

## **Improving the learning outcome of laboratory work in higher education**

Three case-studies from Roskilde University

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## *Improving the learning outcome of laboratory work in higher education – three case studies from Roskilde University*

Jeppe Kari, Thomas Skou Grindsted and Martin Severin Frandsen  
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### 1. General introduction

In recent years a variety of new laboratories have opened at Roskilde University (RUC). In 2011 Experience Lab opened in the Department for Communication, Business and Information Technologies (CBIT). Two years later RUC launched FabLab, a laboratory makerspace intended to support the HUMTEK education, which in 2017 was extended with a BioFabLab focusing on living matter and materials. Most recently, in January 2018, a virtual laboratory has been launched to support a new education program at the Department of Science and Environment (INM). Hence, in a period of 7 years RUC has invested in four new laboratories, which are intended to support laboratory teaching at the university.

To the extent that they are used as educational facilities this investment in new and costly laboratories could be seen as somewhat of a paradox. Research into the use of laboratories in higher education has shown that putting students through laboratory exercises often does not work very well and fails to produce the intended learning outcomes. Students get stuck in technical problems, lose orientation and learning becomes a matter of sticking to a laboratory protocol. As laboratory teaching is generally costly this means a lot of resources are invested into teaching activities that often yield poor results (Johnstone 2006).

In the case of Roskilde University investments in new laboratories for educational purposes, however, might be less of a paradox. As we will account for in the following the Roskilde University model of problem-oriented project learning (PPL) seems to provide a unique and well-tailored institutional framework for the style of laboratory teaching and learning that is promoted in much of the research literature – namely inquiry and project-based laboratory instruction (Domin 1999, Johnstone, Sleet, and Vianna 1994, Johnstone and Al-Shuaili 2001). A recent study of laboratory work in the natural science bachelor program at Roskilde University supports this claim (Josephsen and Hvidt 2015).

Although Roskilde University might provide a unique institutional setting for high quality laboratory teaching and learning, this does not mean that there is no need or room for improvement – especially as the cost of laboratory work is very high compared to normal ‘class room’ teaching. In other words the development and improvement of laboratory teaching strategies and methods are still highly relevant. At the same time one should be aware of the idea that one style of laboratory instruction – ie. inquiry and project-based learning – fits all learning purposes. Other styles of laboratory instruction styles might be necessary, at least as supplements to, or stepping-stones towards, the ideal model of inquiry-based learning.

This study explores the potential of introducing pre- and post-lab activities as strategies to improve the learning outcome of laboratory work in both a more traditional course setting as well as in problem-oriented project work. The research in

laboratory teaching indicates that the activities done before (pre-lab) and after (post-lab) are a key to quality learning (Reid and Shah 2007). Students learning outcome and engagement is improved if they obtain a sense of the purpose and the principles guiding the design of the experiment through pre-lab activities (Hart et al. 2000). Similar post-lab activities allow students to conceptualize and reflect on the ideas and results developed in the laboratory, which foster higher-order cognitive skills. Hence, there seems to be a clear potential for improvement of the learning outcome of laboratory work by introducing pre- and post-lab activities.

## 2. Methodology and research question

The common research question for the report is *how the learning outcome of laboratory work can be improved by pre- and post-lab activities*. The methodology of the study is inspired by the action research approach to teacher development proposed by Loucks-Horsley et al. (1999) where university teachers develop their own practice through experiments in their own teaching that are assessed by the teachers themselves as well as consultants or researchers from pedagogical university units or centers. We will explore our research question by designing and carrying out three experiments with pre- and post-lab activities: a) the coordination of academic and technological co-supervision of project groups using FabLab facilities in problem-oriented project work on urban design, b) the use of a virtual laboratory in an experimental laboratory course in chemistry, and c) the introduction of a fieldwork as a preparation for using GIS (Geographical Information Systems) in a Spatial Lab. The authors have different scientific backgrounds, coming from chemistry, geography and urban design and planning. Consequently, the case span provides the opportunity to examine the applicability of pre- and post-labs in different types of university laboratories.

The first section of the report presents the common theoretical framework for the analysis of the experiments and case studies. Following the theoretical section we introduce and present the three case studies. In each case study the findings from the individual experiment are summarized. The findings from the three case studies together with the reading of the research literature form the basis of the concluding discussion, which closes the report.

## 3. John Dewey and laboratory work

Discussions of the usefulness of laboratory teaching in science education can be traced back to the early Twentieth Century. In an address to The American Association for the Advancement of Science in 1909 (published the following year), pragmatist and educational philosopher John Dewey raised a number of questions in regard to the effectiveness of laboratory teaching that echoes in the discussions among educational researchers today.

Like others of his contemporaries Dewey was critical towards the textbook method of science teaching and the belief that an existing body of knowledge could be directly ‘transmitted’ from teacher to student. For Dewey science was first and foremost a method of knowing, a process “*by which something fit to be called knowledge is brought into existence*” (Dewey 1910, p. 125). Science teaching had suffered because science had been taught “*as an accumulation of ready-made material with which students are to be made familiar*” rather than “*as a method of thought, an attitude of mind, after the pattern*

*of which mental habits are to be transformed?* (Dewey 1910, p. 122). But contrary to what he saw as a commonplace of scientific instruction, Dewey did not believe that the answer to the shortcomings of “*mere book instruction*” was to just put pupils through some laboratory exercises.

*“A student may acquire laboratory methods as so much isolated and final stuff, just as he may so acquire material from a textbook. One’s mental attitude is not necessarily changed just because he engages in certain physical manipulations and handles certain tools and materials. Many a student has acquired dexterity and skill in laboratory methods without its ever occurring to him that they have anything to do with constructing beliefs that are alone worthy of the title of knowledge”* (Dewey 1910, p. 125).

What Dewey was saying, put differently, was that when laboratory teaching was undertaken as merely an instruction in technical methods it did not in essence differ from the method of traditional textbook teaching. The only difference was that instead of a transmission of an already accumulated and ready-made body of textbook knowledge, what was transmitted to the student was an accumulated and ready-made set of laboratory methods and techniques.

The challenge and difficult problem for laboratory teaching was thus “*to conduct matters so that the technical methods employed in a subject shall become conscious instrumentalities of realizing the meaning of knowledge – what is required in the way of thinking and of search for evidence before anything passes from the realm of opinion, guess work and dogma into that of knowledge*” (Dewey 1910, p. 125-126). In other words in order for laboratory methods and techniques to become a valuable and relevant part of science education they need to be learned and mastered as *instruments and tools of inquiry* – inquiry understood as the process of transforming ideas and hypotheses into knowledge through a process of conscious experimenting and testing. Furthermore, the only way for students to acquire laboratory methods for such purposes is to engage the students themselves in self-directed processes of bringing knowledge into existence:

*“Only by taking a hand in the making of knowledge, by transferring guess and opinion into belief authorized by inquiry, does one ever get a knowledge of the method of knowing”* (Dewey 1910, p. 125).

#### 4. Laboratory work in science education today

Turning to the more recent scholarly discussions on laboratory work in science education it seems Dewey’s thoughts have not lost their relevance. Cutting across several studies one finds the idea that “*the ‘hands-on’ laboratory time*” (Reid and Shah 2007, p. 173) should be seen as part of wider processes of inquiry and learning (Baird, 1990; Hodson, 1993; Reid & Shah, 2007; Hofstein and Lunetta, 2004).

A meta-study by Hofstein and Lunetta (2004) points to two current tendencies that echo Dewey’s analysis. Firstly, according to Hofstein and Lunetta (2004, p. 30) “*inquiry has re-emerged as a central style advocated for science teaching and learning*” promoted among others by the US National Research Council. Alongside the NRC educational researchers like Baird (1990) have argued for “*a radical shift from teacher-directed learning to ‘purposeful-inquiry’ that is more student-directed*” (Hofmeister & Lunetta 2003, p. 31). Hodson (1993) has proposed that “*the principal focus of laboratory activities should*

*not be limited to learning specific scientific methods or particular laboratory techniques; instead, students in the laboratory should use the methods and procedures of science to investigate phenomena, solve problems, and pursue inquiry and interests*" (Hodson 1993, here quoted in Hofstein and Lunetta 2004, p. 31). Moreover, Driver, Newton and Osborne (2000) have suggested the idea of seeing science education as a process of 'enculturation' into science through an experiential learning process of "*weighing and interpreting evidence, thinking about alternatives, and assessing the viability of scientific claims*" (Hofstein and Lunetta, 2004, p. 34).

Secondly, the study by Hofstein and Lunetta indicates, that though the ideal of learning through inquiry may seem to have re-emerged, several studies have shown that in practice teachers and students are often "*preoccupied with technical and manipulative details that consume most of their time and energy*" and that "*limits the time they can devote to meaningful, conceptually driven inquiry*" (Hofstein and Lunetta 2004, pp. 31-32). For example a study by Gunstone (1991) showed that "*students generally did not have time or opportunity to interact and reflect on central ideas in the laboratory since they are usually involved technical activities with few opportunities to express their interpretation and beliefs about the meaning of their inquiry*" (Hofstein and Lunetta 2004, p. 32). Paradoxically, and maybe due to the path-dependency of handed down institutional practices, although science teachers may have embraced Deweyan or more recent constructionist philosophies of learning comprehensive studies have shown, that "*the classroom practice of these teachers did not generally appear to be consistent with their stated philosophies*" (Hofstein and Lunetta 2004, p. 32). To sum up, the challenging and difficult problem of making laboratory methods and techniques, in Dewey's words, "*conscious instrumentalities of realizing the meaning of knowledge*" seems still to be a task before us.

In the following we will examine the challenges of laboratory work in a more detailed and systematic manner by reviewing some types of laboratory instruction styles.

## 5. Types of laboratory instruction styles

In this section we will briefly review 4 types of laboratory instruction styles as proposed by Domin (1999). We will use this taxonomy (see table 1) to categorize the type of laboratory teaching that each of the three case studies draw on. Furthermore, we will use the different types of instruction styles to understand the individual challenges of different types of laboratory instruction and what may be needed in order to address these challenges in our teaching and supervision. We hasten to emphasize that the laboratory taxonomy is developed for chemistry and hence its application in other fields may be criticized. We will return to this point in the discussion. For now, however, we assume that the reviewed laboratory instructional styles are somewhat applicable across fields.

According to Domin (1999) 4 types of laboratory instruction styles exists: *expository*, *inquiry*, *discovery*, and *problem-based*, which can be distinguished by 3 descriptors, *outcome*, *approach*, and *procedure* (see table 1). The outcome of any laboratory activity is either predetermined or undetermined by the teacher. However, the student may not be aware that the outcome is predetermined by the teacher as is usually the case with discovery and problem-based instruction styles. Domin (1999) also distinguishes between inductive and deductive instruction styles. Inquiry and discovery are both inductive in the sense that the students derive or realize a general conclu-

sion (principle or theory) from observations and experiences in the laboratory. Opposing this approach is deduction where students apply a general theory in the laboratory to understand a specific problem or phenomenon. In addition to the outcome and approach Domin (1999) also classifies laboratory instruction styles according to the procedure of the laboratory activity. This procedure can either be provided by an external source (the instructor, a laboratory manual) or designed by the students themselves.

**Table 1. Description of the laboratory instruction styles\***

Style	Outcome	Descriptor	
		Approach	Procedure
Expository	Predetermined	Deductive	Given
Inquiry	Undetermined	Inductive	Student generated
Discovery	Predetermined	Inductive	Given
Problem-based	Predetermined	Deductive	Student generated

\*Table taken from Domin (1999)

### The expository instruction style

In natural science education the expository instruction style is the most common type of laboratory teaching. The laboratory session is teacher-directed and the topics to be investigated as well as the outcome is given by the teacher in advance. In the laboratory the students follow a manual or repeat the teacher's instructions. The procedure is thoroughly explained in a "cookbook" manner such that the students can finalize the experiment by following the manual/instruction point-by-point. According to Domin (1999) the expository approach to laboratory instruction has been designed such that a large number of students can finalize an experimental activity within a few hours with minimal resources such as time, space, materials and personnel. This type of instruction style has been heavily criticized as it repeatedly has been found that little meaningful learning take place in such an environment (Hofstein and Lunetta 1982, 2004). Another critique is that the instruction style is "*unrealistic in its portrayal of scientific experimentation*" (Domin 1999, p. 543) as students focus more on obtaining the 'correct' result than thinking about the experimental design (Johnstone and Al-Shuaili 2001).

### The discovery instruction style (guided-inquiry)

Like the inquiry-based instruction style the discovery approach is inductive and tries to train students to develop a generalized understanding through the study of a specific example. However, unlike the inquiry style the outcome of discovery-based exercises are predetermined and the teacher guides the students toward the discovery of this (predetermined) outcome. According to Domin (1999) the strengths of this approach is its ability to increase the students engagement in the laboratory work by mimicking the scientific process of experimental work. However, the style has been criticized for being difficult to implement as the students seldom have any experience with the kind of laboratory work that they are expected to do. Hudson expresses this point by saying that "*you cannot discover something that you are conceptually unprepared for. You don't know where to look, how to look, or how to recognize it when you have found it*" (Hodson 1996).

### **Problem-based laboratory instruction**

In a problem-based instruction style the problem serves to guide the laboratory investigations and their outcome. The problem is given in advance but is open-ended such that students have a well-defined goal but no recipe for solving it. This forces the student to think about the aim of the experimental work and take active part in the experimental design. This instruction style intends to train students in being problem-solvers that can create testable hypotheses rather than reporting correct results. The teacher facilitates this process by providing the necessary material for the students to test their hypotheses. This instruction style has been criticized for being time-consuming and be more demanding for both the students and the teacher than the expository instruction style (Domin 1999). Furthermore, Domin (1999) argues that the combination of a student-driven procedure and a deductive approach creates a need for a pre-laboratory session since the students need prior knowledge of the experimental methods before entering the laboratory.

### **Inquiry (Open-Inquiry)**

The inquiry instruction style is inductive and has an undetermined outcome that requires the students to design their own procedures. Inquiry-based activities are student-driven which give the students much more responsibility and ownership over the laboratory activity. If done properly, this instruction style contains a big learning potential as it fosters higher order cognitive task during the laboratory work (Domin 1999). The strength of the instruction style is, however, also its weakness. The highly student-driven procedure demands that the students have the required knowledge to critically engage in the laboratory work. This in turn puts a lot of pressure on the teacher which not only needs to determine how much content knowledge the students need, he or she also needs to secure that the students have obtained this knowledge prior to the laboratory work. For this reason it has been pointed out by Johnstone and Al-Shuaili (2001) that inquiry-based laboratory work is impractical at most universities.

In the following we will highlight two strategies that may be used to move from a teacher-directed and close-ended laboratory instruction style, to a more open-ended and student-directed instruction style.

## **6. Pre- and post-laboratory activities**

In an attempt to improve the learning outcome of traditional laboratory work, Johnstone, Sleet, and Vianna (1994) proposed a simple information processing model of learning to guide the design of effective laboratory exercises. The authors' hypothesis was that students are subjected to a torrent of unfamiliar information in the laboratory that overload the working memory space and leave little room for cognitive processing. In a recent review Johnstone expresses this point: *"Written and verbal instructions, unfamiliar equipment and chemicals, observing and recording; all these together occupied Working Memory Space leaving no room for cognitive processing. Students, in an effort to reduce the discomfort of the overload, used the written instructions as a 'mind-in-neutral' recipe"* (Johnstone 2006, p. 58).

Unlike the expert that is able to filter out relevant information, the novice student seldom has the experience to distinguish between essential and peripheral laboratory information. Hence, Johnstone and co-workers introduced pre-

laboratory exercises to reduce the information overload by preparing “students to take an intelligent interest in the experiment by knowing where they were going, why they were going there and how they were going to get there” (Johnstone, Watt, and Zaman 1998, p. 25). There are many examples of pre-laboratory exercises but common for them all is that they take place before the laboratory session and prepare the student to be an active participant in the laboratory (Reid and Shah 2007). For this reason, teachers need to plan the pre-laboratory exercise according to the intended learning outcome of the laboratory work. Quoting Johnstone (2006, p. 47), “teachers have to determine how much content knowledge is necessary for learners to be able to engage mentally with a particular investigation and to what extent students have acquired this prior to beginning a task. This is the essence of what Johnstone means by Pre-Laboratory work”.

Pre-laboratory exercises have been found effective in improving students’ performance in the laboratory as well as their learning outcome (Johnstone, Watt, and Zaman 1998, Johnstone, Sleet, and Vianna 1994). In the latter study the authors also found that pre-laboratory exercises were particular effective for open-ended mini-projects (Johnstone, Sleet, and Vianna 1994). This observation is an important finding since an inquiry laboratory style with open-ended laboratory exercises generally is difficult to carry out in practice (Reid and Shah 2007, Hofstein and Lunetta 2004, Domin 1999). The findings by Johnstone, Sleet, and Vianna (1994) indicate that pre-lab may be an important tool to facilitate an inquiry-based instruction style.

### Post-laboratory exercises

In contrast to pre-laboratory exercises post-laboratory exercises serve the purpose of making sure that the laboratory experience is linked to existing knowledge and understanding (Johnstone, Watt, and Zaman 1998). It is important that post-laboratory exercises are aligned with the pre-laboratory and laboratory work such that they become meaningful for the student and enables the student to use higher order cognitive skills (Reid and Shah 2007). Hence, Reid and Shah (2007) have emphasized the need for post-lab activities that train students to plan and design their own experiment and apply the idea they have just learned in new setting.

## 7. Overview of the three case stories

Since the authors have different scientific background, the basis of the three case stories are very different. In table 2 we have listed course form, laboratory type, initial instruction style and intended instruction style.

Table 2

Case	Form	Lab type	Initial style	Intended style
1	Project	FabLab	Inquiry	Inquiry
2	Course	Research lab	Expository	Problem-based
3	Field course	Spatial Lab	Discovery	Inquiry

As shown in table 2 the initial laboratory instruction style was different in all the three cases. Thus, each of the three experiments were faced with different challenges in their respective use of laboratory work. To improve the intended learning outcome the experiment in case 2 and 3 tried to modify the initial instruction style



with the aid of pre- and post-laboratory activities. In all cases the experiments either aimed at changing the procedure (given→student-generated) or the approach (deductive→inductive) to a more open-ended instruction style that resembles the type of laboratory work that is done by researchers.

## 8. Case 1. Co-supervising the use of FabLab facilities in problem-oriented project work

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### Introduction

This case study will document and reflect on an experiment to improve the learning outcome of using FabLab facilities in urban design and planning projects at the Humanities and Technology (HumTek) bachelor program at Roskilde University. To improve the students' learning outcome I attempted to co-supervise problem-oriented project work together with a 'technology guru' from the FabLab through all phases of the project from initiation to completion and evaluation. Through the co-supervision process I attempted to deal with problem that there most often not is any direct communication between supervisor and Fablab gurus during project work on HumTek and hence the learning potential of doing laboratory work is not fully explored.

My research question is thus: *Can co-supervision improve the learning outcome of using FabLab facilities in problem-oriented project work at HumTek?*

### Problem-oriented project work in Design and Construction

HumTek is a transdisciplinary program that cuts across design research, technology studies, social science and the humanities. The core of the program is defined through three so-called dimensions – Design and Construction, Technological Systems and Artefacts and Subjectivity, Technology and Society. The first semester in the program focuses on Design and Construction, the second on Technological Systems and Artefacts and the third on Subjectivity, Technology and Society. After the three first semesters the students branch out in different and more specific subject modules and disciplines (Blomhøj et al. 2015)

The program rests on the pedagogical model of Roskilde University – problem-oriented project learning (PPL) – where half of the study program is dedicated to problem-oriented project work, while the other half consists of more traditional courses and workshops. The key principles of PPL are: project work, problem-orientation, interdisciplinarity, participant control, exemplarity and group work (Andersen & Heilesen 2015). Thus on each semester on HumTek the students do participant-directed problem-oriented project work in groups that runs for 5 months and deals with exemplary objects of investigation for the academic field in question. In the first semester the project work has to cover the field of Design and Construction as the compulsory dimension and one of the two others dimensions as optional choices.

According to the study regulation the Design and Construction-dimension is “rooted in a design science tradition and focuses on the development and evaluation of systems, processes and artifacts.” The dimension in particular draws “on theories and concepts in design and architecture as well as philosophy of science issues related thereto, focusing on methods

and tools that aim to support and organize design processes”. In extension hereof the learning objectives for the first semester project work are formulated as in the table below (table 3).

Table 3

Knowledge:	<ul style="list-style-type: none"> <li>• about basic methods, theories, concepts and issues within the dimension of Design and Construction.</li> </ul>
Skills:	<ul style="list-style-type: none"> <li>• in setting up a problem and performing project work involving the Design and Construction dimension in conjunction with another dimension.</li> <li>• in conducting an analysis of design and design needs, and suggest a solution to a design problem.</li> </ul>
Competencies:	<ul style="list-style-type: none"> <li>• to organize, orchestrate and evaluate design processes, including prioritizing resources and time usage, and delivering design solutions within a limited timeframe.</li> <li>• to participate in project collaboration in connection with group formation, topic selection, problem formulation, information and literature search, report writing and evaluations, including demonstrating project management knowledge.</li> <li>• to account for and evaluate the design and work processes that are part of the project work and describe their own learning processes during the course of the project.</li> </ul>

As part of the project work the student groups have to develop a design proposal and to document the theory, analysis and iterative development process behind the final proposal in a written report. Within this very broad frame students can choose to work with designing a diverse array of artefacts and systems – from software user interfaces, robot technology, performances and computer games to health care technologies, ‘green’ technologies and energy systems and, as is the case in this study, urban designs.

## Fablab RUC

Since the HumTek program was launched RUC has provided hands-on and digital fabrication workshop facilities for students. In 2013 these facilities were formalized in the shape of a FabLab that works as an open learning facility for HumTek students as well as students from other programs at RUC (Haldrup et al. 2018). The FabLab labels itself a “*rapid prototyping laboratory and digital production workshop*”. The laboratory is equipped with a range of digital production machinery for laser cutting, CNC milling and 3D printing and the ambition is “*to be able to make (almost) everything*” (Haldrup et al. 2018, p. 330)

In relation to urban design the FabLab to some extent works as an architectural design studio in the classical sense, where the students can develop digital drawings and small-scale models of urban designs. But the particularity of the FabLab as a design laboratory is the possibility of rapid production of smaller-scale prototypes that can be tested in ‘natural’ and real life settings: “*... users are able to fabricate truly functioning prototypes, artefacts and installations to be explored and examined in a diversity of use situations and contexts. Enabling users to experiment with fully functioning prototypes creates an explorative space for evaluating and reflecting on actual users performances and interactions with*

*technological installations and objects that moves beyond what may be anticipated from a purely conceptual design process”* (Haldrup et al. 2018, p. 333).

