

Industrial Involvement in Engineering Education and Industrial Structural Change

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Abstract

This paper aims – in a constructive critical way - at highlighting the interconnectedness between engineering education and industrial structural change. This way, it connects to the core of the CDIO-initiative. When discussing the customer-metaphor in the final discussion, the paper connects to the topic of student involvement, albeit in an indirect way, and through the practical implications discussed at the end, the paper provides practical advice to engineering educators.

Keywords

Engineering education; Industry involvement; Structural change; Employability

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INTRODUCTION

It seems to be generally accepted that the aim of engineering education in Europe, as well as in other parts of the world today, is to satisfy the need of industry with skilled engineers that have the kind of theoretical and practical knowledge that industry sees fit. A basic reason for this is the expressed wish for example in the Bologna-initiative to increase the employability of engineering students (Leuven and Louvain-la-Neuve Communiqué, 2009), and from a CDIO-perspective, industrial involvement is important, since it helps engineering educators to equip students with the abilities required in real-world engineering situations.

Three European countries that are sometimes heralded as good examples when it comes to academia-industry cooperation in general higher education are Great Britain, Finland and Norway, where specific money is set aside for developing academia's cooperation with industry. In countries like for example Sweden, this is not the case. Here, industry-academia-cooperation is dependent on the initiatives of individual departments and teachers, even though industrial involvement in higher education in Sweden is encouraged from a policy-making perspective; not as "the third task" of academia, but as an integrated practice in the daily activities of Swedish universities. (Högskoleverket Rapport 2008:10 R) What the practices in the daily activities of engineering educators look like and which problems and possibilities with industry-academia-cooperation are is however not known.

Furthermore, the consequences of viewing Industry as the "customer" of universities' efforts has not been discussed either. And which effect may this have on industrial development at large? Based on theories of industrial dynamics it could be argued that a mismatch between the skills and knowledge of engineering students and the task they are expected to perform as engineers might also have an effect on industrial change.

The purpose of this paper is hence to explore what industrial involvement in engineering look like, with a special focus on the Swedish case, and to interpret this in the light of industrial change. The paper presents the results of a qualitative study where 10 Deans, responsible for the education of future engineers at the Royal Institute of Technology, Sweden's largest university when it comes to engineering education, were

interviewed regarding how they work with and view industrial involvement in engineering education.

After a general overview of the premises for industry involvement in engineering education as can be found in various policy-documents, an introduction is provided as to how some of the countries that generally are considered to be at the forefront of industry-academia cooperation is provided. Then follows an introduction to industrial change. After that the case – The Royal Institute of Technology in Stockholm, Sweden, is presented, together with a few words on how the study has been carried out.

INVOLVING INDUSTRY AS “CUSTOMERS” IN ENGINEERING EDUCATION

On a policy-level, there are several decrees emphasizing the need for Academia-Industry cooperation in Europe. In a declaration from a conference in Belgium in 2009, where 46 European ministers responsible for higher education agreed upon the basic principles for the coming work regarding “the Bologna-process 2020”, it is for example emphasized that future higher education needs to be designed in such a way that the students entering the job market are employable. It is also pointed out that Academia carries a responsibility for the continuous development of competence of the already skilled workforce that is on the job market already. This should be done according to a close cooperation between the public sector, Academia, Industry and students, it is proposed. Work placements embedded in study programs are encouraged, as well as on-the-job learning. The ultimate aim is to stimulate creativity, innovation and life-long learning, as well as widening the participation in higher education in order to reform higher education so that it better meets future challenges of an aging population, globalization, a changed job market, and to stimulate cultural and social development. (Leuven and Louvain-la-Neuve Communiqué, 2009)

Naturally, the Bologna-process 2020 regards higher education in Europe in general. When it comes to engineering education, Academia-Industry-cooperation is also emphasized. One of the three basic goals of the CDIO-initiative is to educate students to master a deeper working knowledge of the technical fundamentals. This idea is based on the observation that Industry in recent years has found that graduating students,

while technically adept, lack many abilities required in real-world engineering situations.

