A MODEL FOR RESEARCH/EDUCATION-INTERACTION AT A DANISH UNIVERSITY COLLEGE

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ABSTRACT

Danish university colleges are currently making a transition from institutions with primary focus on education to institutions that incorporate applied research as well. As part of this change, university college programs are now required by legislation to provide research-based education. This article discusses various understandings of the term “research-based education” and provides a visual model to promote a clearer understanding of the various approaches that can be utilized to achieve research-based education. The approaches described in this article are intentionally pragmatic in nature as opposed to idealized, extolled and conceptual statements of intentions. The model is embedded in the context of a bachelor degree program for engineering and an engineering research program at a Danish university college. By utilizing this explicit case, it is intended that the model will provide greater practical value. The article concludes that multiple channels for providing research-based engineering education are available. The “right” choice or choices for an institution must be identified through a prioritization procedure. The final selection of approaches to provide research-based education depends on the organizational structure of the educational institution, the teaching/research staff identity and the student body. In addition, the selection of approaches depends on how many students are touched, the profoundness of the learning experience and the ease of implementation.

KEYWORDS

Research-based education, teaching-research nexus, University College, CDIO competences, CDIO syllabus, CDIO Standards: 2, 3, 4, 7 and 10

INTRODUCTION

Engineering education in Denmark

The Danish engineering education landscape consists of two players: Universities and University Colleges. A master’s degree (typically 5-year duration) is offered at 4 of the 8 universities in Denmark, while a bachelor’s degree (typically 3½-year duration) is offered at these same institutions as well as at 2 of the 8 University Colleges in Denmark. The institutions typically offer engineering degrees in several cities.

Through the decades, numerous changes in engineering education have taken place (Froyd, et al., 2012). For several decades, a few engineering programs in Denmark have applied a problem-based learning approach, specifically at Aalborg University and at VIA University College. Recently, several of the engineering programs in Denmark have embraced the CDIO initiative (Crawley, 2014). The CDIO approach aims to produce well-rounded engineers who understand how to Conceive, Design, Implement and Operate complex products, processes and systems. The main goals of CDIO are to educate students who 1) master deep knowledge of technical fundamentals, 2) lead innovative creation and operation and 3) understand the importance and impact of research and technological development on society.

Engineering research

Examples of practical engineering accomplishments such as the pyramids, aqueducts and the steam engine have been apparent throughout history. Engineering research at academic institutions as we know it today, however, was only developed in the 1900's. In addition to engineering research in academia, engineering research today may also be carried out by government agencies or by private businesses.

The OECD Frascatti manual (OECD, 2015) provides a general definition of the term research. The manual states "research and experimental development (R&D) comprise creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge". In addition, the manual states that the research must be novel, creative, uncertain, systematic, transferable and/or reproducible.

This definition - along with the five criteria – may seem daunting to the individual charged with carrying out the research. Nowhere in the Manual does it state that it is adequate for the research to be novel only to the researcher - or that the increase in the stock of knowledge may be related to the researcher's own stock of knowledge. This means that research, by definition, has a global perspective. Therefore, institutions or individuals attempting to carry out research without giving full attention to this challenging work are not likely to be successful. In other words, research cannot be simply a means to provide students with better education or provide staff with professional development opportunities but must have value unto itself.

The research/education-relationship

The relationship between research and education was strengthened in the early 1800s at German universities by combining both activities at the same institution. This change was led by the work of the philosopher Humboldt (Huet, 2018) and allows for a close relationship, often termed the teaching-research nexus (Neumann, 1996). Since its inception, however, the value of the research/education-relationship has been contested (Prince, et at., 2007) and it might be suggested that the relationship is of great value for certain courses and of no value for others.

Today, a requirement for providing so-called "research-based education" may be exemplified through national education regulations. Although Danish Universities have a long-standing research/education-relationship, a requirement for research-based education has only recently been imposed on the Danish University Colleges. In Denmark, the current executive order for university colleges (Ministry for Education and Research, 2018) states (translated from Danish):

"The degree programs at the university colleges must be based on research and development knowledge from relevant fields as well as knowledge of praxis in those locations at which the programs are aimed."

Legislation – and the literature in general – is often remiss, however, in specific definitions of the term research-based education and especially in describing methods for implementation of research-based education (Sørensen, et al., 2017).
A framework for understanding undergraduate research is shown in Figure 1 below (modified from Healey et al, 2014). Here, four categories of the relationship between students and research are identified. The figure emphasizes that students may become producers of knowledge and not just be consumers of knowledge.

