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Engineering Students as Innovation Facilitators for Enterprises*

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This paper addresses the role that Engineering Master Students may play in contributing to the development of innovation for enterprises. Based on a formalized tripartite cooperation between a student, an enterprise and a Danish university, the programme combines traditional academic curricula with a mentor company. Drawing on the concepts of Mode 2 knowledge production and knowledge governance the circumstances under which these innovations can take place are described and analysed. The empirical material is taken from a longitudinal study (2009-2011) of the master programme; the study combines qualitative and quantitative approaches. Both students and enterprises assess the master programme very positively and more than half of the companies confirmed that the students have contributed to innovation processes. The analysis shows how formal and informal governance mechanisms need to complement each other in order to enable a successful progression for all the parties involved. However the study also underlines that the master programme faces challenges which are usually not part of engineering curricula, for example, improving students' social and communication competences and autonomy.

Keywords: engineering education; innovation; knowledge governance; mentorship; Mode 2

1. Introduction

In contemporary society, knowledge and competences are fundamental factors for industry's economic performance, innovative capacity and ability to create new markets. Enterprises need to face new demands from all areas of society and to adapt to rapidly changing markets. To do so, collaboration with external partners in the form of networks, user-driven or open innovation initiatives are encouraged. The benefits of creating relationships between universities and industry have also been emphasised [1] Moreover, recent years have seen an increasing focus on the "third mission" of the universities, requiring that production of knowledge should contribute to the development of society including the private sector [1, 2].

The role of technical universities is usually seen as offering education to provide a qualified workforce, conducting basic research and collaborating with industry to develop innovation. Often these contributions are discussed in terms of transfer or impacts and are measured by numbers of contracts, patents or spin-offs. The fostering of engineers is particularly central to university-industry collaboration which puts pressure on engineering education. As industry is changing rapidly, technical universities not only need to update and renew their courses but also to prepare their students to become professionals who are able to cope with rapid socio-economic changes [3].

One way of meeting these challenges is to refer to Mode 2 production of knowledge. Mode 2 was defined some seventeen years ago to capture the on-going changes in the world of science, science policy and the knowledge economy. This concept suggests other forms of collaboration where knowledge is developed jointly by actors from universities and industries, and contextualized in a problem-solving-oriented process [4, 5]. Knowledge created is not exclusively reserved for qualified academic researchers; it is both communally produced and shared by various actors in their respective contexts. Knowledge is then assessed in terms of its social value and its relevance to the various stakeholders involved in its process of production. This form of collaboration between universities and companies increases the potential for innovation and can be seen as a win-win situation for both parties [6].

However Mode 2 also has its downsides and faces three mains criticisms: it lacks a systematic process of investigation compared to carefully designed research executed with regard to relevant methodological principles; it lacks newness, as research is expected to advance knowledge within the field of inquiry and not just apply it in a new context; and it lacks transparency when commercial interests may prevent findings and methods from being made public and therefore their validity may be questioned [7].

The mutual benefit and challenges of Mode 2 have been described in numerous publications [8, 9]; however, the specific role that students may play in this collaboration has rarely been discussed. This paper addresses this gap by exploring the circumstances under which students enrolled in an engineering master programme may actively contribute to knowledge production. In the programme, stu-

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dents divide their time between a mentor company and the University. The education combines a traditional academic curriculum with problem oriented approaches based on a company's specific situation and needs. The students must use the company's context to develop their own academic production which, in turn, should be valuable and usable for the company. To do so, the students need to understand and comply with the formal and informal university and company norms and expectations.

The mentorship is fairly similar to some of American collaborations between industry and university known as "Coop" developed under the auspices of ABET [10]. This comparison can be used to underline the difference with other types of mentorships [11, 12], such as an internship or traineeship, which is usually more focused on learning the everyday operational routines of the company, and not directly connected with the students' studies. Coops in their various forms serve to socialise students and to prepare them for employment [13, 14]. However the present mentorship is placed at the very centre of the curriculum, involving learning processes and building of competences on innovation.

