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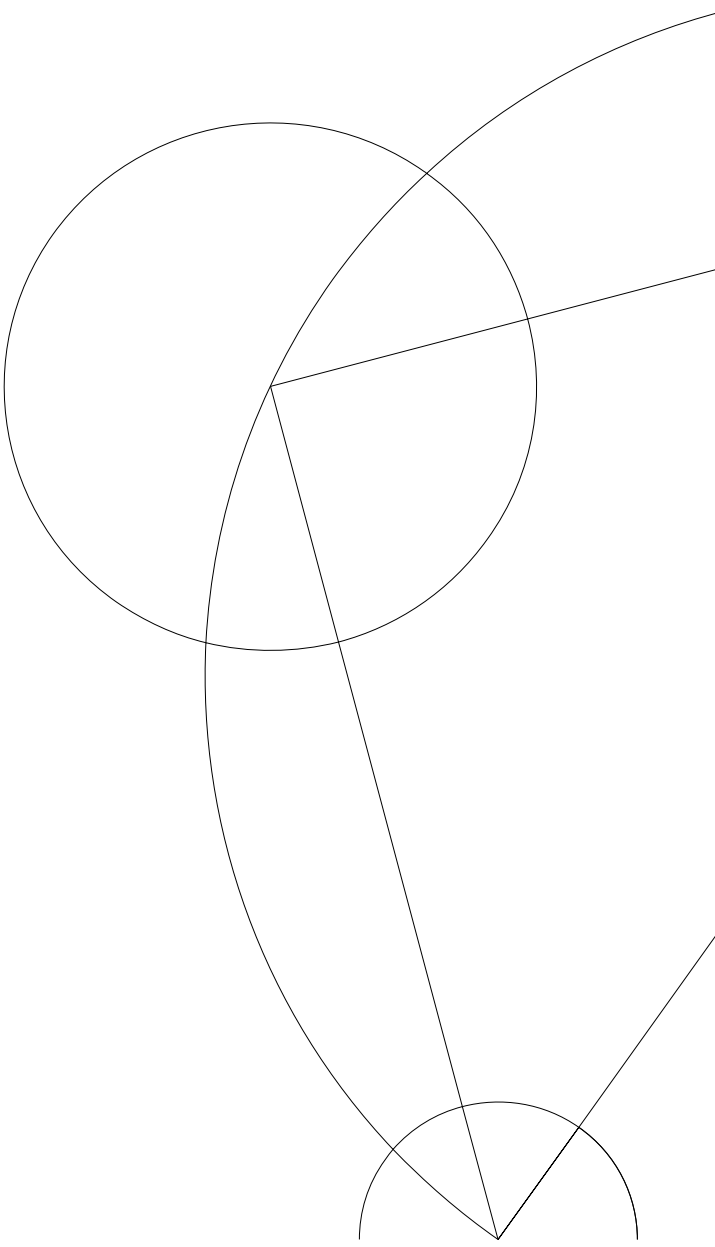
“Super Yeast”
The motivational potential of an inquiry-based experimental exercise



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Bachelorprojekt – Biologi

Vejleder: Robert Harry Evans

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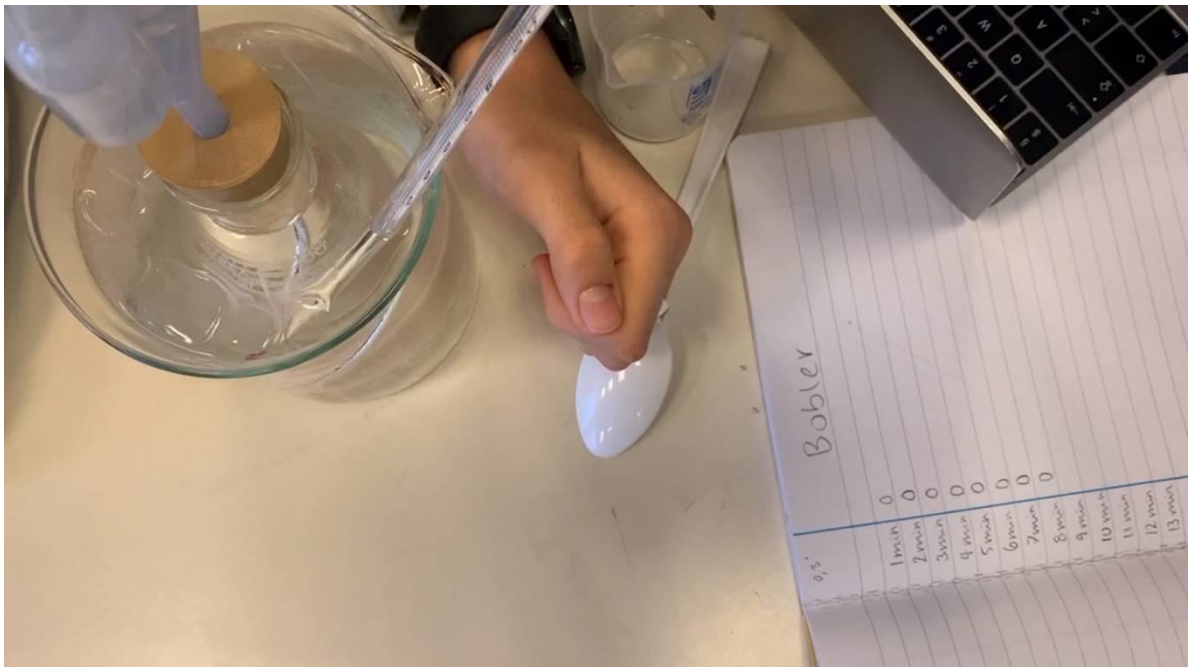

Bachelor Project

Caroline Woergaard Gram

“Super Yeast”

The motivational potential of an inquiry-based experimental exercise

Supervisor: Robert Harry Evans, Associate Professor

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Submitted: 18th January 2021

15 ECTS

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Abstract:

A key theme in the educational research is the motivational and learning potential of Inquiry-based Science Education and the challenges in implementation the educational method in the science subjects. Additionally, motivational research and theories states that the external regulation often used in education often diminish student motivation and well-being with negative influence on their learning outcome and academic achievement. To investigate the motivational potential of inquiry-based experimental work in biology, an existing instructional learning material was redeveloped following the structure of the 6F model. The developed module was taught in 6 different classes in 3 different gymnasiums in the Copenhagen area in the months of November and December 2020. Student responses to the content and learning activities of the developed module were collected using an online Survey and interviews. The responses of the students were analysed using qualitative content analysis and the central concepts of the Self-Determination Theory. Student responses revealed that it is possible to influence the way students are motivated through the facilitation of the learning activities. Moreover, findings suggested that students' motivation to engage in experimental work could be positively influenced by giving students a choice, using a problem to contextualize the experiments and through social interactions. Based on the findings the 6F model was found to positive influence students' motivation as well as having a potential of changing students' perceptions of experimental work in biology.

Table of Contents

List of Appendixes:

List of Abbreviations:

CARTAGO: Competence, Autonomy, Relatedness, Attributions, Goal-Orientations.

STEM: Science, Technology, Engineering and Mathematics.

IBSE: Inquiry-based Science Education.

SDT: Self-determination theory.

Introduction

Today, the world faces complex challenges which requires transdisciplinary, international solutions through global collaboration. Science is one of the main strategies for solving the global challenges, and faith is put in future STEM (Science, Technology, Engineering and Mathematics) candidates that they will find solutions, to the problems, facing society. Regardless, students' enrolment in STEM educations is a concern today as it was in 1910 when Dewey wrote *"Considering the opportunities, students have not flocked to the study of science in the numbers predicted, nor has science modified the spirit and purport of all education in a degree commensurate with the claims made for it."* (Dewey, 1910). Despite students' career choices being a complex issue, one of the reasons being highlighted as part of the explanation is students' lack of interest in science. This tendency has resulted in several EU funded projects including the "ROSE project" and "Science Education NOW: A Renewed Pedagogy for the Future", as a response to the decreasing number of young Europeans choosing a career within the field of science and technology (Rocard *et al.*, 2007; Sjøberg and Schreiner, 2010). Students' lacking interest in science is also addressed by Danish researchers see for example Ulriksen *et al.* 2013 and Dohn (2014). Despite, the higher educational institutions experiencing an increase in students enrolling in science degrees (Uddannelses- og Forskningsministeriet, 2018), a general lack of interest in science constitutes a democratic and societal problem. If students are less interested in science they would be less likely to choose a career within the STEM fields, as well as being less *scientific literate* which would be democratic problem since society aspires to make decisions based on science (Ulriksen *et al.*, 2013). An example of this is Covid-19 and the citizens understanding the rationale behind restrictions and regulations such as virology, graphic and numerical explanations including contact numbers and projections. To address the above an extensive amount of literature and projects investigate how student motivation in science and their *scientific literacy* can be improved.