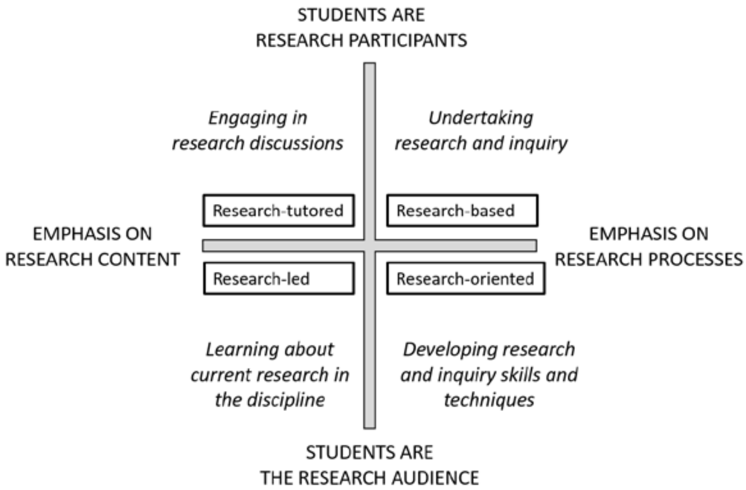

Figure 1. The nature of undergraduate research and inquiry
(modified from Healey et al., 2014)

The above figure classifies four ways in which students may interact with research. All four ways are valid and valuable and education should apply all of them (Healey et al., 2014).

The CDIO syllabus is a list of knowledge, skills, and attitudes desired of engineering graduates (Crawley et al., 2014). The syllabus embraces all four ways of students/research-interaction. Part 1 of the syllabus focusses mainly on research content, e.g. Part 1.2 (Core Engineering Fundamental Knowledge). To ensure the CDIO learning outcomes in Part 1, the left side of Figure 1 should be emphasized. Part 2 of the CDIO syllabus focusses on research processes and problems through learning outcomes regarding personal and professional skills and attitudes. Examples include Part 2.1 (Analytical Reasoning and Problem Solving - also called “engineering thinking”) and Part 2.2 (Knowledge Discovery). At the third level of detail in the CDIO syllabus, other examples include Part 2.1.1 (Problem Identification and Formulation), Part 2.4.4 (Critical Thinking) and Part 2.2.1 (Hypothesis Formulation). These learning outcomes are ensured through an emphasis on activities placed at the right side of Figure 1.

Purpose

The purpose of this article is to develop a conceptual model for research-based education by understanding the various channels through which interaction between engineering education and engineering research can take place.

Method

This study develops a model for research-based education through a case. By utilizing an explicit case it is expected that the model will provide greater practical value. The VIA University College Engineering Department was chosen as the case because it is in a period of significant change with respect to research and because of the authors’ intimate knowledge of the Department. This article first describes several aspects of the Department. The aspects described are the institutional organization, the engineering programs offered, the identity of the staff and students as well as the engineering research and development activities. Then the article develops a conceptual model for research-based education seen from the point of view of a Danish University College Engineering Department. Finally, the article discusses research-based education in light of the model.

CASE STUDY – VIA ENGINEERING

Organization of the institution

To promote a good interaction between research and education in an educational institution, it is important to consider how the institution's organization affects this interaction. In general, research and education may be mixed together in departments in individual fields or they may be separated in two silos since excellence in research and didactic competences is not always found in the same individual staff member. Since the immediate goals of research and education are different, antagonism between these two parties can appear.

The term "interaction" is used frequently in this article. This is to emphasize that the quality of research, as well as the quality of the education, may be improved through close cooperation, rather than advantages flowing unidirectionally from the one party to the other. In other words, both parties can benefit.

At VIA University College, engineering research and engineering educational activities are organized in two silos, each with its own director with staff responsibilities. In this way, the dichotomy between researching and teaching is embraced rather than ignored.

VIA Engineering educational program

The Engineering Department at VIA University College includes seven different engineering disciplines; Global Business, Material Science, Civil, Software, Mechanical, Production and Climate & Supply. Most of these disciplines are provided in Danish as well as in English. There are approximately 1400 students and 110 teachers in the various VIA Engineering programs.