The programme presented here is an Engineering Master in Technology-Based Business Development at a Danish university. The master is accredited by the independent Danish body for university education (ACE). Both the title of the degree programme and its curriculum indicate that the programme employs a fairly broad understanding of development that focuses not only on the development of new technologies but also on the development of business in general. This also means that when discussing innovation as a driver of development, the understanding of the concept is quite broad which may, in turn, be reflected in the types of innovation the students work within their company projects.

A previous evaluation of 69 projects showed that the scope of the innovations within the companies encompassed starting with the highest occurrence: products, organisation, process, services, marketing and institutional innovations [15]. Hence, the purpose of this study is to assess the conditions under which students may contribute to the innovative activities in their mentor companies.

2. Theoretical frame

As knowledge production involving sharing, integrating and creating knowledge is central to both innovation processes and learning processes, mentorship is viewed as a tripartite cooperation that includes student, university and company, all of which are aiming at knowledge production. The notion of Knowledge Governance is used here to discuss the frame of this knowledge production which is the master programme. Knowledge Governance (KG) seeks to integrate knowledge processes and formal organisational processes [16]. This approach has emerged from the identification of the lack of organisational structure and directions in current knowledge management approaches [17]. Foss & Mahoney describe KG as "to consider how deployment of governance mechanisms influences knowledge processes" [17, p.93]: KG implies, for example, that management has an organisational role to play in knowledge production and can through various mechanisms monitor and improve the frame for knowledge processes. Michailova and Foss [16] differentiate between formal and informal coordination mechanisms. Among the formal mechanisms are organizational structures, contracts, directives, reward schemes or incentives; the informal mechanisms include informal hierarchy, communities of practice, networks, different types of culture such as national, organizational or professional culture and management styles.

Grandori [18] claims that:

> . . . only some mechanisms are actually well suited for the growth of knowledge and innovation: high-level, general rules and norms (rather than detailed); and diversified and epistemic communities and groups [18, p.91].

Moreover she underlines the need for multiple players in purposeful knowledge production activities in the context of innovation. KG recognises the importance of individuals and therefore roles and motivations play a part in the knowledge processes "deep structure" [17]. Foss & Foss [19] deal with the issues of authority in organisations related to knowledge governance. They point out that knowledge is distributed and tacit in organisations, which limits the authority of managers and requires other forms of alignment mechanisms. As will be shown below, issues of authority and loyalty are also central in the students' learning processes. By conceptualising the mentor organisation as a type of knowledge governance, the possibility to frame and monitor innovative activities, are recognised, and so are the mechanisms that enable them.

3. Methods

The data in focus in this paper are taken from a longitudinal study aimed at assessing the outcomes of master programme launched in 2007; the data are from the years 2009–2011. The study was designed as a case study using a mixed methods approach combining qualitative and quantitative data [20].

Semi-structured interviews and participant observations served to explore and understand how students may contribute to innovation. Subsequent questionnaires provided an estimation of the students' and the mentors' evaluations of the programme both at university and in their company.

The empirical data were collected as follows:

- Semi-structured interviews with 6 students.
- Participant observations including teaching hours, negotiations of contract with the mentor companies, supervision of more than 40 students and examination of their projects in the presence of external examiners (2009–2011).
- Semi-structured interviews with four companies and pre-test questionnaire with three others.
- A questionnaire to students attending the course in the spring 2011; 41 completed questionnaires were returned giving a response rate of 58%.
- Questionnaires among enterprises hosting students, during winter 2011, 26 completed questionnaires were returned giving a rate of 56%.

During the academic year 2010–2011, 56 companies participated in the programme. They can broadly be divided into three groups of equal size. The first group encompasses local manufacturing Small and Medium Enterprises and service industries including municipal or regional projects of innovation houses; the second group comprises large Danish companies such as private manufacturing firms and service firms; and the third group consists of large international production companies having facilities in the region active in particular in wind turbines, pomp or thermostats. In this latter group, the students are usually distributed in departments such as engineering, production development, business development, innovation or radical innovation and marketing. The variety of enterprises and departments shows the diversity of the students' interests regarding the organisation and domain of activity. For this paper, only the private enterprises have been investigated.

