Innovation Project versus Master's Thesis

Greet Langie*, Fien Verelst en André Lauwers

Faculty of Engineering Technology, KU Leuven, 3001 Heverlee, Belgium
*Leuven Engineering and Science Education Centre (LESEC), KU Leuven, 3001 Heverlee, Belgium

Email: greet.langie@iiw.kuleuven.be, fien.verelst@iiw.kuleuven.be en andre.lauwers@khbo.be

Abstract

The Faculty of Engineering Technology (FIIW) is a new multicampus faculty in KU Leuven (Belgium). It's the result of the merger of the students and the staff linked to the master programmes in Engineering Technology of six different institutions spread all over Flanders.

Students have to learn to do research, to design, to develop and to implement in an innovative way. The Master's thesis, an obligatory element of the programme, emphasizes the research and design elements of an industrial innovation (mostly in a R&D environment) reflecting on the scientific and technological relevance, whereas the innovation project, the keystone of a new postgraduate programme, lays the stress on the innovative implementation in an industrial setting reflecting on the economic, social and ethical relevance. A clear distinction can be made, but nevertheless both projects should be major elements of an engineering curriculum, what is not the case for the moment in Flanders.

Keywords: Master's thesis; innovation project; multicampus; evaluation criteria.

1. Introduction

To implement the Bologna declaration on the European space for higher education (1999), Flanders has adapted its legislation (2003) and introduced the concept of associations of universities and university colleges. 12 institutions have joined their forces in the KU Leuven Association. Six of them organize Bachelor and Master programmes in Engineering Technology. Starting from the first of October 2013 the new Faculty of Engineering Technology of KU Leuven (FIIW) will be responsible for all curricula in Engineering Technology of the KU Leuven Association. These are: a unified Bachelor programme, seven Master programmes, two master after master programmes and one Erasmus Mundus programme.

Students with a degree 'Master of Science in Engineering Technology' are 'industrial engineers' in professional life. Whereas students with a degree 'Master of Science in Engineering' hold the title 'civil engineer'. Both will be organized at universities starting from the academic year 2013-2014, but their profile is fundamentally different. Civil engineers are oriented to conceptual and managerial tasks, whereas industrial engineers are directed at applications and development (Baert et al, 2010).

2. Hurdles to take

2.1 Unity in multiplicity

Before the merger, each University College had his individual set of learning outcomes. Since we will become one institution starting from the 1st of October 2013, we need common objectives which are obtained by all students wherever they study in the multicampus faculty. On the other hand, it's important we preserve the richness of the different profiles of the six campuses based on the local expertise and view. Graduating bachelors have by consequence the opportunity to choose the specific master education on that campus that meets his or her special interest.

2.2 Becoming academic

Since 2003 the programmes in Engineering Technology are obliged to become increasingly research-based as a consequence of the obtained academic character. By consequence, the Master's thesis is executed more and more in R&D environments. For example, at one specific campus for one specific major, the percentage of master students who operate in industry has decreased with 24% since 2004. Nowadays around half of the students realize their Master's thesis in industry, whereas in 2004 80% of the students performed in industry (for the specific major).

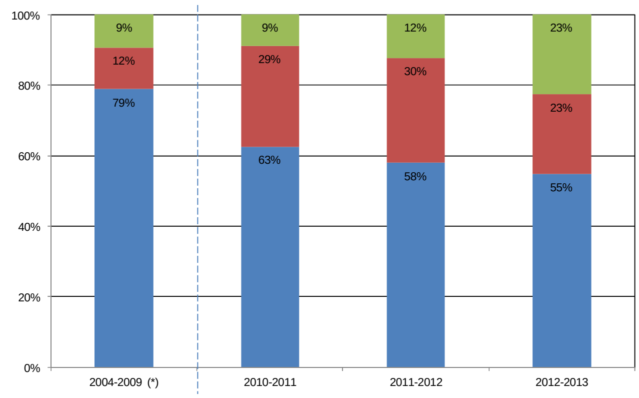

Figure 1: Evolution of the percentage of students who perform their Master's thesis in industry (blue), in an external research group (red) and in an internal research group (green) at one of the campuses of FIIW

This evolution has a beneficial effect on the development of research skills. However, the increasing lack of strong ties with industry should be compensated with a work placement focusing on the typical competences one needs to be successful as an industrial engineer in industry. We cannot guarantee any more that every student has a relevant working environment experience. Accreditation bodies (such as NVAO or QAA) emphasize the value of providing engineering students with opportunities to work with industry (QAA, 2012).