The teaching approach at VIA Engineering is entrenched in problem-based and project-based learning. Students learn through work on realistic engineering problems and projects in close cooperation with companies. Students learn engineering skills and competences through active participation in the classroom and there is a close relationship between the teachers and the students.

The teaching staff is dominated by staff without a PhD degree. In 2015, the University Colleges prepared an action plan with a goal of raising the number of teachers with PhD-degrees to 50%. The great majority of the professional staff are employed as full-time teachers and are not required to undertake research. The authors' experience suggests that this staff, in general, is dominated by an educator identity, with some occupational (practicing engineer) identity mixed in and with very little or no researcher identity. This means that staff identity is in alignment with the staff function.

The student body at VIA Engineering is composed of 62% international students. Some of the students come to VIA with a craftsman background, but the majority come with a high-school degree. Virtually all students can be assumed to have first-hand knowledge or special interest in knowledge of praxis. Since there is not a cut-off level for grades, any student with a high school degree may be accepted. This results in a student body with a wide variety of academic competencies.

VIA Engineering research and development program

In 2017, the Engineering Department of VIA University College had approximately 11 staff (full-time equivalents) employed in research on 31 research and development projects with external financing. This resulted in 35 publications and 16 conference appearances. The efforts mentioned here were assisted by 3 PhD-students. No postdocs were involved.

The typical researcher in the Engineering Department uses 80% of his/her time doing research and 20% teaching. However, a small number of teachers used approximately 10% of their time doing research. The authors' experience suggests that this staff, in general, is dominated by a researcher identity.

The research group carries out applied research in the following focus areas: geothermal energy, geology and groundwater, climate solutions, drinking water, wastewater, corrosion and materials, circular economy, indoor climate and comfort, digital building and augmented/virtual reality. Due to the relatively small size of the research team, it is only able to engage in subject matter from one or two of the engineering disciplines. This means that many of the engineering disciplines are not supported by research in a directly relevant field.

A MODEL FOR RESEARCH/EDUCATION-INTERACTION

In the context of a University College, a conceptual model for visualizing potential interactions between engineering research and engineering education was developed. The model - shown in Figure 2 - shows research and educational activities as two separate silos, with different staff identities and different outcomes. Between the silos, various methods of interaction between the silos are illustrated as numbered arrows. Advantages and disadvantages of each of the numbered interactions are described below.

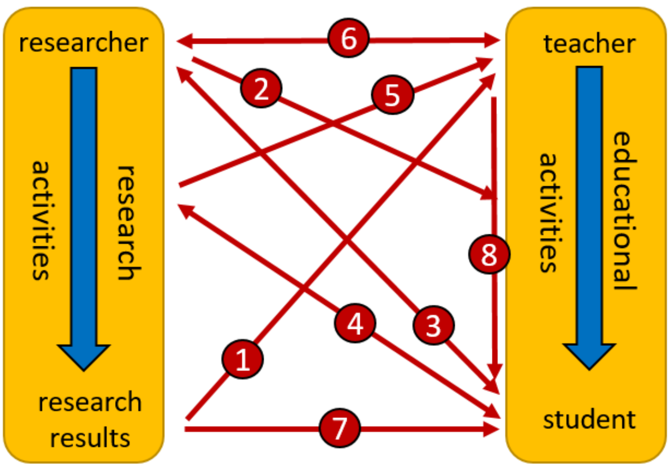

Figure 2. Conceptual model for research/education-interaction at VIA University College.

1. The product approach

A typical understanding of the role of research in education is that research contributes to education by producing results that are then fed into the educational system through the teacher (lower left quadrant of Figure 1). This product approach supports the CDIO syllabus by implementing learning aim 1.2 Core engineering fundamental knowledge.

Here, the research results that are utilized in educational activities include the results produced by the institution’s own researchers as well as results drawn the global pool of engineering research. When considering the institution’s own research results, this approach has a severe drawback in that the learning objectives for the student in terms of knowledge and skills are not in alignment with the research results. In general, the curriculum taught at engineering programs at University Colleges is broad-based and simplified, while research results are typically narrow in scope and highly complex. Therefore, this product approach may be referred to as the classical misunderstanding when referring to the institution’s own research. The product approach is more suited when using the global pool of research. Here, the teacher must sift through the world’s literature to identify parts that are relevant in scope and complexity.

