CREATING THE INTEGRAL ENGINEER

Combining development education, sustainability, entrepreneurship and technology at Delft University of Technology

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Abstract

A modern engineer is more than a technical specialist. Training an integral engineer requires education in non-technical skills, including social and ethical aspects. Therefore, Delft University of Technology (DUT) introduced sustainable development and entrepreneurship into its bachelor and master programs.

The university of the future is developing towards an entrepreneurial university. As a result of an interaction shift of government, industry and academia, the university mission will evolve towards global economic development. Confirmed by the UNDP and the Worldbank, engineers play a significant role in world's biggest challenge concerning economic development: poverty alleviation. Globally, only a few examples of technical universities applying development education exist.

The use of entrepreneurship from a technological perspective in poverty alleviation is used as an input during the design of a new educational program titled 'International Entrepreneurship and Development' at DUT.

This program is executed in the format of an elective minor, separating it from existing programs and making it accessible for third year bachelor students from all departments. The minor combines theoretical courses and practical real life projects, performed in teamwork, a method especially recommended for engineering studies.

Since the start of the minor program in 2008, the minor program has been executed twice with a total of 65 participants. After participating in the 09/10 program, 30% of the students expressed in interviews their ambition to continue working in the field of international development entrepreneurship. Next to a description of the lessons learnt, the paper

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analyzes the results of the program both from a theoretical education design perspective as from a practical relevance point-of-view.

Keywords

Sustainable development, development education, social entrepreneurship, technology.

1. Introduction

As a result of global time-space-compression, world's most significant problems, obtrude itself upon every citizen (Harvey, 1989). As a result, every institution will be influenced in some degree by the global problems. The modern university strategically adapts its policy towards this development: the global time-space compression is an excellent opportunity to valorise university knowledge resulting in large scale impact in the attempt to solve the global problems through research and the development of technology.

The recent trend of significant increase in population density, artefact consumption and energy demand causes suppression of the qualities of livelihoods. A trade-off among population growth, economic well-being, environmental quality and cultural values has to be made (Cohen, 1995). As concluded by Lele (1991), poverty and environmental degradation have structural interrelated technological and cultural causes. Already for several decades, sustainable development (SD) is considered to be the answer to this stressed world. Barbier (1987) defines SD as "the ability to maintain desired social values, traditions, institutions, cultures, or other social characteristics". However, Jacobs (1987) expands this definition by including the satisfaction of basic human needs and the focus on the environment. According to Jacobs, SD is the "integration of conservation and development, satisfaction of basic human needs, achievement of equity and social justice, provision of social self-determination and cultural diversity and maintenance of ecological integrity". A complete and therefore often used definition is by the hand of Brundtland and Khalid. In the World Commission on Environment and Development Report of 1987, they state that "sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland and Khalid, 1987). The report furthermore explains the two key concepts: "the concept of 'needs', in particular the essential needs of the world's poor, to which overriding priority should be given; and the idea of limitations imposed by the state of technology and social organization on the environment's ability to meet present and future need". This definition shows the disparity in needs between world's poor and world's rich. Concerning a sustainable world, the essential needs of the developing nations are considered to be more valuable than the needs of the developed part of the world.

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From all definitions, it can be concluded that SD covers both the state of the mankind and the state of nature, the so-called social SD and ecological SD. Since mankind is a part of nature, both types of SD are interrelated and can have the same cause. Therefore, on a global system level, SD is a highly extensive and deeply complex process that affects all its citizens. As a result of frequent use by different stakeholders with their own interest and interpretation, Tolba (1984) argues that SD devaluated over the years to an article of fait, that is often used, but little explained. To prevent devaluation as a result of the inexistence of practical applications, specific cases should be studied to determine the interaction between the different causes of the environmental degradation and poverty to formulate political, institutional and educational solutions (Lele, 1991).

As a result of the technological focus of DUT, many of its activities are related to product development. Berchicci (2005) showed that the complexity of the product innovation process increases in case of a high level of environmental ambition. The engineers of the future have to be well prepared to face the highly complex global challenges necessary for sustainable development. A modern integral engineer does not fit the description of a technical specialist. Training an integral engineer requires education in non-technical skills, including social, ethical and entrepreneurial aspects (De Graaff and Ravesteijn, 2001). As a result, Delft University of Technology (DUT) introduced SD and entrepreneurship into its bachelor (Bonnet et al., 2006) and master programs (Quist et al., 2006).

According to Etzkowitz et al. (2000), the university of the future is an entrepreneurial university. As a result of an interaction shift of government, industry and academia, the university mission will evolve towards global economic development. Stated by the UNDP (2001) and the Worldbank (2004), engineers play a significant role in world's biggest challenge concerning economic development: poverty alleviation. A focus of universities to solve the global poverty problem would be a sound consequence. Globally, few examples of technical universities applying development education exist (Diehl and Brezet, 2004, Perez-Foguet et al., 2005, Smit et al., 2009, Sandekian et al., 2007).