When it comes to the laboratory teaching and learning style developed and advocated by FabLab RUC, the laboratory promotes a radical form of student-directed, non-hierarchical, explorative and open-ended inquiry. In this sense one could speak of an atypical and extreme case in comparison with more traditional university laboratories:

*“Through the years, a set of core pedagogical principles have materialized... The first and foremost principle is that students do not have to justify their reason for using the lab. All students have access and are free to use the machines. There is not a complex, formal, test-based certification system, but rather apprenticeship and learning by doing. Non-dangerous machines can be used after perusing guides on our online tutorials. Unlike most comparable workshops, there is no booking system. This deliberate ‘inefficiency’, is a central idea in providing the ‘bizarre bazaar’: we want to foster a vibrant, creative and collaborative community”* (Haldrup et al. 2018, pp. 330-331).

The lab is run by so-called ‘technology gurus’ – a term commonly used in the international FabLab community. Rather than being technical experts in a narrow sense, the gurus work as *“multidisciplinary specialists, capable of getting students started on projects from programming to windmills to biotech. The guru is used as a concept to facilitate opening the mindset of the users in the Fablab to think of it as a space of exploration and wonder, where they can seek guidance on multiple levels from ideation, design iteration to concrete technical challenges”* (Haldrup et al. 2018, p. 331).

Students on HumTek doing project work in Design and Construction can thus seek and apply for guidance from a technology guru to develop, construct and test their ideas and design proposals.

## Teaching and learning problem

Students who choose to use FabLab facilities in their project work on Design and Construction receive teacher supervision and guidance from both their ‘normal supervisor’ and the technology guru. Although the role of the supervisor and the guru sometimes overlap there is a more or less distinct division of labor.

The supervisor is a researcher and expert in specific subject fields and disciplines as well as being an expert in problem-oriented project supervision. It is the supervisor’s responsibility to guide the project group through the overall inquiry and design process from problem formulation to evaluation of the final design proposal. The supervisor also guides the students through their work with the written report and finally also assesses whether the project and the students have met the intended learning objectives. The technology guru in turn instructs and guides the students on the use of machinery in the FabLab and the construction of prototypes, installations and technical artefacts. As mentioned the guru is however not only a technical lab instructor but also facilitates the creative use of the FabLab and the development and test of ideas and designs through prototyping.

As noted earlier in the section 6 studies have shown that prelab activities are especially important in more student-directed, open-ended and inquiry types of labo-

ratory teaching and learning to avoid cognitive overload and that students lose orientation and sense of direction when working in laboratories – in others words students need to have an idea of “*where they were going, why they were going there and how they were going to get there*” for laboratory work to be an effective part of inquiry (Johnstone, Watt, and Zaman 1998). Seen from this viewpoint the very open-ended and explorative pedagogical principles developed in the FabLab could run the risk of leading to a lot of ineffective laboratory time at least in relation to what is demanded from the students in the study regulation. As shown in table 3 above one of the learning goals for the problem-oriented project work in Design and Construction is that the students become able “*to organize, orchestrate and evaluate design processes, including prioritizing resource and time usage, and delivering design solutions within a limited timeframe.*” This sets a limit to how much time students can spend on “*the use of hi-tech machinery for creating playful interactions and experiments is an unknown territory*” (Haldrup et al. 2018, p. 331). In other words it is important to strike the right balance between playful explorations of the technological possibilities of the FabLab and the demands for using the laboratory facilities as effective tools in a design and inquiry process.

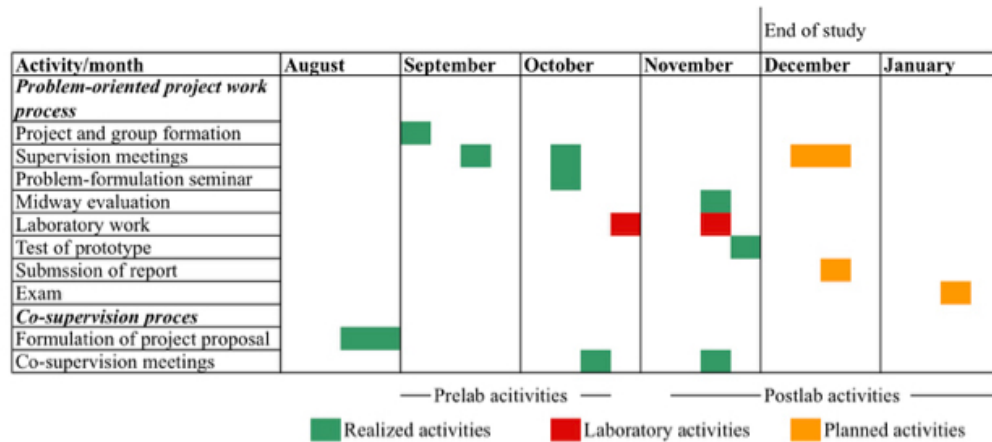
Striking this balance and guiding the students in using the laboratory facilities as effective tools of inquiry in project work is the task of both supervisor and technology guru. At the same time it would seem that this task would be best achieved when there is direct communication and collaboration between supervisor and guru before and to some extent also after the students do their laboratory work. A better alignment of expectations and a common understanding between supervisor and guru would reduce the risk that students spend time in the laboratory that is not productive in relation to the problems they are trying to solve in their projects.

However in practice direct communication and co-supervision between supervisor and technology guru during project work is rarely the case. Although different study directors on HumTek on many occasions have encouraged closer coordinating between supervisors and gurus, the head of FabLab RUC estimates, that direct communication only takes places in 5% of cases (appendix 1). This lack of direct communication has also been the case in my own supervision on HumTek since I started supervising in 2012. The reason for this is probably due to time constraints and the difficulty of coordinating very busy calendars and maybe also a lack of a culture of collaboration between supervisors and gurus. Nonetheless it, in the words of the head of FabLab RUC, is “*a missed opportunity*”, that could “*raise the level of security and professionalism all the way around*” (appendix 1).

### Co-supervising the use of FabLab facilities

To explore the possibilities for improving the learning outcome of using FabLab facilities in problem-oriented project work on HumTek I therefore during the fall semester of 2018 organized a close cooperation with a technology guru to coordinate co-supervision of on or more projects on HUMTEK through all phases of project work from initiation to completion and evaluation. Table 4 shows an overview of the co-supervision process in relation to the ‘standard activities’ during project work on the first semester of the HumTek program.

Table 4: The co-supervision process



In the standard project work process there are a number of mandatory and scheduled activities that support the formation and development of group project work. The project work process is initiated from the start of the semester, where a project formation process organizes a group of around 100-120 students into project groups around chosen problems that the students formulate themselves with guidance from supervisors. After the groups are formed each group is assigned a supervisor which in average is allocated time for 5 meetings that run parallel to the scheduled activities during the semester. After the groups are formed the next phase consists of further developing the problem formulation towards the problem formulation seminar where the projects groups are teamed up in pairs to receive peer-feedback as well as response from a feedback-supervisor. The next scheduled activity is the midway evaluation, which in form is similar to the problem formulation seminar. The student groups are now midway through the semester and have at this point usually completed their courses. The midway evaluation thus serves to ensure that the project is on its due course and the direction is clear before the students embark on the so-called 'intensive project period', where the students can devote all their study time to work on and finish their written project reports.

My experiment with co-supervision added an extra layer to this standard project work process, which is illustrated in the lower rows of table 4 above. Before the project and group formation process I met with the technology guru to formulate two common project proposals as inspiration for the students own project formulation process. During the project work process I, together with the technological guru and the students, coordinated two co-supervision meetings, one before the students entered the laboratory and one after they had completed the bulk of their laboratory work and before they went on to test their prototype in its 'natural setting'. In the following I will outline broadly how the students project work evolved through both the standard activities and the extra layer of co-supervision.

### Formulation of a common project proposal

In the bachelor programs at RUC the project and group formation process is most often opened with a presentation of a variety of brief project proposals for-

ulated by the supervisors that are allocated to a so-called ‘house’ or team of students. The project proposals work “*as inspirational examples on the basis of which the students can advance their own problem formulations*” (Blomhøj et al. 2015, p. 99). As the first step in the co-supervision experiment I met with technology guru Sara Almeida Santos Daugbjerg with the purpose of formulating a common project proposal. Apart from formulating an inspirational example for the students the creation of a common proposal maybe more importantly worked as a means to create a common understanding on how FabLab facilities could be used in a first semester problem-oriented project work focusing on urban design and planning. After considering a number of possible uses of the FabLab we identified two suggestions, which were subsequently written into project proposals. The first proposal outlined a suggestion for working with urban prototyping, and the second proposal outlined the possibility of working with what we termed ‘data driven studies of urban life’ (appendix 1).

## Prelab activities

In the group formation process, maybe partly inspired by the project proposal on urban prototyping, a group of students found a common interest in working with the area around Søerne (The Lakes) in Copenhagen. After the formation of the project group a period of one and a half month followed with project work, standard supervision meetings, problem formulation and finally the first co-supervision meeting before the students entered the laboratory. All of these activities together constituted the prelab activities (see table 4).

To begin with both area as well as the problem formulation was very vaguely defined. After touring the area the group decided to narrow down their area of investigation to Dronning Louises Bro (Queen Louise’s Bridge) that crosses the lakes and connects the inner part of Copenhagen with the neighborhood of Nørrebro. The bridge was designed in the second part of the 19<sup>th</sup> century in a historicist style inspired by the bridges over the river Seine in Paris and has recently undergone a renovation (Appendix 1). Still the formulation of the problem was quite vague, but in the course of the various project development and prelab activities the problem definition gradually become more clear and defined. After the recent renovation of the bridge especially young people had started to use the bridge not as the space of transit that it was designed for, but as a place for gathering and meeting. The problem to be solved was thus how to make the bridge more accommodating as a place of gathering.

After narrowing down this task the project group develop a design proposal that consisted of a long and multifunctional bench stretching along the inner side of the stone bridge railing (se figure 1). The group developed the design as part of an exam assignment for the 1. semester course in Design and Construction. In this way the course activities also became part of the project development and pre-lab activities.



*Figure 1: Visualisation of design proposal. Thea Ulrik Jørgensen, Sofia Dick Graversen, Nina Marie Faarup, Amalie Schon Christensen, Patrick Wüinholt Mølholm & Charlotte Pihl Nielsen*

The first co-supervision meeting took place after this design proposal had been developed. During the meeting it was decided the project group should construct a prototype of a section of the multifunctional bench using a CNC mill. The section of bench should subsequently be tested in use in the ‘natural setting’ of the bridge.

### Laboratory work

The construction of the prototype in the FabLab took place during a week of intensive work. The students used a laser cutter to first make a prototype in cardboard, then made drawings in CorelDraw and SketchUp before fabricating the different sides of the bench in the CNC mill. The different sides of the bench were then assembled (Appendix 1).





*Figure 2: Constructing the prototype. Photos: Thea Ulrik Jørgensen, Sofia Dick Graversen, Nina Marie Faarup, Amalie Schou Christensen, Patrick Wiinholt Mølholm & Charlotte Pihl Nielsen*

## Postlab activities

After an intensive week of laboratory work the students had to prepare a written presentation for the midway evaluation. At this point in the process the project work started to move into the post-lab phase although the prototype was not entirely finished. As part of their written presentation for the midway evaluation the students started to write up and reflect on their experiences from the laboratory work (Appendix 1). Shortly after the midway evaluation the second co-supervision meeting was held. This time the topic of the meeting was how the prototype could be tested on Dronning Louises Bro and which strategies for observation the group could try out. After the meeting the group painted and install LED-lights on the bench and in the subsequent week they installed and tested it on the bridge. At this

point in the project this study had to be finalized and the results from the test are thus not included as empirical data (see table 4).

## Findings from the experiment

As stated in the introduction to this case study, the research question behind the experiment with co-supervision was: *Can co-supervision improve the learning outcome of using FabLab facilities in problem-oriented project work at HumTek?* The hypotheses guiding the experiment was thus that direct communication and co-supervision between supervisor and technology guru would create a more effective use of FabLab facilities as tools in an inquiry and design process. As the experiment and case study had to be finalized before the project work had run its completion the findings from the experiment must be seen as preliminary.

The formulation of a shared proposal for the project formation process contributed to an alignment of expectations between supervisor and technology guru and a common understanding on how FabLab facilities could be used as tools of inquiry in problem-oriented project work on Design and Construction. This meant that coordination between supervisor and guru during co-supervision meetings ran very smoothly. As the student project group were first year students, they had no prior experience with guidance from either supervisor or guru to compare with. Nonetheless answering a mail questionnaire they reported that the co-supervision meetings had been “*good and constructive, and there has been a good co-ordination between the two supervisors*” (Appendix 1). They at the same time suggested that the co-supervision could have been further improved if there had been “*more co-supervision between the two supervisors during our FabLab / construction process – in other words that we could also have received guidance from our project supervisor about the design work in FabLab*” (Appendix 1).

Judging from the midway evaluation (appendix 1) and the students reports (appendix 1) it seems fair to say, that the students have acquired a clear picture and idea of how FabLab techniques such as laser cutting and CNC milling as well additional techniques can be used as tools of inquiry in a research based urban design process. As formulated in their own words the purpose of their laboratory work was to “*build a prototype of our product to take to Dronning Louises Bro to do field studies, and to work with rapid prototyping to start our field work quickly. To get an insight into how “research through design” works*” (Appendix 1).

To sum up the overall and preliminary findings from the case study were that co-supervision as part of pre-lab activities contributed to an effective and productive use of FabLab facilities and a clear sense of the purpose and potential of using FabLab among the students. In relation to the learning objectives (see table 3) it seems fair to say that the process contributed to the development of skills on how to use FabLab facilities as tools in the development “*a solution to a design problem*” as well as the development of competencies in “*prioritizing resources and time usage, and delivering design solutions within a limited timeframe.*”

## 9. Case 2: Application of virtual laboratories in a biochemical laboratory course

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### Introduction to the course

The course “Methods in biophysical chemistry” is an elective course, offered at the master program in chemistry. The course is a combination of lectures, laboratory and report work through which the students are presented to different experimental methods in chemistry. In figure 3, the intended learning outcome of the course is given. As seen from the figure the course aims to give the student skills in problem-solving, analysis, interpretation and cognitive competences in critical thinking and evaluation. The experimental part of the course is central as more than half of lessons take place in the laboratory or consists of working with experimental data obtained from the laboratory exercises. During the course the student work together in groups of 2-3 persons and apply various chemical techniques to experimentally characterize different biomolecules. At the end of the course each group hand in a report for each of the laboratory exercises. These reports form the basis of an oral examination in which student need to demonstrate that they can apply different techniques, analyze the obtained experimental data and interpret the results

Knowledge of
<ul style="list-style-type: none"> <li>• Different techniques available in biophysical chemistry.</li> <li>• Fundamental laws determining structure and function of biomolecules.</li> <li>• Macromolecules.</li> <li>• Role of water in biophysical processes.</li> </ul>
Skills in
<ul style="list-style-type: none"> <li>• Problem-solving, independent learning and the application of methods to solve unfamiliar problems.</li> <li>• Analysis of own experimental data and interpretation in terms of physics-chemical models.</li> <li>• Presentation of research literature.</li> </ul>
Competences to
<ul style="list-style-type: none"> <li>• Choose between different experimental techniques in solving a specific problem.</li> <li>• Be critical of techniques with respect to challenges and accuracy.</li> <li>• Use and understand fundamental basis for techniques.</li> </ul>

*Figure 3. Intended learning outcome of Methods in Biophysical Chemistry as described in the course description.*

The content of the course is divided into two parts covering physicochemical methods (first part) and biochemical methods (last part). The author of this study teaches the latter part of the course. The curriculum in the biochemical part of the course cover different aspects of enzyme kinetics. This topic is known to be a challenge for students as it is a highly interdisciplinary field, which require both mathe-

matical, biological and chemical skills (Skriver et al. 2016). The laboratory flow can be divided into four parts: preparation, experimentation, analysis and modelling. Preparation and experimentation takes place in the laboratory where the students prepare solutions, setup the experiment, conduct the experiment and collect the results. The two other parts (analysis and modelling) are done in the classroom. The students analyze the obtained data and fit the results to different biochemical models. The analysis and modelling are done in groups and form the basis of a report, which each group will hand in 4 weeks after the last day of class.

## The didactic challenge

Previously the laboratory work has been following an expository instruction style where the students followed a point-by-point laboratory manual. As explained in section 5 this type of instruction style has been heavily criticized for its poor learning outcome and little emphasis on thinking (Domin 1999, Hofstein and Lunetta 1982, 2004). Furthermore, when students are not forced to reflect upon what they are doing in the laboratory they take little intelligent interest in the experiments (Johnstone, Watt, and Zaman 1998). The pitfalls of the expository approach can intensify if the students do not prepare for the laboratory work because students use the manual as a “*mind-in-neutral*” recipe to reduce the information overload (Johnstone 2006). This analysis is in agreement with my own experience as teacher at the course in 2017. For instance, many of the students did not read the laboratory manual prior to the laboratory work, which probably reflects that the students regarded the manual as “cook-book” which did not make much sense outside the physical laboratory. The evaluation result from the 2017 course (see figure 4) also showed that many of the students felt that they were not sufficiently prepared for the laboratory work and that the time spent in the laboratory was too short.

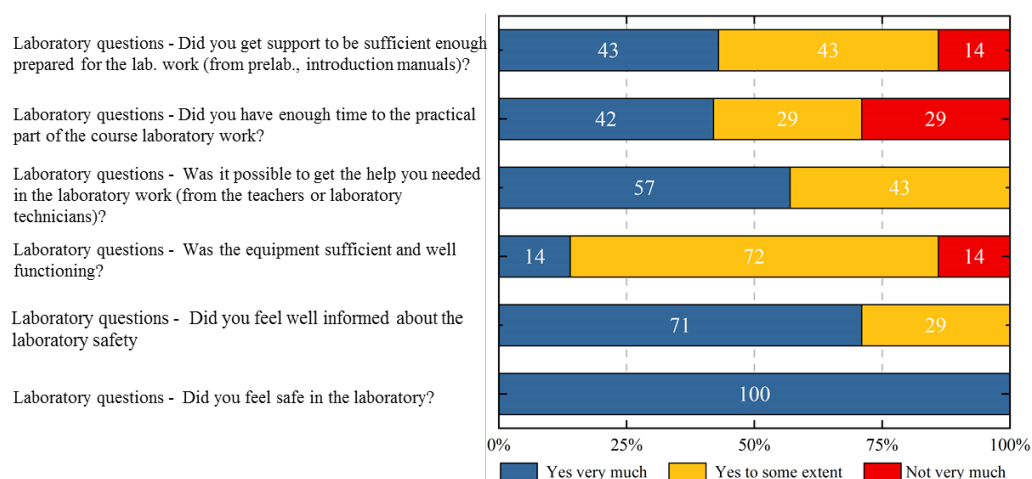


Figure 4. Course evaluation in SurveyXact 2017. Only the results concerning the laboratory work is shown.

Taken together these results stress the need for some modification of the laboratory instruction style. However, several aggravating circumstances complicate a

simple shift in laboratory instruction style. Firstly, the highly advanced instruments and materials that are used in the course, are very expensive and pose real safety risk if not handled properly. Hence, students cannot freely design experiments and test new ideas during the laboratory session. Secondly, the experiments need to be finalized and the data collected during the 3 hours that is allocated to each laboratory exercise. This creates a need for highly organized and well tested exercises where materials and instruments are prepared and tested prior to the laboratory work. In that context the “cook-book” approach becomes a tool to get the job done with minimal expense.

Although the previous laboratory work did not foster higher order cognitive skills in the laboratory, one cannot conclude that the overall course failed to meet its intended learning outcome. The course has been planned such that the main learning experience takes place in the post-laboratory section, where the students in groups are forced to reflect upon their experimental work. Thus, the didactic challenge that I have chosen to work with in the current case is *how I can improve the laboratory work within the current structure of the course?*

## Practical approach

The main problem with laboratory work is the expository instruction style, which does not facilitate laboratory preparation and reflection. In an attempt to overcome these challenges, the following modifications of the course were done:

- Introduction of pre-laboratory exercises
- Introduction of a new laboratory manual
- Introduction of post-laboratory exercises

### Pre-lab exercises

Two pre-lab exercises were developed along with two small interactive programs (see appendix 2.III), in order to let the students prepare for the laboratory work. The hypothesis was that the virtual laboratory would enable the students to experiment before entering the laboratory and that this would free some working memory in the following laboratory work. The pre-lab experimentations were guided by both close- and open-ended questions to direct the students towards the kind of knowledge and understanding that could support critical reflection in the laboratory. An example of such a question could be “Use the app called “Enzyme\_kin” to find conditions where you observe steady-state in your simulation” (appendix 2.III). The question intended to help students simulate different experimental setups and design an experiment, which later could be tested in the laboratory.

### New laboratory manual

A new laboratory manual was written in order to make it less like a “cook-book” and more like a guide (see appendix 2.IV). The necessary theoretical (background) knowledge, which was needed for the students in the laboratory, was written in the manual. Further, the point-by-point instructions were significantly reduced and, in some cases, replaced by open-ended instructions. For instance, the students were asked to design some parts of the experiment. The design part of the laboratory

manual was made such that the students could draw upon their findings from the pre-laboratory exercises.

### Post-lab exercises

As a post-laboratory exercise the students were introduced to a virtual laboratory called SimBiology®. SimBiology provides a graphical and intuitive interface, which can be used to setup kinetic models and further analyze and evaluate these models through simulations. One major advantage of SimBiology is that it allows the students to gain insight into simple systems without knowing the deeper mathematical formalism behind the simulation. Hence, it enables the students to combine a conceptual approach to modelling with the quantitative data analysis. In the post-laboratory exercise the students should design their own model and test this against their own experimental data within the virtual laboratory. Hence, the exercise intended to create the connection between theory and experiments in an environment where the students could experiment further and test the implication of their theoretical models. For the post-exercise two videos were made in order to guide the students through some of the technicalities of the software (see appendix 2.I).



Figure 5. Pictures of a student group during the pre-lab, laboratory and post-lab exercises.

## Results

To test the impact of the three modifications made in the course (pre-lab, lab and post-lab) a survey (see table 5) and an interview (see appendix 2. II) was done at the end of the course. The survey was done after the pre-lab, physical lab and post-lab exercise, while the interview was conducted the last day of class before the post-laboratory (but after the pre-lab and the laboratory work). In order to compare with the previous course, the survey was done using the same 6 laboratory questions (see table 5) as the year before. 7 out of 10 students responded, which was the same amount as the previous year. All responses were voluntary and anonymous.