2. Researcher-Teacher

At some instances, the active researcher may also be the teacher. This is an excellent way to impart a structured, inquiry-based scientific method to the students since the knowledge, skills and attitudes of the researcher can be “person-borne” to the students. This is one way to meet the CDIO aim of students gaining competences such as 2.1 Analytic reasoning and problem solving as well as 2.4.4 critical thinking.

At University Colleges in Denmark, the ratio of researchers to teachers is quite small, however, which creates a major challenge for this approach. As seen in Figure 3, the number of courses that can be taught by the active researchers at VIA Engineering is less than 1% of all engineering courses, even if the researchers spend 90% of their time teaching (which entails the risk of lower quality research) and carry a heavy teaching load of 20 ECTS points per semester. In addition, researchers are generally not qualified to teach in all engineering fields and can only support one or two of the most closely related engineering disciplines. It is not expected that the researcher/teacher ratio at VIA Engineering will increase drastically in the near future, as an increase would likely require increased governmental funding.

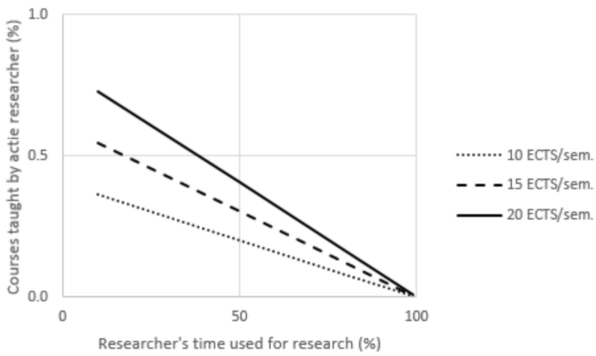

Figure 3. Potential for person-borne teaching by active researchers.

The typical teaching load of a VIA Engineering staff member using 80% of their time as a researcher is approximately one course every semester or one course every other semester. In addition, supervision of one or more semester projects may be included in the teaching load.

In some cases, the teacher does not have to be a researcher employed at the institution in question. For example, students may be invited to participate in a conference which includes platform presentations, posters and possibilities for the students to network with recognized researchers from outside the institution. This approach has been used with success at VIA Engineering and appears to produce a profound effect on the learning as well as the motivation of the participating students.

3. The Humboldtian Exchange

The research-education interaction is a two-way street in which the researchers, as well as the students, can benefit. The German philosopher Humboldt suggests that research and education should take place side-by-side – the so-called "Humboldtian model of higher education" (Andersen, 2004) in order to create opportunities for exchange of knowledge, skills and attitudes. Therefore, the interaction arrow in Figure 2 points in both direction.

In one direction, researchers benefit from the students. This is because students strive eagerly in all directions, as opposed to experienced researchers, who are more one-sided (Andersen, 2004). This keeps the researcher on his toes. In addition, students require researchers to deconstruct their research objectives and procedures and to sharpen their communicative skills. Even if only a small portion of the student body is in contact with a researcher, this contact can be an advantage to the researcher.

In the other direction, students gain insight into research processes through discussions with researchers. This supports students in the CDIO aim regarding engineering thinking and critical thinking competences. This approach also suffers from a scaling-up challenge. The student/researcher-ratio is naturally very large, reducing the breadth of the impact.

4. Student participation in research

In this approach to research-education interaction, the student takes an active role in the production of research results, either in connection with a course or as hired help. This closely resembles the "research-based" category of the research-student relationship defined by Healey (top right quadrant of Figure 1). It provides the student with valuable hands-on experience, changing the student from a receiver of research knowledge (audience) to a co-producer (participant). This approach supports many CDIO competences in terms of personal and professional skills and attributes. It develops the ability to identify problems, create problem formulations and hypotheses, undertake qualitative analysis, as well as to find solutions and recommendations. The advantage of students learning how to learn through inquiry is that this is a transferable skill and is a higher-order thinking at "extended abstract" level of SOLO taxonomy.

The success of student research depends highly on a creative environment where the students learn by inquiry. This is a process approach where the scientific way of thinking is in focus as opposed to a product approach where the research results for a specific subject matter is in focus.

Figure 2 shows that this approach has a double-headed arrow since the research carried out by the student has at least the potential to be an advantage to the research efforts of the researcher. At VIA Engineering, student research efforts have in several cases, for example, provided results which allowed the researcher to write a more qualified funding application.