For the moment there is no space in the curriculum to include this extra engineering project in close cooperation with industry. To compensate this deficiency, we will start a Postgraduate Programme in Enterprising Engineering in which an innovation project in industry of 40 ECTS points will be the keystone.

Since this innovation project has another focus than the Master's thesis, we should define clear objectives which differ from the learning outcomes of the Master's thesis. The latter are well-defined but vary between the campuses.

3. Generic profile – campus profile

We made an inventory of the competences defined at the involved campuses and composed one set of generic competences for the whole Faculty of Engineering Technology, whatever major the students select. On every campus, this unified view is made explicit in a different way (different methodology, specialization, etc.). This guarantees that students, wherever they study, have a great choice of subjects fitting their personal interests during their study.

In the first paragraph we describe these generic competences and compare them with other models. In the following paragraph we focus on their relevance to industry.

3.1 Generic competences of the Faculty of Engineering Technology (FIIW)

The new Faculty of Engineering Technology is in search of a unity which is sufficiently general such that there is still the possibility to enrich it with local views.

We studied the competences defined at all six campuses and deduced from it a new set of generic competences which should be obtained by every FIIW-student wherever he or she studies.

The generic competences of FIIW are based on the Flemish decree of 2003 (article 58, §2) in which the learning outcomes of a bachelor and a master are defined. Most of the learning outcomes are completely preserved when we translated them into our set of competences. But, in addition, we have added three typical engineering learning outcomes: design in a creative way, put into operation and entrepreneurship. The learning outcomes are classified, according to the Engineering Benchmark Statement (QAA, 2000) in four groups: knowledge and understanding, intellectual abilities, practical skills and general transferable skills.

Moreover, these competences are in accordance with the important attributes engineers will need in 2020 (National Academy of Engineering, 2004), the competencies of the Olin College of Engineering (Miller, 2005) and the ACQA-criteria developed for technical engineering curricula (Meijers, 2005). An overview is given in Table 1.

Table 1: comparison of the attributes of engineers in 2020, the competencies of Olin College, the ACQA-criteria and the generic competences of a master in FIIW

Generic competences of a master in the Faculty of Engineering Technology	Attributes of engineers in 2020	Olin competencies	ACQA-criteria Competence Area (competence number)
complex problem solving capability	strong analytical skills	- qualitative analysis - quantitative analysis - diagnosis	5 (2,3,4)
critical reflection and translation of these results into the development of more adequate solutions			4 (2) 5 (1,5,7)
understanding and knowledge of science and discipline knowledge in a specific domain			1 (1,2,3) 4 (4) 7 (1)
integrate the public consequences of new trends in science, technology and research into research and implementation	high ethical standards and professionalism	context	7 (2,3,4)
communicate with peers and laymen	communication	communication	6 (1,2,4)
capability to work together in a multidisciplinary team	Leadership	teamwork	6 (6,7) 7 (5)
integrated and applied research	practical ingenuity creativity	design	1 (4,5,6,8) 2 (1,2,3,4,5,6,7) 4 (3)
innovative and creative implementation			1 (4,8) 3 (1,2,3,4,5,6,7) 4 (3)
entrepreneurship (understand the managerial aspects, management techniques, HRM and working in an international environment)	business and management dynamism, agility, resilience and flexibility	opportunity assessment	6 (8) 7 (2)
Life-long learning (bachelor competence)	Life-long learner	life-long learning	4(1)

3.2 Significance of the generic competences of FIIW

The importance of a competence for a curriculum can be described with the study time a student spends on this specific competence (Meijers, 2005) or the ECTS-points dedicated to this competence in the programme.