Scientific literacy can be understood as the competencies describe by the Danish Ministry of Children and Education and the Danish concept of *Naturfaglig Dannelse* (Dolin, 2020, p. 624). All students attending the Danish Gymnasium are expected to develop and acquire these competencies throughout their education. For students to do so, experimental work has been given an essential role in the external didactic transposition of the science subjects, and thereby defining the science subjects, but also in students' learning process and perception of the subject. Nevertheless, no clear guidelines have been giving to design and structure experimental work (Jacobsen, 2020, p. 634). This leads into a discussion about the learning potential of experimental work in the Danish schooling system (see for example Hodson, 2008). Moreover, the science subjects are filled with concepts and terms which are often abstract and difficult for students to relate to everyday life. The deductive, hypothetically characteristics and structure of the natural science are not easily translated into student's more narrative approach to the world.

One way to reduce the difference between science and everyday life is to emphasis the process and methods of natural sciences instead of the results (Dolin, 2020, p. 629). This reflects the concept of *Inquiry-based Science Education* (IBSE), which has been emphasised as a method to increase students' motivation and interest in science as well as their learning outcome - also in a Danish educational context (see for example Østergaard *et al.*, 2010). Additionally, large projects such as the Fibonnacci and PROFILES projects have been funded by the European Union to enhance and strengthen IBSE across Europe (Bolthe and Rauch, 2014; Harlen, Guldager and Auning, 2012). In Denmark, several initiatives such as *Naturvidenskabens hus* and LIFE have been piloted to strengthen science education and students' interest in science through IBSE practices (Østergaard, 2012; LIFE, 2020).

Despite an extensive amount of research and initiatives advocating for the implementation of IBSE practices in the science subjects, there are no clearly defined model or strategy for implementing IBSE (Capps and Crawford, 2013: Michelsen, 2011). Research has tried to identify and define Inquiry-based activities to support implementation (e.g., Sofoklis, Rodger W. and Bogner, 2017), while many studies have suggested several difficulties in the implementation of IBSE in science education including but not limited to; teachers' having limited competencies in teaching Inquiry-based (Michelsen, 2011; Kang, Bianchini and Kelly, 2013; Fillippi and Agarwal, 2014; Sofoklis, Rodger W. and Bogner, 2017; van Uum, Verhoeff and Peeters, 2017), implementing IBSE in the education of teachers (Østergaard, Sillasen, Hagelskjær and Bavnhøj, 2010) misconceptions of women's capabilities of science, barriers of technology (Fillippi and Agarwal, 2014), schematic structure of the school and a lack of resources and evaluative assessments (Michelsen, 2011; Harlen, 2013). Despite all of these difficulties, it is still the author's believe that the method has a place in the Danish gymnasium and a potential to motivate students to engage in science and expand their perception of science subjects from a long repetition of factual knowledge into something they can contribute and attribute value to, no matter what their future career choice will be.

To explore the motivational potential of IBSE, this thesis aims to redevelop an existing instructional learning material to reflect the characteristics and structure of IBSE while still apply to the schematic structure and core curriculum of biology in the Danish gymnasium. Thus, exploring if IBSE only holds a potential in the form of extensive projects or long resource costly teaching courses. An important aim of this study is to create an output which can be shared and applied by all teachers, and thereby hopefully be a resource to teachers who wishes to teach inquiry based. Student responses will be collected and analysed to investigate how students are motivated by the activities and content of the developed module. To understand how students are motivated by the context in which they learn, the principles and concepts from the Self-Determination Theory are applied.

The structure of the thesis:

First, this thesis will outline and define the background and research used to define the problem statement. Secondly, the development and implementation of the "Super Yeast" module is described in the first part of Chapter 2. This is followed by a description and evaluation of the methods applied for collecting and analysing data. In Chapter 3, results from in classroom observations, the online Survey, student interviews and analysis are presented. These findings are discussed in relation to the central concepts of the Self-Determination Theory, followed by a conclusion. Lastly, this thesis ends with a brief outlook on future research and motivational theories in educational contexts.

1.Background:

1.1 What is motivation and how does it relate to learning?

The concept of motivation is defined in several ways, which is also reflected in the wide variety of research of motivation. Andersen and Krogh (2020, p. 251) defines motivation as an inner cognitive process, which results in determined behaviour. This process begins in our conscience minds, with the identification of goals, which might not be distinct in character or easily formulated but still reflects a conscious process. Therefore, instinctive behaviour is not a result of motivation (Andersen and Krogh, 2020, p. 251). Motivational processes are responsible for making us initiate an action, directing it and be persistent in achieving a goal (Andersen and Krogh, 2020, p. 251). Learning is an active cognitive action, hence motivation influences learning processes and are therefore a significant aspect to teaching (Dohn, 2014). In an educational setting, motivation affects how students behave in a specific context and what determines their persistence in situational context. Hence, the concept of motivation is a qualitative, descriptive concept (Andersen and Krogh, 2020, p. 251). The concept of motivation encapsulates what inner processes are occurring within the students' in different learning situations to a greater extent than the concept of interest, hence those two concepts cannot be used synonymously (Andersen and Krogh, 2020, p. 251), however interest and motivation are two concepts influencing each other.

1.2 The link between motivation and student engagement:

The aim of this thesis is to develop a module which will motivate students to engage in experimental work. It has been identified through several studies that engagement is a result of motivation (Nikou, 2018; Saeed and Zyngier, 2012; Wood, 2019). Additionally, Student engagement are a significant indication and predictor of student motivation, learning outcome, well-being, and academic achievement (Niemiec and Ryan, 2009; Saeed and Zyngier, 2012; Wood, 2019).

A difficult aspect of student engagement is that it cannot be observed (Saeed and Zyngier, 2012). Students are characterized as authentically engaged when they work enthusiastically, meaning putting effort and concentration into a task, which has innate value to them. Authentically students are invested and involved in

their own learning process and are not driving by grades but internalize what they have learned in their own lives (Saed and Zyngier 2012). To engage students' activities must spark student curiosity, allowing for creativity and collaboration, and resulting in a feeling of success (Saed and Zyngier 2012).

Previous studies have explored the connection between student motivation and engagement by applying the Self-determination Theory (Saeed and Zyngier, 2012; Wood, 2019). Saeed and Zyngier (2012) found that different types of motivation, defined by the SDT, influenced the way students engaged in the learning activities. For example, in studies done by Wood (2019) and De Loof *et al.* (2019), student engagement was influenced by students' self-perceived feeling of competence and autonomy. Another important finding was that *the way* the teacher supports students autonomy and competence influences students self-perception of competence (Wood, 2019) and autonomy (Lavigne, Vallerand and Miquelon, 2007; De Loof *et al.*, 2019; Wood, 2019) which positively influence students motivation and engagement in learning activities (Nikou, 2018; Kolovou and Kim, 2020). For an elaboration of the link between the different motivational types, described by the Self-determination theory, and different engagement behaviours exhibited by students can exhibit see Figure 3 in Saeed and Zyngier (2012).

In this study, student engagement, is defined as a combination of students participating actively in the learning activities and students' self-reported engagement. This is a similarly approach to the studies done by Saeed and Zyngier (2012) and Wood (2019). This study will investigate how the teachers' facilitation of a learning environment can change the way students are motivated and thereby their engagement in the experimental work. Thus, the focus will not be on characterizing student engagement but how students are motivated to engage.

1.3 Self- determination Theory in an educational context:

Are students intrinsically motivated?

In the reforms of the Danish Gymnasium, students are perceived to be motivated to learn and be engaged, thereby not including an objective addressing student motivation (Andersen and Krogh, 2020, p. 250). While it is not a question *if* students are motivated a more pressing questions is *how* students are motivated to learn.

