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PURSUING DIVERSITY IN ENGINEERING EDUCATION; A CASE STUDY ON RD&I-COOPERATION WITHIN CIVIL ENGINEERING

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ABSTRACT
This paper describes how cooperation on research, development and innovation (RD&I) between building-clients, industry, and the university was initiated and facilitated to develop (localised) capabilities. The initiator was the regional university; aiming both at supporting the societal development and benefiting engineering education.
A year after entering the agreement, substantial measures can be traced in the engineering education: More than 150 industrial stakeholders from the constructional value chain have been participating innovation workshops at the campus. Four industry-academy advisory boards for innovation have been established, covering selected topics within the construction industry.
One result is a series of capstone courses proposed not as traditionally by individual companies, but by multiple companies cooperating vertically and/or horizontally in the value chain. Seven students have already completed their master theses, and 34 students are presently working with their master or bachelor assignment within this RD&I-cooperation.
An RD&I-programme (MEERC) has been launched, funding 4.1 mill USD including 6 Ph.D. scholarships. Other research and educational institutions have been invited and given substantial responsibilities in the cooperation, to secure quality in work and dialogue between related organisations supporting the industry.
All universities in Norway are subject to the same rigid governmental quality assurance system. Given a variety of educational institutions distributed over a scarcely populated country, standardisation of requirements and comprehensive control systems are vital for securing quality in education. However, there is a risk that this standardisation conforms the institutions, preventing the development of diversity benefiting from localised capabilities – preventing innovation. This project demonstrates the potential for pursuing diversity under a control regime suspected to promote conformity.

Keywords: RD&I cooperation, Constructional value chain, Road construction, capstone courses, localised capabilities

1 INTRODUCTION

Planning and construction of roads is traditionally the responsibility of the governmental organisation "Norwegian Public Road Administration" (NPRA). NPRA is highly respected for professional level and integrity. However, suspicions are that innovation might suffer in this near monopolistic situation. To increase innovation, the government recently launched a second building client organisation within road construction; Nye Veier (NV). NV is given the societal mission to build parts of the national highways – and to do so "more efficiently and smarter" than before. The headquarters for NV was politically localised to Agder county – the home county of the University of Agder (UiA).
To gain from the localisation of the new headquarter, and at the same time contribute to the success of NV in pursuing its societal mission, UiA approached NV suggesting to cooperate on Research, Development, and Innovation (RD&I). This agreement was signed in January 2017. The scope of the agreement is to "support fulfilling of the two governmental organisations' societal mission"; NV to build roads more efficient and smart, and UiA to educate the academic professionals needed in

working life and to contribute to developing and implementing new knowledge in cooperation with industry and public service.

2 METHODS

2.1 Involving industry

Prior to starting the scientific work in our project and to avoid initial friction, we sought enrichment from earlier research on cooperation between societal actors.

2.1.1 Getting on terms with industry

Sandnes et al. [1] worked with cultural awareness. The article focuses on cultural differences between international cooperation partners, concluding that cultural awareness is vital when actors from different cultural spheres seek cooperation. Cultural awareness is highly relevant also for cooperation between industry and university, as frictions are well known also in this area. Consequently, we sought to foresee cultural obstacles and worked to reduce these prior to experiencing them.

To gain respect from industry for being a valuable partner and to support mutual dialogue, the university sought capacity for understanding the worldview and challenges of the industry and mastering the industrial language and expectations. One vital measure was to employ a retired industrial expert as project manager for the RD&I-cooperation. After a career as entrepreneur and leader of companies, he became an architect and initial leader of the industrial cluster NODE. During his leadership, NODE grew to become the world's leading cluster within design and production of offshore drilling equipment, hosting both international corporate and local SMEs.

To further nurture the modus operandi of the RD&I cooperation, inspiration was sought from procedures well known to promote cooperation between business actors – typically in industrial clusters. "Industrial cluster" is a theoretical concept constructed to explain why some networks of related businesses perform far better than others. According to Porter, "Clusters are geographic concentrations of interconnected companies and institutions in a particular field. Clusters encompass an array of linked industries and other entities important to competition" [2].

Porter explains the success of industrial clusters by "Geographic, cultural and institutional proximity leads to special access, closer relationship, better information, powerful incentives and other advantages in productivity and innovation that are difficult to tap from a distance."

It is also noteworthy that Porter concludes "Companies no less than governments and universities, have a stake in education. Universities have a stake in the competitiveness of local businesses" [2].

Our idea of searching inspiration from cluster-theory was to create surplus value from interconnecting entities in a permanent "array of linked industries and other entities important to competition".

