novel educational aspects.
- Quality, coherence and sustainability of the work.
- Impact of the work on the academic activities of the European Universities.

During the two periods, 46 proposals were delivered (22 for the first edition and 26 for the second edition). In total 10 submissions were awarded prizes (see Table 4).

It is observed that they cover a very wide range of technological disciplines and focus on a number of different topics including; integration of SHD in the formal curricula, promotion of practical works among the students, computer games for promoting sustainable development, strength of educational capabilities, among many others. All of these examples of best practice follow all, or most of the pedagogical theory presented above.

Table 4 10 Best practise awards

Initiative title	Academic and affiliation
Beyond Traditional Education in Engineering: A Systemic Approach to Strengthen Development	Politecnico di Milano (Italy)
B.E.S.T. (Best Environmental Sustainable Technologies) for International Cooperation	Università degli Studi di Brescia (Italy)
Real-world Water and Sanitation M.Sc. Thesis Research with Cranfield University	Cranfield University (UK)
SHD—Tackling Interdisciplinary Early: Transforming Technical Expertise into Global Citizenship	Imperial College London (UK)
Incorporating Sustainable Wool Processing using Engineering Solutions into the Academic Curriculum	Manchester Metropolitan University (UK)
The Integration of Education for Development in the Civil Engineering School of the University of Granada	Universidad de Granada (Spain)
A global perspective. Environmental Sustainability and Cooperation Workshop in southern Morocco	Universidad de Alcalá (Spain)
ECOLOGY: A Game-experiment to Approximate Engineer Students to Sustainable Human Development and the Limits to Growth Concepts	Universidad de Valladolid (Spain)
Integrated Development Aid Awareness into Architecture	Universidad Politécnica de Madrid (Spain)
Strengthening the Education Capabilities of University of Makeni (Sierra Leona)	Universidad San Pablo CEU (Spain)

7 Conclusions

This chapter has highlighted characteristics of best practice pedagogical strategies and their role in Global Development Engineering Education. It also outlines an approach for training academics within this field which has shown high levels of engagement and motivation from academics (and others!).

It highlights that imparting knowledge is an important activity, but not a guarantee for change. Learning about Global Development does not guarantee realisation of actions and activities supporting changes necessary for effective sustainable development. Learning for change needs a deep knowledge of the basics of Global Development and the development of specific competencies and values through active participatory methods for both students, and training academics within this field. Furthermore, it has to capacitate students with the appropriate competences in relation to their future profession, but also arm them with capabilities in systemic thinking and multi-disciplinary working. To create a pedagogical approach that optimises systemic thinking the understanding of flows of relationships between concepts of all kind is needed.

The need to address global challenges and provide a more rounded and relevant curriculum for engineering education has brought together academics and practitioners from across Europe who have worked together to develop a new pedagogy. By designing courses to engage academics with Global Development a deeper understanding of effective pedagogy has been explored. The skills and knowledge developed can be used to address current curriculum failings, though tweaks and changes to the existing education structure. The overarching aim and consensus from GDEE partners is that the integration of this Global Dimension would not be an 'add on' to existing curriculum development, but should be fully embraced and embedded into the core content.

It is recognised that Global Development requires core competencies, such as, systemic thinking, knowledge acquisition, the ability to question beliefs and assumptions, show leadership and empathy, and get involved in solutions through participatory problem solving. Multi-disciplinary team working and the use of transdisciplinary research is fundamental to the development of Global Engineering students and desired by industry leaders. These skills do not only meet the requirements of the profession, but will help change the mind-set of an engineer towards developing future solutions which are globally appropriate. It is also clear that the Global Development agenda is a 'fast moving beast', and as such regular reviews, underpinned by continued research in this field, are required.

The main limitations of this study are twofold. The first is related to data availability to contrast the real impact of activities; results presented are biased on Spain since no comparable results are currently available. Furthermore, only impact data on GDEE courses are provided as the diffusion of case studies is still on going. The second is related to the methodology adopted to evaluate the changes in participant's interest and ability; a highly quantitative approach was followed during the initiative. More qualitative data is now required to further understanding of the success of the pedagogical approach.

It is worth highlighting that special attention has been given to enhance replicability of this experience at different levels. Courses' content and structure, contextual case studies, and supporting resources are available at the webpage (www.gdee.eu) along with a number of other Global Development resources for academics. All academic resources have been published under a Creative Commons license. Therefore they can be translated, improved and adapted to different contexts. While all training materials are directly downloadable from the webpage, files with the courses' structure are available under request.

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