The Self- determination theory (SDT) distinguish between the two types of motivation. The first reflects a perception of humans as naturally driving by assimilation, mastery, spontaneous interest, and exploration, which is fundamental source of joy and vitality through life (Ryan and Deci, 2000). This human disposition is termed *intrinsic motivation.* We engage in activities for the enjoyment, challenge, and excitement of the activities, when we are intrinsically motivated. Moreover, these behaviours have *an internal perceived locus of causality* (Niemiec and Ryan, 2009). In other words, we experience ourselves as being the source of events and as our behaviour originates from ourselves. This inherent fundamental curiosity and excitement to learn and engage, could be an enormous resource in schools. However, students rarely exhibit intrinsic moti-

vation in the learning context of the gymnasium, hence student motivation presents an important question in educational contexts.

Intrinsic motivation can be undermined by external conditions

Despite intrinsic motivation being an innate characteristic to human nature it needs to be maintained and supported in the social contexts, in which an individual develops and function. According to the SDT, external conditions can undermine intrinsic motivation and well-being of an individual (Ryan and Deci, 2000). This is relevant in an educational context, where external measures are often used to direct and control student behaviour and to facilitate learning e.g., by using rewards or punishments. The applied measures and conditions of the learning context can have significant negative consequences for students' self-determination and engagement in learning activities and might lead to feelings of anxiety, boredom, alienation (Niemiec and Ryan, 2009).

Extrinsic motivation in learning contexts

Far from all aspects of attending school are interesting and intrinsically motivation and students might not be intrinsically motivated to attend gymnasium at all. Therefore, it is relevant to include another type of motivation from the SDT in an educational context: *Extrinsic motivation.* An extrinsically motivated individual is motivated by a *separate* consequence of the individuals' action (Ryan and Deci, 2000). The individual's behaviour is thereby externally regulated. Intrinsic and extrinsic motivation are considered as opposites but not exclusives. In the SDT, the concept of motivation is not a unitary concept but includes several kinds of motivation. Thus, the SDT provides explanations of *how* and not *if* a student is motivated (Ryan and Deci, 2000; Niemiec and Ryan, 2009). Since students are regulated by various external factors in school, student motivation must be understood in relation of both intrinsic and extrinsic motivation (Andersen and Krogh, 2020, p. 253). Given that it would be unrealistic to expect students being intrinsically motivated by all aspects of school, a central question is how teachers can introduce learning activities, assignments, and tasks in a way which results in students *internalizing* tasks as their own. If students internalize a certain instruction or task, they perceive their behaviour as originating from themselves and therefore they would be increasingly self-determined (Ryan and Deci, 2000; Niemiec and Ryan, 2009). The connecting between self-determined behaviour, autonomy, extrinsic and intrinsic motivation is illustrated in Figure:

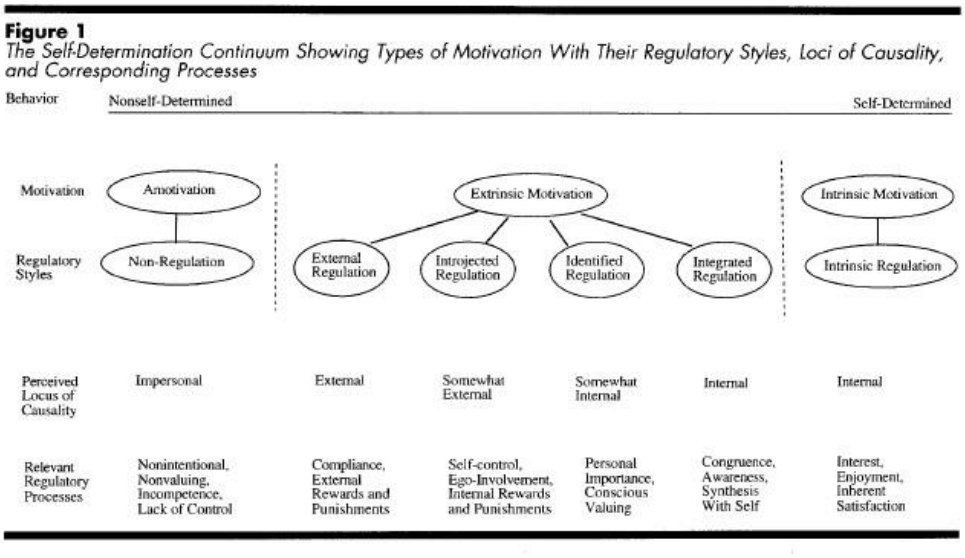


Figure 1. Illustrating the Self-Determination Continuum which describes the connection between self-determined behaviour, types of motivation, perceived locus of causality (Ryan and Deci, 2000).

In the SDT, self-determination follows a continuum with nonself-determined behaviour linked with amotivation and self-determined behaviour being driven by intrinsically motivation. Between those two opposites, extrinsic motivation follows a continuum of different types of extrinsic motivational types, following an increasing experience of autonomy (Ryan and Deci, 2000). For an explanation of the different types of extrinsic motivation see Niemiec and Ryan (2009). In conclusion, the extent in which students perceive the level of control from external factors determines their experience autonomy and thereby determining the way they are motivated to engage in learning activities, with consequences for the students' learning outcome and well-being (Ryan and Deci, 2000; Niemiec and Ryan, 2009).

Autonomy, competence, and relatedness

The objective of the STD is to determine which conditions of a social context can make students internalize external regulations leading to self-determined behaviour (Ryan and Deci, 2000). The following three psychological needs have been identified to support internalization and enhance intrinsic motivation: *autonomy*, *competence*, and *relatedness* (Ryan and Deci, 2000). When all three psychological needs are satisfied, students will be self-determined, more intrinsically motivated and feel autonomous.

An experience of autonomy is determined by the extent a behaviour is perceived as voluntary and self-governed (Ryan and Deci, 2000). An important aspect of the experience of autonomy and internalization is that students accept the rationale of an activity e.g., when the teacher is presenting a task (Niemiec and Ryan, 2009). Unlike competence and relatedness, autonomy can only be experienced in learning contexts which are autonomy-supportive (Ryan and Deci, 2000) for examples contexts with a reduced emphasis on exams or other measures which encourage a specific way of thinking.

Additionally, to an autonomy-supportive learning environment, students need to feel competent and capable to achieve a specific task to perceive autonomy as motivating (Andersen and Krogh, 2020, p. 257). Autonomy is not necessarily linked to independency (Ryan and Deci, 2000) but the extent of choice and influence on a learning activity needs to be according to the students' perception of competence (Andersen and Krogh, 2020, p. 257). Students will experience competence when they feel capable of meeting the requirements and demands of the learning activities and task, resulting in an internalization of regulation (Niemiec and Ryan, 2009; Krogh and Andersen, 2020, p. 255). Regardless of competence, controlling external factors in a learning context will undermine students' experience of autonomy which would result in lower self-determination, student learning outcome and initiative (Niemiec and Ryan, 2009).

Lastly, the need for relatedness encapsulates the need to be acknowledge and feel a sense of belonging to others in a social context (Andersen and Krogh, 2020, p. 257). Relatedness facilitates the process of internalization because students will be more dispositioned to internalize external regulation from others whom they feel connected too. The teacher is especially influential on the students' need of relatedness (Niemiec and Ryan, 2009). When students feel appreciated and respected by their teacher, they will be more inclined to internalize external factors and make them their own, whereas students who feel rejected or distanced from their teacher will only respond to externally controls (Niemiec and Ryan, 2009).

When all the three fundamental psychological needs, defined by SDT, are satisfied in an educational context, students will tend to engage in less interesting activities and assign a higher value to their schoolwork. Moreover, they would be increasingly intrinsically motivated and self-determined with positive influence on their achievements, learning outcomes and well-being (Niemiec and Ryan, 2009). The teacher plays a central role in satisfying the three fundamental needs of the students by creating a learning environment, which promote intrinsic motivation and internalization which would result in students who are engaged even though they are motivated by external factors (Ryan and Deci, 2000).

1.4 Inquiry-based Science Education and its potential for supporting student motivation:

What is Inquiry-based Science Education?