It's up to each campus to decide the impact of each learning outcome on the curriculum. On every campus every defined generic competence should have a minimum relevance, but on top they are completely free to add extra attention. This offers the campuses the freedom to develop and enhance the local profile. This process attains its full development.

However, we should make sure that the significances of the learning outcomes in a curriculum of engineering technology are in proportion with their relevance for industry. In Figure 4 the most needed competences of an engineer in technological industry in Flanders are reported (Agoria, 2006).

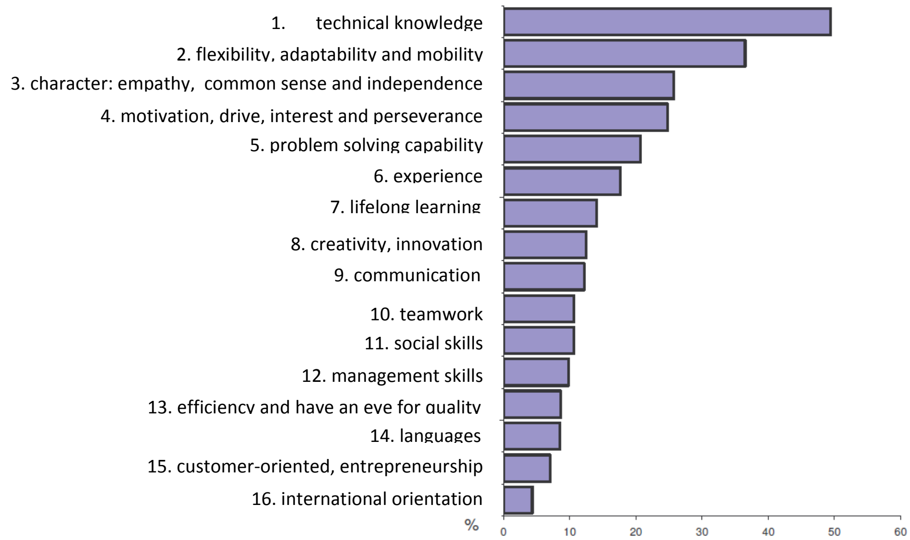

Figure 2: Importance of the competences for technological industry in Flanders (the percentage of respondents for each competence are marked, each respondent could indicate three competences), (Agoria, 2006)

'Technical knowledge' stands at the first place of the ranking and is in our faculty also the competence students spend most time on. It's the basis of a traditional curriculum of engineering education (Lemaitre, 2006). The following two competences 'flexibility, adaptability and mobility' and 'character' are not explicitly included in the FIIW-learning outcomes, but they are indirectly assessed since students who do not possess these attitudes have less chances to succeed at university. All the other competences are part of the generic competences of FIIW, except 'experience' which will be obtained during the professional carreer and 'languages' which are trained intensively in secondary schools in Flanders and need by consequence no extra training during higher education.

We are measuring the significance of each competence at the different institutions with the help of the ACQA-criteria. The different profiles of the campuses and the link with the industrial relevance will be the topic of future research.

4. Master's thesis – innovation project

There is a long tradition in Master's theses in our faculty. The introduction of an innovation project is new, but very important in order to preserve our profile. In the following we make a comparison between the objectives of the Master's thesis of the six campuses of our Faculty and the learning outcomes of six selected engineering projects at other institutions focusing on strong ties with industry and entrepreneurship.

4.1 Competences of the Master's thesis

The Master's thesis (final-year project) is an open-ended, research-based project during which the students pass through all stages of research (KU Leuven). Such a project gives the student the opportunity to prove that he or she is capable to integrate in an independent way the knowledge, techniques and tools studied during the previous years.

Vitner and Rozenes (2009) give an overview of the goals of final-year projects in some engineering departments. They appear fairly scattered depending on the strategies used to align the learning outcomes (Thambyah, 2011). Thambyah (2011) proposes a template with 24 learning outcomes based on the revised Bloom's taxonomy of Anderson and Krathwohl (2001). The University of Nottingham defines four headings to group the learning outcomes: knowledge and understanding, intellectual abilities, practical skills and general transferable skills (University of Nottingham, 2003). They advice: "Learning acquired by students from project work in engineering will often touch on a great many programme learning outcomes. For the purposes of making assessment both valid and manageable, it is important to focus on the key learning outcomes attached to the project."