This approach requires the existence of projects that are relevant to the student's field and work hours from a supervisor. The approach is often thought to be even more suitable for master's degree students than bachelor's degree students and is naturally the basis for research carried out by PhD students.

5. Teacher involvement in research

At University Colleges, teachers without research training may be included by the staff employed as active researchers in research activities. In this way, teachers gain insights that may be useful in their teaching activities in which research processes and problems are emphasized as already mentioned in approach 2.

Similar to the student research approach, hands-on research experience provides teachers with opportunities for participating in an inquiry-based learning environment, for becoming familiar with cutting-edge results, for practicing written communication skills, etc. For teaching staff to support the CDIO syllabus it is necessary for teachers to possess competences such as problem formulation and critical thinking themselves.

This approach of teacher involvement in research projects has the added advantage of providing cohesiveness between staff groups where research and education are organized in separate silos. This approach also helps researchers avoid the "ivory tower" syndrome and learn about the educational challenges facing teachers – and may even become inspired to write a needed textbook or the like.

6. *Cooperative dialogue*

In instances where the teacher and the researcher are two different people, opportunities for dialogue are provided by working together on common projects outside of the field of research. Examples of such cooperation that the authors have been involved in at VIA Engineering include designing new courses, preparing guidelines for student project work and testing various didactic methods. Each party can learn from the other, creating a win-win situation. This approach is relevant for developing interpersonal skills such as teamwork and communication in the CDIO syllabus. It is easier to support these competences among students if the teaching staff also possess these competences. A challenge for this method is aligning scheduling demands between the researcher's project and the teacher's educational activities.

In addition to formal cooperation, informal meetings between the teacher and the researcher can provide mutual inspiration. For example, one of the authors recently experienced that a teacher identified a potential solution to a troubling research problem during a 15-minute discussion over lunch. A physical framework that encourages informal meetings (such as a common area for coffee breaks) is therefore seen as an advantage.

7. *Student literature searches*

The student does not need to be limited by the researcher and teachers at the local educational institution but may use search engines to search the literature from the entire world for relevant research results. This approach suggests that engineering educations should be built on disciplinary knowledge and reasoning. The fact that students have access to worldwide research makes this approach possible to be used by all students. The CDIO syllabus emphasizes the importance of engineering students of critical thinking and prioritizing among endless amounts of research.

8. *Teacher development*

Due to the low active researcher - teacher ratio at VIA Engineering, it is essential to have a teaching staff with some level of research competences, even though they do not carry out research in their daily work. To support students with competences as stated in the CDIO syllabus, such competencies such as critical thinking, problem identification and problem formulation, should be possessed by the teachers.

As teachers are often hired directly from an engineering profession, they might not always possess these competences. Consequently, it is essential to build up these competences through supplementary education and opportunities to participate or get insight into research projects driven by the research department.

DISCUSSION AND CONCLUSIONS

As seen in the model in Figure 2, research and education can interact through multiple approaches. In practice, the interaction may also be a mix of above-mentioned approaches. To be of value, these approaches must be prioritized, and selected approaches must be implemented. Which approaches should be prioritized depends highly on the individual institution, including its organization and the identity of the staff and the student body.

In Figure 4, the various approaches in research-education interaction model are subjectively rated as highly suitable (green), partially suitable (yellow) and less suitable (red) for the three parameters, breadth, depth and ease of implementation. Impact breadth is a measure of how many students at the educational institution are likely to participate in the approach. Impact depth is a measure of how profoundly the students are affected, i.e. how much the students learn through participating in the approach. Finally, ease of implementation reflects the cost and effort required to operationalize the approach. It should be noted that additional parameters could be rated to assist in the prioritization of the different approaches.

	Approach	Impact breadth	Impact depth	Ease of implementation
1a	The product approach, local			
1b	The product approach, global			
2	Researcher-teacher			
3a	The Humboldt exchange, researcher			
3b	The Humboldt exchange, student			
4	Student participation in research			
5	Teacher involvement			
6	Cooperative dialog, teachers & researchers			
7	Student literature searches			
8	Teacher development			

Figure 4. Characteristics of the various approaches for research-based education.

It appears that none of the listed approaches has a perfect score of three green parameters. Each approach is unique with respect to impact breadth, impact depth and ease of implementation. It does, however, appear that obtaining an acceptable impact breadth is especially challenging. In this situation, it would seem appropriate to test multiple approaches.

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