The word *inquiry* is widely used in educational contexts but also relates to everyday life (Harlen, 2013). The interpretation of the word has been a topic of discussion throughout the 19th century (see Barrow, 2006). This thesis has included the following description of inquiry:

> *"[…] the process of investigating a problem issue that requires critical thinking, observing, asking questions, testing out ideas and hypotheses, and engaging in collaborative discussions to communicate scientific knowledge and develop explanations or solutions on the topic under discussion."* (Gilies, 2020, p. 3).

To teach inquiry-based refers to the internationally acknowledge educational method, Inquiry-based Science Education (IBSE) which has the objective of increasing students' interest and learning outcome of science (Østergaard, Sillasen, Hagelskjær and Bavnhøj, 2010). Many characteristics have been used to define IBSE, but it can be described as an inductive, investigative teaching method in which students pose questions for investigation, design experiments, collects data and formulate results and conclusions (Dohn, 2014). Similarly, the principle of IBSE is characterized by Østergaard, Sillasen, Hagelskjær and Bavnhøj (2010) with the central aspect of IBSE being the students' work with open-ended questions, problems, and solutions through different investigations, supported by their teacher. By working with IBSE based teaching practices, students develop their scientific competencies and scientific literacy (Østergaard, Sillasen, Hagelskjær and Bavnhøj, 2010).

Inquiry-based teaching practices vary according to context and teacher applying the method. Differences can for example be in relation to openness, meaning the extent students influence the learning activities and content (Dohn, 2014). However, The American National Science Education Standards has identified the following essential characteristics of inquiry, which applies across all grade levels and contexts (Abell, 2000, p. 38). Inquiry is when students:

- *Are engaged with scientifically oriented questions;*
- *Give priority to evidence;*
- *Formulate evidence-based explanations;*
- *Compare and evaluate the merit of explanations; and*
- *Communicate and justify explanations.*

When working inquiry-based, Østergaard, Sillasen, Hagelskjær and Bavnhøj (2010) put emphasize on the students' work is based on their engagement and ideas. Similarly, Barrow (2006) states that: *"Every inquiry must engage students in a scientifically oriented question. These questions must be of interest to the student; otherwise, they will not establish ownership"*. To achieve this, teacher has an important role as guide or supporter of the student's cognitive process in inquiry-based learning activities and the teacher's ability to do so determines the learning potential of IBSE (Kruse, 2013). In some way, the didactic contract between teacher and student changes in inquiry-based activities since the teacher does not have the correct answer. Instead, it is the students who are actively constructing the knowledge. Accordingly, the IBSE method is funded in constructivist ideal of students working with the problem solution actively - as a quasi-scientist (Østergaard, Sillasen, Hagelskjær and Bavnhøj, 2010; Harlen, 2013). According to the constructivist perspective, Piaget states that learning is a cognitive action where knowledge is adopted through either assimilation or accommodation, determined by how the individuals' already existing world schemes (Dolin and Kaspersen, 2020 p.174). Learning is thereby an active action, and it builds on the students' pre-exiting knowledge.

IBSE teaching practices have been attributed several qualities. IBSE can develop students' competencies and abilities to formulate hypothesis, ideas and to work independently in experimental work, as well as increase student motivation (Østergaard, Sillasen, Hagelskjær and Bavnhøj, 2010; Harlen, 2013)

How can IBSE stimulate students' motivation?

Various studies have highlighted IBSE as an educational method to engage students, enhance student motivation, interest and excitement in science (Østergaard, 2012; Shamsudin, Abdullah and Yaamat, 2013; Dohn, 2014; Fillippi and Agarwal, 2014). IBSE teaching often contributes with variation and something new which stimulates the students' interest (Dohn, 2014) and possibly their curiosity. By giving the students' choices and influence in the learning activities, students will be inherently motivated according to SDT. Additionally, the teaching method supports groupwork, which can motivate students through group dynamics (Dohn, 2014). The possibility of discussing from different positions and decide on a position independently, are motivating to students. In science subjects, many students experience that they have to acquire factual knowledge so by applying contributions from the science subjects to the solutions of societal problems, students will be more interested and motivated (Dohn, 2014).

Despite the motivational and learning potential of IBSE teaching practices, there are several difficulties in implementing the methods as a teacher (Krämer, Nessler and Schlüter, 2015). One of the biggest challenges of IBSE is to create alignment between the inquiry-based approach and the theoretical models and concepts. Failed attempts to do so would result in students not being able to apply their knowledge (Michelsen, 2011). To create alignment between the inquiry-based approach and the theoretical models, this study has applied the 6F model, which has been highlighted as a useful supporting structure for inquiry-based teaching practices (Korsager, 2020; Madsen, Evans and Bruun, 2020).

1.6 A description of the 6F model and its potential for motivating students in experimental work

Teachers have expressed a need for supporting structures to implement IBSE teaching practices (Østergaard, Sillasen, Hagelskjær and Bavnhøj, 2010), which have been highlighted as being time demanding and complex (Korsager, 2020). The 6F model has been designed as a supporting structure to plan, design, and conduct IBSE teaching practices (Korsager, 2020; Madsen, Evans and Bruun, 2020). The amount of instruction in a 6F model is somewhere between the traditional teaching methods and a completely open IBSE teaching practices. Similarly, to IBSE, the 6F model is founded on a constructive learning. Throughout the phases of the 6F model students will experience a cognitive imbalance which will be brought in balance through learning activities in the phases (Madsen, Evans and Bruun, 2020). The 6F model constitutes of 6 phases - *Forudsætning, Fang, Forsk, Forklar, Forlæng* and *Feedback* (see Figure 2). By planning the teaching as a 6F model, the teacher creates a learning situation where the students explore new phenomena and learn through teaching instruction and discussion. The design of the model guides the students to internalize the knowledge

which is presented for the students in their work with the learning activities (Madsen, Evans and Bruun, 2020). The basis of learning activities in the *Forudsætning*, *Fang* og *Forsk* phase, is the students' pre-existing knowledge. In the 6F model *Forudsætning* is added as an independently phase. Similarly, *Feedback* is an independent phase emphasizing the importance of formative feedback in IBSE (Madsen, Evans and Bruun, 2020).

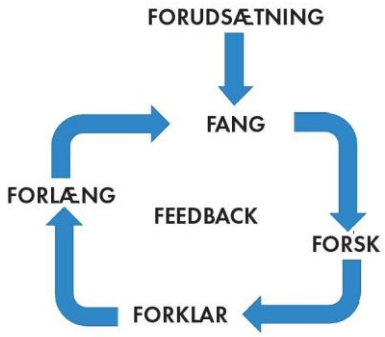


Figure 2 The 6F model (Madsen, Evans and Bruun, 2020)

How the 6F model can motivate students

All the phases in the 6F model are embedded in the students pre-existing knowledge. In the *Fang* and *Forudsætnings* phase students' share their own ideas, and therefore will experience their ideas as valuable and useful, resulting in the students' feeling a greater sense of competence, ownership, and autonomy, which will motivate students to investigate their ideas (Korsager, 2020). By letting the students' influence the learning activities by including their ideas, students will be more inherently motivated (Dohn, 2014). To do so, it is necessary to avoid any emphasis on right/wrong answers since that would undermine the students' motivation for investigating their own ideas (Korsager, 2020; Madsen, Evans and Bruun, 2020). When students investigate their own ideas, they can communicate, discuss, and reflect upon their own understanding, which are essential for their learning outcome and a central element of IBSE (Korsager, 2020). All the activities in the 6F model include social interactions, which can motivate students through the dynamics of groupwork (Dohn, 2014). Studies have emphasized that the structure of the learning activities and teacher's educational method have a greater influence on the students' motivation, than the topic (De Loof, 2019; Korsager, 2020), therefore the 6F model might potentially to change the way students are motivated when working with uninteresting topics. Challenges of applying the 6F model includes fitting the activities into the schematic structures of the gymnasium and giving constructive formative feedback in classroom consisting of many students. Even so, teachers have experience more positive outcomes than negative, when applying the 6F model in their teaching - especially on a motivational aspect (Holm, 2019: Madsen, Evans and Bruun, 2020).