2.1.2 Involving the value chain

A model promoting a broad dialogue was selected as the primary method for accelerating innovation. To secure involvement, the cooperation started by NV and UiA together inviting for an industrial workshop. It was emphasised that participants should represent all the value chain of road construction, by including building clients, consultancies, contractors, a broad scope of suppliers, regulatory authorities, and recognised research institutes, in addition to universities. This initial workshop was used to identify central challenges, and to prioritise four topics for further exploration.

Several workshops have subsequently been arranged according to the same value chain concept, to advance on the prioritised topics. The primary intention of these workshops was to identify obstacles preventing innovation. Further work is then to challenge these obstacles.

Advisory boards have been established or are under establishment for each of the four topics. The advisory boards meet regularly to advance the work following up the challenges towards innovation.

2.1.3 Mobilizing university

Establishing RD&I-projects is often a slow process, requiring strategic anchoring in organisations, allocating resources and securing external funding. However, universities possess numerous rapid "task forces" consisting of committed, competent and motivated personnel; students completing their education through master or bachelor assignments – often referred to as capstone courses.

Engaging students in capstone courses have been chosen both as a low-threshold initiative to start working on specific challenges and for supporting larger research initiatives – like Ph.D.-projects.

2.2 Securing educational gaining

Some prior published research papers addressing how education might gain from cooperation with industry, have been used for inspiration: Jorgensen et al. [3] worked with industry collaborative capstone design projects. The article concludes that "Involving industry in the project activity raises the interest and performance of the students" and that "the real-life experience they [students] gain through the interaction with the industrial client is extremely valuable (…)".

In our RD&I cooperation, we are focusing on engaging industry to suggest research areas for capstone courses for students at all levels; bachelor, master, and Ph.D. This is done to motivate students to perform, but also to involve industry in academic work and vice versa – all to promote development.

Buckley et al. [4] work with socially relevant projects in engineering education. It is concluded that not only technical real-life experiences motivate students. However, students "also experience greater motivation because the projects are socially relevant". We consider that working interconnected with a plurality of industry stakeholders in an array representative for the value chain, promotes making the capstone courses socially relevant. Hence, this should constitute an extra motivational factor for participating students.

Students working in capstone courses are expected to satisfy both industry's need for rapid action and results, and students' requirements for real-life challenges and desire for establishing professional networks. University might gain from both aspects; by delivering results in pace acceptable for industry and hence earn respect for being a valuable partner, and by updating educational programmes with relevant competence for industry and public service and hence educating attractive professionals.

3 RESULTS AND DISCUSSION

3.1 Challenging university

University staffs are normally superior in competence within some specialised areas, but do often have small skills on industrial cluster culture and operations. Close cooperation between university and industry is normal, but this mostly happens on a one-to-one basis. We now want to build the interconnected capacities characterising clusters. Our first step to achieve operational cluster competence was to employ an experienced cluster architect and leader as the university's project manager. Immediately, the university worldview and routines were challenged;

1. University tends to think and act in half-year-schedules and to patiently expect results in due time. The industry is impatiently requesting results as soon as an order is placed.
2. University staff tends to prioritise scheduled tasks like teaching. The industry expects the customer to be prioritised (even when the deliverable is establishment and execution of student projects and the cost is zero).
3. University tends to think that access to students and academic staff is an attractive resource. Industry often considers involvement in education to be an act of Corporate Societal Responsibility (CSR) rather than being commercially attractive. Both parties expect the other to be the active participant, and both tend to irritate the other when this is not happening.
4. The industry expects the university to be capable of allocating large efforts instantly when given interesting challenges. However, universities are staffed mainly to handle scheduled activities.
5. Industry leaders expect university leaders to possess the power to redirect the workforce to new challenges when expressing interest in these areas. The vast majority of the university working force is however occupied with "running business as usual" - that is educating students - independently of what draws the interest of their leaders.

These are just a few of the dichotomies revealed when introducing industrial cluster expertise in the university. Though all these issues might be familiar, we find it valuable to identify and clearly express them. Obviously, both parties need to broaden their understanding of the other part. However, to gain the respect needed from industry to be considered an equal and valuable partner in the cooperation and not just remain a subject for CSR, university need to understand and communicate these contradictory concepts – and to some degree to adjust. Hiring a university project manager mainly possessing the industrial competence to lead our interaction towards industry strongly facilitated revealing these cultural contradictions.

3.2 Challenging industry

The vital point on being inspired by cluster theory is the interconnectedness between entities that characterises industrial clusters, as defined by Porter [2]. This is in opposition to the industry just sharing geographical proximity, businesses participating in some sort of professional or social network, or businesses cooperating on ad-hoc basis – as often is the case in the construction industry.

Successfully cooperating internally within one entity (e.g. a company or a university), is often challenging. Yet, it is far more challenging to successfully cooperate with entities not having common leadership or even common scope and motivation. However, the sustainable commercial success proven by industrial clusters have made leaders and communities continuously striving for building cluster capabilities. Thus, it seemed meaningful to adopt some modus operandi from industrial cluster theory and practice, when looking for operational guidelines to make our industry-university cooperation successful.

