

## Developing interdisciplinary and intercultural skills in engineers through short-term field experiences

Short-term field study experiences are increasingly popular in engineering education. Where they include an international dimension, they can also develop skills and knowledge needed for working across cultures and in interdisciplinary teams. Such programs can take students out of their ‘comfort zone’, thereby enabling them to question their previously taken-for-granted assumptions. Here we analyze four different case studies of organizing short-term international field study programs in engineering education which share a methodology of mixing student disciplines and skills, of interaction with people from other cultures or contexts, and using reflection tools drawn from social and human sciences. While such programs appear to directly address skills desired in engineering students, it was extremely challenging to fit them within the constraints of a traditional university program and to have their modes of reflection accepted as valid by more traditional engineering education practitioners.

**Keywords:** *Field-studies, engineering education, project learning, intercultural education, reflection, interdisciplinary education*

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## 1. Introduction

Engineers may in the past have been perceived as tool-makers who solve technical problems by applying mathematics and scientific knowledge, however, in a world which is increasingly globalized and complex, the boundaries for engineering knowledge becomes ever more difficult to define (Lehmann et.al. 2008). This has led to shift in emphasis in the formal requirements for the education of engineering students. The American Accreditation Board for Engineering and Technology (ABET), for example, requires that, in addition to knowledge of and ability to apply scientific knowledge and skills, students are also educated to solve problems in ways that take into account global, cultural, social, environmental, and economic factors; to recognize ethical and professional responsibilities; and to function effectively on a team that creates a collaborative and inclusive environment (ABET 2019). One way of trying to meet some of these goals is through the use of international placements. While there is growing interest in international experiences in engineering education, there appears to be relatively few studies that look at how such international experiences are organized in engineering education.

This paper looks at the experience of organizing field-based experiences for engineering and science students. It draws on four different case studies of international field-based experiences in China, Colombia, Russia and Switzerland. The goal of the study was to document the opportunities, challenges and some of the good practices which had been experienced within these cases. The paper identifies that, while such programs appear to directly address the goals of developing what are sometimes called twenty-first century skills with engineering students, the challenge of fitting them within the constraints of a traditional university program are considerable. It also highlights the ways in which the experiences of liminality and alterity can be scaffolded drawing on reflective tools from social sciences to maximize the possible learning of the engineering students.

## 2. Context

The growth in technological knowledge in the latter part of the twentieth century led to increasing specialisation and diversification in engineering education but also to an increased need for engineers to interact with other professionals and to understand the needs, wants and constraints of the users of the products of engineering design (Crawley et. al. 2014). Economic, social and cultural globalization also changed the context in which engineers work and meant that the development of intercultural skills have also become a priority for engineers (Handford et. al. 2019). These wider set of skills and knowledge are referred to in various ways, including transversal skills and professional skills. One commonly cited framework for making sense of these

skills is the idea of twenty-first century skills (Binkley et. al. 2012). They identify four groups of skills which include:

- Ways of thinking, including (1) innovating and creating, (2) problem solving, decision making and critical thinking, and (3) metacognition and self-regulation in learning.
- Ways of working, including (1) communication skills and (2) collaboration skills in the contexts of heterogeneous and diverse groups.
- Using tools for working, including (1) information tools and (2) technological tools.
- Living in the world, which focuses on skills of (1) global and local citizenship, (2) managing life and career and (3) cultural awareness and social responsibility.

One of the ways in which engineering educators have sought to address at least some of these skills is through the inclusion of international placements or field study. Field studies are commonly used in social scientific disciplines like Sociology or Anthropology and indeed in professional training in disciplines like social work or teaching which draw on such social scientific disciplines (e.g., Wayne, Bogo and Raskin 2010). However, while such placements are becoming more common internationally, not all countries have normalized the practice: in the US, for example, it has been estimated that as few as 3% of engineering students study abroad (as compared to some 20% of social science and business/management students) (Maldonado et. al. 2014).