The background of this thesis lead to the formulation of the following problem statement:

Problem statement:

A defining and essential part of science subjects in the Danish Gymnasium is experimental work. Many students are not motivated by the science subjects. Their lacking motivation in science subjects can potentially have a negative impact on their educational outcome and potentially decrease numbers of STEM candidates. Inquiry-based science education has been highlighted as a method to promote student motivation and interest in science subjects. Even so, there is still discussion about the effectiveness of the method and challenges in the implementation of the method in the existing structures of the Danish Gymnasium. Therefore, this study explores the possibility of motivating students to engage in experimental work in biology by redeveloping existing instructional learning material according to the characteristics of (IBSE). To investigate the potential of this educational method the following problem, aim and research questions were identified:

Aim: The aim of this study is to understand what motivate students to engage in experimental work in biology and develop an inquiry-based module which can be applied by teachers in the gymnasium. The aim of this study will be achieved by answering the following research questions:

Research questions:

1) *How and to what extent can the application of the 6F model motivate students to engage in experimental work in biology in the Gymnasium?*
2) *To what extent are student responses to experimental work affected by:*

- *Choice*
- *Working with a case*
- *Video*

The problem statement is investigated from the perspective of student motivation and engagement being determined through the students' perception of the learning environment and trough their interactions with peers and teacher. Motivation is defined as an *internal* process, but it is determined by *context*. This study focuses on the learning environment the teacher facilitates and how students respond to it. This study does not focus on the individual student's learning process but explores how learning is a result of a collective process between teachers and students. In that way, student motivation and engagement are viewed as products of the conditions of the learning environment and can therefore be changed by changing the conditions of the learning environment. It should be noted that students also affect the learning environment by the way they are motivated, engaged and participate but this aspect will not be addressed in this study.

Chapter 2 Methodology

To answer the posed research questions and to achieve the aim of this study, both developmental, qualitative, and quantitative approaches were applied in this study. The following section describes the development of

the teaching module "Super Yeast" and the rationale behind the content and structure. Next the applied methods for collecting and analysing data are described and evaluated.

2.1 The Development of the module "Super Yeast"

The experimental exercise *Forsøg med gær - illustration af det kontrollerede forsøg* (Hansen *et al.*, 2012) was redeveloped according to the following:

- Research-based definitions/principles and characteristics of IBSE outlined in the theoretical framework of this thesis (cf. Chapter 1).
- The principles, didactical basis of the constructivist 6F model outlined in the theoretical framework of this thesis (cf. Chapter 1).
- Results within the field of educational and pedagogical research.

The module was developed through collaboration with a teacher working at a gymnasium and the learning material by Jørgensen (2017). Throughout the development of the module, it was important that the module was reflecting the context of the teaching practices in the Danish gymnasium, making it applicable to other teachers. Therefore, the activities of the module can be completed within 90 minutes, which reflects the duration of one module in the schematic structure of many gymnasiums. Furthermore, the module's content covers several topics and objectives defined in the core curriculum of biology in the Danish STX gymnasium. Additionally, the intended learning outcome of the module supports the student's development/strengthening of the four competencies of natural science, formulated by the Danish Ministry of Children and Education (Andersen *et al.*, 2003). The learning outcome and objectives of the module are as follows:

Learning objectives

Instructional learning outcomes (ILO)

Observable behaviour: 1) Students can produce a graph reflecting their experimental data, using software such as Loggerpro or Excel. 2) The students can produce a 2 min video explaining their experimental design and measurements of specific factors' influence on the activity of yeast.

Condition and degree: At the end of the module students will be able to explain what a growth curve represents and recognize and explain the different phases of growth reflected on the growth curve.

Curriculum objectives:

The teaching module seeks to acquire students with knowledge of microbial growth and microbial metabolic processes. The teaching module underlines the four competencies within natural science (Andersen *et al.*, 2003); *empiri* - (empiricism), *repræsentation*s - (representation), *modellerings*- (modelling), and *perspek*-

tiveringskompetence (contextualizing) and supports the following objectives of the core curriculum of STX C and B levels of Biology (Undervisningsministeriet, 2017):

- Application and use of models to describe and explain observations.
- Complete quantitative experiments and document experimental work appropriately.
- Apply mathematical representations, models, and methods.
- Analyse and discuss experimental data.
- Apply relevant digital tools in a relevant context.

Students work with the following subjects within the core curriculum:

- Microbiology: growth and growth factors.
- Biochemical processes: respiration and fermentation.

An important aspect in the module was the content and activities being according to the principles and characteristics of IBSE teaching practices. Therefore, the module was structured according to the principles and structure of the 6F model (see Figure 2) The following section will describe the development of the 6F phases, the rationale behind the design and how they follow the principles of IBSE and the 6F model.

An important aspect of IBSE is students collaboratively investigating a problem or a question while reflecting on their own and other students' ideas through sharing and discussion (Østergaard, Sillasen, Hagelskjær and Bavnhøj, 2010). In IBSE it is a resource that students have different starting points, thereby bringing different perspectives and ideas into the investigation and solution of a problem or questions. Therefore, students worked in groups of 3 - 4 throughout the module. To assist students in their group work and allow all students to contribute, each student in the group were assigned a task which they were responsible for. It was up to the students to assign the different tasks within the group.

Feedback throughout the "Super Yeast" module

Formative feedback is an essential part of the 6F module, and therefore constitute an individual phase (Madsen, Evans and Bruun, 2020). How to give and receive formative feedback has been a central aspect of the design of each phase e.g., having students share their ideas using the software Padlet. The different forms of formative feedback in the "Super Yeast" module are indicated in the table of the module.

Feedback was assured throughout the module by formulating different open-ended questions to 1) guide students through the challenges of an inquiry-based activity and 2) to understand the students' learning process and thereby regulate the activities of the module according to the students' understanding. For an example of research describing possible ways to give formative feedback in a learning context see for example Black *et al.* (2004).

Development of the *Fang* Phase

To avoid students perceiving the different activities of the "Super Yeast" module as fragmented (Michelsen, 2011) an overall idea needed to link the different phases of the module. Furthermore, an IBSE approach to teaching requires that the teacher presents a problem which will challenge students existing understanding. Therefore, the experimental exercise was contextualized by using a situation which students could recognize and relate too and thereby potentially, translating science's more deductive, analytic approach. This required taking student's pre-existing knowledge and experience as a starting point by asking the question: "what "narrative" about yeast do students have?".

The *Fang* phase is linked with the *Forudsætnings* phase since it is necessary to consider students pre-existing knowledge when presenting a problem or topic in an interesting and engaging way (Madsen, Evans and Bruun, 2020) e.g., students will not find a topic particular interesting if it is too difficult, abstract or too easy. All the students were assumed to have a previous experience with using Baker's yeast as a raising agent when baking. Therefore, I wanted to present students with something new about Baker's yeast, potentially making them interested in learning more. Therefore, the students were presented with a picture of yeast cells taken by an electron microscope (see Image 2) By showing them the morphology of yeast cells, students' perception of Baker's yeast might be expanded from something they buy in the supermarket to a single-celled biological organism. This is important since students need to perceive Baker's yeast as a biological organism to apply their pre-existing biological knowledge in the *Forsk* phase.

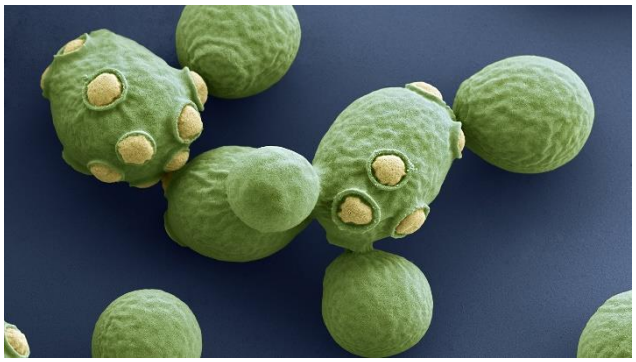
The case of the super yeast "Strain 323"

To motivate students to engage in investigating problem or a question, it is important that they can contribute meaning and value to the activity (Niemiec and Ryan, 2009). Therefore, it was important to present students with the learning objectives and different phases of the module in a way which would make students aware that they are responsible for finding solutions to the problem and that the problem has relevance to them. A fictional case was used to tell the story of a newly discovered Baker's yeast Strain 323, which had been responsible for several incidents of doughs rising excessively (Appendix 1). Students were told that scientists do not know what controls the growth of Strain 323, and that it was their task to inform the Danish Minister of Food and Agriculture about the factors influencing the growth of this new type of yeast. The case of Strain 323 puts the experimental exercise and the content of the module into a real-world context which students could relate to since they all have used Baker's yeast as a rising agent. At the same time, students were asked to *discover* something about yeast instead of replicating results.