Recently, the paradigm concerning development has shifted from passive helping to searching for opportunities to valorise the fortune at the bottom of the pyramid (Prahalad, 2006). It is plausible that the themes entrepreneurship, poverty alleviation and SD have to be combined to address the global challenges in a holistic way. Linking entrepreneurship to global SD has one more significant advantage: it gives the opportunity to study SD on a practical case study level and prevents therefore the search for an overall solution on the highly complex global system level.

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The importance of the three themes – social SD, ecological SD and entrepreneurship – for prospective engineers and the inexistence of the combination of these subjects in current curricula were the incentive to start a minor program in 2008 at DUT titled 'International Entrepreneurship and Development' (IED).

After executing this minor for several years, questions about the effect of the program arise. This paper aims to answer the question: does the program meet its aim to create the integral engineer? To answer this question, both the content and the method of the education will be compared with the initial aim of the minor.

Besides the university, two other stakeholders are involved in this minor program. Therefore, the second question is: what is the added value of the IED minor for each of the involved stakeholders and how are their stakes interrelated; this concerns {A} the university, {B} the individual students and {C} the local actors of the development projects that are part of the program? A major part of the research method exists of interviews among all IED students, both at the beginning and at the end of their minor program. The first interview was mainly focussed on expectations, the second one on evaluation.

To answer question one, this paper firstly describes the content and the evaluation of the 2009/2010 minor program. Subsequently, three examples of minor projects are shown. Finally, to answer question two, the minor program is regarded from the point of view of the involved stakeholders: the university, the individual student and the local actors.

2 Description of the minor program

The first question of the paper is whether the IED program meets its aim to create the integral engineer. This chapter will answer this question by comparing both the content and the method with the aim of the minor.

Although the concept of a major/minor structure is established decades ago (Sharp, 1963), DUT started introducing it in its Bachelor's programmes in September 2006. In addition to providing a focus on the major or main degree subject, this system enables the student to add another dimension to their studies in the form of a minor.

A minor at DUT is a cohesive fulltime program containing courses worth a total of 30 European Credits (1 European Credit equals a study load of 28 hours), accounting for six months and taking place in the first semester of the third Bachelor's year. Students are free in their choice of minor and are not depending on their major background. It therefore provides an opportunity to either look beyond the bounds of the major discipline or to specialise in a single subject related to the major discipline.

Two years after the introduction of the minor system at DUT, the IED program was launched. The minor format made the IED educational program accessible for bachelor students from

all DUT departments and prevented problems with integration into existing major programs. The minor was created to offer the opportunity for the students to extend their knowledge beyond the limits of their major. The minor was placed under the responsibility of the faculty of Technology, Policy and Management (TPM) and executed by the Delft Centre for Entrepreneurship (DCE). The initial goal of the minor was twofold:

- Stimulating students to grow a vision on global development challenges and the accompanying role of technology and entrepreneurship. This vision enables prospective global engineers to act in a professional social responsible manner.
- Provide a solid theoretical and practical background to enable the students to start, or to participate in a sustainable project in a developing country.

The hypothesis of the founders of the minor was that attending the educational program would influence the (professional) future attitude of the participants by creating insight in the multidimensional en interlinked characteristics of global technology.

It cannot be expected that every participating student has the ambition to start or to participate in a project in a developing country. On the other hand, due to the previously described time-space compression, it is highly likely that every future engineer will face the worldwide development challenges. Therefore, the second aim of the minor will only be relevant for a share of the minor students, while the first aim will affect the whole student population.

The exit qualifications for the IED students were to develop insight through knowledge and experience in an extensive range of topics:

1. Development challenges related to social and environmental SD
2. Historical development of poor and rich nations
3. Development strategies
4. Political systems and economical systems
5. Finances: fundraising, budgeting, business administration design
6. Business model design
7. Intercultural communication
8. Social and non-governmental entrepreneurship
9. Globalization

The minor combined theoretical courses with practical real life projects, performed in teamwork, a method especially recommended for engineering studies (Felder, 1988). After the introduction in 2008, the minor was executed twice; the third edition is scheduled for September 2010. During these two years, the number of participants grew from 20 to 45. For 2010, the number of applications largely outnumbered the 65 available positions. Comparing

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this to other minor programs of DUT, the number of participants is kept relatively small to assure the quality of the education. Some minor programs at DUT have over a 200 students, however offering as much personal attention to the students as in case of the IED minor becomes a serious challenge with these sizes.