Students who have participated in international experiences have been found to have experienced a number of benefits, including a measureable increase in participants' intercultural sensitivity (Olsen and Lalley 2012; Davis and Knight 2017), and an increase in ethical sensitivity or in 'global citizenship' (Tarrant, Rubin and Stoner 2013). The idea that contact with those from other social groups can lead to a reduction in prejudice and a development of intercultural competence is not new, indeed the so-called intergroup contact hypothesis is commonly associated with the post-World War II work of Gordon Allport (1954), who hypothesized that intergroup contact will improve intercultural competence when (a) the different groups are afforded equal status in the relationship, (b) both groups work together towards a common goal ('superordinate task') that requires the pooling of their resources, (c) the superordinate task is structured to ensure there is not competition between the groups, and (d) the contact between the group is supported by an institution or authority that is meaningful to both groups (Allport 1954). Allport's conditions are perhaps all the more important to bear in mind in the context of international contact, where post-colonial implicit cultural beliefs may mean that (well-educated) western students may easily slip into post-colonial mindsets when faced with an experience of 'the other' (e.g. Loomba 2005; Sin 2009). A meta-analysis of 515 studies on intergroup contact has found support both for the general hypothesis that contact, on average, reduces prejudice and for the added value which arises when Allport's four conditions are met (Pettigrew and Tropp 2006).

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One important dimension of being confronted with alterity in the form of different social and cultural systems is that it can allow the ‘decentering’ experience which is often identified as being central to the epistemology of sociology and anthropology but can be unsettling for students who can struggle with the idea that much of their ‘taken for granted’ knowledge, beliefs and practices are in fact culturally specific and situationally contingent. Some engineering educators have recently adopted the anthropological concept of ‘liminality’ to explain these opportunities (Rose et. al. 2018): the term ‘liminal’ indicates a sense of disorientation, typically during a rite of passage, when a person’s socially ascribed status, identity or role is changing. Liminal experiences are sometimes uncomfortable and emotionally challenging for learners as well as being potentially rewarding in terms of new learning; as such, the concept of liminality draws attention to the ‘whole body’ nature of the learning experience which encompasses physical and emotional experiences as well as intellectual ones.

### 3. Methodology

This paper looks at the experience of introducing short-term field studies which include an explicit focus on cultural difference and alterity into engineering programmes. As with other studies in this domain (Maldonado et al. 2014), a case study approach is used. A case study is defined as an empirical enquiry that investigates a contemporary phenomenon in its real life context using multiple sources of evidence, and in which there are generally more variables of interest than data points (Yin 1994). As with multiple experiments, multiple case studies allow for cross case comparison which can help to make clear what is distinctive to a single case and what is a feature of the wider phenomenon (Hakim 1987).

This paper is based on an analysis of four different case studies of international experiences offered to engineering students. Initial interviews were conducted with three of the four field study coordinators to explore if there was something meaningful to be gained from a comparative case study approach. Written notes of the meeting were collected and transcribed. Following this, data was collected from each of the four coordinators using a series of open-ended questions which were responded to either in writing (2 coordinators) or in a one-to-one interview setting (2 coordinators). A thematic analysis of this data was followed by a group interview/discussion with three of the coordinators (also transcribed by hand) which provided a further opportunities to tease out themes and comparisons, as well as an analysis of documentation and written reflections by the coordinators. The emergent themes were reflected back to and clarified with the coordinators.

The key themes which emerged from this data collection were:

- the development of interdisciplinary and intercultural competence in engineers was achieved through using the concepts and methodologies

of social sciences to structure their reflection. Key concepts linked to this theme were interdisciplinary work, reflection, and liminality.

- the challenges of ‘fitting’ interdisciplinary international experiences into the curriculum of the school. Key concepts linked to this theme were academic discipline, institutional culture, and power.