The industry was also challenged by our cluster expert; actors in the value chain of the construction industry are normally used to focus on optimising own gaining, independent of what gains the construction client. Thus, construction industry tends to focus on sub-optimising profit for each company rather than optimising on the project, even if optimising on the project might gain all actors more. Thus, improved control on the overall process is required to avoid sub-optimising. Even when cooperating with trusted partners, there is a need for improved overall control in the constructional value chain. In this case, it is not even because of lack of trust, but to reduce uncertainty due to factors beyond the control of each actor [5].

Stopping focusing on sub-optimising and rather focus on gaining through cooperation between equal partners, is provocative. However, driven by innovative curiosity and the desire to get close to the mighty construction client NV, multiple companies joined our invitations for cooperation. This process was lubricated by the university now possessing operational cluster competence, designing the process to challenge and excite the industrial representatives to work towards interconnectedness.

During execution of several industrial workshops where actors from a different position in the value chain (both vertically and horizontally) worked together, scopes for innovation was refined to four initial topics. For each topic, an advisory board of selected experts was established – all governed by the steering committee. Subject to each advisory board is an industrial reference group with a wide range of members (Figure 1). It soon became clear that the four topics are not independent, but strongly interconnected. The organisational structure is however maintained so far, to promote operability of the project.

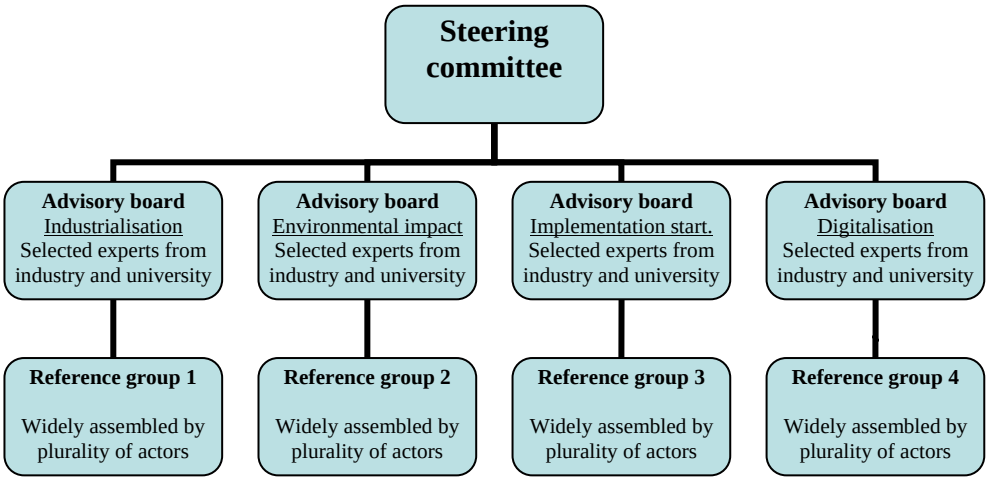

Figure 1. Organisation of industrial involvement in RD&I project

3.3 Gaining results

The scope of the organisation illustrated in Figure 1, is to pursue development and innovation in the industry. Parallel to this – and as a result of the RD&I organisation, a research project (MEERC) was established, partly funded by the Research Council of Norway (NFR) through a programme aiming at strengthening educational programmes through research. The scope of the project is to strengthen the engineering programme in civil and structural engineering, but repercussions positively affect far wider.

The design of the research programme of MEERC is close to a copy of that of the RD&I cooperation between NV and UiA. The organisation built to service the RD&I cooperation (Figure 1), also serve as support for MEERC. The two initiatives are so interwoven; it might be suspected that few but selected persons at the university actually can separate them.
The funding application for MEERC was evaluated by an international expert panel established by NFR and received top grades. From the evaluation report, it is emphasised that the already existing organisation comprising cooperating businesses representing the complete value chain of the construction industry and supporting institutions (as inspired by cluster theory), is reinforcing the project in several ways and that this was honoured by the expert panel.