Although the goals and the exit qualifications did not change, minor parts of the program were adjusted as a result of student and staff evaluation. The 2009/2010 curriculum, as shown in figure 1, will be described into more detail. Paragraph 2.1 to 2.8 explains how all exit qualifications for the students are covered by the courses in the IED minor program.
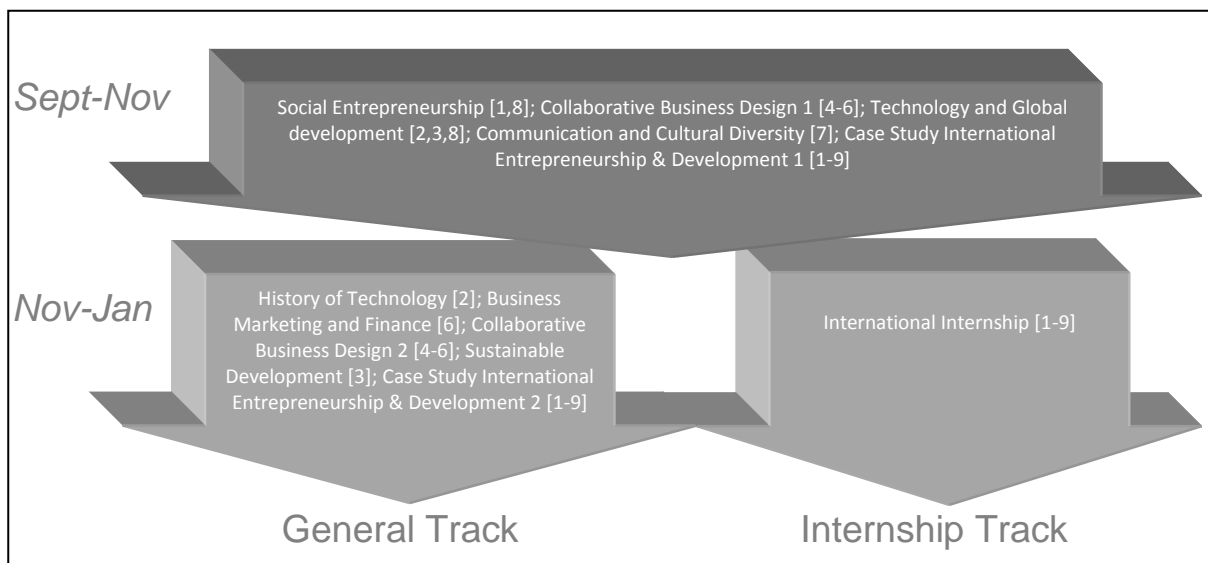

Figure 1: The 2009/2010 program with previously described exit qualifications for IED students [1..9]

2.1 Social Entrepreneurship

Within the course Social Entrepreneurship, the student is introduced to entrepreneurship in general, and more specific to the differences between traditional entrepreneurship and sustainable entrepreneurship with a focus on social aspects. Traditional entrepreneurship focuses on creating financial profit, while social entrepreneurship aims to add social and ecological value to the financial profit. Recent and practical developments of sustainable entrepreneurship, such as the concept of Fair Trade, Micro Credit and Cradle to Cradle, are discussed. Furthermore, students learn which steps need to be taken to start or improve a sustainable enterprise. Two main subjects are discussed: business model design and stakeholder management. 'Sustainable development for engineers' by Mulder (2006) is used as background literature.

2.2 Collaborative Business Design 1 and 2

Collaborative Business Design describes the business aspects of collaboration, creative problem solving and management of creativity. Furthermore, it depicts on different business

models and types of collaboration cross functional and cross cultural within the value chain. The essence of cooperation is clarified by describing the effectiveness of working with multiple stakeholders.

The aim of the course is to create insight in collaboration based entrepreneurship in developing countries. Based on experience-oriented education through discussions and group sessions, students will learn how to define cooperation and collaboration in international networks and value chains.

2.3 Technology and Global Development

Modern technology has different global effects. In most cases, the emphasis is mainly on the environmental effects. Since UNCED conference in Rio de Janeiro 1992, both world poverty problems and the environmental problems are regarded as interrelated effects of today's technology. The course Technology and Global Development stimulates the discussion on the role of technology in developing countries, with a focus on relations and connections between the development of the third world countries and the modern industrialized countries.

Based on 'The end of poverty', by Jeffery Sachs (2005), three learning objectives for the students were formulated. First, to gain knowledge in the visions of the North on development and their development theories; second, to gain insight in sustainable development related to South-North problems; and third to discover the consequents of technology transfer and technology adaptation from the industrialized countries to the Third World.

2.4 Communication and Cultural Diversity

Cross cultural communication starts with awareness. Therefore the course Communication and Cultural Diversity focuses on cultural dimensions as a conceptual grid in understanding and interpreting cultural differences. Based on the awareness, both verbal and non-verbal communication and different perspectives on responsibility are explained.