In figure 6 the result from the survey is shown (+) together with the result from the previous year (-). Although the sample size ( $n=7$ ) is too small to draw any sound statistical conclusions there seems to be a clear improvement. If these results are combined with the student interview and my own observations it appears that the three changes improved the outcome of the laboratory work. Especially the pre-laboratory exercises and the open-ended laboratory questions in the new laboratory manual worked very well. Since the interview was done before the post-lab exercise



it is unclear whether this activity improved the learning outcome of the laboratory work.

A challenge that was addressed by the students in the interview, was the technical barrier associated with the pre- and post-lab software. For some of the students this hindered the use of the programs and it was only because these students were a part of a group that they got something out of it.

Table 5. Survey questions

Label	Question
Q1	<i>Did you get support to be sufficient enough prepared for the lab work (from prelab, introduction and manuals)?</i>
Q2	<i>Did you have enough time to the practical part of the course laboratory work?</i>
Q3	<i>Was it possible to get the help you needed in the laboratory work (from the teachers or laboratory technicians)?</i>
Q4	<i>Was the equipment sufficient and well functioning?</i>
Q5	<i>Did you feel well informed about the laboratory safety?</i>
Q6	<i>Did you feel safe in the laboratory?</i>

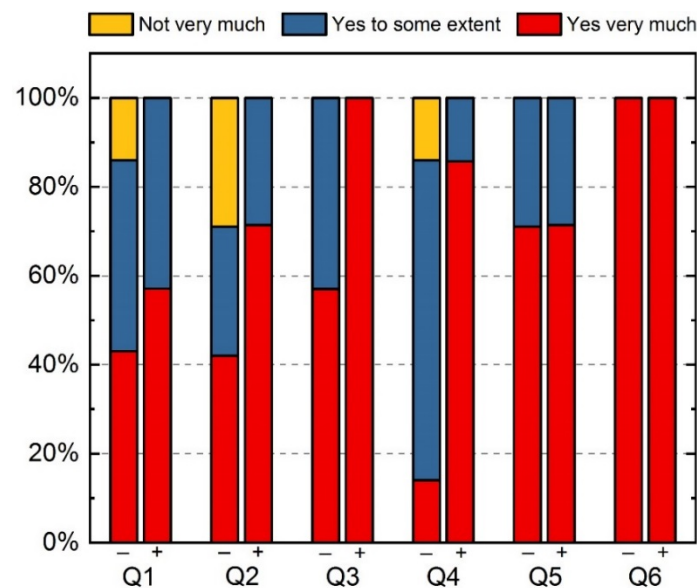


Figure 6. Results from the two survey done in 2017 (-) and 2018 (+). The Labels Q1, Q2, Q3, Q4 and Q6 represent the 6 questions in table 5

## Discussion

Laboratory work has historically been and still is a central part of natural science education. This is partly due to the epistemological conviction of science and partly because natural science is an experimental discipline that requires practical skills. There is a wide acceptance that laboratory work is one of the most essential elements in the teaching and learning of science (Johnstone and Al-Shuaili 2001). However, it is interesting to notice that little justification is generally given for the

presence of laboratory work in natural science education (Reid and Shah 2007). While much research focuses on curriculum and teaching methods, relatively few studies have been done to examine the intended learning outcome of laboratory work (Feisel and Rosa 2005). In a review concerning the role of laboratory work in university chemistry, Reid and Shah (2007) conclude that laboratory work is an important but expensive learning experience, which does not commensurate with the cost in time and material. Similar conclusion was reached by Hofstein and Lunetta that in 2004 published a follow-up study to their original review of the role of laboratories in science teaching (Hofstein and Lunetta 1982). The authors found that despite 20 years of research in laboratory instruction and learning outcome of laboratory exercises, no significant change has been observed in the way laboratory work is used in science education (Hofstein and Lunetta 2004).

Domin has argued that the problem originates from the instructional style of the laboratory work, where the experimental procedures and expected results often are given in advance (Domin 1999). Laboratory exercises generally use a “cook book” approach where the student follows a laboratory manual, which leaves little room for higher-level cognitive skills or metacognitive activities.

In this case-story I aimed to change an expository-based laboratory course with the aid of virtual pre- and post-labs as well as modifications of the laboratory manual. Students responses to these changes were positive and a combination of student interview, post-survey and my own observations indicated that these changes increased the learning outcome of the laboratory work. Especially the pre-lab simulations worked well when they were linked to open-ended questions in the laboratory manual. For instance it was pointed out by the students that the best laboratory exercise was the exercise in which the students were asked to calculate the concentrations needed for the titrations experiments. This forced the students to think about the system that they were characterizing, and many used the pre-laboratory simulations to design this part of the laboratory experiment. All groups used the simulations and not only for the pre-laboratory exercises. During and after the laboratory work the students consulted the simulation to aid their understanding of the phenomena. The application of the simulations was beyond the simple mandatory pre- and post-lab activities, which indicated that these tools were useful for the students. Several technicalities regarding the application of the software hindered some of the students’ use of these virtual labs. It was my impression that some of the students, which were unfamiliar with the application of scientific software, did not use the simulations on their own computer. Hence, the group work was very important for the pre-laboratory exercises as all groups were able to use the simulations since at least one person in the group could use the software. Although the students responded positively towards the pre-laboratory exercises the outcome of the exercises could be improved. In retrospective I should have been more focused on what the students needed to know before they started the laboratory work. If the outcome of the pre-lab had been more explicitly aligned with the laboratory work, the synergy between pre-lab and the actual laboratory work might have been improved.



## 10. Case 3: Spaces of learning – practicing geographical methods through fieldwork as an outdoor laboratory

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### Abstract

Whereas the second case study examined virtual laboratories as a pre-laboratory, the third case examines pre-laboratories both as an outdoor laboratory and as GIS in a Spatial Lab. This third case study concerns an undergraduate geography course entitled “Geography in Practice”. The course aims to introduce students to a number of geographical methods. Each lecture presents a new method. The case study concerned the lecture on business regionalization and a workshop in Spatial Lab. In the following, I first present the course, its form, content and learning goal. Then, I outlay the areas of concern based on my own experiences. Next, the specific lecture and didactical thoughts on fieldwork as an outdoor laboratory in contrast to Spatial Lab follows. Finally I present an experiment that introduces a post- and a pre-lab that may, may not, address issues raised.

### Presenting the course – Geography in Practice

Geography in practice is an undergraduate course that aims to introduce students to geographical methods by acquiring a new method each lecture. A number of dogmas frame the course. First, each method is practiced, not only taught! This implies that a short lecture (approx. 10-20 minutes) introduces the geographical method. Then students practice the method at a given location in Region Zealand. The dogma here is that students work with the method in its right geographical context. A third dogma concern the flipped classroom. This implies that we do not present the reading material, which should have been prepared prior to the lecture. Fourth, each lecture consists of a short introduction, working with the method in the field and at a homework café. A fifth dogma concern student’s ability to reflect personally on their competences acquired, and in this context, competences relevant to employment.

Finally the course ends with a three-day field trip in which the students work with a real-world problem prepared in collaboration with local stakeholders, municipalities, local business associations, NGOs etc. During the fieldtrip students work with one or more of the methods presented during the course. The students present their work to a panel of city representatives and in some cases citizens too. This ends the course.

Besides presenting a new geographical method at each lecture, the learning goals aims to acquire skills that enable them to carry geographical analysis and applying the methods to real-world problems (see box 1 or study regulation).

### Box 1 - Learning goals – Geography in Practice

#### Knowledge:

- Knowledge on basic, geographical relevant fieldwork methods.
- Knowledge on circumstances and limitations to each fieldwork method.
- Knowledge on the umbrella of methods within geographical research.

#### Skills

- Acquire and use relevant methods during fieldwork.
- To be able to create an overview of the literature on geographical methods and acquaint oneself with the methods applicability to a specific geographical context.
- Apply the methods to tangible problems and challenges.

#### Competences

- Competences to use relevant geographical methods in the analysis of complex problems and challenges.
- Competence to plan fieldwork and to conduct relevant data and knowledge production.
- The competence to clearly and precisely circumstances relevant to the geographical analysis, and disseminate its results to non-experts (own translation).

As far as the lecture on business regionalization concerned, it aims to introduce the students to a method that allows one to conduct spatial analysis of physical commercial functions, structures, networks and/or relations. Moreover, the method allows one to produce geographical data on business characteristics (apply a geographical reference either as a point, surface or network to the data collected). This semester (fall 2018), the lecture on business regionalization took place in Mulsicon, an urban creative commercial, recreational cultural-industrial area in Roskilde. The site was selected due to its vibrant and oftentimes Klondike-like commercial activities. Beforehand my co-lecturer and I visited the site to test the method in practice and revise the planned fieldwork exercise. One lecture is given in the Spatial Lab in which we specifically work with digital geodata and GIS. Why this is relevant to outdoor fieldwork methodologies will be elaborated further in the experimental section.

## Areas of Concern

Generally the dogmas, the planning of the course, the structure and learning goals run well. As with any teacher, course and lecture, areas of concern arise. I will present two areas of concern that I have. While the two areas of concern may and may not be linked and commensurable in their own right, the pre-lab and post-lab experiment aims to address both of them. After all a lecture works as an entity.

The first area of concern is that data collection and analysis can be conducted with digital geodata in the spatial laboratory or in the field. One neither needs to go to the field nor spend hours collecting data oneself. One could easily teach business regionalization at campus. So why spend effort and time in the field? Didactical considerations spans activating the field as an outdoor laboratory; and working with the geographical materiality in the field in contrast to working with digital geodata and GIS analysis in the spatial laboratory. Each holds their specific approach in their own right, but serves the learning goals in different ways. While the field as an outdoor laboratory serves as a learning strategy in its own right as many geographers advocate, literately all geographical analysis relevant to urban planning de-

depends on GIS and digital geodata. In other words, there are good reasons for introducing GIS to the students.

The second area of concern is of another sort. Over time I have come to learn that many students come unprepared to lectures. And yet, preparation is essential for learning. In my classes at least 25-50 % of the students tend to come unprepared, evaluation after evaluation informs us. Approximately half of the students recognize they are well prepared, or more or less prepared. This I find deeply problematic in general and for laboratory work and the didactical approach, I wish to undertake in particular. Those students that turn up unprepared may acquire some practical skills, but fail to change mental attitude (they work with a method, material and tool as if a simple cookbook of instructions style obtained after a 10-20 minute lecture). They fail to understand scientific work, the serendipity of geographical research, why they do what they do and for what reason. Understanding scientific work has to do with their own ability to construct and validate the knowledge produced. Having outlaid the areas of concern, my hypothesis is that pre- and post-lab help improving preparation and hence better fulfillment of learning goals as Reid and Shah (2007, p. 179) argue. I will test this through an intervention.

The aim of this case study, is not to find evidence of x, w and z, improving or disproving the quality of teaching and students associated learning outcome. Rather, I adopt the tradition of experience-based practice in addressing the following research questions:

### **Research Question:**

*Can student preparation become satisfactory through pre- and post-labs, and will the outdoor laboratory and spatial laboratory advance learning goals by introducing pre- and post-labs?*

### Supplementary questions:

- How can fieldwork and Spatial Lab work together and what are the didactical concerns?
- Do students' acquisition of methods change by introducing a post- and pre-lab?

### **Situating the laboratory: Fieldwork as an outdoor laboratory and spatial laboratory (Spatial Lab)**

In a recent paper Freiss et al. (2017, p. 547) find that the digitalization of geodata and the use of GIS increasingly happens at the expense of fieldwork. While Spatial Labs access digital geodata in the laboratory, one can undertake spatial analysis without visiting the places under examination. By contrast fieldwork as an outdoor laboratory serve as a learning strategy in which students use all senses to experience an academic problem. Fieldwork encompass an outdoor laboratory, and ones task is to teach geography students to comprehend the field as such (Wall and Speak 2012, p. 422).

Conceiving the field as an outdoor laboratory holds a special didactical as well as scientific approach that is not possible to copy or upscale in the (spatial) laboratory. The contextual elements of the field are catalyzed into the data and learning situations. Henceforth, fieldwork holds a learning strategy that helps students to under-

stand under which contextual and geospatial circumstances the methods applies and needs adjustment. Understanding the circumstances, during which data are produced, is most valuable in order to interpret the spatiality and contextual elements in analyzing such data. Fieldwork as an outdoor laboratory may be characterized as: *“The transference of the laboratory to the field as more than merely upscaling the laboratory. Fieldwork as an outdoor laboratory offers an approach not possible to duplicate at home. The contextuality of the field is actively being involved in data sampling, processing and analysis. From spatio-temporal ‘aba’ erlebnis towards erfahrung”* (Grindsted et al., 2013, p. 19).

As a teacher, I have come to learn that many students find they obtain valuable skills that cannot be learned in a classroom or through a textbook – away from expository-based instruction styles, and toward discovery, problem-based and inquiry instruction styles as Domin (1999, p. 547) and others advocate. Nevertheless many human geographers resist the temptation to work in laboratories, and less to designate the field as an outdoor laboratory.

Seldom combined in courses, fieldwork and spatial laboratories embody their specific domains. In contrast to fieldwork spatial laboratories require computer-aided instructions. When students embark on GIS, Møller et al., (2014, p. 262) discuss how it divides students. For those who don’t have the technical skills, it often-times becomes an intermediate that limits the student’s creative process. A requisite for successful workshops is that students possess certain technical skills. The poorer technical skills the more one needs to compensate to reach the learning objectives and not find students giving up and losing touch with the task. In those cases, technical skills serve as add on, a passive set of tacit knowledge to acquire what is really the aim: mastering geographical methods.

A conversation with Frederik V. Christensen (13.06.18) confirms that much laboratory teaching works quite poorly as many students often run into technical barriers. Such cases reduce laboratory teaching to a matter of following instruction styles. Along these lines, Kongsted (2016, p. 188) like Domin (1999, p. 544) and (Johnstone 2006) suggest that way too much laboratory teaching depends on written instructions, that may improve technical skills, but nevertheless, fail to acknowledge the learning goal. By contrast, one should pay more attention to the learning process, not the techniques, Kongsted (2016, p. 196) suggests. Correspondingly, Frederik V. Christensen finds good laboratory teaching holds a didactical approach in which students know what they do, how and why. Information overload is forbidden. Frederik directed us towards pre- and post-labs, as they increase learning goals. The literature on pre- and post-labs e.g. Domin (1999), (Johnstone 2006), Reid and Shah (2007) confirm this. Likewise literature on geography education find fieldwork enhances the learning potential. Friess et al., (2017, p. 547) suggest, though not framed as a pre-lab, that classical fieldwork is best in terms of deep learning but, that virtual fieldtrips (like virtual labs) in itself also holds potentials. Friess et al., (2017) do not consider virtual fieldtrips, say pre-labs, as preparation before going to the field.

As demonstrated previously, laboratories are expensive, have large running costs, and the learning outcome is often limited as documented by Ma and Nickerson (2006) and Johnstone (1994) among others. Fieldwork is expensive too. This reflects the second area of concern: We simply waste money and time when students

are not well prepared. Designing pre- and post-labs don't matter, if students attend unprepared in the first place.

Preparation is essential to learning and I wish to take this into account in the experiment too. Most studies on assignment reading, Brost and Bradley (2006, p. 101) argue, presume the problem of preparation as student-centered. The time assigned to reading and preparation oftentimes overshoot the time spent in the class. As a consequence Brost and Bradley (2006) made an experiment in which students were required to hand in a written assignment after each lecture. The assignment basically had to give a critique of the lecture, among others based on the reading. I worked this sort of required assignments into the pre- and post-lab experiments.

### Experimenting with pre- and post-labs – the field as an outdoor laboratory

Having students to prepare is essential to the student-centered approach in which I believe. Although homework and preparedness may not apply to pre- and post-labs as described in the literature. Nevertheless, the foremost role of post- and pre-labs is to prepare for the laboratory, hence frame the learning situation.

The pre-lab: consists of a) a representative from Musicon briefly introducing the students to the place, and indicating the relevance of their work, b) a student test of today's reading, c) a mini lecture introducing business regionalization as a method, and d) an introduction to the specific exercise (30 minutes in total). The representative from Musicon coins the authentic learning situation. What is of interest in the pre-lab, is to ensure the students capability of interrogating with the exercise. That they know what to do and why, hence are forced to shift mindset, before they go to the field.

In previous semesters, we stated clearly to the students, that we did not present the reading material. That might have been misinterpreted to some. While I acknowledge no difference from other courses I teach, some students might think, that they may not need to prepare. The intention was the contrary, that so much more preparation is needed, when we expect you to be able to work with your fieldwork method right away.

This semester, we questioned students about today's reading. E.g. questioned about how they believe to conduct business regionalization according to today's reading. Thus, the students know, they're to be questioned about their reading. Randomly, different students were asked detailed questions e.g. how to categorize commercial features in the field according to the text. In terms of reading, this intervention worked well. However, the pre-lab preparation task didn't receive applause. Some found it uncomfortable, as if a test. The purpose, was to be well prepared, but even more to let them prepare and reflect upon the outdoor laboratory exercise.

The outdoor laboratory: During fieldwork, students work in groups of 2-3 persons, under supervision, as suggested by Kongsted (2016). The outdoor laboratory consists of collecting data, adjust the field note protocol in accordance with observations, and making notes that might compromise the planned categorization for analysis. Students produce two maps of the business structure in Musicon (90 minutes).

The first map reflects the student's registration of business features and attributes in the field. The second map is based on digital geodata (CVR). Thus, the second intervention encouraged students to use GIS producing the digital data driven map.

Post-lab: The post lab, consisted of the homework café (120 minutes). Although a voluntarily offer to the students, all participated. Introducing two maps to the exercise, a digital data driven and a fieldwork driven, had a specific purpose. They served as a written assignment. The written assignment consists of the two maps produced, including one page reflecting on the differences between the two maps and their methodological implications. Thus, students do not only work in groups producing the two maps. The real strength of written assignment, is that the students compare and discuss the two different maps in the post-lab. Methodological implications are discussed, and reflected against curricula. E.g. could one acknowledge relations between the urban structure and business structure, as indicated in the reading.

## Results

Pre-lab and post-lab functions well as a frame for preparation. It provides a valuable frame for student learning. The pre-lab setup to improve student preparation, however, did not work well. Or rather, in terms of reading, this intervention worked well. The pre-lab preparation task many students claimed felt painful, having not prepared or if one were unable to answer. Next semester I plan to adjust the exercise, having them prepare a field protocol, or skip the entire task. The post-lab in terms of a written assignment, worked much better, also I believe in terms of preparation. Whether learning objectives were better reached, I cannot say.

Pre- and post-labs are valuable concepts in framing fieldwork and making spatial lab activities and fieldwork come together. Fieldwork as the outdoor laboratory, in which students collect data functions as a pre-lab when the data are brought into the spatial Lab. Likewise, and we actually did that intervention (see appendix 3, case study 3) spatial Lab functioned as a pre-lab to the field trip (outdoor laboratory), when we had an GIS exercise on the urban context (Sakskøbing). But, it's even better bringing digital data into the field.

## 11. General discussion

It seems that laboratory work has started to play a greater role in both courses and projects at Roskilde University as may be seen from the many new laboratories that have been launched the past 7 years. In contrast to this trend is a growing critique of the learning outcome of more traditional laboratory work in higher education (Hofstein and Lunetta 2004). As outlined in the general introduction, laboratory work is an expensive and time-consuming task, which, if not done properly, does not result in any meaningful learning. The obvious contradiction between on the one hand more laboratory work and on the other hand potentially low learning outcome was the common motivation for this project uniting us as researchers and teachers from different academic disciplines cutting across chemistry, geography and urban design and planning.

Inspired by previous studies (Johnstone, Sleet, and Vianna 1994, Johnstone, Watt, and Zaman 1998), which successfully improved laboratory learning by using pre- and post-lab activities, we designed three experiments in our own teaching. In the experiments pre- and post-labs were applied in either course teaching or project supervision.

As both the literature on pre- and post-labs as well as Domin's taxonomy of teaching styles concerns laboratory work in the natural sciences and in particular in chemistry, using this theoretical frame for analyzing experiences with laboratory teaching and supervision in social science laboratory (Spatial Lab) and a design and digital fabrication laboratory (FabLab) is in itself an experiment in transdisciplinarity. We will therefore open the discussion with reflections on whether our chosen theoretical framework is a potentially relevant and fruitful outset for developing teaching strategies across natural science, social science and design science laboratories. Furthermore, we will relate the findings in our experiments and case studies to the overall RUC context, since the unique educational PPL model at Roskilde University intensifies both the opportunities and concerns regarding laboratory work.

### Do Domin's laboratory instruction styles apply to different types of laboratories?

Our overall conclusion from working with and 'testing' the relevance of Domin's taxonomy of laboratory instruction styles, is that the taxonomy makes sense and seems productive across the three case studies and the three types of laboratories. While the taxonomy has been developed within the epistemological borders of chemistry, we found it transdisciplinary and generic in nature, hence applicable so that it can serve to qualify one's teaching practice across different types of laboratories. This finding (experiment driven practice development) suggests that the instruction styles are applicable to other disciplinary labs, and that they may qualify and clarify teaching strategies and methods in the many new laboratories that open on the university campus these years.

When working with and applying the different types of laboratory instruction, an important issue is, to quote Reid and Shah, "*that the university teacher needs to decide which skills are to be developed in a particular laboratory course, to set these out in clear, unambiguous terms*

*for the students, and to ensure that the whole design of the laboratory experience is consistent with the specified skills*” (Reid and Shah, 2007, p.78). In other words the learning objectives should serve as guiding criteria for which instruction style to work with. Although the ideal model may be the inquiry style of laboratory teaching as originally argued by Dewey more than a century ago, one style of laboratory instruction does in our view not fit all purposes. The expository style may for example be relevant, when the students are to learn to handle more advanced laboratory equipment – while it seems easier to move on towards the ideal model of learning through inquiry in less technically complex and more easy to use laboratories. A combination of different instruction styles seems to be the most reasonable solution. In relation to chemistry laboratories Johnstone thus argues for a core of expository laboratories with ‘inserts’ of inquiry:

*“It would seem that laboratories that are totally expository miss some of the desirable aims of laboratory work. Totally inquiry laboratories are probably impracticable in the present situation in universities. A core of expository laboratories with substantial ‘inserts’ of inquiry will go a long way towards achieving the desirable aims of laboratory work.”* (Johnstone, 2001, p. 49).

Although we agree with Johnstone that one should combine different instructions styles, we would argue that “*the present situation*” at Roskilde University allows for more than just “*inserts’ of inquiry*”. As we will return to below the model of problem-oriented project learning allows for a greater role for the inquiry style of laboratory teaching.