The Master's thesis in the Faculty of Engineering Technology stands for 20 ECTS points. This is one third of the Master's programme and by consequence a major element of the curriculum. Although the six campuses of FIIW worked out the learning outcomes of the Master's thesis completely independent during the previous years, they focus mainly on the same competences (Table 2). The differences are a consequence of the local traditions.

Table 2: Comparison of the aimed competences of the Master's thesis at the six campuses of FIIW

Generic competences of a master in the Faculty of Engineering Technology	1	2	3	4	5	6
complex problem solving capability	x	x	X	x	x	x
critical reflection and translation of these results into the development of more adequate solutions	x	x	X	x	x	x
knowledge and understanding of science and discipline knowledge in a specific domain	x	x	X	x	x	x
integrate the public consequences of new trends in science, technology and research into research and implementation		x			x	x
communicate with peers and laymen	x	x	X	x	x	x
capability to work together in a multidisciplinary team	x	x	X		x	
integrated and applied research	x	x	X	x	x	x
innovative and creative implementation			X		x	x
Entrepreneurship					x	
+ explicit focus on						
Creativity	x	x	X	x	x	x
independence	x	x	X	x	x	x
drive and motivation	x	x	X	x	x	x
time management		x		x	x	x

Since this project is viewed as the culminating learning experience of the engineering programme it's logical that almost all objectives of the Master's programme in FIIW are included in the Master's thesis.

However 'innovative and creative implementation', 'entrepreneurship' and 'capability to work together in a multidisciplinary team' are important competences for an engineer which are not always marked in Table 2. We are in need of a project focussing on the latter.

4.2 Aims of an innovation project

Oehme (2000) describes the need for projects in strong collaboration with industry in the following way: "The students come with an academic attitude, thinking that they have learnt enough and have plenty of time to develop optimal technical solutions. When starting to work at the Fraunhofer Institute, they are confronted with the shock that resources are limited, they have to produce certain results in a limited time, .. Instead of efforts being spent to develop them, as at the university, they are expected to make efforts themselves to obtain a certain result. This is indeed a cultural shock,.. However, those who decide to become entrepreneurs themselves by starting their own businesses are relatively small in number. A tentative conclusion is that more education for economic and business development and operation is needed for engineering students. There seems to be a long journey from the general public understanding that small and medium enterprises are indispensable for maintaining business and labour in an economy, via the establishment of innovation centers, technology transfer and public funding of R&D programmes, to the individual decision to become an entrepreneur."

The new innovation project in FIIW is an attempt to meet these needs. The objectives should be clear and distinctive from the Master's thesis. A review of the aims of comparable projects at five different institutions results in the overview in Table 3. The data is based on information on the institutional websites.

These projects are in strong collaboration with industry and make use of problem based learning in order to bridge the gap between academic theory and industrial practice. The technical content remains important, but typical engineering skills become more essential, such as project management, taking care of the development process and succeeding in customer satisfaction. Anette Kolmos (2010) describes why it's so interesting to incorporate problem-based learning in these types of projects: "Problem-based learning concerns a scientific level transcending the barrier of cognitive and affective aspects by letting the learner direct a researching and investigating learning process. So as a learner-centred process, problem-based learning meets the learners' interests and as such gives room for developing learning motivation. Furthermore, problem-based learning emphasizes a development of analytic, methodical and transferable skills."

The world's top-ranked engineering universities (Ward, 2013) emphasize active industry stakeholder involvement in capstone projects for tasks such as topic selection, student advisor, provide funding and assess the projects.