#### 4. The Case Studies

Field study location	Lausanne, Switzerland; Bengaluru, India; Shanghai, China	Greater China – Shenzhen and Hong Kong	Russian Arctic and Yamal peninsula	Amazon basin, Leticia City, Colombia
Nature of project/activity in field study location	International summer schools (academic courses and applied field visits)	Applied engineering design project with prototyping activity in China	Academic courses & Field research (e.g. oceanographic research, or civil engineering historical reconstruction)	Scientific & social research or a design project
Typical number of students per group	15–30	24	23	14
Balance between technical university students and those from other schools	75% STEM. Others from Social and Human Sciences, & Asian studies.	50% STEM. Others from Business, Industrial Design & Media Interaction Design.	50% STEM. Others from Social and Human Sciences, Environmental Sciences, Global health, & Law.	40% STEM. Others from Health, & Social and Human Sciences
Length of field study component	6 weeks	2 weeks	3-4 weeks	3 weeks
Years active	2009–2016	2015-present	2015-present	2018-present

*Table 1.* Overview of the Case study field studies programs

All four case studies are based on field study opportunities offered to students in scientific and engineering programmes in a European technical university. The four field study coordinators are all social scientists, and are all university teachers in the institution responsible. They each provide academic leadership and direction for the field study that they coordinate. The field studies in question are offered across a number of universities so that engineering students are mixed in groups with social science students.

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The four case studies are:

- An international summer school programme in which students participated in summer schools in Europe, India and China, studying the history, political science, anthropology, cultural studies and economics of each location, including field visits and language learning
- A hardware innovation programme, in which students design a connected device in their ‘home’ location, then travel to China to work to produce a prototype
- A Russian Arctic research program, in which students work on oceanographic, climate, historical, and geographical research and documentation projects in the Arctic and Siberia
- An Amazon basin field study, in which students research the effect of urbanisation on indigenous people’s lives focusing on the eco-epidemiology of health or on the development of on-line tools to aid indigenous language learning.

There are a number of similarities between the four programmes:

- the field study is either an option for students within their programme or offered outside the programme
- the students engage with a different culture and language
- students work on a project which involves some combination skills from social and natural sciences
- reflective activities while in the field study location provide an important part of the learning in the field study.

A number of issues and challenges have been experienced by those responsible for the programmes. These are described below.

#### *4.1. Reflection based on social science epistemologies*

One of the challenges faced by engineering students in learning from field studies is that learning will require some reflection. The field study is a manifestation of liminal space – a space away in which a person is separated from their ‘normal life’ and in which the taken for granted becomes uncertain and a change in beliefs but also identity becomes possible. The journey through this liminal space is scaffolded by teachers who engage students in a process of reflection. But students may well be unclear as to what it means to ‘reflect’. Indeed, this issue is not restricted to engineering education: McGarr and McCormack (2014) note that, although ‘reflective practice’ is the dominant paradigm in teacher education, student teacher’s engagement with reflection is typically quite superficial, in part because students are being trained within a system which is essentially conservative and focused on conformity to established practices (see Kazeronian and Foley [2007] on the similar dominant paradigm in engineering education).

A strategy shared across the case studies is to use the conceptual frameworks and methodologies drawn from social sciences in order to make clear to students what it means to engage in ‘deep’ reflection on their experiences. Students on the China field trip, for example, draw on practices from management studies to draw up customer profiles, value propositions and business models for both Chinese and Swiss markets. Students who participate in the Amazon field study are required to have a fieldwork notebook and to document their own experiences in anthropological field notes on the practices, concepts, and emotions they experience or observe (Wagner 1981). Students on the Siberia field trip are also involved in documenting their experiences drawing on methods and conceptual tools from investigative journalism. As such, ‘reflection’ moves from being something fuzzy and unclear to being clearly framed as ‘thinking like a social scientist’. Interdisciplinarity is, then, not just a function of having students from different disciplines present in the team, but also as a result of having students engage with the methods and concept of disciplines other than their own. Such (inter)disciplinary tools are perhaps all the more important since both ‘cultural shock’ and post-colonial images of ‘the other’ can get in the way of student learning. The interdisciplinary use of social scientific concepts and methods by engineering students in this setting can enable a ‘slowing down of reasoning’, which in turn allows students to avoid jumping to post-colonial conclusions.