The fact that the three researchers engaged in the longitudinal study were at that time part of the academic team of the master programme provides an in-depth understanding. However, they had to be careful to maintain a critical distance in terms of their involvement, commitment and interpretation. The trustworthiness of the results was achieved through triangulation of information collected from different sources [21].

4. The master programme

The Master of Sciences in Engineering Programme is a joint venture between private and public interests aimed at enhancing the collaboration of university and enterprises and supporting innovation process in a peripheral area in Denmark, (West Jutland) that is known for its manufacturing industries. Enterprises lacked qualified employees and politicians were keen on maintaining and developing employment in the region. Considering the size and the budget of the university in question, combining business administration and engineering, to develop similar educations to traditional and specialised technical universities was not an option. However, the opportunity emerged to develop an engineering curriculum focusing on innovation and business development. The curriculum was to be closely connected to the local enterprises, which in return would actively support it; the curriculum was to be innovative and should not compete with any existing curriculum. Based on a trans-disciplinary approach, aiming at redefining problems, methods and solutions outside the boundaries of normal disciplines, the programme combines traditional courses with problem- and project-based learning and experiential learning that requires students to actively participate in their studies.

4.1 The academic curriculum

The master programme is a 2-years degree that includes a compulsory halftime company placement during 3 of the 4 semesters. The first semester of the academic curriculum concentrates on technology management topics such as forecasting, innovation, project management and implementation processes. A specific methods course has been designed to equip students with tools to support the production of systematic knowledge during the company placement as the students must be able to critically search for, retrieve, design and analyse the information needed to fulfil their projects. The second term focuses on organisation and strategy. Many of the tasks performed within these courses are done in groups and the courses culminate with traditional oral or written exams. The specialisation in the third semester encourages students to seek university courses abroad; the fourth semester is dedicated to the Master's Thesis.

Each semester the students are expected to prepare two projects in relation with their company. The larger project is a company project (10 European Credit Transfer Scores (ECTS)) whose subject and content have to be closely connected to the business development aspects of the company. Here the students have to define the scope and the objectives of their projects in cooperation with the company mentor and in compliance with specific topics treated during the curriculum; formulating projects related to relevant issues for the company is seen as primordial. The second project is called a technology specialisation (5 ECTS) and focuses on

Table 1. The Master Programme in 2011 (as described in the course material)

	University		**Enterprises**	
Time	**Courses**		**Company Project**	**Technology specialization**
1 term	Management of Technology I-II Technology in Enterprises	(10 ECTS) (5ECTS)	CP 1 (10 ECTS)	TS 1 (5ECTS)
2 term	Organization & Human Resources Strategy	(10 ECTS) (5ECTS)	CP 2 (10 ECTS)	TS 2 (5ECTS)
3 term	Foreign University or Technical Specialization	(25ECTS) or (25ECTS)		TS 3 (5ECTS)
4 term			Master Thesis (30ECTS)	
Total	55 ECTS		50 ECTS	15 ECTS

matching technical issues with technological solutions oriented towards the company in question. Often the technical competences needed to solve these tasks are specific and require the consultation with specialists outside the present university or even the country. The students need to be able to find these competences and act as intermediaries between different institutions and actors. Each company project is assessed during an oral exam with an external examiner from another academic institution or from a company. The assessment takes account of the academic consistency of the report, the realistic and feasible aspects of the proposed solution and the quality of the student oral performance.

The courses and the programme in its entirety were assessed regularly by the students. Following the feedback of the students, several revisions of the programme were made, in particular regarding course contents, deadlines or group work organisations.

To complement and support the industry placement, the students are allotted individual supervision at the university. For each of their two projects, the students are free to choose a supervisor among the academic staff who helps them with theory and methods aspects of their projects. The academic supervisor is assigned time to visit the student's company and meet the mentor twice per semester. In addition, three workshops are organised over each term to share and discuss the advancement of the students' projects. The various projects linked to the industrial placement serve as a basis for 54% of the academic assessments of the students.