## Do pre- and post-lab activities improve learning outcome in all laboratories?

In all three case studies the preliminary findings are, that pre- and post-lab activities improve student learning. Like with Domin’s instruction styles we also believe that pre- and post-labs are relevant as general didactical strategies and methods that can improve learning outcomes outside of natural science laboratories at Roskilde University and elsewhere.

Pre-labs work well as a frame for preparing students for laboratory work while post-labs help the students to process their laboratory experiences and reflect upon these. Hence, in all cases the pre- and post-labs were useful tools to improve the laboratory work. For instance case study 2 found that virtual laboratories served well as a both pre- and post-laboratories and that their use improved the laboratory work when they were aligned with actual laboratory exercise. The intervention in case 3 suggests that Spatial Lab functioned as a pre-lab to the field trip (outdoor laboratory) but also point towards limitations of the pre-lab. Pre-lab exercises properly need to be conceptual and technical simple such that they do not demand much prior knowledge and skills. Otherwise they create the same problem that they were intended to solve, namely to lower the information overload of the students. This observation was also found in case 2 where the technical barrier for applying the pre-lab simulation hindered the overall aim with the exercises.

The experiment with co-supervision of pre- and post-lab activities in problem-oriented project work at HumTek also seems to support the argument put forward



by Johnstone, Sleet & Vianna that pre-laboratory exercises are particularly important in the inquiry style of laboratory teaching (Johnstone, Sleet, and Vianna 1994). When there is very little that is predetermined by the teacher – neither problem, experimental procedure nor outcome – there is a bigger risk that students lose orientation and laboratory work becomes ineffective. Domin thus refers to a study that showed “*that the inquiry approach of the 1960’s placed too much demand on the learners short term memory by requiring students to simultaneously attend to new subject matter concepts, unfamiliar laboratory equipment and novel problem solving tasks*” (Domin 1999, p. 544). A similar argument can be found in Johnstone and Al-Shuaili (2001):

*“The necessity for some kind of pre-laboratory preparation is patently obvious. It applies as much to conventional laboratories as it does to more open-ended and investigative laboratories. A student entering a laboratory without some preparation is likely to spend hours in fruitless, routine handle turning and non-learning. As learning environments, laboratories are very costly in terms of specialist accommodation, consumables, breakages and staff time. If they are not being used for their potential strengths and the time is spent unproductively, they are a massive sink of scarce resources” (Johnstone and Al-Shuaili 2001)*

These findings point to some special concerns for Roskilde University, where the inquiry style of laboratory teaching and learning holds a prominent place.

## Laboratory work at RUC – special opportunities and concerns

As stated in general introduction Roskilde University with its model of problem-oriented project learning seems to provide a unique opportunity structure for using laboratory work in a very effective way. Laboratory work in a PPL context make ‘real’ inquiry-based laboratory work possible (Josephsen and Hvidt 2015). The PPL model however, not only holds special opportunities, but also contains special risks – namely, that laboratory work if it is not supervised and guided properly through pre- and post-lab activities becomes very ineffective.

This points to the need for special concern and care for effective teaching and learning strategies like the pre- and post-labs activities examined here. It also points to the important role of the supervisor and of laboratory staff. It is role of the supervisor and laboratory personnel like the technology gurus in the FabLab to help the student to obtain the necessary knowledge needed to use the laboratory in a meaningful and effective way as a tool of inquiry. An effective use of the investments in laboratories in other words also depends on not only the teaching skills of the supervisor and laboratory personnel but also the time allocated to the important task of supervision. Without sufficient time for project supervision the investments in laboratories as educational facilities will not yield the intended results.

## 12. Conclusion

Through three experiments in our own teaching and supervision at Roskilde University, we have explored the common research question: *How can the learning outcome of laboratory work be improved by pre- and post-laboratory activities?* Our collective findings can be summarized as follows.

In order to improve the outcome of laboratory work it is necessary to align the instruction style with the intended learning outcome of the laboratory work. Pre- and post-laboratory activities can be used to facilitate this alignment if they are designed with this alignment in mind. Well-designed pre- and post-lab activities also need to be conceptual and technical simple such that they do not demand too much prior knowledge of the students. Laboratory work at RUC has a huge potential if done in a PPL context since it allows for a 'real' inquiry-based instruction style. However, this also creates some challenges since it obligates the supervisor to help the student in obtaining the necessary knowledge to engage in the laboratory work in a meaningful and effective way. This is a time-consuming type of supervision but at the same time it holds a unique potential for laboratory work at Roskilde University.

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# Appendix 1

## Projektforslag HumTek BP1

*Martin Severin Frandsen (Plan, By & Proces) & Sara Almeida Santos Daugbjerg (Fablab)*

### 1/ Urban prototyping

I København og andre byer findes der en række eksempler på nye eller renoverede torve og pladser, hvor det umiddelbart efter indvielsen har vist sig, at byrummet ikke fungerede som ramme og scene for socialt liv. Dette selv om der har stået velrenommerede arkitekter bag, og der er brugt mange arbejdstimer og penge på udvikling af designet og anlæggelse af pladsen. En del af forklaringen på de mislykkede pladسدannelser er, at arkitekterne har lavet et færdigt design, som er blevet anlagt uden at blive testet eller afprøvet i praksis og uden at lokale byboere har deltaget i design- og udviklingsprocessen.

Som svar på denne problemstilling er et nyt paradigme for byrumsdesign vokset frem som kan benævnes urban prototyping. Urban prototyping går kort fortalt ud på at udvikle og teste midlertidige byrumsdesign og prototyper som led i en iterativ udvikling af den mere permanente og færdige designløsning. Ofte inddrages lokale byboere i både udvikling og afprøvning af byrumseksperimenterne, og man taler parallelt om urban samskabelse, hvor arkitekter, planlæggere og byboere skaber byrummet i fællesskab.



Med de nye digitale produktionsteknologier i Fablabs og Makerspaces er der åbnet på for yderligere udvikling inden for urban prototyping i form

af, hvad man kunne kalde rapid urban prototyping. I Fablabs og Makerspaces kan man hurtigt og med få midler producere byrumsprototyper, som kan testes i 1:1 forhold i praksis.



I et projekt om rapid urban prototyping kunne I arbejde med analyse af en konkret plads og udvikle byrumsprototyper, som I byggede og testede i praksis i samarbejde med f.eks. lokale byfornyelsesprojekter og lokale byboere.

Link:

[https://www.youtube.com/watch?v=ZG\\_ogpGJNDQ&feature=youtu.be](https://www.youtube.com/watch?v=ZG_ogpGJNDQ&feature=youtu.be)

## **2/ Datadrevne bylivsstudier**

Bylivsstudier er en disciplin inden for byforskningen, der går ud på at studere og observere menneskers adfærd i byen og interaktion med det fysiske miljø. Den danske arkitekt Jan Gehl er i de senere år blevet verdensberømt for sine metoder til at studere byliv og bruge bylivsstudier som grundlag for at designe mere velfungerende byrum.

Som noget nyt er tegnestuen Gehl Architects nu begyndt at bruge digitale data til at indsamle data om menneskers brug af byen. Benchmark, et projekt udviklet af MIT i samarbejde med Gehl Architects, undersøger muligheden for at måle byliv og social adfærd i det urbane rum ved hjælp af open-source software, let tilgængelige sensorer og CNC-fræsede udendørsmøbler. Ved at installere en måleenhed på en række flytbare bænke i en park indsamler projektet data 24/7 om fodgængeres aktivitet,



vejrforhold og fysisk interaktion for at blive klogere på hvordan byrum bruges. Benchmark forsøger med andre ord at vise muligheden ved at bruge nye måleteknologier i samspil med Gehls metoder at studere byens liv.



I et projekt om datadrevne bylivsstudier kunne I arbejde med undersøge folks brug af en konkret plads ved hjælp af mobile byrumsmøbler og digitale måleteknologier, som I selv have lavet i Fablab.

Links:

<http://civicdatadesignlab.mit.edu/projects/BENCHMARK/>

[http://civicdatadesignlab.mit.edu/files/Benchmark\\_Final.pdf](http://civicdatadesignlab.mit.edu/files/Benchmark_Final.pdf)

# Problemformuleringsseminar

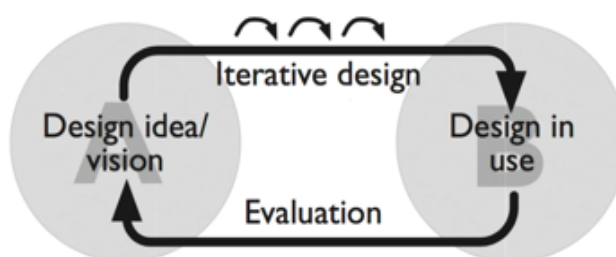
1. semester - efterår 2018

<b>Eksamensgruppe nr. og hus:</b> V1824788563, Hus 04.2
<b>Projekt(arbejds)titel:</b> Søerne i København
<b>Gruppens medlemmer:</b> Patrick Wiinholt Mølholm, Amalie Schou Christensen, Nina Marie Faarup, Thea Ulrik Jørgensen, Charlotte Pihl Nielsen og Sofia Graversen
<b>Vejleder:</b> Martin Severin Frandsen
<b>Dato:</b> 23/9-2018





# 1. Projektemne



(Figure 14.3, p. 207 fra Design Research (2010) præsenteret ved forelæsningen d. 12. september: Introduktion til HumTeks faglighed 1)

Vi har valgt at arbejde med området omkring Dronning Louises bro, der forbinder Nørrebro og Indre By. Vi kunne godt tænke os at skabe nogle attraktive samlingspunkter både på land og i vand. Med udgangspunkt i figur 14.3, udspringer vores projekt fra “B”, fordi søerne og Dronning Louises bro er et eksisterende design. Vi vil derfor evaluere på dette design, med udgangspunkt i vores problemstilling og finde frem til en ny designløsning. Vi vil ikke kunne nå hele vejen igennem figuren med vores projekt, da vi ikke forventer at kunne teste vores designløsninger af i virkeligheden.

## 2. Problemfelt

Søerne i København fylder en stor del af byens centrum. De strækker sig hele vejen fra Frederiksberg til Østerbro og er dermed omdrejningspunkt for en stor del af Københavns byliv. Oprindeligt blev søerne i de mange første år brugt som et vandreservoir for hovedstadens borgere, men det har i gennem tiden ændret sig i takt med fremførslen af nye søer og de mange bygninger der blev bygget omkring dem. Mange af Københavns beboere nyder i dag at sidde omkring søen, da det er et oplagt sted for sociale sammenkomster, pga. dets centrale beliggenhed samt idylliske omgivelser.

Vi mener dog, at mulighederne for at benytte sig af området er begrænsede. Det store areal, som søerne optager, mener vi kan udnyttes bedre da det rummer en masse potentiale. Det område søerne dækker er meget stort og vi har derfor valgt, at vi skal indskrænke vores arbejdsområde og fokusere på et specifikt sted, hvor vi mener, at vi kan skabe de bedst mulige forhold for brugerne.

Søerne har hver deres karakter og særlige præg på byen. Derfor har vi som start på projektet gået en tur rundt om de forskellige søer, for at gøre os nogle observationer i forhold til udvælgelsen af den sø, som vi vil gå i dybden med i vores projekt. Indtil videre har vi gået en tur i gråvej og i solskin for at se forskellen. Vi vil i vores projekt fortsætte med at observere de forskellige faktorer, som er vigtige for at få et indblik i, hvordan byrummet udfolder sig. Vi vil se på faktorer som forskelligt vejr, tidspunkter på dagen, og om det er en hverdag eller weekend.





Vi startede ved Dr. Louises bro som ligger ved Peblingesøen og Sortedamssøen, hvor vi observerede, at området var meget befærdet, i sær på en solskinsdag. Der ligger blandt andet mange cafeer, restauranter og butikker i området, som er med til at skabe en masse liv og flere brugte broen og de omkringliggende arealer som opholdssted. Derudover er det også et af de steder, hvor der er mere støj og flere forbipasserende, hvilket skaber et pulserende byrum. Området er til forskel for nogle af de andre søer, omringet på begge sider af store veje med cykler og biler, der skaber en større fysisk afstand fra beboerne til søen.



Vi gik videre ned til Sankt Jørgens sø, hvor der var en meget anderledes atmosfære. Vi oplevede, at der var mere stille og roligt, sammenlignet med Peblingesøen og Sortedamssøen. På den ene side af søen lå der store villaer langs stien, som alle var afskærmet af buske. Gennem buskene kunne vi ane

haver med terrasser og liggestole. Det gav en fornemmelse af, at de folk der bor der, ønsker ro og privatliv. Derudover var der mere beplantning rundt om søen, der gav en fornemmelse af at være ude i naturen. Det var som at komme ind i en lille oase midt i byen.

Vi bemærkede også, at der var blevet bygget små platforme, på søbredden et par steder, som lagde op til ophold og kunne være en god inspirationskilde til vores projekt.



Vi gik over på den anden side af Dronning Louises bro og videre til Østerbro, hvor det igen er tydeligt at mærke en forskel på byrummet. På denne strækning er der mange der er ude at gå ture eller løbe langs stierne, hvor der er færre mennesker, som vælger at slå sig ned. For enden af søen på Østerbro er der metrobyggeri, som også kan være en faktor der spiller ind, da det af den grund ikke er lige så attraktivt at sidde og nyde udsigten til søen.

Undervejs på vores test-gåtur bemærkede vi hurtigt, at Skt. Jørgens Sø ikke ville passe til det design vi ville producere, grundet dens naturlige og meget æstetiske udtryk. Dette ville ikke korrespondere med vores hidtidige idé, om at skabe et mere bruger-anvendeligt område. Derfor fravalgte vi området omkring Skt. Jørgens Sø.

Udover at observere søerne, har vi været til et borgermøde, der omhandlede at skybrudssikre ved skt. Jørgens sø. Her sad vi i et tætpakket rum, hvor størstedelen udgjorde ældre pensionerede, som alle boede i området omkring Skt. Jørgens sø. Vi fik præsenteret 3 mulige scenarier som i fremtiden skulle sikre mod skybrud. To af scenarierne omhandlede b.la. at bygge et grønt areal ude på søen, i form af en park. Dette vakte stor foragt blandt publikum. Der var ingen tvivl om, at der ikke var



stemning for nogen form for ændringer af søen, og slet ikke ændringer, der ville tiltrække flere mennesker. Efter et to timer langt borgermøde, var der ingen tvivl om, at vi ville møde stor modstand, hvis vi begyndte at bygge et opholdssted, på Skt. Jørgens sø. Dette var med til at bekræfte vores beslutning, om at fravælge søen.

Under vores gåtur til Østerbro fandt vi ud af, at den på mange måder mindede om Sankt Jørgens sø, da der bl.a. er anlagt gå og cykelsti på den ene side hvilket gør, at bebyggelsen ligger tættere på søen. Der var ikke så meget liv som oppe ved Dronning Louises bro, så hvis vi skulle arbejdet med denne del af søerne så var det for at tiltrække mere liv.

Selvom søerne rummer mange muligheder, blev vi tiltrukket af den allerede eksisterende larm og befolkning ved Dronning Louises bro. Vi ser det som et samlingspunkt ikke blot for folk fra indre by og Nørrebro, men for hele København. Vi synes derfor det kunne være interessant at se på, hvad det er, der gør dette sted så attraktivt, og hvordan man kan udnytte området endnu bedre. Vi vil gerne skabe et rum, hvor folk kan samles og hvor der er plads til alle, hvilket vi mener Dronning Louises bro i den grad lægger op til. Da vi gik rundt og observerede, fandt vi ud af, at der er masser af muligheder, for at skabe et mere attraktivt byrum, end det der i forvejen er, da broen, søen, stierne og de små græsarealer rummer mange muligheder.

Vores problemstilling henvender sig primært til de brugergrupper, der allerede benytter sig af byrummet omkring Dronning Louises bro. Dermed er det vigtigt i vores design at have et kendskab til hvilke grupper det er. I området er der i forvejen mange besøgende, der benytter byrummet til at gå ture, dyrke motion og drikke en øl. Samtidig med det, er der mange transit besøgende, og til sidst er der den faste garnison, af folk der bor eller arbejder i området.

Vi har allerede indledt det første metodiske skridt ved at gå en test-tur rundt om søerne, for at få skabt et førstehåndsindtryk af områdets ulemper såvel som fordele. Vi noterede og fotograferede mens vi gik på ruten (se beskrivelse og billeder på side 3, 4 og 5).

Vi vil fortsat undersøge de nuværende ressourcer, der ligger i området, via metoder som fotografering, undersøgelse af muligheder for borgerinddragelse, interviews og observationer. Da et af vores formål er at bidrage til et mere levende byliv, er det essentielt at tage områdets potentialer i betragtning og anvende disse på rette vis. Et potentiale kan være alt fra et sted til en allerede eksisterende konstruktion, eksempelvis søen der allerede er der, men som vi mener kan gøres mere attraktivt og brugbart. Vi ønsker samtidig at tage forbehold til den oprindelig konstruktion og

mening såvel som klimamæssige perspektiver, som forbliver, selvom at man ændrer rummets karakter. Derfor er det vigtigt, at vi går i dybden med den teori der ligger bag den historiske baggrund samt de praktiske aspekter af søerne.

### **3. Problemformuleringen**

#### **Problemformuleringer:**

Vi arbejder med fire versioner af den samme problemformulering.

1. Hvordan kan vi udnytte pladsen i og omkring søerne ved Dronning Louises bro til gavn for brugerne, (ved at skabe et anvendeligt design?)
2. Hvordan kan vi gøre området i og omkring søerne ved Dronning Louises bro til et mere anvendeligt byrum for brugerne?
3. Hvordan kan man gennem et (re-design?), gøre området omkring Dronning Louises bro til et mere anvendeligt byrum?
4. Hvordan kan vi med udgangspunkt i Dronning Louises bro, skabe et mere anvendeligt byrum som arbejder med det eksisterende potentiale?

#### **Arbejdsspørgsmål:**

Hvilke brugergrupper anvender byrummet?

Hvilke brugergrupper forventes at anvende byrummet?

Hvilke kriterier er der for et anvendeligt byrum?

Hvordan kan man aktualisere søerne i forhold til klimatilpasningsplanen?

Hvordan skal søerne re-designes for at imødekomme klimaet?

Hvad var de oprindelige tanker omkring designet af søerne og byrummet omkring?

Hvilke metodiske redskaber findes relevante i studiet af byrum?

Hvilke elementer har en funktion i forhold til udsmykning af byrummet?

## 4. Metodiske overvejelser (evt.)

## 5. Semesterbindingen (evt.)

Vores semesterbinding for dette projekt er design og konstruktion. Dette vil man kunne se, da vores projekt vil bestå af forskellige designs og konstruktioner i og omkring søen. Vi vil både tage højde for designet, da vi gerne vil have det skal passe ind i det design, som broen allerede er bygget op omkring. Derudover vil vi gerne konstruerer brugervenlige løsninger, der kan fungerer i mange henseende.

Den anden dimension vi har valgt at inddrage er Subjektivitet, Teknologi og Samfund. Vi vil gerne finde ud af, hvad broen betyder for brugerne og hvordan den bliver brugt. Derudover er det interessant at kigge på placeringen og hvilken betydning det har for atmosfæren. I forhold til teknologi, vil vi gerne undersøge hvor stor en rolle klimatilpasning kan spille, i forhold til søen og hvad man kan gøre for at imødekomme dette.

## 6. Litteraturliste (evt.)

Gehl, J., & Svarre, B. (2013). *Bylivsstudier: Studier af samspillet mellem byens form og byens liv*. København, Danmark: Bogværket.

Teknik- og Miljøforvaltningen. (2012). *Kbh 2025 Klimaplanen: En grøn, smart og CO2-neutral by*. Lokaliseret på/fra: [kk.sites.itera.dk/apps/kk\\_pub2/pdf/930\\_QP7u8mn5bb.pdf](http://kk.sites.itera.dk/apps/kk_pub2/pdf/930_QP7u8mn5bb.pdf)

White - social life in small public places: <https://www.scribd.com/doc/32984768/The-Social-Life-of-Small-Urban-Spaces>

Byplanlægning - et produkt af tiden - dansk byplanlægning 1945-2010 af Ellen Højgaard Jensen

Byer for mennesker af Jan Gehl

New city spaces - Indbundet Af: Lars Gemzøe og Jan Gehl

City, Rediscovering the Center - William H. Whyte

<http://www.arkark.dk/building.aspx?buildingid=13045>

## **7. Samarbejdet og aftaler med vejleder og gruppen**

Der har fra start været en god dialog i gruppen. Vi har været gode til at aftale dage og tidspunkter at mødes, og alle har interesse for at komme i gang med processen hurtigst muligt. Der er gode initiativer i gruppen – Initiativer som at gå tur omkring søen, for at finde det passende område til projektet, deltagelse i borgermøde i forhold til Sankt Jørgens sø, og booking af bibliotekar.

I forhold til den fremtidige arbejdsfordeling mm., har vi aftalt, at vi alle ikke nødvendigvis behøver at være til stede, hvert eneste gang vi mødes. Der er derfor mulighed for, at arbejde selvstændigt derhjemme, hvorefter vi vil samle op på det efterfølgende. Derudover vil vi i løbet af arbejdsprocessen udlevere opgaver til hver enkelt person, som de har ansvaret for at færdiggøre bedst muligt. Vores samarbejde med vores vejleder, vil foregå således, at vi løbende aftaler og afholder vejledermøder. Dette betyder at der i nogle perioder vil forekomme flere vejledermøder end andre, alt efter gruppens behov og vejlederens tid. Tilmed vil vi så vidt det er muligt, sende materialer til vejlederen, så vi har mulighed for at få respons på det foreløbige resultat.

I gruppen har der været en udfordring fra start. Vi har været i tvivl om hvad projektet egentlig skulle indebære, i forhold til design og placeringen af designet. Dette har været en hæmsko for arbejdsprocessen, at vi ikke tidligere i forløbet har haft et mere entydigt billede af en problemformulering.