Not all students engage positively in this task. Some remain resistant to the use of social scientific methods and concepts while others seek to divide the tasks in their group in such a way that it allows them to focus on their pre-existing skillset rather than on developing the new thinking skills which are intended to underpin their reflections. This provides a difficult challenge which needs to be mediated by the fieldwork academic co-ordinators in interaction with the students.

#### *4.2. The ‘value’ and ‘costs’ of field study experiences*

All of the field study experiences described here involve substantial investment from students, including investment of time during the summer to travel to the field study location, and paying a portion of the associated travel and accommodation costs. While some students are ‘rewarded’ by academic credit for participation in the field study, in other cases the field study seems to be regarded as being, in itself, a reward for this investment: as one of the co-ordinators put it, “...the trip itself was viewed as the reward. The idea of the school was very much [to say to the student] ‘you get a free trip to China, so you should do the work required [by the project] for free [i.e., without getting academic credit]’”.

Indeed, at various times, the field study has struggled for acceptance and legitimacy within the technical university. There was initially a resistance on

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the part of the school to assign credits to the field study in the same way as they would be assigned to traditional courses. First, the field study needed to establish a track record which justified its inclusion. This meant that newer field studies (such as the Amazon basin program) had to establish their value by running for a number of years without significant academic credit before being accepted as ‘creditworthy’. It is notable that this is a higher bar than is set for traditional courses offered (which received academic approval on the basis of a short written description rather than having to be first offered without credit).

One of the features of a field study is that the students are engaged in a realistic professional activity; either a design activity, a scientific research activity, or in some mix of the two. This development has probably made it easier to ‘legitimate’ the field study in that this superordinate activity (to use the language of Allport) is clearly an engineering or scientific activity. At the same time, it also poses potential difficulties in that the superordinate activity itself becomes central to the experience and reflection on that practice runs the risk of being marginalised. Where credits are now assigned to the field study, the majority are assigned for the product of the work undertaken. The ‘voluntary’ or underweighted nature of the social scientific reflection places significant additional pressure on coordinators who are left in the role of having to negotiate with students their commitment to group project activities.

The challenges of embedding in the curriculum are increased when multiple universities are involved. Within those field studies that are currently embedded in a curriculum (the China and Russian Arctic field studies) in the technical university, two different models of doing this emerged. In the case of the China program, each university managed the process differently, with, for example, different weights being assigned to the field study in different institutions. As a result, students were sometimes doing similar work for different credit. As noted above, this puts additional pressure on coordinators who are left in the role of having to negotiate learning activities with students. In the Russian field study, a single model for the program was developed and offered to different partner universities who either chose to ‘buy-in’ or not. Perhaps because the program was perceived as prestigious, this did not have a negative impact on student uptake.

## **5. Summary and Conclusions**

Field studies can play an important role in enabling engineering students to learn through experiencing engineering and scientific practices in different social and cultural settings, and through reflecting on those experiences. Based on the case studies discussed here, there is reason to think that there are a number of characteristics that should be considered in designing such experiences. These include (a) working on a project which requires inputs



from multiple disciplines and building teams drawn from multiple disciplines (and perhaps multiple universities), (b) physically moving the project group to a fieldwork location radically different from a classroom setting, (c) interacting with people from other cultures or contexts in a way that ensures that both students and those from the ‘host’ culture are equally necessary to the success of the project, (d) using concepts and methodologies from social sciences (e.g., methods like customer profiles and value propositions from management studies or fieldwork notes from anthropology) to structure ‘reflection’ in the liminal space that students enter, and (e) valuing the field study experience and the reflection by providing it with appropriate academic credit.

At the same time, embedding these experiences in an already crowded curriculum however, is not without its challenges. First, the field studies discussed here differ from traditional courses. They do not follow the traditional timetable or semester structure, and their experiential nature means that what and how students learn may be hard to describe in advance within the limitations of a taxonomy of cognitive outcomes. All of this meant that the bar to be accepted within the academic program seems higher for field studies than is the case for more traditional courses. Embedding within the formal program does, however, appear to be worthwhile, given the challenges for coordinators raised by more ad hoc solutions.

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