After successful accomplishment of this course, a student would be able to recognize and apply a set of different cultural dimensions and social values. Furthermore, a student is expected to be able to apply a dynamic model of effective communication within an international team. Different levels of responsible action have to be discerned. And, finally, the last learning goal is to recognize and apply the different requirements and priorities of communicative action in policy seeking discussions.

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The course uses both 'Cultures and organisations, software of the mind' by Hofstede et al. (2004) and 'Riding the waves of culture, understanding diversity in global business' by Trompenaars et al. (1998) as baseline literature.

2.5 History of Technology

The course History of Technology focuses on the development of worldwide technology towards the current situation. The global history of technology including theories on technological development, the tension between technology and society and the corresponding responsibility of engineers are the main subjects in the course History of Technology. Based on 'The wealth and the poverty of nations' by David S. Landes (1998), the course aims to give students a thorough insight in the social, economic and political dimensions of technology in history.

2.6 Business Marketing and Finance

One central part of business economy is marketing. Since the multidisciplinary subject of marketing has close relations with finances, the module of Business Marketing and Finance integrates the two business subjects. The course describes the process of marketing as a social management process in which the needs of consumers are met by creating value. At the end of the course students are expected to have a basic understanding about how to start a company. Using 'Creating a business' by J. van Sten-van 't Hof (2009) and 'Guerrilla marketing' by J.C. Levinson (1998), the students will become familiar with management, juridical aspects, marketing and finances. Both the subjects of marketing and finances are explained into more detail. Concerning marketing, the students have to be able to determine target groups, to make a competitor analysis, to use the marketing mix and to estimate the marketing risks. Concerning finances, the course provides the material to deal with financial analysis and calculations, investments and authoring financial reports.

2.7 Sustainable Development

Translating the Brundtland definition of sustainable development (1987) into practical design criteria is the central theme of the course Sustainable Development. In addition, the global effects of large scale use of technology are introduced. The study goal of this course is twofold. First, the students have to know and to use the tools to design in a sustainable manner; and second, the students have to be able to critically evaluate their own technological project concerning sustainable development. As a result of this evaluation, design improvements have to be formulated. 'Sustainable development for engineers' by Mulder (2006) and relevant papers are used as backbone.

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2.8 Case Study International Entrepreneurship and Development 1 and 2 / International Internship

To stimulate the students to amalgamate all obtained knowledge and skills, integrating case studies were organized. The case studies in the IED program comprise real life projects, commissioned by a company or a non-governmental organisation (NGO). In line with the entrepreneurial characteristics of the minor, the students are also allowed to start their own project. Working in teams, the students define the problem by interviewing the external initiator. To resemble teams in professional organisations, multidisciplinary teams are formed by the minor management. Different aspects of entrepreneurship in developing countries have to be used to formulate a solution to their previously defined problem. The final product of the case studies is a well-founded advice for the external initiator. The learning objective for the students is to apply both knowledge and skills in the field of technology based international entrepreneurship. In the solution process, it is expected from the students to be able to filter relevant and irrelevant results. In the end, the results have to be reported to the stakeholders where improvement has to be made based on obtained feedback. All literature used by the previously described courses can be used. By using a provided structure consisting of different assignments, the students will learn how to apply entrepreneurship for the benefit of sustainable development.

For highly motivated students, an opportunity was created to (partly) exchange courses in the second part of the semester for an internship in a developing country (figure 1 – the internship track). The main difference between the second part of Case Study International Entrepreneurship and Development is the location of execution: the internship is practiced in a developing country at the location of the problems.

The purpose of all three courses is to exchange between theory and practice, to apply both conceptual and theoretical approaches and to put practical questions in perspective.

After completing either the internship or the case studies on international entrepreneurship and development, a student is expected to be able to operate in an international, intercultural context. This implies the listing of needs and problems in consultation with target groups to define a project. These projects have to be executed by applying the concepts and theories from the previously described courses. Finally, students have to be able to formulate policies, advice or recommendations on the basis of such analysis in the service of an NGO, firm or other relevant stakeholder. Since students are in direct contact with the stakeholder, they feel the responsibility to bring the projects to an end in a successful way.

Both the case studies and the internships are of key importance in the minor program. Using the Problem Based Learning (PBL) method, students are likely to develop flexible

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understanding and lifelong learning skills (Hmelo-Silver, 2004). This is aligned with the main goal of the minor to teach the students to act in their (long term) professional life in a social responsible manner. In this minor program, both the internship and the case study link the specific minor subjects, stimulate teamwork, require communication with professional partners and force the students to develop their problem solving capacities. The internship adds the dimension of practical experience in cultural diversity. As a result of these PBL based integration courses, students will be able to link IED knowledge in their prospective professional career to solve potential problems.