## **8. Arbejdsplan (evt.)**



# Midtvejsevaluering

1. semester - efterår 2018

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<b>Gruppenr. og hus:</b> V1824788563, Hus 04.2
<b>Arbejdstitel:</b> Dronning Louises Bro - fra transit til ophold
<b>Gruppens medlemmer:</b> Patrick Wiinholt Mølholm, Amalie Schou Christensen, Nina Marie Faarup, Thea Ulrik Jørgensen, Charlotte Pihl Nielsen og Sofia Graversen
<b>Vejleder:</b> Martin Severin Frandsen
<b>Dato:</b> 13/11-2018

## 1. Status

Siden sidste seminar har vi været ude på broen og gøre os nogle observationer på baggrund af Jan Gehls bog om bylivsstudier. Vi havde én dag hvor vi observerede ophold på broen og én dag hvor vi observerede transit på broen. Efter vores observationer fik vi indsamlet nok empiri til at igangsætte vores designprocess. Vi startede vores designprocess i sammenhæng med vores eksamen i Design og Konstruktion, hvor vi skulle lave et storyboard og et color cognitive map. Dette var en god måde at påbegynde vores designproces på, da vi så det som en form for brainstorm fordi vi var nødsaget til at tage højde for alle aspekter af vores design.

Vi endte med at arbejde videre med det design vi havde udarbejdet igennem storyboardet og vores color cognitive map. Nu da vi allerede havde idéen til vores design klar, gik vi igang med at konstruere. Med hjælp fra vores FabLab vejleder Sara fik vi næsten lavet vores produkt færdig og det er kun de sidste detaljer der mangler.

Lige nu er vi i gang med at finde ud af hvilke metoder vi skal bruge når vi skal observere bænken på broen. Derudover arbejder vi på at finde mere teori om byrum og byrumsdesign. Fremadrettet vil vi gerne finde informationer om lys i byrum, da det også indgår i vores produkt.

### Feedback fra opponentergruppe

- Vi vil gerne have feedback på vores metode afsnit. Er det relevant at have vores storyboard og color mapping med i vores metode afsnit?
- Vi har forsøgt at formulere en ny problemformulering, og kunne godt tænke os noget feedback på den, stemmer den godt overens med det vi gerne vil belyse i vores projekt?
- Hvordan fungerer opbygningen af vores opgave?
- Hvilke teorier kan vi bruge til vores FabLab afsnit?
- Hvilke andre teorier og teoretikere kunne være relevante at anvende, i forhold til vores metodeafsnit?
- Har vi nok i vores nuværende design, eller skal vi udvide?

## 2. Rapportdesign

Udkast til indholdsfortegnelse

- 1. Resumé**
- 2. Indledning og problemstilling**
  - 2.1. Motivation
  - 2.2. Problemfelt
  - 2.3. Problemformulering
  - 2.4. Hvad er et attraktivt byrum
  - 2.5. Afgrænsning
  - 2.6. Semesterbinding
- 3. Metode**
  - 3.1. Indledning
  - 3.2. Observation som metode
  - 3.3. Hevners tre-cyklus model
  - 3.4. FabLab og vores designproces
  - 3.5. Jan Gehl
- 4. Teori**
  - 4.1. Historisk empiri
  - 4.2. Ferdinand Meldahl og æstetik
  - 4.3. Det fysiske byrum
  - 4.4. Det sociale byrum
- 5. Analyse**
  - 5.1. Transit
  - 5.2. Ophold
  - 5.3. 12-punktsmatricen
  - 5.4. Byrummets placering
  - 5.5. Søtorvet og arkitektur
  - 5.6. Brugernes mening
  - 5.7. Potentialer og barrierer
- 6. Designrationale**
  - 6.1. Idégenerering
  - 6.2. Iterationer og proces
  - 6.3. Endeligt design
  - 6.4. Illustrationer
- 7. Diskussion**
  - 7.1. Byrummets muligheder
  - 7.2. Mangfoldighed
  - 7.3. Designevaluering
- 8. Konklusion**
- 9. Bibliograf**

### 3. Indledning og problemfelt

Trods al den transit som finder sted på Dronning Louises Bro, er broen også blevet et attraktivt sted at opholde sig, uden at det har været tiltænkt som formål. Dronning Louises Bro forbinder indre by og Nørrebro, og formålet har derfor været passage mellem de to bydele. De seneste år er det blevet et populært sted at opholde sig og især om sommeren er det et stort samlingspunkt for københavnernes. Broen rummer nemlig mange af de faciliteter vi ser i et velfungerende byrum; den centrale beliggenhed, udsigten til søerne og pladsen til at opholde sig. Hvis man eksempelvis, går en tur over broen på en solskinsdag, vil man netop se dette, et velfungerende byrum. Man ville kunne mærke bylivet og den gode stemning, men man vil også bemærke at det er svært at få en siddeplads, på en af de få københavnernes bænke, der er placeret på broen. Det er dermed tydeligt at se populariteten af broen, da de manglende siddepladser bevirker at folk er nødsaget til at sætte sig på jorden, på broens kant, og på græsarealerne omkring broen.

#### Motivation

Alle i gruppen har en fælles interesse, nemlig byplanlægning. Vi synes det er spændende at undersøge, hvad der gør et byrum velfungerende og attraktivt. Vi vil gerne komme med vores bud på, hvad der kunne forbedre et byrum yderligere. Dronning Louises Bro er projektets omdrejningspunkt, hvor vi er interesseret i at udnytte områdets potentiale. Dertil vil vi lave en designløsning, der forbedre folks muligheder for at opholde sig. Vi har valgt Dronning Louises Bro ud fra en fælles interesse samt byrummets popularitet, vi synes, at der skal ske noget nyt, i form af et innovativt design. Mulighederne for at sidde ned på broen er begrænsede og vi vil gerne imødekomme behovet for siddepladser, i vores design ved at skabe en bänk.

#### Problemfelt

Da Dronning Louises Bro i 1880'erne blev bygget, var tanken at der skulle skabes mere plads til den voksende trafik i mellem Indre by og Nørrebro og derfor blev den ikke designet med henblik på muligheder for ophold. Dronning Louises Bro rummer alt hvad der kræves til et velfungerende byrum nemlig udsigt, plads, sol og en central beliggenhed.

I året 2011 gjorde man fortovene bredere og der blev derfor lukket op for flere cykler og fodgænger end biltrafik. Dette medførte en stigning af siddende ophold på broens fortov og der blev derfor i 2012 sat 14 nye bænke på broen <sup>1</sup>. Vi mener dog at selvom der er kommet nye bænke til, er der stadig mange muligheder for forbedringer. Derfor kunne det være interessant at arbejde med at skabe nogle flere siddepladser på broen, da broen tilbyder et stort attraktivt areal til dette. Der er brede stier for både fodgængere og cyklister, og da selve vejbanen ikke fylder det store, er der rig mulighed for designløsninger.

Vi har indtil videre observeret forskellige faktorer som er vigtige for at få et indblik i hvordan byrummet udfolder sig, såsom vejr, tidspunkter på dagen, trafik og i hvor lang tid brugerne rent faktisk opholder sig på broen. Vi ser Dronning Louises Bro som et samlingssted for hele København og vi synes derfor det kunne være interessant at se på, hvad det er, der gør stedet attraktivt. Da Broen efter omlægningen i 2011 rummer hele 5,3 meter brede fortove, 4 meter bred cykelsti og 3,25 meter vej, samt gode udsigt lægger den i høj grad op til ophold<sup>2</sup>. Da byrummet allerede rummer mange mennesker og har de rette rammer, er det interessant at finde ud af hvad man så kan gøre, dette vil vi undersøge nærmere via forskellige observations- og interview metoder.

Vores problemstilling henvender sig primært til de brugergrupper, der i forvejen benytter sig af byrummet på Dronning Louises Bro. I området er der i forvejen mange besøgende, der benytter byrummet til at gå ture, dyrke motion, drikke en øl eller nyde udsigten. Samtidig med det, er der mange transit-besøgende, og til sidst er der den faste garnison, af folk der bor eller arbejder i området. Det er essentielt at tage områdets potentialer i betragtning og anvende disse på rette vis, vi ønsker samtidig at tage forbehold til den oprindelig konstruktion og funktion, som forbliver selvom at man ændrer rummets karakter. Derfor er det vigtigt, at vi tager højde for empirien og den historiske baggrund, samt de praktiske aspekter ved Dronning Louises Bro. Vi ønsker at forstærke byrummet som samlingspunktet, ved at gøre det mere egnet til ophold.

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<sup>1</sup> Jeppesen, Anette . (29/5/2012). Hovsa, sikke en succes-bro!. *Magasinetkbh*. Fundet [11/08/2018]. På [<https://www.magasinetkbh.dk/indhold/dronning-louises-bro>]

<sup>2</sup> Jeppesen, Anette . (29/5/2012). Hovsa, sikke en succes-bro!. *Magasinetkbh*. Fundet [11/08/2018]. På [<https://www.magasinetkbh.dk/indhold/dronning-louises-bro>](se fakta boks)

## Problemformulering

Hvordan kan man imødekomme opholdet på Dronning Louises Bro, gennem et nyt design?

## Arbejdsspørgsmål

1. Hvad var de oprindelige tanker omkring designet af søerne og byrummet omkring Dronning Louises Bro?

Kommentar: Da vi i vores design af byrummet gerne vil tage højde for de oprindelige tanker om broen og områdets æstetik. Derudover er det interessant at se hvordan broen bliver brugt i dag, i forhold til de oprindelige tanker om broens anvendelse.

2. Hvilke brugergrupper anvender byrummet på Dronning Louises Bro og hvordan?

Kommentar: Hvem skal vi designe til, og er der noget vi skal tage højde for i vores design i forhold til brugergrupper? Hvordan anvender brugerne byrummet, og kan vi designe et produkt der imødekommer det? Det er nogle af de spørgsmål vi gerne vil undersøge for at skabe et brugbart design til netop det byrum.

3. Hvilke kriterier er der for et godt byrum?

Kommentar: Som udgangspunkt er det vigtigt, at vi er bekendt med, hvad et godt byrum er. Dette er væsentlig for hele vores projekt, men specielt også i forhold til vores design.

3. Hvad har gjort netop Dronning Louises Bro til et populært opholdssted?

Kommentar: Ved at forstå de mekanismer der, trods et design orienteret mod transit, har gjort Dronning Louises Bro til et populært opholdssted, kan vi forbedre designet med henblik på ophold.

4. Hvordan skaber vi en rød tråd mellem broens æstetiske udtryk og vores bænks design?

Kommentar: Da ændringer på Dronning Louises Bro kan påvirke brugernes opfattelse af byrummet, vil det være relevant at se på hvordan man kan tilgodese så mange brugere som muligt, igennem designet.

5. Hvilken effekt har lys, i et byrum?

Kommentar: Vi har valgt at installere lys i vores design, og det er derfor interessant at undersøge hvordan lys fungerer i et byrum.

## 4. Foreløbigt metodeafsnit

### Observation som metode

Jan Gehl beskriver en række forskellige metoder til at observere byrum i sin bog om bylivsstudier (Gehl, 2013). I vores projekt har vi valgt at tage brug af nogle af de metoder, som er beskrevet i Jan Gehls bog, for at observere, hvordan folk opholder sig på Dronning Louises Bro. I sammenhæng med dette satte vi os på broen i en time af gangen for at observere. Dette gjorde vi hen over to dage. For at få en overordnet forståelse af, hvordan folk bruger broen. Under vores observation brugte vi tælling som en metode. En helt grundlæggende metode inden for bylivsstudier. Man kan i princippet tælle alt. Typisk registreres det, hvor mange der er i bevægelse, og hvor mange der har taget ophold. Tællinger giver os kvantitativ data, som vi kan bruge til at kvalificere et projekt.

Jan Gehl skriver om en række forskellige spørgsmål, man kan stille, når man tæller (Gehl 2013 :23, 24, 27, 29) Vi har ladet os inspirere af Gehls spørgsmål, og har valgt at undersøge følgende: 1) Hvem der opholder sig, 2) Hvor længe de opholder sig og 3) Hvad folk gør, når de opholder sig.

### **Hvem opholder sig?**

Når man kigger på, hvem der opholder sig, kan man vælge at kigge på individet, men det giver ofte bedre mening at undersøge mere overordnet. I vores tilfælde valgte vi at have fokus på alder og køn. Det gjorde vi, for at få en ide om, hvilken målgruppe vi skal imødekomme, i vores design.

### **Hvor længe opholder de sig?**

Varigheden af ophold i et byrum, kan give viden om kvaliteten af byrummet. Vi havde en teori om, at Dronning Louises Bro er et godt byrum, hvor folk har lyst til at opholde sig. Derfor var det interessant for os at undersøge, om denne teori passede ved at observere varigheden af ophold. Derudover havde vi en teori om, at udbuddet af siddepladserne ikke levede op til efterspørgslen. For at undersøge den teori, tog vi tid på, hvor længe en bæk stod fri, før at der var nogen, der satte sig.

### **Hvad gør folk, når de opholder sig?**

Når man kigger på aktiviteter i et byrum, skelner man mellem nødvendige og valgfrie aktiviteter. Nødvendige aktiviteter, er eksempelvis når man skal handle eller fra et sted til et andet. Frivillige aktiviteter kan være at sidde på en bæk og slappe af eller at gå en tur. I vores observation noterede vi, at de, som havde slået sig ned, sad og drak en øl, nød det gode vejr el. lign. Altså i høj grad valgfri aktivitet.

Gehl skriver i sin bog: ”Historisk er der sket en udvikling i brugen af byens rum fra overvejende at have været præget af nødvendige aktiviteter til højere grad at omfatte valgfrie aktiviteter.” (Gehl 2013: 27). Dette citat er især interessant for os, da vi netop har kunne se, at broen bliver anvendt på en anderledes måde end den måde, som man normalt forbinder med broer. Dette kom ligeledes til udtryk igennem vores observationer på Dronning Louises bro, og derfor ønsker vi at ændre Dr. Louises bro til et byrum, der i højere grad indbyder til valgfri aktivitet, frem for den nødvendig aktivitet, altså transit, som den oprindeligt blev bygget til.

### **Transit**

Udover at kigge på ophold, undersøgte vi også transit. Da Dronning Louises Bro er et centralt sted, der forbinder det indre København med Nørrebro, er der også en del, der bruger



byrummet til transit. Vi brugte igen tælling som metode til at undersøge transit. Vi delte de passerende op i 5 kategorier: cyklister, biler, busser, folk der gik mod København og folk der gik mod Nørrebro. Vi valgte at undersøge transit, for at få et indblik i, hvor trafikeret broen er. Vi gik ikke mere i dybden ved at stille spørgsmål, da det ikke er interessant for os at vide mere om de, som passerer.

## **Metodeovervejelser og fremgangsmåde - FabLab**

En metodisk overvejelse vi havde helt fra projektets begyndelse, i forhold til udarbejdelsen af vores design var, at benytte os af Humtek's FabLab værksted. Dette mente vi nemlig, ville stemme godt overens med vores ønske om, at skulle producere et fysisk design, som vi kunne bruge til vores metodiske undersøgelser og senere evaluere på det, for at nå frem til det bedst mulige design. Ud over at vi gerne ville anvende FabLab værkstedet, blev vi også bekendt med, at vi kunne få tilknyttet en FabLab vejleder, hvilket der var klar enighed om at gøre.

Vores fremgangsmåde var derfor til at starte med, at få booket en FabLab vejleder, som kunne guide os og hjælpe os i gang med vores designproces. Herefter holdt vi et møde med vejlederen, hvor vi blev bekendt med alle FabLabs mange forskellige redskaber, som vi kunne bruge, til udarbejdelsen af vores design. I gruppen aftalte vi derfor fremadrettet, at vi skulle mødes i FabLab, så vi kunne arbejde intensivt, på vores kommende design. Til vores møde med FabLab vejlederen blev vi også fortalt, at vi til at starte med, skulle lave en prototype af vores design, før at vi måtte gå videre til at arbejde med en endelig udgave af vores design. Dette stemte godt overens med 3D figur af vores design, som vi tidligere havde udarbejdet. Så vi startede derfor med at lave, en prototype af vores design i FabLab. Her anvendte vi dog ikke nogen af værkstedets redskaber eller fik hjælp fra vores tilknyttede vejleder, men i stedet klippe-klistrede vi selv en papfigur af vores design, så vi kunne få en ide omkring, hvordan det endelige resultat kunne blive. Herefter byggede vi endnu en prototype i pap, men her gjorde vi så brug af en laserskærer, hvor vi også fik hjælp fra vores FabLab vejleder. Med de rette mål og information for vores FabLab vejleder i forhold til valg af materiale, påbegyndte vi processen med at lave det endelige design.

Vores valg i forhold til at anvende FabLab værkstedet og tilknytningen af en vejleder, har som udgangspunkt givet os et rigtig godt startpunkt i forhold til hvordan vi skulle påbegynde udarbejdelsen af vores design. Derudover har vi fået tilknyttet nogle forslag og ideer, som vi har taget med i vores proces, i forhold til vores overvejelser om designets holdbarhed og størrelse mm.

Nu hvor vi har lavet en faktisk model af vores design, vil vi fremadrettet observere vores design i brug, til det vil vi igen tage fat i Gehl, og bruge tælling. Det er netop interessant at bruge tælling før og efter et initiativ. Da dette kan give en ide om at der er sket en forbedring af byrummet, hvilket er vores formål med designet. (Gehl, 2013) Udover dette vil vi interviewe folk, da vi med interviews kan få mere detaljerede perspektiver fra folks oplevelser med at anvende bænken. Med den kvalitative metode, kommer vi mere i dybden og kan få svar på, om vores design er med til at forbedre byrummet.

## 5. Semesterbinding

Vores semesterbinding for dette projekt er design og konstruktion. Dette vil vi opfylde ved at designe og konstruere en bæk/flere bænke med en lysinstallation placeret i bænken. Dette design har vi på baggrund af observationer og analyser udarbejdet for at skabe flere siddepladser på Dronning Louises Bro, og dette skal dermed belyse vores problemformulering. Da vi ikke har mulighed for at lave den helt færdige konstruktion af vores design, har vi lavet en visualiseringsmodel der viser vores designløsning på Dronning Louises Bro. Derudover har vi lavet en prototype af et udsnit af designet, som vi på baggrund af vores teori vil teste, og ud fra den feedback vi får, evaluere på designet.

Den anden dimension vi har valgt at inddrage er subjektivitet, teknologi, og samfund. Vi vil på baggrund af vores observationer, undersøge sammenhængen mellem brugeren og omgivelserne i byrummet. Derefter vil vi foretage os en analyse af dette, ved brug af de lærte metoder indenfor dimensionen. Vi vil udføre kvantitative og kvalitative undersøgelser på broen, og udarbejde et spørgeskema, samt interviews.

## 6. Substantielt afsnit/kapitel

### Teoriafsnit - Historisk

Der har siden 1500-tallet været etableret en forbindelse mellem indre by og Nørrebro, men da trafikken voksede, blev Dronning Louises Bro senere i 1880'erne bygget. Broen er tegnet af arkitekt Vilhelm Dahlerup og opkaldt efter Christians den 9.'s dronning Louise<sup>3</sup>. Dronning Louises Bro ligger i forbindelse med Søtorvet. Søtorvet er tegnet af arkitekten Ferdinand Meldahl, som står bag mange ikoniske bygninger og parker i København. Meldahl havde været i Paris inden den store omlægning af byplanen 1857 og blev stærkt fascineret af deres levestandard, med store boulevarder og pladser, som skabte lys og luft i byen<sup>4</sup>. I starten af 1800 bar København stadig præg af tæt befolkning og faldefærdige bygninger, især nutidens Nørrebro. Søtorvet blev derfor ud fra Meldahls fascination, tegnet og bygget ud fra inspiration fra Paris, med lange gader der løber sammen i en plads og med god vilje kunne søerne i baggrunden ligne Seinen.

Historicisme var en stilperiode i Danmark mellem 1820-1900, her var det tilladt at gå tilbage til tidligere stilarter kendte og formsprog og søge inspiration i disse, man kunne sagtens tage inspiration fra en søjle fra et græsk tempel og overdådigt udsmykning af bygninger fra barokken og overflytte det til en anden kontekst<sup>5</sup>. Da broen blev bygget i Historicismen kunne det tænkes at den som Søtorvet er stærkt inspireret af Paris, broen bærer især præg af samme karakteristika som Pont Neuf i Paris, med dens tre buer til gennemsejling og i alt otte lygter.

Stadig den dag i dag er pariser stemningen til stede når man bevæger sig over broen og det er derfor vigtigt for os at bevare denne stemning i vores design.

<sup>3</sup>(01/01/2016). Dronning Louises Bro. *Hovedstadshistorie*. Fundet [11/07/2018]. På <http://www.hovedstadshistorie.dk/oestervold/dronning-louises-bro/>.

<sup>4</sup>(22/10/2014). Ferdinand Meldahl. *Den Store Danske*. Fundet [11/08/2018]. På [http://denstoredanske.dk/Kunst\\_og\\_kultur/Arkitektur/Danmark/Ferdinand\\_Meldahl](http://denstoredanske.dk/Kunst_og_kultur/Arkitektur/Danmark/Ferdinand_Meldahl)].

<sup>5</sup>(26/03/2014). Historicisme . *Den Store Danske*. Fundet [11/08/2018]. På [http://denstoredanske.dk/Kunst\\_og\\_kultur/Arkitektur/Arkitektur\\_og\\_bygningskunst/Stilretninger\\_og\\_perioder\\_i\\_kunsten/Historicisme](http://denstoredanske.dk/Kunst_og_kultur/Arkitektur/Arkitektur_og_bygningskunst/Stilretninger_og_perioder_i_kunsten/Historicisme)].

*Dronning Louises Bro, København.*



*Pont Neuf, Paris.*



## **Empirisk analyse - Observationer på broen**

Vi har valgt at dele vores indsamling af data op i to kategorier; den ene omhandlende transit og den anden omhandlende ophold på broen.

### **Transit**

Ud fra vores data på Dronning Louises Bro kan vi blandt andet se hvilken form for trafik der er mest af på broen. Vores data viser at størstedelen af trafikken består af fodgængere og cyklister, som tilsammen udgør 89,1% af andelen af trafikanter, hvor biler og busser kun udgør 10,9%. Dette kunne man forestille sig havde meget at sige, i forhold til atmosfæren på broen, da det ikke er forurene og larmende køretøjer der udgør størstedelen af trafikken, men at det er fodgængere (41,4 %) og cyklister (47,7%) som både støjer og fylder mindre men også bevæger sig i et langsommere tempo.

Ydermere kan vi ud fra vores data omkring transit se, at der er omtrent lige meget trafik gældende for fodgængere, cykler og køretøjer i begge retninger, dog med en mindre overvægt af trafikanter mod Indre by. Dronning Louises Bro er altså et sted hvor folk fra begge ender af

byen krydser hinanden, hvilket også kan hænge sammen med broens popularitet. Det er altså et epicenter for bløde trafikanter.

## **Ophold**

Vores data omhandlende ophold på broen giver os en god mulighed for at finde ud af hvem brugerne er og hvordan de benytter sig af broen.