An important aspect of the 6F model is that students are not confirming the textbook but finding their own solutions to the problem (Madsen, Evans and Bruun, 2020). Therefore, it is important that students did not read or study prior to the class. In the *Fang* phase, students are also introduced to the learning outcome of the module because it is essential that students experience alignment between the activity of the module and how

they are evaluated (Madsen, Evans and Bruun, 2020). The Table below gives an overview of the activities in the *Fang* phase and the presentation of the case of *Strain 323*:

Table 1. Overview of the *Fang* phase of the "Super Yeast" module

6F phase	Duration	Activity	Feedback
Fang	3 min.	• Students are shown a picture of yeast cells taken with an electron microscope (Image 2). They are asked if they can identify which organism it is shown on the picture.  **Image 2**: Micropia (2020) • Students are introduced to the learning outcomes of the module: 1. *You can investigate the biology of microorganisms experimentally.* 2. *You have knowledge about factors affecting the growth of microorganisms.* 3. *You can produce a mathematical and visual representation of the growth of microorganisms.* 4. *You can advise others how to examine the growth of microorganisms scientifically*. • Students are introduced to the fictional case of a yeast Strain 323. It is still unknown which factors affect the growth of Strain 323. Students are shown a fake frontpage of a newspaper and several pictures of accidents with dough (See Appendix 1, p. 5). • Students are given the task of informing the Minister of	Student responses to questions and reactions to case

		Food, Agriculture and Fisheries about the factors controlling Strain 323's growth.	

Development of the *Forudsætning* phase

To support students' investigations of a problem or a question it is important to use student's pre-existing knowledge when giving formative feedback. In the 6F model, students' pre-existing knowledge are revealed through the *Forudsætning* phase (Madsen, Evans and Bruun, 2020). In the *Forudsætnings* phase of the "Super Yeast" module students were asked to share their ideas and answers to the open-ended question; *What influences the growth of yeast* using the website Padlet.com (see Appendix 7). Since it is important in this phase that no answers are emphasized as right or wrong (Madsen, Evans and Bruun, 2020) the student ideas which could be tested by the available materials were highlighted in the Padlet.

6F Phase	**Duration**	**Table 2. Overview of the *Forudsætningsphase* of the "Super Yeast" module**	**Feedback**
Forudsætning	10 min.	• Information about the students pre-existing knowledge regarding microbial growth is made explicit by asking the student groups to answer the question *"What influences the growth of yeast?".* Groups share their ideas in the online platform padlet.com. The students are given appx. 3 min. to answer the question and write their ideas. • Without emphasizing any right/wrong answers different contributions from the student groups are discussed in the class. • In class, students are asked to elaborate their suggestions and suggest ways to measure suggested factors. • The factors, which are available for experimental testing are highlighted by changing the colour of the sticky note in the Padlet. • Students are presented with the available materials for their experiments: - Ice cubes - Kettle - Baker's yeast - Sugar	Students' participation in classroom dialogue

		- Acetic acid - Baking soda (Sodium hydrogen carbonate)[1]	

Development of the *Forsk* phase

In the original experimental exercise *Forsøg med gær* (Hansen *et al.*, 2012) students are investigating the influence of temperature on yeast cells. The purpose of the original experiment is to demonstrate and conduct a single variable experiment and to find out at which temperature yeast cells would be most active, represented by the release of carbon dioxide bubbles. All student groups are asked to conduct the same experiments by following the instructional learning material (Hansen *et al.*, 2012). The biggest modification of the original exercise was to incorporate more variables in the experiment and give students the choice to choose which variable they wanted to investigate to find answers to the question: "*What influences the growth of yeast"*. When students chose their own variable the learning context is characterized by differentiated instruction (Dohn, 2014). In differentiated instruction, students' pre-existing competencies and knowledge becomes a resource in the students' learning process because it leads to more ideas which contributes to students' solution of the problem (Højmark, 2020, p. 329). Giving students' choices might be the greatest motivational factor, which the teacher can control (Dohn, 2014) since it gives students influence and allows them to choose to work with the variable, they find the most interesting.

Students were also presented with the experimental set up, which is similar to the original experimental exercise (see Image 3). It would be possible to let students design their own experimental set up, which would require students to reflect on how the growth of yeast can be measured and quantified when the yeast cells are too small to be visible. However, this exercise has not been incorporated in the "Super Yeast" module since the students were assumed to have limited experience with IBSE teaching and due to the time restrictions of the module.

Formulating a hypothesis

In the original exercise of the yeast experiment, students are asked to formulate a hypothesis (Hansen *et al.*, 2012). Similarly, student groups were asked to formulate a hypothesis in the "Super Yeast" module and thereby define how they expected their chosen factor to influence the growth of yeast. To expand the students' work with questions and hypothesis, students were asked to answer four questions about their experiment while filming their experiments (See Table 4).

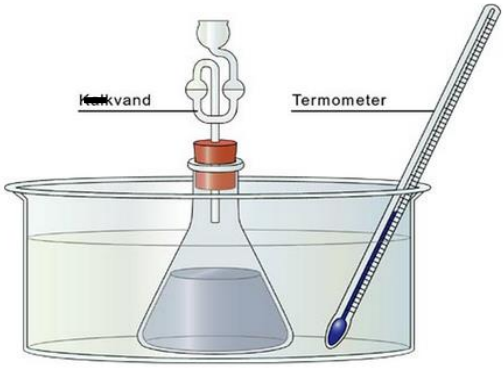
[1] It was not obvious how baking soda affects the cells of Baker's yeast. Baking soda is an alkaline compound which forms carbon dioxide, when in contact with acid. Therefore, baking soda can be an error in the experiment. Students could measure pH if they chose to investigate the influence of baking soda.

Inquiry-based experiments:

By excluding the theory from the experimental exercise, students are not given any explanation or pre-assumption and thereby they have the possibility to *experience* and reflect on how yeast could produce the bubbles they were observing. Contrary, presenting students for the theory they are confirming can either remove students' motivation to find their own results or make them perceive their results as "wrong results" if they are different from what the teacher presents. Therefore, students were not given any classic instructional teaching material, like the original experimental exercise by Hansen *et al.*, 2012.

Still, students need guidance and to assist them in recording their observations, but not restricting them or leading them to any answers, one person in the student groups were made responsible for documenting the experiments by producing a 2 min. video on their phones. Students were asked to answer four questions relating to their hypothesis and experiment (see Table 4) but can freely choose what they find important to incorporate experiment. In this way students are guided but not restricted to find a specific result.

Similarly, students were instructed to document their data directly into software such as Excel or LoggerPro. Two students recorded the number of bubbles at every minute. After the experiment, student groups produced a graph reflecting their observations. The students' results were shared with the rest of the class by uploading them to the Padlet along with their hypothesis see example in Appendix 7. The *Forsk* phase of the "Super Yeast" module is a quite teacher closed inquiry in the way that students are given a lot of instructions but by letting the students influence what they are investigating and how to document their experiment, students were still constructing their own knowledge.