2.9 Evaluation of the minor program 2009/2010

During the first year of execution of the minor (2008/2009) 20 students participated. The second year of execution (2009/2010), the number of applications grew excessively. To guard the quality, only the first 45 students were accepted.

In 2009/2010, the total of 45 participants was split into the two tracks shown in figure 1: 25 and 20 students participated into respectively the general track and the internship track. According to a survey of Haski-Leventhal (2008), enterprising-type students (business) are less likely to volunteer than social and humanitarian type students, while investigative-type students (natural sciences and engineering) are ranked in the middle. This medium interest in locally participating in developmental projects was not illustrated by the popularity of the internship track. Apparently, participating in technology-based project without any compensation was impressively popular during the minor program. Moreover, six students from the general track spent their summer holiday to visit the organisation of their case studies for an additional voluntary internship abroad.

Figure 2 shows the different backgrounds of the IED 09/10 minor participants. The teams for both the case study and the internship were composed in a multidisciplinary manner, to result in diverse teamwork, to enable students to look beyond their own point of view and to reflect the multidimensional characteristics of global technology.

After the 2009/2010 minor evaluation, some improvements were suggested. Small course adaptations were executed, such as the extension of the literature list of History of Technology and Social Entrepreneurship.
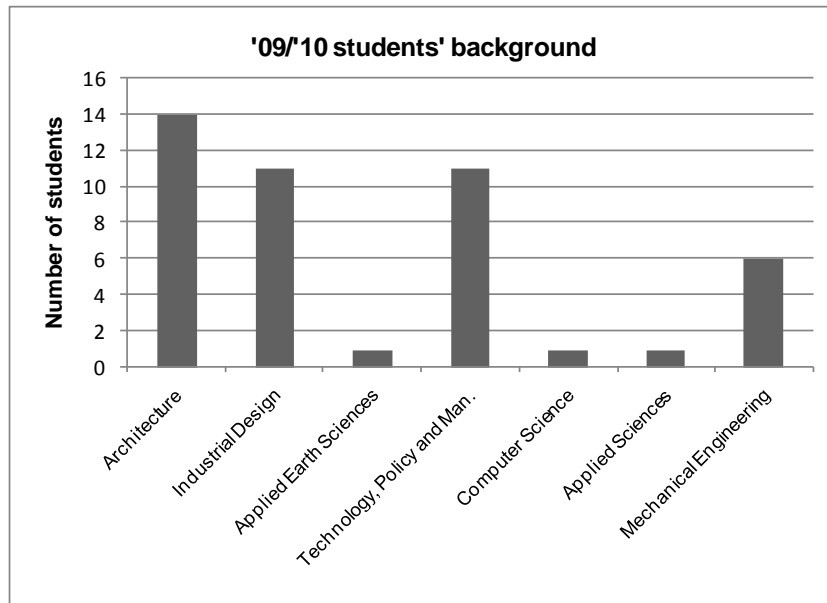
Figure 2: The background of the 2009/2010 students

At the beginning and at the end of the minor program a personal learning log had to be written by the students. The motivation behind these learning logs was twofold: to stimulate students to take an active role in their own development and to gain insight for the teachers and coordinators in the personal motivation and background of the students. The purpose of the personal learning log at the beginning (PLL 1) was to force the students to generate their own learning goals, the second personal learning log (PLL 2) acted as a final check for the students to determine whether they had reached their own learning goals. Additionally, the information in the logs could also be used by the organisation to improve the minor program. The students had to cover four subjects in their PLL 1 and three in their PLL 2. All subjects are shown in table 1.

Table 1: Subjects of PLL 1 and PLL 2

PLL 1
1. Motivation of choice for this specific minor program
2. Experience in international entrepreneurship or development
3. Personal qualities at the beginning of the program
4. Skills to be developed
PLL 2
1. The group process
2. Developed skills
3. Evaluation of the minor program

At the moment of writing, PLL 1 of the 2009/2010 minor program had 45 responses, PLL 2 only 44. 40 of the 44 responders to PLL 2 evaluated the minor explicitly positive. Krippendorff (2004) argues that the discomfort–relief ratio (Dollard and Mowrer, 1947) not always indicates the opinion of the writers accurately, only in very restricted situations a positive correlation with other methods was found. This case can be described as restricted: the considered data consists solely of written texts and subject 3 of PLL2 forces all the students to choose between a positive, neutral or negative evaluation. Moreover, as a result of a small sample size, the texts were interpreted as a whole, not as single sentences or words.