Table 3: Comparison of the goals of six different engineering projects in collaboration with industry: PDP (Aalto University), CIVL (British Columbia Institute of Technology), PIP (Technical University Graz), Learning Factory (Penn State College of Engineering), SHIPS (University of Sheffield) and ICT project (University of Tasmania)

Goals	PDP	CIVL	PIP	Learning Factory	SHIPS	ICT project business solution	ICT project market potential
securing an industry sponsor		x					
identify an engineer problem		x	x				
analysing the market							x
planning	x		x	x		x	x
searching for information	x	x	x	x		x	x
selecting methods		x	x	x		x	x
creating concepts	x	x	x	x		x	x
creativity	x	x	x	x		x	x
decision making	x	x	x	x		x	x
developing	x	x	x	x	x	x	x
fulfilling the customer's expectations	x	x	x	x	x	x	x
controlling the budget			x	x			
communicating with the sponsor, the team and academic members (presentation, client report, technical report, manual, poster, project website, project folder, press release, instruction sheet, ..)		x	x	x		x	x
working in (interdisciplinary) teams	x		x	x	x	x	x
making a business plan			x			x	

The 15 gathered learning outcomes mentioned in Table 3 can be divided into the seven thematic approaches that higher education can use to articulate learning outcomes for enterprise and entrepreneurship education (QAA, 2012), see Table 4.

Table 4: Classification of the 15 learning outcomes from Table 3 with the help of the thematic approaches of QAA.

15 learning outcomes from Table 3	thematic approaches (QAA, 2012)
identifying an engineering problem	opportunity recognition, creation and evaluation
analysing the market	
Developing	
selecting methods	creativity and innovation
creating concepts	
Creativity	
searching for information	decision making supported by critical analysis and judgement
decision making	
Planning	implementation of ideas through leadership and management
fulfilling the customer's expectations	
controlling the budget	
making a business plan	
securing an industry sponsor	communication and strategy skills
communicating with the sponsor, the team and academic members (presentation, client report, technical report, manual, poster, project website, project folder, press release, instruction sheet, ..)	
working in (interdisciplinary) teams	interpersonal skills

It's clear that some typical engineering skills needed in an innovation project are honoured in the Master's thesis, such as 'selecting methods', 'searching for information', 'communicating', etc. But most of them are very typical for an innovation project in strong collaboration with industry, such as 'controlling the budget', 'analyzing the market', etc.
As Casar (2000) stated "The best, if not the only, possible way to acquire the attitude and skills required to be safely in the business of modern engineering education is through research: research trains curiosity, creativity, reasoning skills, sense of relevance and application and many other modern engineering teaching skills." On the other hand Oehme (2000) indicates that the new requirements of research can be included in engineering education with the help of student projects in industry. By consequence, there are some transformational needs of the curriculum

(Shrivastava, 2013). Badran (2007) indicates that a curriculum should contain the five following packages in order to enhance innovation and creativity: (1) core scientific knowledge; (2) co-curricula inter-related creativity-oriented workshops, seminaries, etc.; (3) engineering projects at different levels; (4) exposure to technology incubators, entrepreneurial projects and small and medium enterprises; (5) interaction with business and industry.

5. Conclusion

There is a clear interplay between the competences one needs to do good research and to innovate in a proper way. One should include both aspects in engineering education. An engineer graduated from the Faculty of Engineering Education should be an innovating developer and masters by consequence research and development skills. In the Master's thesis we focus mostly on these research skills applied in a technological R&D environment, forcing the students to reflect on the technological and scientific relevance. Whereas during the innovation project students implement creative concepts and ideas in an enterprise or are entrepreneurs themselves. They reflect on economic and social relevance.   The next step in our curriculum development will be the definition of the learning outcomes and the evaluation criteria of this innovation project based on the previous analysis. In near future this innovation project will be included in a new postgraduate programme, but we hope that one day we will have the opportunity to organize a two-year master programme and at that moment the innovation project will be included in the expanded master programme.

References

Aalto University, product development project (pdp), retrieved April 8, 2013 from: http://pdp.fi/course-overview/what-is-pdp/

Agoria. (2006). *Skills for the future. Competentieagenda 2015. De technologische industrie in Vlaanderen.* Retrieved from: http://www.agoria.be/WWW.wsc/webextra/prg/izContentWeb?vApplication=leren_is_groeien&sessionlid=1&vUserID=999999&t=Daily&ENewsID=42467&TopicID=0&ComingFrom=Back2search&FWordsSearchQ=skills%20for%20the%20future&FTopicIDSearchQ=0&ShowSummary=no&From=0&FAction=SearchQ

Anderson, L. W., & Krathwohl, D.R. (2001). A taxonomy for learning, teaching and assessing: a revision of Bloom's taxonomy of educational objectives. New York: Addison Wesley Longman.