6F Phase	Duration	Table 3. Overview of the *Forsk* phase of the "Super Yeast" module	Feedback
Forsk	40 - 45 min.	 **Image 3**: (Hansen *et al.*, 2012). • Students are introduced and shown how to set up and conduct the experiment: • Image 3 should be made available to the students throughout the whole *Forsk* phase either by sending it to the students or put it on a large screen. • Student groups are given 3 min. to formulate a hypothesis about the growth of yeast by using the experimental set up and the materials available. • Each student in the student groups is assigned a task during the experiment: - Counts bubbles. - Record data in software e.g., LoggerPro or Excel. - Manage time. - Film a 2 min. video. The student groups decide who is responsible for each task. • Student groups set up the experiment and wait 3 min. before they start counting bubbles appearing in the water of fermentation pipe. • Students count the number of bubbles appearing in 1 minute. After 1 minute they reset and count the number of bubbles in the 2nd minute … • Students count in 20 minutes. Students should end up with 20	Dialogue

Forsk (cont.)	40 - 45 min.	datapoints. • Video: the video is the students note from the experiment and replace questions on instructional learning material. Students are given four questions to include in their video: 1. *What is the purpose of your experiment?* 2. *What growth factor are you investigating?* 3. *What is your hypothesis?* 4. *How are you investigating your hypothesis?* • Students can share their video by using websites such as wetranser.com, google drive, dropbox etc. • By using software, students produce a graphic representation of their data. • Students share their data in the Padlet used in the *Forudsætnings* phase and write the groups' hypothesis. • While visiting the student groups, the teacher gains an overview over the student experiments and learning process and can therefore prepare the *Forklar* phase and how students' experiments can be compared and discussed.	Dialogue

Development of the *Forklar* phase

According to a constructionist point of view, students are, tthroughout the 6F module, working cognitively with constructing new schemes structures through an accommodative process which are completed in the *Forklar* phase (Madsen, Evans and Bruun, 2020). To get feedback on the students' accommodating of their new knowledge, and to make students reflect and discuss their own and their peer's results, each group were asked to share their hypothesis and findings with the rest of the class. Since the students choose their own variable to investigate, it was not possible to prepare the content of the *Forklar* phase. Nevertheless, throughout the *Forsk* phase, the teacher could circulate amongst the student groups and through dialogues and questions receive feedback about what aspects of the experiments and understanding of the content were difficult for the students and should be addressed in the *Forklar* phase.

The *Forklar* phase is an important step in the students' learning process, hence it is important that the teacher has an overview of what has taken place in the student groups throughout the *Forsk* phase. To get a better overview, the Padlet software was used to gather the students' results at the same place. The students' ideas

from the *Forudsætnings* phase were kept in the Padlet, showing the students' starting point. By using the Padlet, throughout the module students had a kind of overview and notes of their own learning process.

In the *Forklar* phase, students' findings were discussed and linked to the other student groups' findings. The teacher asked elaborating questions, assessing the students' understanding. The *Forklar phase* was based on the findings of the students, but depending on the purpose and the student group, the teacher can use the students' findings as reference point for a discussion about what is means to work scientifically.

6F phase	**Duration**	**Table 4. Overview of the *Forklar* phase of the "Super Yeast" module**	**Feedback**
Forklar	15 min.	• After students have shared their data from their experiment, each student group are asked to explain their experiment, hypothesis, and findings to the rest of the class. Student can also share their videos. • The teacher asks elaborating questions to the student groups about their experiment e.g., *What could you have done differently? What would happen if…? What can be concluded from your graph?* • Using the students experiments the class answers the following questions: 1. *What growth conditions are optimal for yeast?* 2. *What factors seem to inhibit the growth of yeast cells?*	Students' responses and participation in classroom discussion.

Developing the *Forlæng* phase

The purpose of the *Forlæng* phase is to increase students' learning outcome by having them applying their accommodated knowledge from the *Forks* phase in a new context. This process is termed assimilation and new knowledge should be acquired relatively easy in this phase (Madsen, Evans and Bruun, 2020). Students were presented with a growth curve from the textbook *Biologi til tiden* (Image 4, Jørgensen, 2017) reflecting the growth phases of a bacterial culture and the concentrations of living and dead cells in a container at different times. Students were told that their graphs are growth curves similar to the graph of the textbook but not necessarily following the same curve since students can have inhibited or increased the growth of the yeast cells in multiple ways.

The student groups are asked to relate their graph with the growth curve from the textbook by placing their graphs on the growth curve. Student groups argued in which phase they believed their yeast culture to be in and when their culture would reach the *death* phase (see Image 4). By relating their own graphs to the

growth curve of the textbook, student assimilate new knowledge. Making the textbook material a part of the students' experiments, students internalize the knowledge from the textbook, leading to students potentially being more motivated to learn about the growth curve from the textbook as well as remembering and understanding the growth curve.

<table>
<tr>
<td>6F phase
Forlæng</td>
<td>Duration
15 min.</td>
<td>Table 5. Overview of the Forlæng phase of the "Super Yeast" module

Students are presented with a growth curve from the textbook "Biologi i udvikling (Jørgensen, 2017, p. 109) (Image 4).

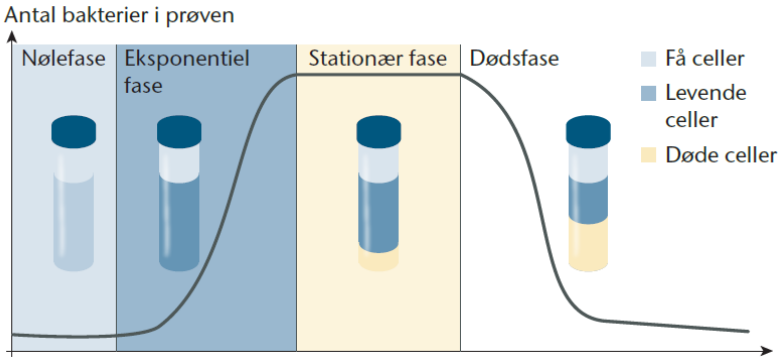


Image 4: Figur 123 (Jørgensen, 2017, p.109)

The student groups are given 3 min. to discuss what the growth curve reflects.

Students share their ideas of what the growth curve represents and what is happening in the different phases. The teacher elaborates and supplement the students' suggestions.
The teacher tells the students that they have produced a growth curve in their experiment. Students are asked to discuss the following questions in their groups: "Where would you place your growth curve on the growth curve on the image?" and "When do you think the yeast cells in your experiment would have reached the death phase?".
Students share their thoughts with the class and the teacher can ask them to elaborate their answers, having their experiment or the student groups experiment in mind. Simultaneously, the teacher shows the Padlet with the students' growth curves during class discussion.

</td>
<td>Feedback
Students' responses and participation in classroom discussion.</td>
</tr>
</table>

In the last part of the module students' findings were summarized by asking the question *"What do we now know about Strain 323 that we can inform the Minister of Food and Agriculture?"* This question had the purpose to algin the different phases and the connecting between the learning activities were made clear.

6F Phase	**Duration**	**Table 6. Overview of the summarize of the "Super Yeast" module**	**Feedback**
N/A **Summarize**	3 min.	• The module is summed up by asking the students what they would tell the Minister of Food, Agriculture and Fisheries. • The teacher can help the students sum up their findings by asking the following: *"What will you advice the Minister to do, if he wants to inhibit a dough rising (the growth of yeast cells)?"* and/or *"What would your advice to the Minister be if he wants a dough to rise (the growth of yeast cells)?*	Student participation and responses.

2.2 Implementation of the module "Super Yeast"

To assess if the intended objectives of the "Super Yeast" module could be achieved and to investigate how the module was engaging the students, the module was taught in 6 different classes at 3 different gymnasiums located in the centre of or in the suburban area of Copenhagen. The module was taught in the period of the 12th of November and the 2nd of December 2020. When teaching the module, the teacher of the class was only observing and assisting in distributing materials and setting up the equipment. The laboratory equipment and materials used for the experimental exercise were provided by the schools. Number of modules spent in each class varied between classes.

Description of the students: 5 of the classes were 1G classes, with biology as a mandatory subject in their curriculum on a basic level C (1yr). One class consisted of students in 2G, 3G and 4G who had chosen to study biology at a medium level B (2yrs). None of the classes were specializing in natural sciences (see Table 8).

Table 7. Description of Students	1G	Combined 2G, 3G, 4G
Number of classes	5	1
Biology level	C (basic level)	B (medium level)
Biology as mandatory/elective	Mandatory	Elective
Natural science specialization	None	None

2.3 Data collection

The collected data consisted of quantitative and qualitative data. The data collection was conducted with a descriptive and explorative purpose, seeking insight into how students perceived and responded to the activities and structure of the "Super Yeast" module.