Various companies have created lists of abilities that they would like their engineers to possess (e.g. Boeing's Desired Attributes of an Engineer) and in order to meet these, the CDIO-initiative was taken. The CDIO-initiative consists of 12 areas according to which engineering education should be reformed. Number 7, "Integrated Learning Experiences", is about the need for systems thinking in engineering education, built upon cooperation between Academia and Industry:

"They incorporate professional engineering issues in contexts where they coexist with disciplinary issues. For example, students might consider the analysis of a product, the design of the product, and the social responsibility of the designer of the product, all in one exercise. Industrial partners, alumni, and other key stakeholders are often helpful in providing examples of such exercises."

In addition, each areas of reform include a scale where the implementation of the reform should be evaluated on a scale from 0-5 and where the criteria for the highest grade often are expressed in terms of to what extent the "customers" are informed and involved. The reforms should be "regularly evaluated and revised, based on feedback from students, instructors, and other stakeholders." (CDIO Homepage)

Not much is know regarding how universities cooperate with industry in Europe, though. In a report issued in 2008 by the Swedish National Agency for Higher Education it is claimed that Great Britain, Finland and Norway are countries that have taken the task of following up the cooperation between Academia and Industry seriously. (Högskoleverket Rapport 2008:2)

In Finland, there is a binary system for higher education where the universities and the schools for vocational training have different but complementary functions in the educational system. Norway is currently undertaking a reform where the regional institutions for higher education have received university-status, and in Great Britain, the research resources seem to be clustered at the 20 largest universities, where the other universities focus on vocational training and regional cooperation. Common to all of these countries is that they have a developed institute-sector where much of Industry-related research is carried out. The reason for why these countries are considered advanced in terms of Academia-Industry cooperation is that they regularly

do follow-ups on how cooperation works and develops over time, by measuring income for research done in cooperation with a “non-academic organization” (often a company); income from higher education; number of patents, etc.

All countries are however not like England, Norway and Finland. In Sweden, for example, despite the admonishment from the Swedish National Agency for Higher Education that universities take the “third task” seriously, i.e. that they cooperate with industry, there is no general financial support for these kinds of activities, and it seems as if there are different forms of cooperation.

It is therefore of interest, not only for Swedish educators and policy makers, but also to their peers in other countries where the situation is similar, to gain an understanding of how the cooperation with industry actually takes place, and the consequences of viewing Industry as a “customer” of Academia in the sense that the policy-documents imply.

Since a metaphor like “customer” is not simply a figure of speech, but also an indication of a world-view; pervasive in thought and action, metaphors can be seen as governing our everyday activities and structuring how and what we perceive things and how we relate to others (Lakoff, 1980; 2002). Hence, metaphors are important to scrutinize.

Furthermore, applying the customer metaphor allows us to see both the actions (the forms of cooperation) as well as the result (the quality) in a different light; making it possible to develop a better understanding for how engineering education may be perceived differently depending on who is seen as its customer, as well as the effects of this.

INDUSTRIAL STRUCTURAL CHANGE

Since the Technical universities aim at educating engineers that are to function well in industry after having finished their degree it is furthermore of important to understand the effects of the cooperation also on industry, and at industrial structural change.

Structural change, or industrial dynamics as it often is called, is a theoretical field that has been of scholarly interest ever since Schumpeter published his seminal work *The Theory of Economic Development* in 1912, where he argued that market economic development is cyclically structured. Ever since then, several studies on economic development have been carried out on a macro level aiming at explaining and forecasting industrial changes. After the second world war, John Maynard Keynes' ideas on how various political policies could be implemented to level the intensity of the changes became spread, and instead of focusing on explaining the changes, previously seen as "healthy" for the economy at large, the need for stimulating or slowing down the different states of the market.

When the market changes, various openings for industrial restructuring emerge. Today, researchers take a general interest in trying to explain and describe the pro- or counter cyclical innovation timing (Geroski and Walters, 1995), and different strategies for research and development (Greer et al., 2001; for an example, see Mathews, 2003) Research also take an interest in the basic causes for changes from a more, endogenous systems perspective (Carlsson & Eliasson, 2003).