4.2 Company placement

The company placements are ideally organized through the students' own efforts as the company chosen should match the students' interests and expectations. Still, assistance is provided by the university through a help desk that lists possible companies and gives practical advice to students to convince potential mentors. This help desk functions as a safety net ensuring company affiliation to all students. The usefulness of the net has not yet proven 100 per cent effective, however. In particular, it has been difficult for first year East European students to enter Danish companies independently of their academic competences. This process also differentiates between the students' search skills: The search for mentor companies tends to leave the extraverted and confident students with more choices than the introverted ones. The teaching team has also used their personal contacts and networks to link students with the industry. However, some bad experiences with underperforming students have damaged these contacts and consequently dampened the teachers' enthusiasm about recommending any students.

There are no specific requirements regarding the size or the types of companies but the possibility of developing innovative processes and the allocation of one or several workplace mentors are mandatory. The formal role of the mentor is to introduce students to the company, guide them during their

Table 2. Number of students enrolled in the master and number of participating companies per year

	2007	**2008**	**2009**	**2010**	**2011**
Male	17	16	22	36	43
Female	0	4	7	15	10
Together	17	20	29	51	53
Companies	16	21	23	41	56*

* The number of companies does not match the numbers of students for different raisons: several students in the same companies, students creating their own companies or students not finishing in time.

projects and ensure that the content of their work complies with the company context.

The collaboration is formalised by a contract signed by the student, the company mentor and a university supervisor. The contract ensures that the projects correspond to specific requirements for the three parties: the student's interest, the company expectations and the curriculum specifications; the contract engages the company for two years. Many companies deemed it necessary to have a confidentiality agreement signed by the students and the academic supervisor, limiting the possibility to use company information in the academic environment.

Students usually spend two days a week to meet at university and spend 2 to 3 days in their company. In contrast to many coops where the students are employed by the company, in this programme the students are not supposed to be remunerated for the work they do in the company. This has happened, however, and has sometimes created misaligned expectations and prevented students from fulfilling their academic obligations.

4.3 Integrating new communities

The first weeks of the programme were marked by uncertainty for the students as they had to tackle two new working contexts—the company and the university—facing new rules, practices and requirements. Entering a company, especially for students without previous work experience which is the large majority, was challenging, e.g. students felt insecure about how to behave and express their own views when meeting experienced practitioners. An integration phase was needed and proved to be time-consuming: the students' answers in both interviews and questionnaire revealed that an average of two to four weeks was needed to understand the company specificities and that for a 25% of them it took up to four months before they felt at ease in their new environment. Companies, especially those which mentor more than one student, recognised that this adaptation phase is necessary for the student to become "operational".

The results also showed that it was a destabilisation moment for the students when they realized that companies did not always share a unified opinion, but that conflicts and disagreements coexisted within the same space. Taking sides most often implied to accept the mentor's view of the issue first (which most of them did); however some students succeeded in supporting different positions and in doing so were able to change the direction of the innovation-process.

Usually, the companies had a rather precise idea of an initial project to allot to the students; it was nevertheless often necessary to define the frame and scope of the task together with the academic supervisor. It was not uncommon that a student who became increasingly knowledgeable over time could reformulate the problem or could identify other aspects of the organisation which needed attention before being able to solve the problem at hand. The resulting tension between what the companies expected and what students might discover had to be tackled. First semester students who found themselves torn between mentor expectations and their own understandings perceived such situations as a crisis.

Even more demanding for the students was the situation where they managed to develop their own understanding of a given issue, definition or solution of problems for example, an understanding which was not shared by other members of the company. Students had to decide between silencing their doubts and playing along with the mentor or confronting the mentor with a different understanding. By choosing the confrontation, students underlined their disagreement and risked damaging their relationship to the community. A way to avoid this was for students to develop and present systematic arguments based on trustworthy methods. Experience has shown that the majority of the students who confronted their mentor gained not only self-confidence but also respect from their mentors. The competitive understandings could, in turn, be developed into a new common view and reinforce the students 'integration in the community'.