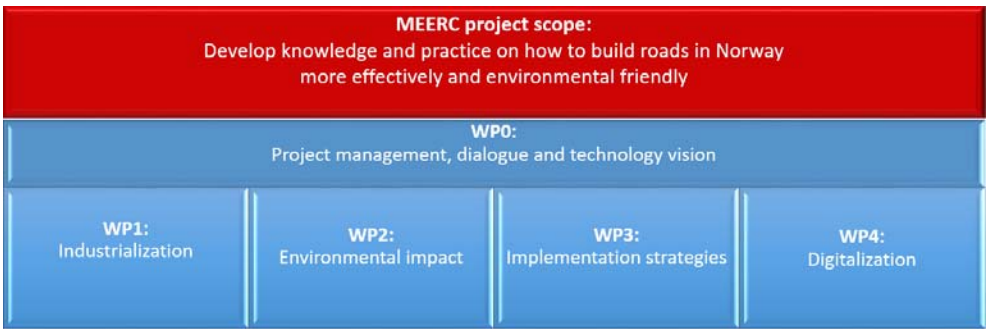

Figure 2. Organisation of the research programme MEERC

The academic core content of each of the technical work packages (WP1-4) is one or more Ph.D. positions supervised by personnel from university and industry in cooperation. The working capacity of Ph.D.-fellows secures that each WP possesses momentum. Most of the Ph.D. positions are presently in the hiring process. In addition, multiple students are expected to contribute to all WPs, through execution of their capstone courses.
Each WP is adopted by the corresponding advisory board from the RD&I cooperation (Figure 1). The advisory boards have been challenged to suggest topics for capstone courses at bachelor and master level. These topics became highly requested by students. Prior to formal start-up of MEERC, 7 students have already completed their master's assignments within this cooperation. 34 students are presently working with capstone courses on topics suggested by the advisory boards.
Once again inspired by the interconnectedness vital in cluster theory, the members of all advisory boards were recently requested to collectively participate in a “student-industry workshop”, acting as a common pool of supervisors for all projects. This student-industry workshop was executed in a two-step process; first, a plenary session where each topic was presented by the students, followed by comments and discussion between the industrial representatives. The next step was a session where all students had an individual dialogue with all industrial representatives, according to a “speed-dating” pattern - only without the speed.
The student-industry workshop was generously donated a full day working hours by all industrial representatives. Initially, this was probably considered by industry to be CSR. However, already during the plenary session, discussions revealed that representatives from the different actors in the value chain had different worldviews and deviating understanding of challenges, and that this was surprising. Of course, this enriches the student works. However, the discussion clearly also challenged the industrial representatives and probably contributed to broadening their knowledge of other actors in the value chain. This can be considered a very careful start on the process towards the creation of capabilities and interconnectedness inspired by cluster theory. Additionally, the process awakened industry’s awareness of potential in cooperating with the university.
The societal mission of NV is to build roads more efficient and smart. Being solely a building client, the strategy for fulfilling its mandate goes through triggering and developing competence and capabilities in the constructional value chain. Being governmentally owned means that the mission should include the whole country – not limited to building capabilities localised to any region.
However, physical institutions and employees are localised. Hosting the headquarters of this vital and important institution represents capabilities that might or might not be utilised. Through the UiA initiative to cooperate on RD&I, this capability has started being utilised. The societal mission of the university is to educate the academic professionals needed in working life and to contribute to developing and implementing new knowledge in cooperation with industry and public service.

Implementation is not restricted to commercialisation, however also applies for educational programmes. The formerly mentioned governmental quality assurance system tends to standardise and conform education at all institutions, as universities have close dialogue and adopt successful solutions from one another. An ongoing national process of university fusions, strengthen this conforming process. This might prevent development driven by universities utilising localised capabilities. Exploiting capabilities in close cooperation with industry present at each location is likely to contribute to innovation. It is also likely to cause diversification between corresponding educational programmes at different universities. Even if presently counterflow; we have met no formal hindrance in the governmental quality assurance system, towards this development.
A matrix in the funding application for MEERC shows 54 interaction points between research activities and courses offered in the Civil & Structural engineering programme. Each interaction point represents the potential for influencing engineering education. One final but important consideration is that industry-university cooperation is great for bringing working life and academic life close and for informing educational programmes. However, the industrial influence must be balanced towards the academic mandate to promote critical thinking and societal gaining prior to short-time profit.

4 CONCLUSIONS

1. There are severe cultural barriers between industry and university. To promote success, it is important to build bilateral awareness on these barriers, and to act to reduce them.
2. To overcome the cultural barriers between industry and university, it is vital for the university to acquire operational competence on industrial language, expectations and modus operandi.
3. Working interconnected with a plurality of actors from the value chain promotes real-life tasks and makes the capstone courses socially relevant. This motivates students.
4. Interacting with the constructional industry on RD&I secures potential for updating educational programmes to continue educating professionals with relevant competence for working life.
5. The RD&I cooperation has contributed to a very humble start on creating cluster-inspired interconnectedness between actors in the construction industry value chain. It has additionally improved industrial awareness of potential in cooperation with the university, and the reputation for university being a valuable partner.
6. Utilising location of a mighty entity (NV) to build competence through cooperation between university and industry helps to build localised capabilities favourable for societal development.
7. Market-relevant diversity in education is achieved by exploiting localised capabilities in the constructional industry value chain.

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