Ud fra dataen kan man se at de der vælger at opholde sig på broen oftest vælger at sidde der, det er der nemlig 65,5% der vælger, hvor 34,5% vælger at stå op. Vi kan også konkludere at de folk der har opholdt sig længst på broen oftest sidder ned.

Af dem der vælger at sidde, er det mest populært, at slå sig ned på de bænke der er til rådighed, det er der nemlig 42,7% der gør. Dog er der 28,7% der vælger at sidde på broens kant og 28,6% der vælger at sidde på jorden op af broens kant. Dette kan både skyldes manglen på bænke, men også at folk foretrækker forskellige niveauer at side i.

Vi kan også se at nord/øst (retning indre by, side mod østerbro), syd/vest (retning frederiksberg, side mod nørrebro) og midt/nord (midterste del af broen, side mod østerbro) er de steder på broen, hvor flest vælger at slå sig ned. Dette kan dog både hænge sammen med bænkenes placering og at der er flere bænke på "østerbro siden" og at det samtidig er den side, at solen skinner på det meste af dage.

Af de der opholder sig på broen kan vi også se at størstedelen, nemlig 30% vælger at opholde sig i intervallet 15-60 minutter og den anden største del 24% vælger at opholde sig 60+ minutter på broen. Ud fra den data kan man altså se at selvom broen oprindeligt er bygget til transit, er der en stor del af brugerne der bruger den til længerevarende ophold.

De folk der benytter sig af broen består af ca. lige stor andel mænd som kvinder, dog kan vi se at det er den yngre del af befolkningen broen tiltrækker, da 66,3% af dem vi observerede var et sted mellem 18-30 år. Dog observerede vi folk i alle aldersgrupper fra 0-60+. Men tidspunkt, ugedag og vejrforhold må forventes at have en stor indflydelse på hvem broen benyttes af, hvor mange der bruger den og hvordan broen benyttes. Vores teori er blot, at de få siddepladser på Dronning Louises Bro, er en hæmsko for det gode ophold i dette byrum.

## **Fra start til slut - Designprocessen**

### **Refleksioner fra vores logbog**

#### **Idégenerering**

Vores problemformulering lyder “Hvordan kan man imødekomme opholdet på Dronning Louises Bro, gennem et nyt design?” og med udgangspunkt i denne startede vi med at overveje hvilke muligheder vi havde. Vi ville gerne skabe flere opholdsmuligheder på broen, da vi i vores observationer kunne se at bænkene på broen var meget attraktive. Vores design skulle være for alle og samtidig passe ind i broens design. Idéen om at arbejde videre på en bänk gave god mening, da vi kunne se de var populære og ikke ville fyldte for meget på broen i forhold til, at der stadig skulle være plads til gågængere. Samtidig observerede vi også at det ikke kun var bænkene, der blev brugt til at opholde sig på, men at flere sad på jorden eller oppe på broens kant. Det var her vi fik idéen til at skabe tre niveauer at sidde i på vores bänk, så at man nu kan sidde højt og nyde udsigten, sidde på det samme niveau som en bänk eller sidde tættere på jorden. Derudover var vores idé også at børn der ikke har højden til at kigge ud over broens kant, nu kunne komme op og nyde udsigten.

Vi fik også den idé at lave skrå sider mellem de forskellige niveauer, så at man kunne sidde og læne sig op af siderne og dermed sidde overfor hinanden.

Ud over broen form, var vi enige om at vores design skulle invitere til ophold, selvom det var blevet mørkt udenfor så den ikke var døgn- eller årstidsbestemt. Derfra kom idéen om at implementere små lysdioder langs bänkens kanter, så den både oplyser bænken, men også fremhæver bänkens form.

#### **Prototyper afprøves**

Vi startede ud med at lave en 3D prototype af vores bänk i pap, hvor længden var skaleret ned til 1:10, af det vi havde udtænkt skulle være en 10-meters bänk. Da vi lavede modellen tog vi ikke højde for mål på bredde, længde og højde og vores første prototype var derfor ikke særlig præcis. Den kunne dog give os en idé om hvordan vi ville placere de forskellige niveauer i forhold til hinanden, og hvad man kunne bruge de forskellige niveauer til.

Vores næste prototype gik ud på at bygge en af siderne til vores bæk i pap. Vi fandt hurtigt ud af at det ville blive et alt for stort projekt at bygge en 1:1 model af vores bæk da den så skulle være ti meter, og vi valgte derfor at arbejde videre med et udsnit af bænken på fire meter. Disse fire meter indeholdte de tre niveauer, som vi gerne ville have i vores bæk og prototypen repræsenterede derfor vores design godt.

Vi fandt ud af målene på vores bæk, ved hjælp af en 1:1 papirmodel vi lagde ud på gulvet. Derefter tegnede vi modellen i CorelDraw, hvor vi også lavede huller i pappen der passede til den LED lyskæde vi havde udarbejdet. LED lyskæden bliver programmeret via en Arduino plade der sættes ind i computeren og derved kan man programmere den til at lyse som man vil, i vores tilfælde valgte vi et lys der ikke er for skarpt, da vi ikke vil have folk skal blive blændet når de cykler eller går forbi, vi valgte derfor et neutralt dæmpet lys.

Modellen gav os en god idé om størrelsesforholdet, både i forhold til niveauerne, men også i forhold til os selv, og samtidig fik vi en god ide om hvordan lyset i bænken ville se ud.

### **Det færdige produkt**

Med siden til bænken tegnet ind i CorelDraw, begyndte vi at gå i gang med at finde ud af toppene til bænken. Vi ville gerne have at bænkens bredde skulle være så lang at man kunne sidde med fødderne oppe på den, men samtidig skulle den heller ikke fylde for meget i forhold til fortovet på Dronning Louises Bro.

Da bredden var på plads, tegnede vi de forskellige længder på bænkens vandrette og skrå sider ind i CorelDraw. Dog var der flere ting der skulle tages højdes for, såsom tykkelsen på bordet til CNC-fræseren, tykkelsen af træet, vinkler på vores niveauer og hvor stort et stykke træ, der kunne ligge i CNC-fræseren. Da der også var begrænsninger i forhold til hvor stort et stykke træ man kunne skære på fræseren, var vi nødt til at dele bænken op i to dele, og tilpasse den til de mål fræseren tillod.

For at få en bedre fornemmelse af om vores mål passede, lavede vi en 3D model i programmet SketchUp. Her fandt vi ud af, at der var flere mål der skulle rettes til, i forhold til bænkens udseende og hvordan de skrå sidder skulle ligge op af de vandrette toppe.

Da målene var på plads, og de nye mål var blevet tegnet ind i CorelDraw, begyndte vi at skære de forskellige stykker i CNC-fræseren.

Da vi havde skåret alle stykkerne til bænken, begyndte vi at samle den. Vi startede med at

skære lægter, som skruer skulle skrues ind i grundet krydsfinerpladerne. Samtidig sleb vi alle bænkenes overflader, så den maling vi brugte ville holde bedre fast på bænkenes overflader.

## **Metodeafsnit om metodeovervejelser og fremgangsmåde – Storyboard**

I den lidt tidligere periode af projektarbejdet, udarbejdede vi et Storyboard, med udgangspunkt i, at vi kunne lave vores ønskede design. Vi lavede derfor nogle visuelle illustrationer af designet, som både indeholdte en designproces og en brugs-proces, hvilket er det, som et storyboard blandt andet kan indeholde. I vores tilfælde er der så tale om, hvilke elementer designet består af, samt hvordan designet skal anvendes.

Det som blev relevant for os i forhold til udarbejdelsen af storyboardet var, at vi fik igangsat vores designproces og vi var derfor nødsaget til at gå helt ned i de mindste detaljer, i forhold til alle de forskellige aspekter, som vi gerne ville have at vores design skulle indeholde. Vi blev altså tvunget til at tage stilling til forskellige ønskede elementer til designet, hvilket skabte adskillige diskussioner i projektgruppen, hvoraf der så kom gode refleksioner, i forhold til, hvordan det endelige design skulle være. En anden ting, som vi også fik ud af vores storyboard var, at vi fik dannet os et mere overskueligt overblik over vores design, samt konkretiseret en masse aspekter, som forhåbentlig kunne gøre begyndelsen af vores designproces mere håndgribelig.

## **Metodeafsnit om metodeovervejelser og fremgangsmåde – Hevners tre-cyklus model**

En metodisk fremgangsmåde, som vi har benyttet os af, i forhold til hvordan vi skulle udarbejde vores design, er Hevners tre-cyklus model. Denne model er opdelt i tre søjler, herunder miljø, design videnskabelig forskning og vidensbase. Ud fra det, vil man ifølge Hevner, kunne opnå et godt design<sup>6</sup>. Med udgangspunkt i søjlen vedrørende miljøet, foretog vi nogle undersøgelser på Dronning Louises Bro, som indebar observationer i form af ophold

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<sup>6</sup> Hevner, A. R. . & March, S. T. (2003) The Information Systems Research Cycle: *IT Systems Perspectives*, 2003. Fundet d. 11/07/2018.



og transit. Derudover blev vi klogere på området, menneskene, funktionalitet osv., i form af teori mm, der er skrevet om stedet. Ud fra det nævnte, kunne vi blandt andet finde frem til nogle problematikker mm., som vi skulle tage højde for. Derudover fik vi bekræftet hvorvidt vores tænkelige problemstilling var en realitet eller ej, i forhold til manglen på siddeplads på Dronning Louises Bro.

Viden er som nævnt, ligeledes en væsentlig faktor, for at kunne udviklet et design, som ville kunne fungere og være helt optimalt til området, menneskerne der opholder sig og miljøet. I søjlen med vidensbase, har vi derfor taget fat i adskillige metoder, teorier mm. for at finde ud af, hvad et godt og velfungerende byrum er, eftersom at det er det, som vi gerne vil ende ud med i vores projekt. Her har vi blandt andet taget fat i Jan Gehl som arbejder med byrum, så vi kan løse problemet bedst muligt, med det bedste design. I forhold til design delen, har vi kigget på nogle teoretikere, som tager udgangspunkt i et godt design, og hvad det skal indeholde.

I forhold til søjlen, design videnskabelig forskning, er det her hvor designprocessen går i gang, udarbejdelsen af designet sker. Her trækkes der den viden og erfaringer fra de to tidligere nævnte søjler, for at kunne nå frem til det bedst mulige design. Vi vil derfor evaluere på vores undersøgelser, opnå en masse viden inden for emne, for så at kunne påbegynde arbejdet med vores design. Dog vil vi løbende i processen, blive præsenteret for ny viden, nye udfordringer mm., hvilket gør, at vi formentligt vil springe frem og tilbage mellem de tre søjler, og hele tiden revurdere på vores design, ud fra de ændringer der må forekomme løbende.

## 7. Tidsplan

Udkast til projektplan frem til projektaflevering:

AKTIVITETER	UGE 46							UGE 47							UGE 48							UGE 49							UGE 50							UGE 51									
	M	T	O	T	F	L	S	M	T	O	T	F	L	S	M	T	O	T	F	L	S	M	T	O	T	F	L	S	M	T	O	T	F	L	S	M	T	O	T	F	L	S			
Aflevering af oplæg, midtvejsevaluering		X																																											
Eksamen STS			X	X	X																																								
Forberede feedback, midtvejsevaluering						X																																							
Midtvejsevaluering							X																																						
Vejledermøde + Fablab vejleder								X																																					
Samlet læseplan for empiri + metoder									X																																				
Afsnit + opbygning af projekt, endeligt udkast										X																																			
Uddelegering afsnit											X																																		
Empiri												X			X	X	X	X	X	X																									
Feltarbejde Dronning Louises bro											X	X									X	X																							
Indledende arbejde på afsnit																	X	X																											
Skrivning uddelegerede afsnit																			X	X																									
Projektmøde, status																					X																								
Skrivning uddelegerede afsnit																						X	X																						
Renskrivning alle afsnit																							X																						
Endeligt projektudkast																								X																					
Revideret projektudkast																									X																				
Korrektur																																													
Projektaflevering (18/12)																																											X		

■ Fælles projektarbejde

■ Individuelt projektarbejde

## 8. Produkt

Vi henviser til det Substantielle afsnit/kapitel, hvor produktet bliver beskrevet.

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## Mail til print

**Martin Frandsen** <martinutf@gmail.com>  
To: Martin Frandsen <martinutf@gmail.com>

Mon, Nov 26, 2018 at 12:16 PM

From: Nicolas Padfield <nicolasp@ruc.dk>  
To: Martin Severin Frandsen <martinfr@ruc.dk>  
Cc: Sara Almeida Santos Daugbjerg <sasd@ruc.dk>  
Bcc:  
Date: Fri, 23 Nov 2018 11:44:46 +0000  
Subject: Re: Spørgsmål vedr. co-supervision  
Kære Martin

Tak for det, her er svar fra Sara og jeg.

*- Hvordan oplever I overordnet set samarbejdet med fagvejledere på HumTek?*

Samarbejdet er rigtig fint - men sjældent direkte. Det gode er at det er mere end 8 år siden, vi har fået "klager", hvor en vejleder synes studerende brugte for meget tid på en fysisk del af deres projekt og for lidt på rapporten. Det dårlige er at selv om vi hvert semester overfor studerende, vejledere og ved hver gruppe direkte opfordrer til at gruppen holder et vejledermøde \*sammen med os\* for at alle kommer på bølgelængde og få forventningsafstemning, så er det sjældent det sker. Det oplever vi sjældent som et problem, idet de studerende jo taler med deres vejleder til vejledningsmøder. Men det er en missed opportunity, og når det sker, kan man mærke at alle er glade og trygge.

*- Kan I give et estimat på, hvor hyppigt fagvejledere og Fablab-/teknologivejledere samarbejder om projektvejledningen i de tilfælde, hvor de HumTek-studerende inddrager Fablab i deres projektarbejde? Med samarbejde menes, at der er direkte kommunikation mellem fagvejleder og teknologi-/Fablab-vejledere og herunder evt. fælles vejledermøder.*

Sjældent - måske 5% af tilfældene

*- Hvordan oplever I de projektvejledningsforløb, hvor der ikke er et samarbejde mellem fagvejledere og Fablab-/teknologivejledere?*

Fint, lidt mindre tryghed for alle parter. Næsten aldrig problemer. Kun i tilfælde hvor vi fornemmer de studerende er svage, kan vi finde på at emaile vejlederen og spørge om alt er ok. Ellers går vi ud fra der er god kommunikation mellem studerende og vejleder til vejledermøder.

- *Hvordan oplever i modsat de projektvejledningsforløb, hvor der er et samarbejde mellem fagvejledere og Fablab-/teknologivejledere?*

Fint, lidt mere tryghed for alle parter.

- *Hvad ser I som de væsentligste barrierer for et tættere samarbejde mellem fagvejledere og Fablab-/teknologivejledere?*

Vi antager at det er vejledernes tidsknaphed, idet tilbuddet om/opfordringen til fælles vejledermøde sjældent bliver taget op. Det er også planlægningsbesvær, det er tydeligt svært nogle gange for de studerende bare at mødes allesammen samtidig, selv uden "+2 vejledere". Det kan selvfølgelig være vi "de voksne" skulle tage mere ansvar for at insistere på det, men det gør vi p.t. ikke, idet vi ikke oplever væsentlige problemer særlig tit.

- *Hvad kunne i jeres øjne være gevinsterne ved et tættere samarbejde mellem fagvejledere og Fablab-/teknologivejledere?*

Det ville nok højne trygheden og fagligheden hele vejen rundt, og det ville fremme en god og iterativ integration med det faglige process, projektrapporten og eksamen.

Jeg vil gerne fremhæve, at det vi foreslår er ikke et ekstra møde, det er blot et almindelig vejledermøde, her i Fablab, eller med deltagelse af os.

Tak!

vh  
Nicolas og Sara

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 **noname**  
21K



Martin Frandsen &lt;martinutf@gmail.com&gt;

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## VS: Spørgsmål og billeder

1 message

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**Martin Severin Frandsen** <martinfr@ruc.dk>  
To: "martinutf@gmail.com" <martinutf@gmail.com>

Wed, Dec 5, 2018 at 2:04 PM

Og her besvarelse på dine spørgsmål:

### - Hvilket laboratorieudstyr og hvilke laboratorieteknikker har I brugt i Fablab?

CNC-skærer (RaptorX-SL1200/S20 med 1200 x 2010 mm arbejdsområde) til udskæring af krydsfiner-elementerne til den endelige prototype.  
Diverse værktøj og powertools til bygning af den endelige prototype.  
Coral Draw (computer software) til tegning af de elementer, som CNC-skæreren skulle programmeres med til at skære.  
Laser cutter til udskæring af pap-elementer til tidlig prototype.  
Lodning af LED-lyskæde (sammensætning af flere lyskæder, for at få én lang LED-kæde til montering i bænken.

### - Hvad var formålet med jeres arbejde i Fablab?

At bygge en prototype af vores produkt, til at tage med ud på Dronnings Louises bro til feltstudier, samt at arbejde med rappit prototyping for at kunne påbegynde vores feltarbejde hurtigt. For at få et indblik i hvordan "research through design" fungerer. Og fordi muligheden var til rådighed og det var en god mulighed for at få vejledning og sparring fra en FabLab-vejleder og få kendskab til værkstedet og dets muligheder til fremadrettede projekter.

### - Hvordan indgår laboratoriearbejdet i jeres designproces?

Vores ideer om den endelige prototypes udtryk, blev ændret en lille smule igennem vores proces i FabLab. Det har fået os til at tage stilling til flere detaljer end forventet og ændret en smule på udførelsen og målene på designet.

### - Hvordan vil I inddrage laboratoriearbejdet i jeres projektrapport?

Vi vil bruge vores laboratoriearbejde under metode-afsnittet i opgaven. Samt til at beskrive vores designrationale, med de iterationer vi har været igennem i FabLab.1

### - Hvordan har I oplevet samarbejdet mellem fagvejleder og teknologi-/Fablabvejleder?

Vi har ikke rigtigt bemærket vores vejlederes samarbejde. Dog har der været god sparring mellem vores vejledere til de vejledermøder, hvor de begge har været til stede. Det havde

givet mening med en større sparring mellem de to vejledere under vores FabLab/bygge proces - altså at vi også kunne have haft sparring med vores fagvejleder om design-arbejdet i FabLab.

**- Hvordan har I oplevet de fælles vejledermøder?**

De har været gode og konstruktive, og der har været en god sparring mellem de to vejledere.

**- Har I nogle foreløbige tanker om styrker og svagheder ved at bruge Fablab i en designproces?**

Styrke: udstyr er hurtigt og let tilgængeligt. Vejledning er ligeledes let tilgængeligt.

Svaghed: Vejledning og enkelte maskiner er dog begrænset af FabLabs åbningstider.

De bedste hilsner  
Patrick og gruppen



## Appendix 2. I

### **Instruction movies**

For some of the post-lab exercises the student were asked to use some specific features in the mathematical software Matlab®. Two movies were made to instruct the student on how to use these functions in Matlab.

- Movie 1: How to build a model and fit it to data using Matlab
- Movie 2: How to do non-linear regression analysis in Matlab

The two movies are uploaded as additional material together with the report.

## Appendix 2. II

### **Interview – 14.11.2018, Roskilde University**

The interview was conducted after the pre-lab and laboratory exercises. The student was asked to elaborate on two questions:

- What was their experience with the pre-laboratory exercise
- What could/should be changed to improve the laboratory work

The feedback was done in plenum for 15 min and the following is a synthesis of the main comments by the students.

- The students were generally happy with the pre-lab exercises (simulations). Particularly they found it useful that it was possible to test different scenarios that was otherwise not possible to do in the physical laboratory. Further some of the student found it very helpful that the simulations were flexible and could be done at home before or after the laboratory session. Several students pointed out that the pre-laboratory exercise with the aim of calculating the concentrations needed in the actual laboratory, made them think about how to design the experiment in order describe system.
- The student points out some important practical problems with the software used for the pre-laboratory exercises. For instance, one of the program did not work on Mac. Another general concern was that the mathematical software (Matlab®), which was used in all the pre-lab exercises and in some of the post-lab exercises, required some prior knowledge before the student was able to use it. Some of the students said that the technical barrier to some extent hinder the use of the simulation since they used a considerable amount of time getting the software to work.
- A general comment was that the amount of laboratory work should be reduced. When asked why the student responded that there was too little time to think about what they were doing before the next laboratory exercise started. One student express this point as "I think that in many of the laboratory exercises you just do the exercise and then it is only afterwards you really think about what you actually have been doing"

- Another critique by the student was the lack of time to do the reports. During the course the student accumulated unfinished report which made it difficult to digest the different experimental techniques.
- The student suggested that the course would be better if it was condensed into an intensive course.

## Appendix 2. III

### Computer exercise 1 - Simulating chemical reactions

Install the two apps called “Kinetic” and “Enzyme\_kin” in Matlab. Program and installation manual can be found on Moodle in the folder “Lab 5: Computational laboratory”.

#### Problem 1)

In this exercise we will use the app called “Kinetic” to investigate the relationship between free energy of the reaction ( $\Delta G^\circ$ ), transition state energy ( $\Delta G^\ddagger$ ) and the kinetics of a simple reversible reaction shown in figure 2.

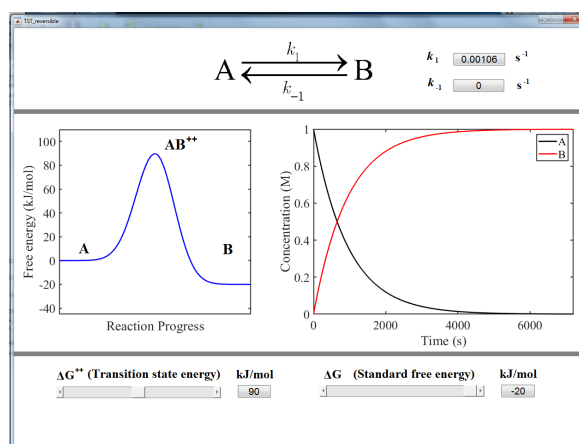


Figure 1. Program interface

Like other cyclic sugars glucose has two configurations when dissolved in water. These anomers are denoted  $\alpha$ -glucose and  $\beta$ -glucose to distinguish between the configuration where the hydroxy group on the anomeric carbon is axial ( $\alpha$ -glucose) or equatorial ( $\beta$ -glucose). The two anomers exist because the ring-structure can open briefly allowing free rotation around the anomeric carbon (see figure 2).