However, a few of the company mentors did not react positively to their understandings being challenged. Some of them blamed the programme for misleading the students into issues or understandings which were not relevant for the company or, more rarely, on the students' lack of competences to accomplish their tasks. The work produced by students, even if outstanding, was not spontaneously recognised by the mentor: a few students saw their results being openly ignored by the company. In some cases, communication problems and authority displays spoiled the process. The "keeping silent" strategy was usually demotivating for the students and could lead them search to for a new mentor or to change company.

The situation, although to a minor degree, was also true when students were either loyal to the company or simply disagreed with their academic supervisor who refused to change or expand the scope of research in the direction suggested by the student. As a consequence, shifting in the middle of the term from one academic supervisor to another took place and sometimes created tensions within the teaching team. Here as well, understandings were also competing regarding how to best help the students or which analytical frame to apply to a specific project.

These conflicting situations led to long discussions between students and their academic supervisors especially during the first term of the programme. As a result, the content of supervision tended to move its focus from discussing theory and methods to discussing behaviour, authority, autonomy or communication skills.

Supervisors and the company mentors recognised a learning curve form the first to the second term and finally to the fourth. The students showed more independence and were able to develop, problematize and develop their analysis being less dependent on the mentor's or the supervisor's understandings.

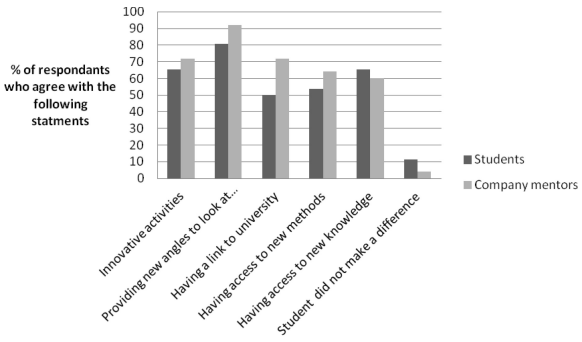
4.4 Evaluation of the programme by the students and the companies

The number of students as well as the number of mentoring companies has increased every year assuring so far the future of the programme.

As shown in Table 3, the results of the questionnaires 3, the master programme has received positive feedback from both companies and students. The study shows that 88% of the companies would recommend the education to other companies and 73% would consider recruiting the students at their companies. Regarding the contributions of programme to the companies (Table 3) over 70% of the enterprises' respondents agreed that the student had contributed to a certain extent to innovation activities and more than 90% estimated that the students had provided new angles from which to view their company's challenges. The company respondents also valued the access to the university and to new theoretical and methodological perspectives. The evaluations by the students were similar to those of the companies, although somewhat a less positive than their mentors.

Nevertheless, there were some issues still pending at the time of study such as the management of underperforming students. Motivation and engagement were necessary ingredients to successfully complete the education and a few students were advised to leave the educational programme because of their lack of commitments and competences.

Table 3. Assessment of the students 'contributions to their mentor companies



The confidentiality of the students' works as well as the intellectual property related to the outcomes was still raising tricky discussions especially between juridical offices. A temporary solution under the form of amicable agreement was exercised by the partners as the case may be.

By May 1st 2011, 32 out of the 60 students who should have graduated had obtained their degree. The figure seems low, but the average of completion for the Danish universities is of 58% calculated with and added year to the official length of the respective educations [22].

Out of the 32 students who graduated, 16 were recruited by their mentor company directly after the completion of their studies; 2 started their own company one active in solar panel solutions and the second in business innovation consulting. There were only a few international students during the first years of the programme and although facing initial difficulty in finding a mentor company, they all became employed in Denmark once they graduated. A year after their degree, all but one of the graduates was working. However, the successful results in term of employability cannot be explained only by the value of the education as perceived by the enterprises. Moreover, the general employment situation for new engineers during the years of the study was relatively good in Denmark.

The university tried to recruit 5 of these students as potential PhD candidate, through temporary short term employment. Most of the students were not really interested in an academic career and left for private companies as soon as they had an occasion. In 2011 there was only one PhD candidate preparing a thesis.

Various explanations account for the drop-out rate of students before graduation. Some students were recruited by the company before having completed their studies and probably felt less motivated to obtain their degree; some decided to stay abroad after the third term; some were delayed in the process and, finally, some dropped out giving up the completion of their master thesis.