The importance of the case studies and the internship was also recognized by the students. The majority of the students considered the teamwork – as practiced in both the internship and the case studies – as an importance source of personal development. Seven of the 44 responses to PLL 2 specifically expressed their appreciation of the combination of the theory presented in the minor program and the practical application of it in the case studies or the internship. For some students the exchange between theory and practice was a totally new experience: *"During my internship in Curaçao I have learned the most. Never before I applied my knowledge in a practical situation"*, and according to another student: *"Never before I have turned my education into practice in such an exiting and fun manner."*

Although the majority of the courses focussed on technological entrepreneurship, the focus of most PLL interviews tended to be more towards soft side. The outcome of the commonly used keyword frequency method from content analysis shows that both words 'people' and 'differences' were used significantly more frequent than 'entrepreneurship' and 'technology'. However, no hard conclusion can be drafted from these word frequencies, since many different theories on how to interpret exists (Krippendorff, 2004).

According to the PLL 2, after attending the minor program, 27% of the students want to choose a Master related to the topic of the IED minor. Slightly more than half of this group expressed this intention already in their PLL1, at the beginning of the minor program.

Concerning the long term future prospective, 30% of the students expressed a preference for a professional career in the field of International Entrepreneurship and Development. At the beginning of the program, this was only 16%.

This chapter started with the question if both the method and content of the minor serve the purpose to create the integral engineer. The descriptions of the different courses show that the minor goals are covered with the individual course goals. Furthermore, the educational method of PBL contributes to the aim of life-long learning. The hypothesis of the founders of the minor that attending the educational program would influence the (professional) future

attitude of the participants by creating insight in the multidimensional en interlinked characteristics of global technology could not be confirmed due to the short term existence of the minor. However, short term influences were measured: both the choice of masters and career ambition were influenced.

As clarified in the introduction, creating the integral engineer is the most important aspect of this minor program. To serve this goal, three stakeholders are included: the university, the individual students and the local actors of the Case Study and the Internship. How can be determined whether this three-stakeholder-minor-program was successful? After three examples of projects related to case studies and internships, this paper will further elaborate on the specific added value for the stakeholders and their interconnectivity.

3 Examples of case studies / internship projects

3.1 Focus on Vision

Figure 3: The FocusSpecs

As an MSc-student at the TU Delft, F. van Asbeck developed the Focusspec, an adaptable pair of glasses (figure 3). The strength of the lenses is adjustable and the production costs are very low. The FocusSpecs are available in four different versions, making it suitable for both far-sighted and the short-sighted people, for both children and adults. This way, the FocusSpec improves daily life, for example by enabling people to enjoy an education. Focus on Vision started the production of the glasses in the Netherlands in 2009. In September 2009, four students from the IED minor program spent their case studies on solving the distribution issue and successfully implement the FocusSpec in Ghana. After the minor program, two of these students continued to work on this project during the summer of 2010.

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3.2 Plakkies

Figure 4: Plakkies footwear

In 2009, two participants of the minor program set up a footwear factory in South Africa producing so-called Plakkies: flip-flops made from recycled materials, such as car tyres (figure 4). The Plakkies are currently being sold in numerous high-end department stores in the Netherlands. This initiative creates employment opportunities for HIV-infected women in the townships of Durban. Profit made by this factory returns to society through prosperity projects for children organized by the KidsRights foundation. Within the minor, this project was executed as an internship. After the minor program, both participants continued to work on this project based on their own initiative. The achievement of Plakkies was a positive surprise for the minor initiators. By using this as an example, the new students are stimulated to copy the successes.
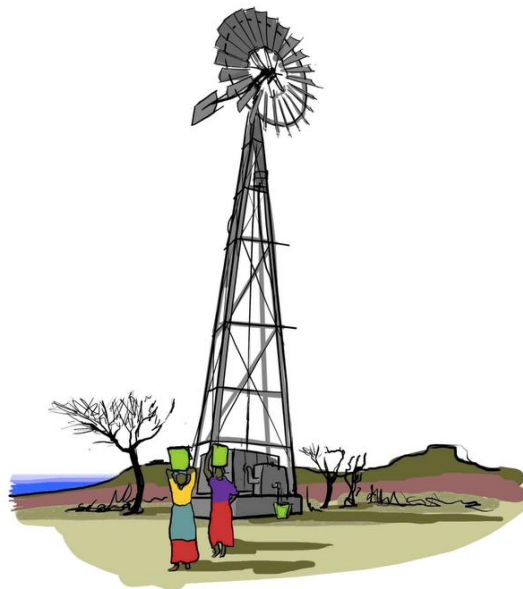
3.3 Fresh water from the sea

Figure 4: The windmill that turns seawater into fresh water

This project fulfils the most essential need of developing countries by providing access to fresh drinking water for the poor. Based on reversed osmosis technology, an uncomplicated

and affordable water windmill is developed. This water windmill turns seawater into fresh water, driven by pure wind energy. Next to providing fresh drinking water, 'Fresh water from the sea' also stimulates local economy by creating a financially sustainable and independent water producing company, operated by local people. The first pilot starts in Djibouti. Like most of the African countries, Djibouti suffers from prolonged periods of droughts and a persistent lack of fresh drinking water. During the 2009/2010 minor program, four students used this project for their case studies. All students continued to contribute to the windmill even after the minor program ended. A follow-up for the 2010/2011 minor program is planned.