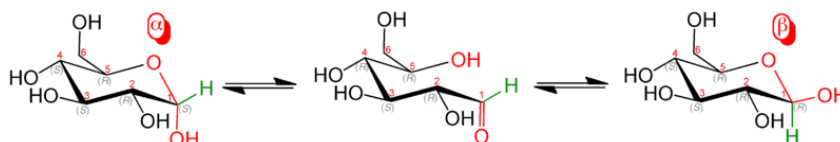
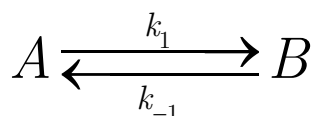


Figure 2. Interconversion of  $\alpha$ - and  $\beta$ -glucose

For reducing sugars, such as glucose, anomerization is referred to as mutarotation and occurs readily in solution. This reversible process leads to an anomeric mixture in which eventually an equilibrium is reached between the two anomers.

We can simplify the mutarotation reaction in a micro kinetic scheme as the one shown below (scheme 1). In this scheme, **A** represent the concentration of  $\alpha$ -glucose while **B** represent the concentration of  $\beta$ -glucose. The forward reaction  $A \rightarrow B$  is governed by the rate-constant  $k_1$  and the reverse reaction  $B \rightarrow A$  is governed by the rate-constant  $k_{-1}$ .



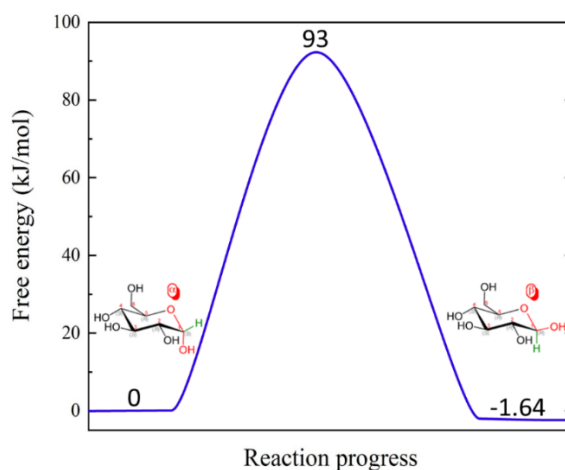
*Scheme 1. Microkinetic scheme for a simple reversible reaction*

**Questions (use the program to answer the following problems)**

- How does the transition state energy ( $\Delta G^\ddagger$ ) effect the reaction?
- How does the free energy of reaction ( $\Delta G^\circ$ ) effect the reaction?

Figure 3 show the energy diagram for the interconversion of  $\alpha$ - to  $\beta$ -glucose.

- Use figure 3 to find  $\Delta G^\circ$  and use this number to estimate the distribution between  $\alpha$ - and  $\beta$ -glucose at equilibrium.
- Use figure 3 to find  $\Delta G^\ddagger$  and use this number to estimate the time needed to reach equilibrium for a solution starting with pure  $\alpha$ -glucose.



*Figure 3. Energy diagram for the interconversion of  $\alpha$ - and  $\beta$ -glucose*

Which of the following effects would be brought about by any enzyme that catalyzed the mutarotation of glucose:

- Increased  $k_1$
- Decreased  $\Delta G^\circ$
- Increased  $K_{eq}$  ( $K_{eq} = k_1/k_{-1}$ )
- Decreased  $\Delta G^\ddagger$
- Increased  $k_{-1}$

## Problem 2)

In this exercise we will use the app called “Enzyme\_kin” to investigate a simple enzyme catalyzed reaction.

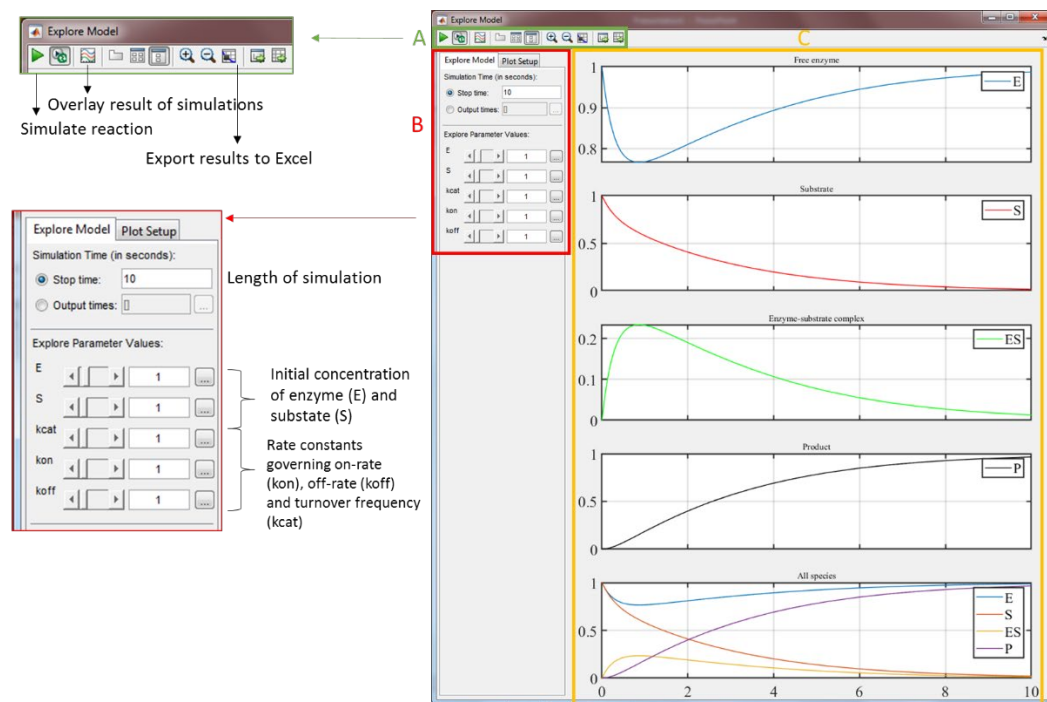


Figure 4. Program interface. Panel A) Run simulation, overlay result and export data to Excel. Panel B) Control simulation time, change rate-constants and initial concentration of substrate and enzyme. Panel C) Visualizing the time-dependent concentration of the different species in the reaction.

Enzymes are highly specialized biological catalysts that speed up chemical reactions without being consumed. If we have a reaction where a substrate (S) spontaneously decomposes to product (P), we can accelerate the reaction by adding an enzyme that catalyzes this process  $S \rightarrow P$ . The simplest microkinetic scheme for an enzyme-catalyzed reaction is shown in scheme 5B. In this scheme, the enzyme binds to the substrate to form an enzyme-substrate intermediate (ES). The binding rate is governed by the rate-constant  $k_{on}$ . When bound, the enzyme-substrate complex can either decay by dissociation ( $ES \rightarrow E + S$ ) or by converting the substrate to product ( $ES \rightarrow E + P$ ). These decay rates are governed by  $k_{off}$  and  $k_{cat}$  respectively.

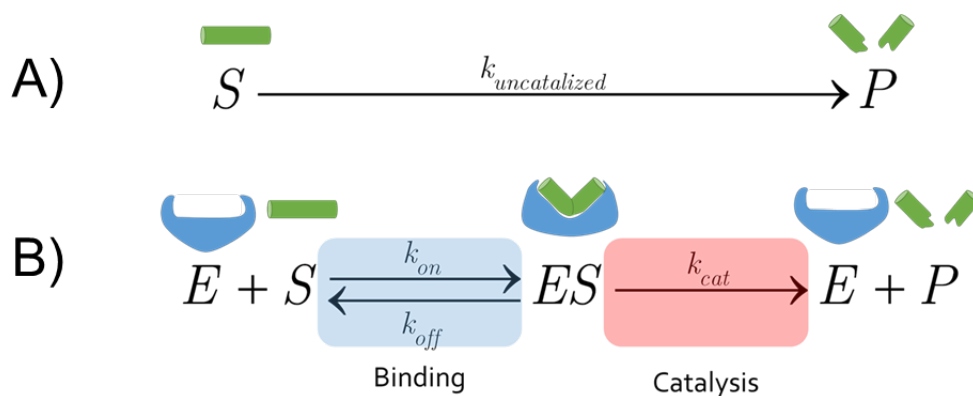


Figure 5. A) Microkinetic scheme for a simple uncatalyzed irreversible reaction. B) Microkinetic scheme for a simple enzyme catalyzed reaction.

**Questions (use the program to answer the following problems)**

At high substrate concentration essentially, all enzyme is bound to substrate.

- Investigate which rate-constant ( $k_{on}$ ,  $k_{off}$ ,  $k_{cat}$ ) that has the greatest influence on the production of product at high substrate concentrations where all enzyme is bound to substrate.

It is convenient to characterize enzymes under some conditions where the enzyme-substrate complex is almost constant in time ( $dES/dt \sim 0$ ). We call this steady-state to distinguish it from the equilibrium state. The steady-state period is illustrated in figure 6. It is important to choose the right initial concentration of substrate and enzyme to get a period in time where there is steady-state.

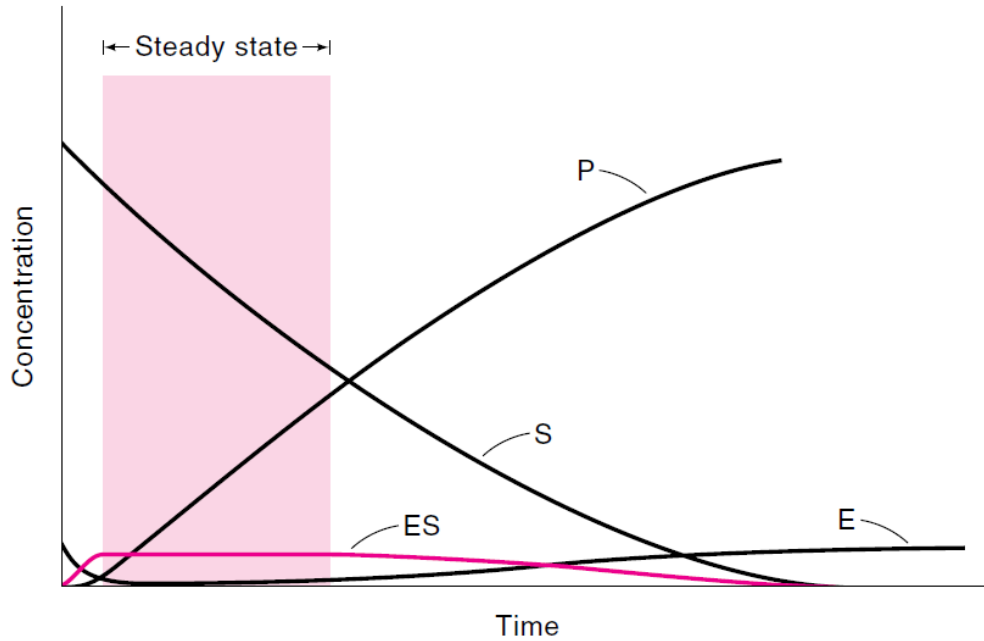


Figure 6. Time-dependent concentration of the four species ( $E$ ,  $S$ ,  $ES$ ,  $P$ ) in an enzyme-catalyzed reaction. As illustrated on the figure there is a short period in time where the enzyme-substrate complex does not change significant in time (steady-state).

- Find condition where you observe steady-state in your simulation by changing:
  - Initial concentration of species ( $E$  and  $S$ )
  - Rate constants ( $k_{cat}$ ,  $k_{on}$ ,  $k_{off}$ )
- Use the rate-constant and initial enzyme concentration ( $E_0$ ) given in table 1 below to find substrate concentration where  $\sim 5\%$ ,  $\sim 10\%$ ,  $\sim 25\%$ ,  $\sim 50\%$ ,  $\sim 75\%$  of the enzyme is bound. (OBS: change simulation stop time to 0.01 before running the simulation)

Table 1

$E_0$	0.0001 mM
$k_{cat}$	600 s <sup>-1</sup>
$k_{on}$	100 mM <sup>-1</sup> s <sup>-1</sup>
$k_{off}$	1500 s <sup>-1</sup>



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## Appendix 2. IV

### Laboratory Exercises in Enzyme Kinetics

*Methods in biophysical chemistry 2018*

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## Laboratory guide

In the laboratory exercises, we will kinetically characterize the enzyme glucose oxidase (GOx) using two different biophysical chemistry methods:

- Electrochemical enzyme assay (Lab. exercise 1)
- Calorimetric enzyme assay (Lab exercise 2)

We will use electrochemical and calorimetric measurements to obtain the steady-state rates for glucose oxidase in order to understand its steady-state kinetics. The measurements will be done together with the instructors in building 28B.1. You need to make your own plans (in the group) for the exact lab work. Below is a short introduction to the methods and some help to conduct the measurements in the lab.

The following chemicals are available in the lab.

- Enzyme stock: 150 nM & 200 pM GOx in buffer, pH5
- Substrate stock: 1 M & 10 mM glucose (equilibrated) in buffer, pH5
- Mediator : Benzoquinone (5 g/L) in buffer, pH5
- Solid chemical  $\alpha$ -glucose (powder)
- Buffer: 50 mM Sodium Acetate adjusted to pH 5

### Time-schedule for lab. exercises

In the table below, you can find a time-schedule for the lab. exercises. Exercise 2 can be done by two groups simultaneously while only one group can do exercise 1. Thus, for the last session (14<sup>th</sup> nov.) it is important that you look at the time-schedule below and rotate such that all group have time to do exercise 1.

Dato	Lab-work	Task	group 1	group 2	group 3
17-okt	prelab (1h)	Lecture and simulations	13 <sup>15</sup> - 14 <sup>15</sup>		
31-okt	lab (2-3 hrs)	Lab. ex. 1 - Biosensor			14 <sup>15</sup> - 17
		Lab. ex. 2 - ITC	14 <sup>15</sup> - 17	14 <sup>15</sup> - 17	
		Work on report	During waiting time		
14-nov	Lab. & postlab (3-4 hrs)	Lab. ex. 1 - Biosensor	13 <sup>30</sup> - 15 <sup>15</sup>	15 <sup>15</sup> - 17	
		Lab. ex. 2 - ITC			13 <sup>30</sup> - 15 <sup>15</sup>
		Fit data	During waiting time		

## Glucose oxidase

Glucose oxidase (GOx) is an oxido-reductase, which means that it catalyze the transfer of electrons from one molecule (reductant) to another (oxidant). As its name suggest GOx catalyze the oxidation of glucose to D-glucono-1,5-lactone (see figure 1). The enzyme is highly specific towards  $\beta$ -glucose as the specialized active site of the enzyme only allow the  $\beta$ -anomer to enter.

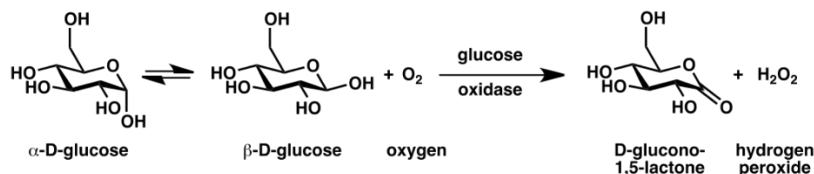


Figure 1. Illustration of the reaction catalyzed by glucose oxidase (GOx).

In order to act as an efficient catalyst, GOx has a cofactor called flavin adenine dinucleotide (FAD), which is found in the in the active site cavity of the protein (see figure 2A). FAD is a common component in biological redox reactions as it mediate the electron transfer (See figure 2B). In GOx, FAD initially acts as an electron acceptor that oxidize glucose and hence become reduced to FADH<sub>2</sub>. Next the reduced FADH<sub>2</sub> is oxidized by the final electron acceptor, molecular oxygen (O<sub>2</sub>), which can oxidize FADH<sub>2</sub> back to FAD due to its higher reduction potential. The molecular oxygen is reduced to hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) in the overall reaction (see figure 1).

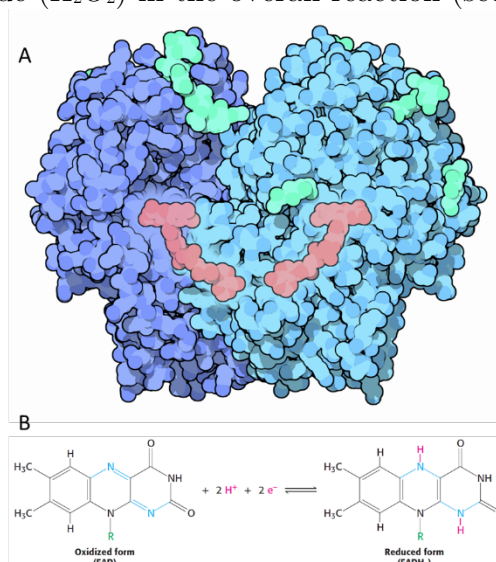
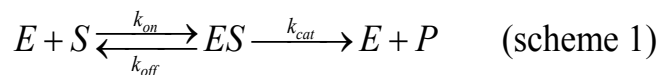


Figure 2. A) Crystal structure of glucose oxidase (dimer) with the cofactor FAD highlighted in red. B) Reaction of the cofactor FAD to form FADH<sub>2</sub>

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## Steady state kinetics

The steady state approximation is a convenient tool to simplify complex reaction schemes. The principle is to assume that an enzyme-substrate intermediate (ES) remains at an approximately constant concentration for a while.



Steady state implies that the concentration of the intermediate, [ES], is (almost) constant over some time (before it eventually starts to decrease as a large part of the substrate is converted to product). A steady state kinetic investigation essentially implies to produce data to make a Michaelis-Menten (MM) plot. Almost all of you have seen the MM equation before, but if you want to recap this, you can consult the material in Cooper. The MM-equation expresses how the initial, steady state rate of the enzymatic reaction ( $v_0$ ) depends on the initial substrate concentration ( $S_0$ ). For the simple reaction scheme stipulated above (scheme 1) the MM equation may be written:

$$v_0 = \frac{V_{\max} S_0}{S_0 + K_M} \quad (\text{eq. 1})$$
$$V_{\max} = k_{cat} E_0$$

Where  $E_0$  is the initial enzyme concentration and  $k_{cat}$  is the turnover frequency. Some aspects of the MM equation are illustrated in the figure below. Make sure that you familiarize yourself with the information illustrated in the figure before the exercise (Further information can be found in Cooper).

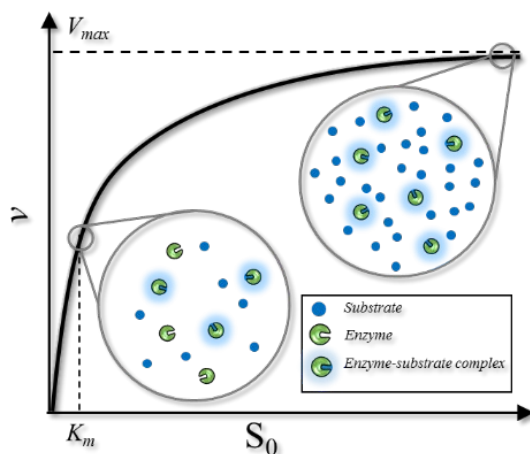


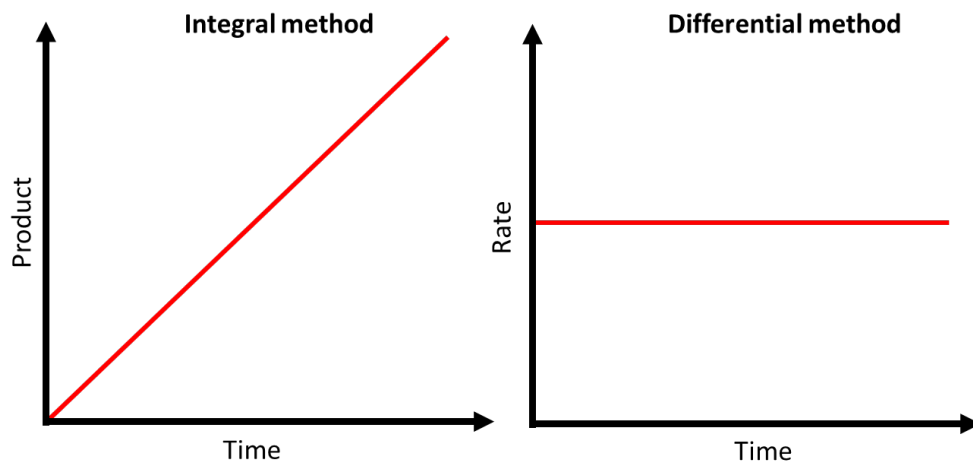
Figure 3. Effect of substrate concentration ( $S_0$ ) on the initial rate ( $v$ ) of an enzyme-catalyzed reaction.

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## Differential Methods

The most common way to obtain steady-state rates from an enzyme-catalyzed reaction is to measure the production of product over time after addition of enzyme to solution of substrate. Such time-dependent curves are called progress curves (see figure 4, left) and the steady-state rate is derived from the slope of the linear part of the progress curve. The progress curve is an example of an “integral method” in the sense that the signal (product) accumulates over time. This has the disadvantage of being difficult to measure if there is a high background noise. If for instance you were interested in measuring inhibition kinetics you would need a high background of product (inhibitor), which in turn could mask the actual signal from the (inhibited) enzyme reaction.

Progress-curves is, however not the only way one can obtain steady-state rates of an enzyme catalyzed reaction. There are several methods that can measure the steady-rates directly as the rate is the primary observable of the technique (see figure 4 right). We will call these types of methods “differential methods” and you will during the lab. exercises obtain steady-state kinetics of GOx using two different differential methods.



*Figure 4. Difference between an “integral method” and “differential method”.*

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## Lab. exercise 1

### Michaelis-Menten kinetics of glucose oxidase by electrochemical measurements

In the first lab. exercise we will measure the steady-state rate using electrochemistry. In this exercise glucose oxidase is immobilized on a screen-printed electrode (see figure 5, left). The screen-printed electrode consists of 3-electrodes, a reference electrode (R.E.), a counter electrode (C.E.) and a working electrode (W.E.) where GOx is immobilized at the surface. The electrochemical measurements are done by applying a constant potential between the R.E. and the W.E. using a potentiostat. Whenever GOx oxidizes  $\beta$ -glucose it transfers 2 electrons to the working electrode which in turn momentarily shifts the potential between the R.E. and the W.E. Since the potential was set to be constant, the potentiostat lets a small current run from the W.E. to the C.E. to restore the potential. This type of measurement is called amperometric detection as we measure an electron current under a constant voltage (potential). The electron transfer happens from the cofactor (FAD), which is buried inside the catalytic cavity of the GOx and for this reason we use a small redox active molecule called benzoquinone to shuttle electrons from the cofactor to the electrode surface (see figure 5). Unlike the reaction in bulk no molecular oxygen is consumed in the reaction as we have replaced this electron acceptor with the working electrode.