In terms of traditional academic knowledge production, as part of one course, students were required to co-author a scientific article related to either the curriculum or their company. Each year, one or two of the best papers were, in consultation with the students' academic supervisors, submitted for review to international engineering and management conferences. And each year students presented their results at a conference. Out of the 6 conferences papers produced in the context of the master programme, one was upgraded to being published in a scientific journal.

According to the European Barometer, the 4 engineer educations provided by the university, which included the master programme described in this article, were ranked as the best in Denmark in 2011: 90 % of the respondents thought the quality of the teaching was good and 94 % evaluated the university cooperation with enterprises' employers was good [22].

5. Discussion

Seen through the lens of knowledge governance, the master programme described here represents a frame for producing knowledge and developing innovation. It combines formal mechanisms by organising and monitoring work in term of contents, academic requirements and deadlines. The contract signed with the companies is also part of these formal mechanisms and provides the physical and contextual structure for innovation to take place. These mechanisms are in practice rather broad, nevertheless they define and constrain, in particular regarding the economy of time, the students 'productions. The specific topics that the students have to address in the curriculum may already contribute toward opening the eyes of their mentors on issues not yet foreseen which in turn may trigger innovation. Even though these formal mechanisms of knowledge governance [16] enable collaboration between the three partners, they do not, however, ensure that the development of innovation processes will take place.

Unlike other internal or external change agents promoting innovation, the position of students is not necessarily perceived as a threat or a challenge [23]. The case showed that during the process of the student project there is an option, to depart from the initial understanding. Gradually, as the students collect actors' interpretations, a new understanding of the problem emerges and new players and their knowledge become relevant. However, a student's ability to develop new knowledge that contributes to innovation does not entail that the company will directly benefit from it. The company mentor has to acknowledge the student as a pertinent actor in the process, and accept different interpretations as valid. In this situation, the student needs to feel confident enough to express or defend his/her positions. To become an innovation potential, the student must resourcefully and intentionally tackle issues of power, authority, loyalty and integrities, as described by Contu & Willmott [24]. While classical mentorship requires loyalty of the mentee, the students can and should act as a change agent. So far, developing the competences for becoming such an agent has been learnt informally by the students through their own experiences and discussions with their academic supervisors and fellow students. Going back to the knowledge governance frame, entering a community, balancing between loyalty and autonomy or developing competing understanding are all processes belonging to the informal mechanisms [23].

Finally, the company's abilities to benefit from the students' innovation potential can be explained at two levels: as an individual relationship between the different actors and as an organisational structure [17]. In the former, the response from the company to the students' production is conditioned by the openness toward deviating from normalised meanings that is shown—or not shown—by the personal mentor. Ellström [25] lists many barriers which may account for a mentor's rejection of students' contributions such as subjective factors, organisational processes, cultural factors or structural conditions. The personal mentor has to be able to accept that the student is moving from his/her peripheral position toward becoming a recognised actor of the community [24]. In this development, an explicit work process defined by the company is challenged by an implicit work process in which the students are developing competitive understandings.

6. Conclusion

The aim of this paper was to describe the contribution to enterprise innovation by students enrolled in a mentor programme based on a Mode 2 production of knowledge. The empirical material presented and discussed here showed that the programme created opportunities to develop enterprise innovation. To conclude, following Grandori [18] some flexibility is needed in formal rules and the epistemic diversity of actors must be suited for the growth of knowledge and innovation. Through a balance between formal and informal governance mechanisms, mentorship can contribute actively to the development of innovation in organisations providing that the companies are ready to accept the value of variations and competitive understandings provided by the students. The knowledge governance integrates a dichotomy between how innovative processes are simultaneously defined, organised, controlled and individually interpreted, transformed and performed in practice.

This analysis may be seen as first step to, if not monitor, at least to inform and prepare the different actors active in the mentorship programme for the sometimes difficult process of contributing toward the development of innovation.

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Denmark, and Christian Koch Construction, Department of Management, Chalmers University of Technology, Gothenburg, Sweden. The three of us were employed at AU Herning during the length of the study. Thanks to both of them for their comments on the present paper.

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