In summary, theories on industrial dynamics propose three main mechanisms that create industrial change: economic shifts in the market, innovation and a mismatch between markets regarding investments, capacities, prices and sales. It could thus also be argued that a mismatch between engineering students, who are to be seen as the human capital invested in for future industrial development, and the tasks they are expected to perform when becoming engineers, might also have affect on industrial dynamics. To investigate the cooperation between academia and industry in the education of future engineers is therefore interesting.

METHOD

In order to develop an understanding for cooperation between academia and industry in engineering education we decided to undertake a case study of The Royal Institute of Technology (KTH), Sweden's largest technical university, with a total of just over 15,000 undergraduate students and more than 1,600 active postgraduate students. KTH has almost 4,300 employees. Situated in Stockholm, the capital of Sweden, this university

was founded in 1827 but has its roots in the first school for engineers “Laboratorium mechanicum” in Sweden, started by “the father of Swedish Mechanics”, Christopher Polhem, in 1697.

One-third of Sweden’s technical research and engineering education capacity at university level is provided by KTH, which means that KTH is the largest single provider of technical research and engineers in Sweden. KTH is also a major partner in two out of three European Knowledge and Innovation Communities formed by the prestigious EU organization EIT (European Institute of Innovation and Technology). Extensive international research and educational exchange programs allow for exchange with universities and colleges in Europe, the U.S. and Australia, but also increasingly in Asia explaining the fact that KTH is an international university with many international researchers and students, especially at Masters’ level. KTH is also a partner in several international university networks such as CLUSTER and T.I.M.E.

In terms of organization, KTH is divided into 10 different schools, each headed by a Dean. These are:

- The School of Architecture and the Built Environment
- The School of Biotechnology
- The School of Chemical Science and Engineering
- The School of Computer Science and Communication
- The School of Electrical Engineering
- The School of Information and Communication Technology
- The School of Industrial Engineering and Management
- The School of Engineering Sciences
- The School of Technology and Health
- The School of Education and Communication in Engineering Science

Interviews were carried out with all of the Deans at KTH. The interviews were semi-structured around the general topic of “industrial cooperation in engineering education” and they were subsequently transcribed and analyzed. In the analysis, different aspects of Industry-Academia cooperation regarding engineering education emerged. In the following, the results will be presented according to these themes. Then, a discussion

will take place where the results of the study will be discussed in through the lense of the “customer”-metaphor, and interpreted in the light of the theories of industrial dynamics.

FINDINGS

Going through the interviews, different aspects of cooperation between Industry and Academia emerges: that there are different forms of cooperation; that Academia not only cooperates with Industry, but with other actors; that cooperation involves various challenges, and that there are certain prerequisites for good cooperation. In the following we will present these in more detailed, based on the interview-material.

Forms of cooperation

In the interviews, all of the Deans mention the same kinds of industry-cooperation. Joint project activities, guest lectures, study visits, industry-participation in the Boards of the Schools, adjunct professors coming from industry, professors fully financed by industry and Master Theses written in conjunction with various companies are a few examples.

Some times, Industry representatives are used as judges in projects carried out by students, evaluating their work from an industrial point of view. In some cases Industry-representatives are also involved in re-designing the engineering education, like in one case at the School of Architecture and the Built Environment, where representations from Industry is currently helping to revise an undergraduate-program. *“They [the industrial representatives] say what they think, but they don’t tell us what to do”*, the Dean says.

Another Dean speaks in the same terms. When meeting with a large Swedish car- and truck manufacturer, the company has expressed the wish for the school to launch a Master in “Gear Technology”. According to the Dean, this is out of the question though, since “Gear Technology” is not a subject that is advanced enough to build a Master around. To build a course in Gear Technology would be possible, he thinks, but not to build a whole Master.

There are also several examples of research activities of various kinds, small and large projects as well as more long-term centers, that are financed by Industry, and that affect engineering education. A few examples here include a long-term co-operation regarding nuclear power plant technology; a lab in acoustics and vibrations and a project in Material Science. In these projects and centers, *“the hot topics from Industry is spread in a natural way to KTH”*, as one of the Deans point out.

Several schools also sell education to companies directly. Since many of these courses are held by the regular teaching staff, this kind of education functions well as an input for the academic staff who gets an idea of what is going on in Industry at the moment.