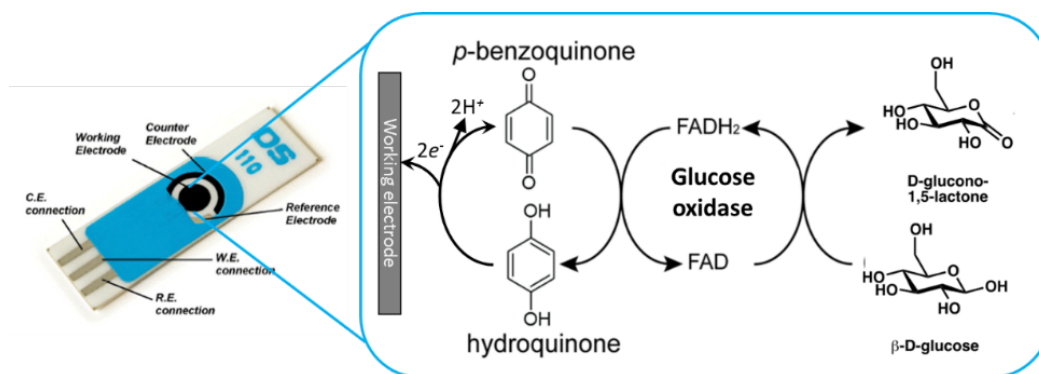


Figure 5. Schematic illustration of the mediated bioelectrocatalytic measuring principle for the amperometric measuring of  $\beta$ -glucose using immobilized glucose oxidase.

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In a stirred solution of substrate, the rate of reaction at the electrode ( $^{electrode}v$ ) is directly proportional to electron current ( $i$ ) from the screen-printed electrode (eq. 2):

$$^{electrode}v = \frac{i}{n \cdot F} \quad (\text{eq. 2})$$

where  $n$  is the stoichiometric number of electrons involved in the redox reaction (in our case  $n=2$ , see figure 5),  $i$  is the current (coulombs/s) and  $F$  is the Faraday constant (coulombs/mol). Notice that the rate ( $^{electrode}v$ ) is given in units of mol/s instead of M/s, which is the normal unit for reactions rate in the bulk. Under steady-state conditions, the steady-state current ( $i_{ss}$ ) is proportional to the steady-state rate ( $v_{ss}$ ) of the immobilized enzyme acting on the surface of the W.E., which we can write as:

$$^{electrode}v_{ss} = \frac{i_{ss}}{n \cdot F} = \frac{S_0 \cdot ^{electrode}V_{max}}{S_0 + K_M} \quad (\text{eq 3})$$

$$^{electrode}V_{max} = \frac{i_{max}}{n \cdot F} = k_{cat} N_{enzyme}$$

where  $N_{enzyme}$  is the number of enzymes immobilized on the surface of the and  $i_{max}$  is the maximum current when  $S_0 \rightarrow \infty$ . Plotting the steady-state current against increasing substrate concentrations give rise to a Michaelis-Menten curve with a slightly different maximal rate ( $V_{max}$ ) then the one defined in eq. 1. Figure 6 show how you can determent steady-state current from an amperometric measurement with subsequent injections of substrate.

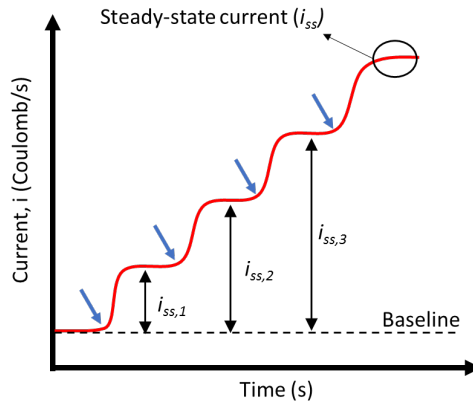


Figure 6. Illustration of the amperometric (current-time) response curve (red-curve) for a glucose oxidase biosensor. The blue arrow marks the injection of substrate to the cell, while the black arrow indicate the steady-state current ( $i_{ss}$ ) for different substrate concentrations.

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### Protocol exercise 1, exp. 1 – Steady-state kinetics

- Load syringe with 1M equilibrated glucose solution, pH5
- Setup the syringe (number of injections and injection volume)
- Connect GOx biosensor to potentiostat and place it in the cell
- Add 1.9 ml buffer and 100  $\mu\text{L}$  benzoquinone (5 g/L) to the cell
- Start the magnetic stirrer
- Setup the software for amperometric detection (potential = 0.12V, sampling rate = 1  $\text{s}^{-1}$ , length of experiment = 1000 s)
- Start the measurement and wait for a stable baseline
- Start glucose injections from the syringe (There should be sufficient spacing between each injections to detect a clear plateau (see figure 6)).

### Protocol exercise 1, exp. 2 – Rate of mutarotation for glucose

- Rinse the cell with water
- Connect GOx biosensor to potentiostat and place it in the cell
- Add 1.9 ml buffer and 100  $\mu\text{L}$  benzoquinone (5 g/L) to the cell
- Start the magnetic stirrer
- Setup the software for amperometric detection (potential = 0.12V, sampling rate = 10  $\text{s}^{-1}$ , length of experiment = 7000 s)
- Start measurement and wait for a stable baseline

*OBS: the next steps have to be done as fast as possible☺.*

- Add 10 ml buffer to a prepared amount of solid  $\alpha$ -glucose to get a 1M solution of  $\alpha$ -glucose.
- Whirl mixer to completely dissolve the powder
- Add 20  $\mu\text{L}$  of  $\alpha$ -glucose to the cell



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## Questions for the report 1

Exp. 1)

1. Calculate the glucose concentration in the cell after each injection. The cell volume is 2 ml.
2. Find the steady-state currents and calculate the steady-state reaction rate after each injection using eq. 2.
3. Plot the steady-state rate against the glucose concentration to obtain the Michaelis-Menten curve and fit equation 3 to the experimental data to obtain the parameters  $^{electrode}V_{max}$  and  $K_m$ . The fit can be done in Matlab (for help with the fitting see the video on moodle “MM-fit in Matlab”. The movie is placed in the folder “Lab 5: Computational laboratory Mappe”).
4. Use the  $k_{cat}$  from exercise 2 and  $^{electrode}V_{max}$  to estimate the amount of enzyme (in mol) that is immobilized on the surface of the biosensor.

Exp. 2)

GOx is highly specific for  $\beta$ -glucose. Hence, we can use the biosensor for measuring the mutarotation of  $\alpha$ -glucose to  $\beta$ -glucose.

5. Build a model in Simbiology and fit the alfa-beta equilibrium rate constants to your experimental data. For help with fitting in Simbiologi see the video on moodle “fit in Simbiologi”. The movie is placed in the folder “Lab 5: Computational laboratory Mappe”.
6. Does your fitted the rate-constants for the mutarotation reaction correspond with the ones reported in literature ( $k_{\alpha}=3.8 \cdot 10^{-4} \text{ s}^{-1}$ ,  $k_{\beta}=2 \cdot 10^{-4} \text{ s}^{-1}$ )

Glucose oxidase biosensors, such as the one you have characterized in this exercise, is widely used to measure e.g. the blood sugar. When used as a biosensor it is recommended that the substrate concentration is lower than the  $K_m$  of the enzyme ( $S_0 < K_m$ ).

7. Use your experimental determined  $K_m$  values to specify the substrate range of your biosensor.
8. Why is it recommended that you use the biosensor in a substrate range below  $K_m$ ?

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## Lab. exercise 2

### Michaelis-Menten kinetics of glucose oxidase by ITC measurements

In the second lab. exercise we will measure the steady-state rate using Isothermal Titration Calorimetry (ITC). Since the rate of a reaction is directly proportional to the heat generation (i.e.  $dQ/dt$  or thermal power) the steady-state rates can be calculated using equation 4:

$$v_{ss} = \frac{1}{\Delta H_{app} \cdot V} \frac{dQ}{dt} \quad (\text{eq. 4})$$

where  $v_{ss}$  is the steady-state rate,  $\Delta H_{app}$  is the enthalpy of the reaction,  $V$  is the volume of the calorimetric cell and  $dQ/dt$  is the change in thermal power after an injection (see figure 7A).

In order to obtain a Michaelis-Menten curve it is necessary to measure (1) the total apparent molar enthalpy  $\Delta H_{app}$  and (2) the heat flow  $dQ/dt$  at different substrate concentrations. We will do the former in the first experiment and the later in the second experiment of this exercise.

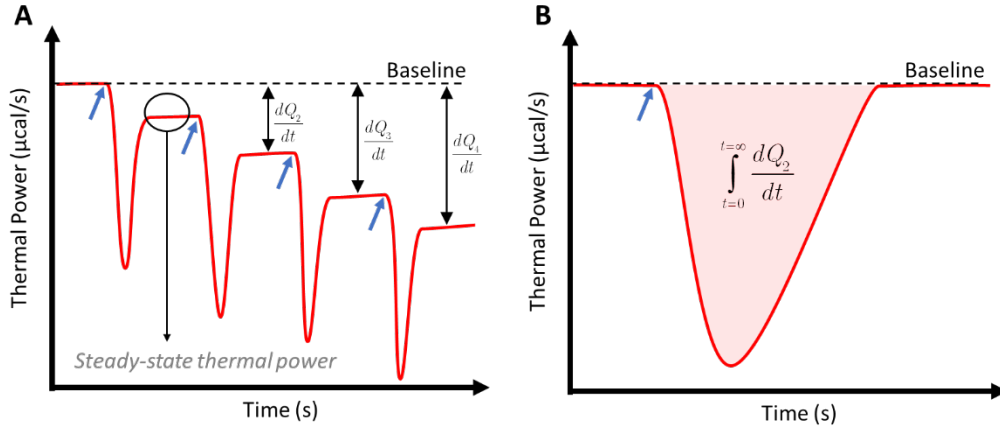


Figure 7. Illustration of the thermogram (thermal power vs. time) for a multiple injection ITC experiment (A) and a single injection ITC experiment (B). The blue arrow marks the injection of substrate (A) or enzyme (B) to the cell with respectively enzyme (A) and substrate (B). The black arrows indicate the steady-state thermal power ( $dQ_{ss}/dt$ ) while the red shaded area indicate the total heat produced by the reaction (area under the peak).

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### Protocol exercise 2, exp. 1 – enthalpy of reaction

- Load the cell with a 150 nM GOx
- Check that the syringe buret is up. Load the syringe with 10 mM glucose (equilibrated)
- Mount the syringe in the cell
- Change/check ITC settings (see tables below).
- Start experiment (Remember to name the data file)

**Experimental parameters**

Parameter	Setting
Total # of injections	2
Cell temperature (°C)	25
Reference power (μCal/s)	30
Initial delay (s)	500
Syringe concentration (mM)	10
Cell concentration (mM)	0.00015

**Injection parameters**

Parameter	Setting
Volume (μL)	10
Duration (s)	20
Spacing (s)	1000
Filter (s)	1

OBS: While exp. 1 is running:

- Calculate injection volumes for exp. 2. You need to cover a substrate concentration range such that you get a hyperbolic MM-curve (Hint:  $K_M \sim 20$  mM, Cell volume = 1.43 ml).
- Estimate how long time it will take to convert all the substrate into product. (Hint: use the enzyme\_kin simulator and the rate-constants from computer exercise 1 (lecture 1))

### Protocol exercise 2, exp. 2 – Steady-state kinetics

- Load the cell with 200 pM GOx
- Check that the syringe buret is up. Load the syringe with 1 M glucose solution (equilibrated)
- Mount the syringe in the cell
- Change/check ITC settings (see tables below).
- Start experiment (Remember to name the data file)

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**Experimental parameters**

Parameter	Setting
Total # of injections	6
Cell temperature (°C)	25
Reference power (μCal/s)	30
Initial delay (s)	500
Syringe concentration (mM)	1000
Cell concentration (mM)	0.0000002

**Injection parameters (Fill out the table)**

Volume (μL)	Duration (s)*	Spacing (s)**	Filter (s)
5	5	275	1
			1
			1
			1
			1
			1

\* Duration = inj. Vol μL \* 1 s/μL (e.g. 10 μL \*1s/μL =10s)

\*\* Spacing = inj. Vol μL \* 5 s/μL +250s (e.g. 10 μL \*5s/μL +250s =300s)

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## Questions for the report, exercise 2

Exp. 1)

The apparent molar enthalpy ( $\Delta H_{app}$ ) is generally measured in experiments in which all the injected substrate is converted into the product, in a given time period. In these experiments, we inject substrate and wait until the heat flow has returned to the baseline (Fig. 7B), and integration of the peak with respect to time yields the total heat produced by the reaction. Dividing this value by the known amount of substrate added gives the total enthalpy change as defined in eq. 5:

$$\Delta H_{app} = \frac{1}{S_0 \cdot V} \cdot \int_{t=0}^{t=\infty} \frac{dQ_2}{dt} \quad (\text{eq. 5})$$

where  $S_0$  is the initial substrate concentration and  $V$  is the volume of the cell.

1. In experiment 1 (exercise 2) you had 1000 second between each injection. Use the enzyme\_kin simulator and the rate-constants from computer exercise 1 (lecture 1) to estimate if 1000 seconds is enough time to convert all the substrate into product.
2. Find  $\Delta H_{app}$  form the single injection experiment. The cell volume is 1.43 ml.
3. When you calculate  $\Delta H_{app}$  you assume that all substrate is converted to product. Is this a valid assumption in our experiment? (Hint: You did two single injections experiments with 500 s spacing. Find the area under both peaks and explain how you can use the two single injections to justify that approximately all substrate is converted to product.)

Exp. 2)

4. Calculate the glucose concentration in the cell after each injection
5. Find steady-state thermal power and calculate the steady-state rate using equation 4.
6. Plot the steady-state rate against the glucose concentration to obtain the Michaelis-Menten curve and fit the MM-equation (eq. 1) to the experimental data to obtain the parameters  $V_{max}$  and  $K_m$ . The fit can be done in Matlab (for help with the fitting see the video on moodle “MM-fit in

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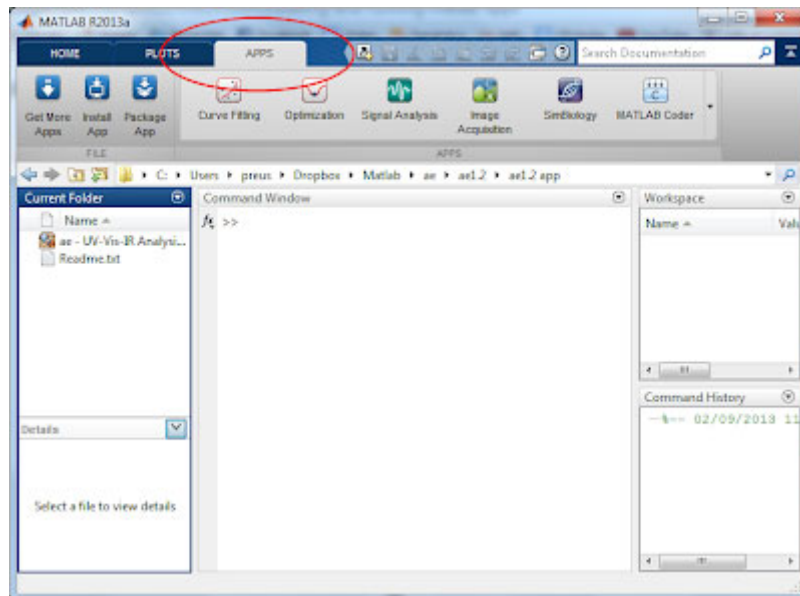
Matlab”. The movie is placed in the folder “Lab 5: Computational laboratory Mapped”).

9. Compare the estimated  $K_m$  value with the one found in exercise 1. Do you expect these two parameters to be the same?
10. Equation 1 is only valid if we can assume that the enzyme-substrate complex (ES) does not change with time ( $dES/dt \approx 0$ ). Is this a valid assumption in our experiment? Explain how you can use the raw-data to justify this assumption.

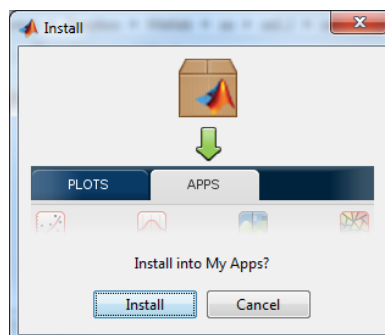
## Appendix 2. V

### Installing and running MATLAB Apps

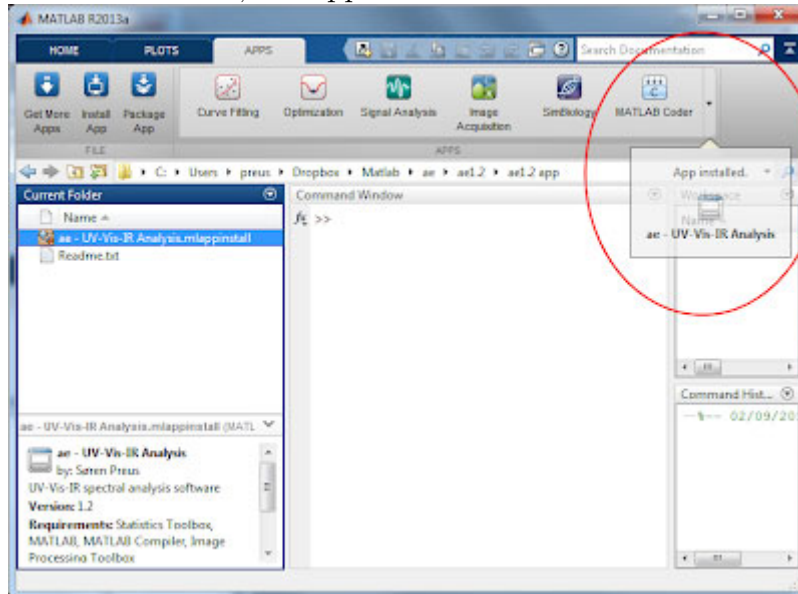
A MATLAB App is a user-interfaced MATLAB-based application requiring a single installation file only. When an app is installed the installed application can be run directly from the MATLAB Toolstrip named 'APPS':



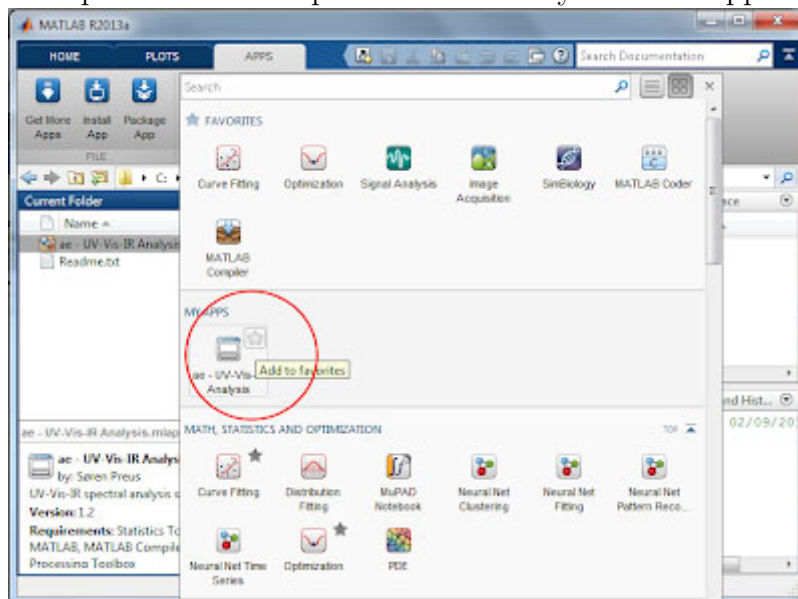
- A. Download the app from Moodle (located in the subfolder “Lab 5: Computational laboratory”). The app installation file is characterized by the suffix '.mlappinstall'.
- B. Open Matlab
- C. Double-click the installation file.
- D. A dialog is opened. Click Install.



5. Once installed, the app is added to the MATLAB Toolstrip.



6. Expand the toolstrip to find the newly installed app



8. Click the icon to run the program.



## Appendix 3

### Case study 3 - Experiment in Spatial Lab (geography in practice)

According to Kongsted (2016), the design of exercises is the most fundamental aspect to good laboratory work. In line with the literature, therefore, we decided to introduce a new set of exercises. Instead of having a fictive set of tasks; the designed the workshop to center around a real world case, that we were going to in the field trip. The case centers on problems the planning department in Gulborgssund Municipality, currently struggles with. Thus, this workshop in spatial lab, not only works as a pre-lab to the fieldtrip, it creates an authentic learning situation for the workshop in itself. The intended learning goal remain: learn to systematically search relevant digital planning data to geographical analysis when preparing planning proposals.

The case is design so no method or results are given in contrast to the fall 2017 exercises. The real-world case, the actuality of the case, and the fact that we were going to visit the place and that the Planning department in Guldborgssund Municipality currently work on the subject, where first introduced to the students. Next, I presented the learning goals and lastly, basic GIS elements, before handing out the task. Otherwise, I ran the workshop as in the fall semester 2017.

#### Case description

"The municipal council in Guldborgssund Municipality is concerned with a number of negative trends in Skakskøbing city. After the municipal reform in 2007, and Sakskøbing municipality merged into the new Guldborgssund Municipality, the city have faced a number of negative urban trends. Among these, declining retail, declining population, remarkably demographic shift, and not a single new construction since then. Moreover, the Citizens feel that the new municipality overlook the city, due to the fact that no physical planning has been conducted since the shift. Consequently, the Mayor, John Brædder, on behalf of the municipal council has requested a new city plan. You have been appointed as lead member of the working group, due to our magnificent qualifications and expertise. The municipal council wish to make use of new regulation in accordance with the planning law. You will become project leader of the group, which comes up with a new city plan, recommendations and planning proposals that support city growth. The mayor wish the following planning investigations commenced: ... and so on...

I am sure the students better learned to access relevant digital data, due to the fact they were going to work with them in Sakskøbing. This require low technical GIS competences. If the exercises, worked in terms of learning GIS I am not sure (which was not a learning objective). Every now and then, I observe students that come up with a solid planning proposal, but does not acquire the skills to accomplish the idea. They skip the idea, and spend much effort in finding a solution they can easily find the required digital data, and conduct the data analysis. However, as they enter into the stage of collecting and managing the relevant digital data (does it conflict with heat distribution networks, sewage system, the lake protection line, or other relevant features), and cannot immediately find storage and manage the data, one students says: "Ok, let's find another idea". In such cases, I intervene. Not so much because of the character of their planning, proposal, but because they would run into the same problem, no matter what. The core aim of the task. The question is, should students acquire technical skills before one can really begin, or should they just start, and learn the technical skills along the way. I believe the latter.