4 Added value for the university: education, research and entrepreneurship

The second question of this paper concerned the added value of the minor to each of the involved stakeholders. This chapter describes the added value for the university using the previously introduced PLL interviews among the students.

Every university has basically two main goals: educating students and performing research. Since the introduction of entrepreneurship into the educational curricula of universities, a third goal was added: valorisation of knowledge to stimulate economic growth (Etzkowitz et al., 2000).

The educational goal is specified in the IED minor goals. The aim of the minor is twofold: to stimulate students to grow a vision on global development challenges and accompanying role of technology and entrepreneurship on the one hand; to lay the foundation for students to start or to participate in a sustainable project in a developing country on the other hand. The purpose is to create the integral engineer that acts in a professional social responsible manner. The second and third university goals were not specified, however, a contribution to the research output and a contribution to the economic development would be favourable for DUT.

The degree of fulfilment of the educational goals can be determined by considering the answers of the previously described PLL interviews among the participating students. The PLL data creates insight in what was learned and why the students are positive about the experience. One subject of the PLL 1 concerned the missing personal skills that a student wants to acquire during the minor program. The PLL 2 asked for a conclusion whether the student has obtained the favoured skill. A frequent mentioned skill to develop was their 'orientation towards the market in developmental countries'. Most of these students concluded at the end of the minor that they acquired this skill. Market orientation is the skill that suits the first aim of the minor: to prepare students for participating and starting entrepreneurial activities in a developmental environment. During the intercultural internship,

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students also experienced how to deal with different cultures. The results of PLL 2 illustrated that knowledge was obtained during courses, while skills were mainly developed trough teamwork for the case studies and the internship.

The internships and case studies integrated the presented theories and translated it into practice. The continuously changing environment of developing countries is an interesting field for scientific case studies. Based on the performed projects and used theories, opportunities are created to conduct scientific research by the staff of the minor program. An example is the case study on cross-cultural management of the Plakkies production facility by Kroesen en Rozendaal (2010) .

The third goal of the university is to valorise knowledge in order to promote economic development. Small scale economic development as a result of a technology based initiative is hard to measure. Additionally, most internships have a timeline of about three months. The long term economic growth is difficult to allocate to the efforts of the university. In contrast to the first two university goals, there is no hard key performance indicator at DUT for economic growth besides the number of start-ups initiated by the university per year. Participating in an entrepreneurial based project is not included in this measurement unit. Only as a result of the right opportunities and the student's enthusiasm and dedication, economic development can be created. Plakkies, as previously described, is an example of a project that is likely to have positively influenced the economic growth. After only four months of production, this project realized 70 job opportunities in their South-African flip-flop factory. Additionally, the profit created by the factory will be directly spent by the partner NGO KidsRights on projects to help children in South Africa. The project is still being executed and the responsibility of management is currently outsourced.

Overall, the added value of the minor for the university depends on the learning curve and the feedback of the students, the initiative of the minor staff to use case studies for their research and the initiative shown by the student to promote economic development. The alleviation of poverty by means of economic development in itself is hard to determine and is not measured at Delft University of Technology.

5 Added value for the individual students: meeting their own learning goals

Chapter four described the added value of the minor program for the university. This chapter focuses at the minor from the individual student's point of view. Again, the PLL answers are studied to create insight in the added value for the students.

The program evaluation showed a positive feedback of 40 out of 44 students. However, a positive feedback does not imply added value for the individual student. Before we can answer the question if and how this program did create additional value for the students, the

definition of additional value needs to be formulated. For the individual students, the added value of the minor is defined in this paper as the degree of acquiring the personally missing knowledge and skills, even beyond the scope of the minor. Using both PLL 1 and PLL 2, it appears that the majority of students succeeded in obtaining their favoured skills.

Remarkably, the gross of mentioned skills did not depend on the successes of the projects they had to perform. Therefore, there is no firm relation between the added value of the minor for the students and the added value for the local actors. On the other hand, the quality of the education is likely to have a big influence on the skills and knowledge developed by the students. As a result, a strong relation between the stakes of the university and the students exist.