Another example of co-operation is the kind of action-research carried out by some researchers at some schools. *“This means that we do change-processes in Industry while researching it simultaneously”*, the Dean at the School of Computer Science and Communication, explains.

In general, it seems as if the co-operation with industry is large at KTH. The Dean at the School of Chemical Science and Engineering says that the staff at his school co-operates with some 200 companies.

Co-operation not only with Industry

Apart from one Dean, who explains that he does not believe in integrating Industry in engineering education, most Deans talk of the need to co-operate more, and about how the nature of cooperating with industry is changing. Instead of visiting, industry and academia need to participate in each other’s daily activities:

”This is about integrating Academia in Society. To not create a bubble around it. Without a University, Society will stop developing. We are the knowledge engine.”

This cooperation should take place, not only with Industry, but also with other parts of society, such as financiers, patent-firms, media and others:

”...co-operation does not only need to take place with the product oriented companies. I think it is important to cooperate also with for example [various] organizations, public authorities, and other organizations that do not have a commercial interest”.

An example lauded by one Dean is the active participation in public debate in media of one of the professors at his school regarding the connection between technology-use, risks and ethics for example in the field of nuclear power.

One Dean points out that such co-operation actually already takes place, exemplifying with the fact that his school is often consulted by public authorities when it comes to issues regarding social development. The Dean at the School of Biotechnology provides another example: Stockholm Science City, which is a joint project between the Cities of Stockholm and Solna, KTH, Stockholm University, Karolinska University and the Stockholm County Council regarding the development of an area in the city of Stockholm. And the Dean at School of Technology and Health describes co-operation of various kinds with the Swedish Military as well as with national top-teams in various sports.

Another example can be found at the School of Education and Communication in Engineering Science, where there is continuous co-operation with public organizations such as the National Library of Sweden, the National Archives and the Swedish National Heritage Board.

Challenges regarding Industry-Academia cooperation

When talking about cooperating with Industry, the Deans use words like “partner”, “synergy” and “symbiosis”. Generally, they are positive to the different kinds of cooperation that is taking place, and the input that Industry gives: “The business representatives indicate the direction of the tangent. What is out there and what kind of knowledge the students need”, as one Dean says.

Several Deans express an interest to cooperate more, but add that this is sometimes difficult, for several reasons.

Differences between Academia and Industry

One challenge to cooperation lie in the differences between Academia and Industry, for example regarding interests. Whereas the companies are interested in having their problems solved, Academia is interested in developing general knowledge and theory.

“It is important that the companies don’t see our students [doing their Master Theses] as unpaid labor. There must still be a scientific contribution [in the Master Theses]”, as the Dean of the School of Computer Science and Communication puts it. A colleague puts it differently:

“The subject [of the Master Theses] should not be of too great interest to the company, because then the students get more involved in solving their problem [than writing a good thesis] [...]; after all, the Master Thesis has an educational purpose”.

There is thus a risk that that which is produced in cooperation between for example students and Industry does not reach sufficient academic quality, a different Dean points out.

A second difference between Academia and Industry is the time-perspective.

“A long perspective in Industry is maybe two years – the Academic world should have a much longer perspective [...] we should [for example] have a more generic approach regarding developing new means of transportation instead of making diesel engines more efficient”,

the Dean at the School for Engineering Sciences argues.

For Academia the long-term commitments are necessary, but it is not always that Industry can provide that kind of commitment.

Communication problems

Several Deans however point out that the problems regarding cooperating with Industry do not arise from the cooperation-activities in themselves, but from differences in communication, when the parties do not reach each other; do not understand each other, or have difficulties in going beyond issues where the parties have different goals.

Industry does not understand the Academic system, one Dean points out. They do understand a single course, but they don’t understand the whole educational structure, he adds. Furthermore, many Industry-representatives do not understand that it is crucial for a researcher to publish, which means that it is problematic if they do not want the results developed in joint projects to be published, since this then may be spread also to competitors. This then affects the way cooperation is carried out:

“Too close cooperation with certain companies may involve situations of competition. It is not possible to have too many competitors in the same ‘package’ of tasks... If there is one supplier in the project one cannot have a second supplier in it as well”,

as the Dean of the School of Electrical Engineering says.