Badran, I. (2007). Enhancing creativity and innovation in engineering education. *European Journal of Engineering Education, 32*(5), 573-585.

Baert, F., & Maex, K. (2010). De integratie van de industrieel ingenieurs in de universiteiten: kansen tot versterking en profilering. Tijdschrift voor onderwijsrecht en onderwijsbeleid 11 (3), 228-238.

British Columbia Institute of Technology, Civil Engineering Industry Project (CIVL). Retrieved April 8, 2013 from: http://commons.bcit.ca/civil/students/proj/index.html

Casar, J. R. (2000). Encouraging students' attitude of innovation in research universities. *European Journal of Engineering Education*, *25*(2), 115-121.

Kolmos, A. (2010). Reflections on Project Work and Problem-based Learning. *European Journal of Engineering Education*, *21*(2), 141-148.

Lemaitre, D., Le Prat, R., De Graaff, E., & Bot, L. (2006) Editorial : focusing on competence. *European Journal of Engineering Education, 31*(1), 45-53.

Meijers, A.W.M., van Overveld, C.W.A.M., & Mutsaers, E.J.P.J. (2005) Criteria voor academische bachelor en master curricula. Technische Universiteit Eindhoven. Retrieved from: http://w3.tm.tue.nl/uploads/media/AC_NL_web_01.pdf

Miller, R. K. (2004) *Defining and assessing the competencies of Olin graduates.* Retrieved from Olin College of engineering Web site: http://www.olin.edu/about_olin/docs/pdf/competencies_white_paper.pdf

National Academy of Engineering. (2004) *The engineer of 2020 : visions of engineering in the new century.* (the national academies press). Washington, DC: National Academy of Engineering. Retrieved from: http://www.nap.edu/ctalog/10999.html .

Oehme, F., & Seitzer, D. (2000) Learn by doing: how to include new requirements of research in engineering education. *European Journal of Engineering Education, 25*(2), 131-137.

Penn State College of Engineering, The Learning Factory, retrieved April 8, 2013 from: http://www.lf.psu.edu/

QAA (2000). Subject benchmark statements: engineering. Gloucester: QAA.

QAA (2012). Enterprise and entrepreneurship education. Guide for UK higher education providers. Quality Assurance Agency for Higher Education (QAA), retrieved from http://www.qaa.ac.uk/Publications/InformationAndGuidance/Pages/EE-draft-consultation.aspx

Shrivastava, G.S., & ASCE, M. (2013). ASCE Vision 2025 and the Capstone Design Project. *Journal of Professional Issues in Engineering Education & Practice, 139*, 5-11.

Thambyah, A. (2011) On the design of learning outcomes for the undergraduate engineer's final year project. *European Journal of Engineering Education, 36*(1), 35-46.

Technical University Graz, Product Innovation Project (PIP), retrieved April 8, 2013 from: http://portal.tugraz.at/portal/page/portal/TU_Graz/Einrichtungen/Institute/i3710/Lehre/PIP/Ergebnisse

University of Nottingham (2003). *Project Based Learning in Engineering*. Fund for the development of teaching and learning. Retrieved from: http://pble.lboro.ac.uk/guide-final.html#_Toc56250143

University of Sheffield, Sheffield Industrial Projects Scheme (SHIPS), retrieved April 9, 2013 from: http://www.shef.ac.uk/eee/industrial/industry/ships

University of Tasmania, ICT projects, retrieved April 9, 2013 from: http://www.utas.edu.au/computing-information-systems/resources/undergraduate-capstone-project

Vitner, G., & Rozenes, S. (2009) Final-year project as a major element in the IE curriculum. *European Journal of Engineering Education, 34*(6), 587 – 592.

Ward, T., A. (2013) Common elements of capstone projects in the world's top-ranked engineering universities. *European Journal of Engineering Education, 38* (2), 1-6.