6 Added value for the local actors: valorization of technology and knowledge

Besides the individual student and the university, the local actor is the third stakeholder in the minor. The local actors are the people living in (extreme) poverty, and form the focus of most entrepreneurial case studies and internships. In some cases, the help of an NGO or commercial organisation is used to approach the local actor. Since these organisations only act as a medium to serve the goal of poverty alleviation, their participation is not included in the key stakeholders in this paper. The most important interest of the local actors is to increase their quality of life. Numerous methods to measure the quality of life exist. The most general one is the contribution to the millennium development goals (UN, 2010). According to Holcombe (1998), entrepreneurship is the engine of economic growth, and will cause therefore an alleviation of poverty and poverty related problems. The added value for the local actors can be defined as the valorisation of the developed technology or provided knowledge.

As a result of a limited scale of the projects and the limited time span of the internships and case studies, the effect of the students' involvement in development is hard to measure. Currently, no hard data is available. The students do not measure the success as a contribution to the millennium development goals. However, the case of Plakkies (Kroesen and Rozendaal, 2010) makes it plausible that a significant economic improvement can be the result of a minor-project.

It can be concluded that the added value for the local actors depends on the successfulness of the project of the students. Although not measured yet, it is related to goals of university and in some specific cases related to the personal goals of students.

7 Discussion and conclusion

The IED minor was introduced at Delft University of Technology in 2008 to prepare prospective engineers to deal with global problems. The main goal of the minor was to stimulate students to develop a vision on global development challenges and the accompanying role of technology and entrepreneurship. This vision enables the prospective global engineers to act in a professional social responsible manner. The first question of this paper was whether the program meets its aim to create the integral engineer.

- Both the content and the educational method of the minor program were designed in a way that the exit qualifications for the students would be obtained by attending the different individual courses. The integration courses combined all theories and forced the students to put their knowledge into practice.

- Since the introduction 65 students participated. The results of the PLL interviews of 2009/2010 minor students showed that the majority of the students evaluated the minor as positive. In the same survey, students acceded to have learned a lot, especially in the field of 'orientation towards the market in developing countries'. The majority of the students succeeded in acquiring their own formulated learning skills. The essence of PBL (Felder, 1988) was recognized by the students: a significant share of the students mentioned the case study based courses as their main source of personal development. It is hard to determine whether the students developed a vision on global development challenges that will have influence during their further professional decisions. 27 and 30 percent of the students expressed after the minor program an ambition to respectively choose a Master or a job in the field of International Entrepreneurship and Development. In both situations, this number was almost doubled compared to the beginning of the minor.

- After the evaluation of the minor, only small changes were favourable, such as the extension of the literature list of some courses.

The second question concerned the added value of the minor for the involved stakeholders and the interrelation of their interests. In creating the integral engineer through this minor program, three stakeholders are involved: the university, the individual students and the local actors in the case study based courses. Their stakes appeared to be interlinked and interdependent.

- *Concerning the university*, the minor has the potential to add value by educating students, providing case studies that can be used for research purposes and the opportunity to valorise knowledge to promote economic development in the poorest parts of the world. Especially the third stake is currently weak defined. It is recommended to define goal of

the university to alleviation of poverty through valorising knowledge more specific. These stakes are related to the dedication of the students, the dedication of their staff and the right environment for economic development.

- *Concerning the individual students*, the minor has the potential to add value by helping them to acquiring their personal missing knowledge and skills, even beyond the scope of the minor. The majority of the 2009/2010 minor participants succeeded to acquire their personally defined learning skills. The degree of success depends on the dedication of the students and the quality of the education of DUT.

- *Concerning the local actors*, the minor has the potential to add value by alleviating poverty and poverty related problems by promoting economic growth through entrepreneurship. It is the valorisation of the developed technology or provided knowledge. The degree of success depends mainly on the dedication of the students and the environmental opportunities.

As a result of only two years of experience with the minor program, the (long term) success for the local actors of the performed projects is hard to measure. This is in line with the difficulties for the university to measure the economic valorisation of their technology and knowledge. Therefore, a database to track the progression of different projects is currently being developed to provide insight in the progression over time. Putting this database into practice enables to measure the long term success of a project. Furthermore, it facilitates student groups to work on one project successively. Further research is needed on the detailed design and the use of this database.

The interaction between the involved stakeholders is not based on equality. A situation can be created where both the university and the students meet their needs, but leave the situation of the local actor unchanged of even worsened. Further research has to be conducted to turn this collaboration into a triple helix model (Etzkowitz and Leydesdorff, 2000), a successful example of a three-stakeholder interaction that benefits all parties. In the triple helix model, government, universities and businesses are involved.

It can be concluded that the both the content and the education method of the minor program meets its aims to create integral engineers. Short term evaluation shows a positive valuation of this minor by students. The long term effects of the minor still have to be measured. The minor program creates opportunities for each involved actor: development of knowledge and skills by the students, providing in research data for the university and poverty alleviation for local actors. The successfulness of this three-stakeholder collaboration depends on personal dedication of the involved actors and the environmental opportunities.

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