Lack of incentives in Industry

One informant point out that it is difficult to get people from Industry interested in coming to University because of lack of incentives in Industry for co-operating with academia: *“only a few wants to come... they get little appreciation [from their companies for doing this]”*.

Lack of incentives in Academia

Another challenge is the lack of incentives in Academia for cooperating with Industry. *“How should Industry-cooperation be evaluated in relation to number of citations”*, one Dean asks rhetorically.

Another Dean says ironically that

“the people that lock themselves into their rooms and write 37 papers to Nature [are] valued higher than [me] who has 17 [heavy] Industry-contacts and who has managed to get 30mSEK from Industry... that is not valued”.

Changes in Industry affecting cooperation

Another Dean point to the fact that many companies have followed the outsourcing trend, and for example outsources their RnD-units, affecting the co-operation regarding Master Thesis-students:

“when I started [at KTH], ABB had a central RnD-unit with resources and hence the possibilities of co-operating. At some point in time this changed, and the Master Thesis-students were put in the business units instead. And the equipment that Master Thesis-student needs in order do his or her job the business units were not interested in paying”.

Too close cooperation

The final challenge that is visible in the interviews is the risk of cooperating too closely with Industry. One Deans tells us of an educational program at one of the campuses in a suburb to Stockholm where Industry participates to a very large degree. Even though

this is good in many respects he also thinks that there is a risk that education loses contact with Academia.

Prerequisites for good cooperation

In relation to the challenges that the Deans identify in Industry-Academia-cooperation, they also point to a couple of prerequisites for good cooperation: geographical proximity and reception competence in Industry.

Geographical proximity

Most of the examples above regarding kinds of co-operation require a geographical proximity between the companies and the University. This is in fact something that the Deans emphasize in order for the co-operation with Industry to work smoothly. The co-operation is upheld by personal contacts, for example since some staff has an industrial background, or through the fact that several companies emerge out of the University-context.

The importance of personal contacts is obvious in the interviews. Several Deans call CEO:s of large and well-known companies by their first name when talking about them, indicating a personal connection, and one Dean argues that at his school, everyone has personal contacts in Industry that can be and are used in a positive way. *“I use Industry representatives to talk to”*, he claims, when describing his work as Dean. Another Dean expresses a similar opinion when talking about the use for Industrial representatives in the Boards of the School: *“These Boards are good, but they don’t reach far since there is only a few Industrial representatives present. And these often only represent themselves.”*

It is quite obvious that the co-operation with Industry does not take place in regulated forms, but very much through the personal contacts and initiatives of individual teachers and other members of staff. *“There is no systematical co-operation between us and Industry”*, as one Dean puts it.

Reception competence in Industry

Another prerequisite for good co-operation with Industry, pointed out by one Dean, is the necessity for what he calls “reception competence” within companies. Small

companies where not many members of staff has an academic degree does not have the same competence of co-operating with academia as larger companies and/or companies with academically trained staff.

DISCUSSION

Since Academia is supposed to educate engineers for the future challenges of Industry a good cooperation between the two parties seem necessary for good quality education. The empirical study indicates that there is a variety of ways as to how Academia co-operate.

In some of these co-operations, Industry affect Academia, for example by requesting courses, having a saying when it comes to education content, requesting specific theses, etc. This means that Industry in some ways can be seen as the customer of Academia, which provides Industry with the “products” of skilled and well-trained engineers.

This means that the industrial companies are seen as actors in a value chain where education is put into people who in the end generate products that are on demand on the market.

This also means that if Industry is seen as the customer of Academia, it is their needs and demands that are most valuable. This fits with for example opinion expressed by the Swedish National Agency for Higher Education who already in 1997 pointed out that it is the stakeholders, i.e. the customers of higher education, that decide what is good quality education. (Högskoleverket, 1997) This is also well in line with the Swedish law for Higher Education (SFS 2001:23).

The idea that Academia has stakeholders, or even “customers” have effects, though:

“Assuming that concepts as ‘customers’, ‘processes’, ‘continuous improvements’ and other concepts making up the vocabulary of TQM are interpreted in a general way, these concepts seem valid and relevant in higher education. A greater emphasis on customer needs, processes and continuous improvements could result in substantial effects on the teaching and learning in higher education.”
(Lundquist, 1998)

And, the interviews do in fact indicate that the view of Industry as customer however is problematic. Not only do the Deans point to the idea that Academia and Industry have different objectives, but that these sometimes clash. Whereas Industry has a more short-term objective of making money, producing products for the market, Academia has a long-term objective of developing theory. In daily cooperation these differences may cause problems, pointing to the importance of commitment from both sides, and the need for a mutual interest for good communication and respect.

It also means that the student is more the raw material that is to be molded into the right shape in order to fit with industry's needs, rather than as human individuals. This perspective could of course be questioned from an ethical, as well as from a pedagogical perspective.

If the student on the other hand is seen as the customer of Academia, who is a sub-contractor to Industry, Academia becomes vulnerable; acting on a market where the demand is theoretically presupposed, increasing the risk that the school produces too many, or too few students with the right skills, over time.

Academia can counteract the general shifts in industry by for example diversifying its offering. This is also done, for example by offering education in non-cyclical businesses like biotechnology, or slow cyclic business like construction industry. It is however not always easy to find a good timing here, since it is easy to attract students to an education aiming at a degree that is of use in an industry like for example the construction industry when this business is popular, but when the students have their degree, several years later, the business is in a different cycle where the demand for new engineers is not as high.

The time-perspective is hence important for the cooperation between Academia and Industry. In the short run, it is of interest to find the best match as possible between the education of engineers and the demand of the companies so that the future engineers get the best possible knowledge. Forms of cooperation that support this are for example Master Theses, guest lectures and various co-operations regarding recruitment. These kinds of co-operation allow for changes in education along side changes in Industry.

CONCLUSION – PRACTICAL ADVICE TO EDUCATORS OF ENGINEERS

The aim of this paper was to explore and discuss the view that Industry today by and large is viewed as a “customer” to which Academia is providing the service of educating skilled engineers. The view of industry as a “customer” is a metaphor, and as such it does not only express views, but also affect them. In this case, it means that Industry gets a special saying in what should be taught in engineering education and what the focus should be, which effects industrial structural change.

As a contrast, we discussed the idea that the students be viewed as the customer of higher education, which means that the content of engineering education might change to better fit their interests. Even though this change may not fit the needs of industry today, it may pave the way for structural changes in industry since such a change would mean that education would depart from the interest of students, and build on their creativity and entrepreneuriality, rather than force them into pre-set molds.

The paper concludes that depending on the time-perspective (short-term vs long-term), the two different kinds of “customers” may be viewed differently, and that it is not self-evident that one perspective is more important than the other.

To perceive a certain actor as customer of the activities of Academia will affect how the product is developed. It will also effect the quality of the product. That Academia, with its various stake-holders – note that the Deans also emphasized that their Schools also cooperate with actors not from Industry – should have a strategy to fit the needs of its various stake-holders seem necessary. Is it however possible to differentiate engineering education in order for it to fit the needs of all stake-holders? As seen above, there are conflicts regarding co-operation, due to differences as well as due to lack of incentives. Is it even possible to fulfill the expectations of all stake-holders? Cf Vroeijstijn, in a report from The Swedish National Agency for Higher Education:

“Of course, one can never fulfil all expectations of all stakeholders in the same way. Therefore, there will always be a discussion about quality. Not because one doesn’t deliver quality, but because for example a government is expecting another quality.” (Högskoleverket 1997; our translation)

In conclusion this means that in order for Academia to produce an engineering education of high quality, it seems necessary to do a through stake-holder analysis, on School-level as well as on educational program-level, in order to rank stake-holders and their needs, and then mold the engineering education accordingly. Hopefully this work will not only lead to an education that in an even better way meets the future needs of Industry, as well as to satisfied and stimulated students, and various ways for industrial involvement in engineering education could then be done in a way that both benefits structural change as well as pedagogical purposes.

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