Survey

All students were asked to answer a questionnaire in the final part of the module. The online platform SurveyMonkey was used for designing, collecting, and visualizing the survey. The questionnaire consisted of an ordinal 5-point Likert scale and included 10 statements, relating to the students' experience of the module's content, structure, and activities:

Q1: Jeg synes, modulet om gærs vækst var interessant.
(I found the module about the growth of yeast interesting)

Q2: Jeg blev engageret af at arbejde med en case.
(*I was engaged by working with a case)*

Q3: Jeg fandt modulet sværere end anden biologiundervisning.
(I found the module more difficult than other biology teaching)

Q4: Jeg har en bedre forståelse af gærs vækst efter modulet.
(*I have a better understanding of the growth of yeast, after completing the module)*

Q5: Jeg kunne godt lide at vælge en vækstfaktor at undersøge.
(*I liked choosing a growth factor to investigate)*

Q6: Jeg kunne godt lide at lære teorien bag eksperimentet efter at have udført eksperimentet selv.
(*I liked learning the theory behind the experiment after working with my own experiment.*)

Q7: Jeg forstod instruktionerne.
(*I understood the instructions)*

Q8: Jeg kan bruge min viden om gærs vækst i anden biologiundervisning.
(*I can apply/use my knowledge about the growth of yeast in other biology teaching)*

Q9*:* Jeg kan bruge min viden om gærs vækst udenfor gymnasiet.
(*I can apply/use my knowledge about the growth of yeast outside of the gymnasium)*

Q10: Jeg kunne godt tænke mig at arbejde på same måde med andre emner i biologi.
(I would like to work in a similar way with other topics in biology)

For each statement students selected one of five wordings reflecting to which extent they agreed with the statement. The response options were ranked with "To a very high extent" reflecting the highest level of agreement to "a very low extent" reflecting the lowest level of agreement. The Likert scale was supplemented with a comment section underneath each statement, where students had the opportunity to add comments and elaborate their answer. Open-ended questions were added to some of the comment sections (See Image 5).

Image 5: Illustrating the set-up of the online questionnaire using the software SurveyMonkey.

Interview

Interviews were conducted for several purposes; 1) to validate the data from the questionnaires and in class observations; and 2) to expand the information from the questionnaires potentially identify variables and relationships in the way students are motivated to engage in the learning activities and context in which they learn. Students were interviewed voluntarily, anonymously and in pairs to make the interview situation more comfortable. Unstructured interviews were conducted with the purpose of students sharing their experiences in their own words (Århus Universitet, 2020), valuing the flexibility and informality of the structure. The sequence and wording of questions were freely modified within the different topics explored and the questions could be explained or changed if the student showed difficulty in understanding, as well as trying to let the interview flow like a conversation (Cohen, 2007, p. 354). During the interview, students were asked questions similar to the statements in the questionnaire. The first question in the interview was "*How did you experience the module about the growth of yeast?" (Hvordan oplevede I modulet om gærs vækst?*) supporting students to open up and share their experience of the module. The interview ended with the question *"According to you, what can I do better next time I am teaching the module?" (Hvad synes I, jeg kan gøre bedre, når jeg skal undervise i det her modul næste gang?*) investigating if students had some concrete feedback to the module.

Transcription:

The interviews were transcribed from audio recordings of the student interviews. The transcription method used was *Verbatim transcription*, which includes all expressed words but interjections such as "øh" or "hm" were left out to improve readability. Other information including pauses or expression of emotions were not included.

In class observations and student products:

While teaching the module, observations of students' active participation and engagement were noted. After teaching the module, a reflection was written based on the observations and notes from the module with input from the observations of the teachers of the class. The reflections were structured following the three questions: *What went well? What went wrong? What could I do better next time?* The products of the students were collected using the websites Padlet.com and WeTranser.com. For Padlets and reflections see Appendix 6 and Appendix 5).

2.4 Evaluation of methods of data collection:

This is a mixed method study where data collected with quantitative measures are expanded by qualitative data through interviews and comments. The different approaches used in this research contributes differently to the answers to the research questions of this study. By collecting both, a more comprehensive and detailed insight into students' experiences and perceptions of the "Super Yeast" module were achieved.

The questionnaire was highly structured with closed questions with students responding according to a fixed set of options., which allows for assessing frequencies and comparison across classes, but the data is less detailed and descriptive (Cohen, 2007, p. 205). Therefore, the questionnaire was used for investigating patterns or differences in how students responded to the "Super Yeast" module across classes. Open-ended questions and comment sections in the questionnaire were added to the statements for collecting more detailed responses. Misunderstandings of the questions in the questionnaire were possible. Moreover, students were responding to the questionnaire at the end of the module, which presumably increased the number of respondents but might affect the time students used for responding.

To collect more detailed and insightful data, students were interviewed. The interviews allowed for students sharing their experiences and perception of the learning environment and activities in their own words. Misunderstandings can be prevented by changing the wordings of the questions. Using unstructured interview and open-ended questions based on topics resulted in a more detailed insights with high validity (Cohen, 2007, p. 355) The flexible structure allows for modifying the questions to fit the students experience resulting in a more authentic experience of students (Cohen, 2007, p. 355), which also allows for getting an insight into new aspects which have not been known when beginning this study. By using both qualitative and quantitative approaches in this study, the responses of the 6 classes could be compared as well as more detailed

descriptions of the students' experiences could be collected through comments and interviews, thereby contributing to answering the research question.

2.5 Methods of Qualitative Content analysis

Two students might share the same views and perceptions of an experience but the words they use to describe the experience might differ (Wood, 2019), therefore the qualitative data of the students' comments, and interview responses were analysed using content analysis as defined and described by Erlingson and Brysiewicz (2017). The qualitative and quantitative approach of content analysis has been emphasized as an appropriate method of analysis in the field of educational research since many studies within this field are based on mixed methods (Gläser-Zikuda, Hagenauer and Stephan, 2020). The applied method of analysis was based on the guidelines developed by Erlingson and Brysiewicz (2017). The objective of the analysis was to convert data into a summary of results through a hermeneutic approach (Erlingsson and Brysiewicz, 2017). The first step in the analysis was to get an impression and overview of the transcribed interviews and students' comments. Thereafter, the transcribed interviews were divided into condensed meaning units, a shortened version of the text which reflects the meaning of the statement (Erlingsson and Brysiewicz, 2017) (see Table 9 and 10). The students' comments were not condensed into meaning units because their initial short number of characters.

Next step was to develop codes which are descriptive concise labels for the meaning units. At this stage the analysis was still close to the data but tried to identify connections between the meaning units through the codes (Erlingsson and Brysiewicz, 2017). Through the analysis of this thesis, data was coded twice. First responses were giving a code, and secondly the identified categories to assess if the responses fitted into the formulated categories see Table 9 and 10 for an example. This approach reflects the hermeneutic spiral, where parts are continuously compared to the whole to ensure that the categories reflect the analysis of the parts (Erlingsson and Brysiewicz, 2017). The codes describing the same issue in relation to answering *who, want, when* or *where* were grouped together into categories. The linking of codes resulted in identified categories which revealed content detectable from the data. Interpretation of the findings is still limited in the categories reflected by short factual sounding category titles (Erlingsson and Brysiewicz, 2017). Another step could be applied to the analysis which is the formulation of themes based on the categories. Themes are used to analysis data with an underlying meaning (Erlingsson and Brysiewicz, 2017) which was found not be relevant since the analysis is summative, meaning that students' responses and statements are understood literally. The categories found from the qualitative content analysis are presented in Chapter 3 and discussed in Chapter 4.

Table 8. Appendix 2 Coding student interviews

Nr.	Response	Meaning unit	Coding 1	Coding 2
7	R1: *Ja, det var lidt.. med brug af begreber, fordi vi nåede ikke at lære så mange begreber i det emne, så i det hele taget havde det været bedre, hvis vi havde nået at lære en lille smule mere også lave forsøget, men det kan jeg godt forstå, hvis der ikke var tid til, når du var her (*Appendix 4, Line 23*).*	*Ville gerne have forstået mere og flere begreber inden forsøg*	Understanding, Support	Guidance
103	*Jeg synes også, det var, at man selv lidt skulle bestemme, hvad der skulle ske, gjorde det lidt mere spændende. Altså, man ville arbejde lidt mere, fordi man ikke bare havde sådan en journal, man skulle følge* (Appendix 4, Line 452).	*Man ville arbejde mere uden en forsøgsjournal.*	Independence, Engagement	Autonomy

Table 9. Appendix 3 Coding student comments

Nr.	Comment	Coding 1	Coding 2
5	*At det på en måde er levende og det vokser*	Living	Learning by doing
97	*Jeg ville foretrække hvis det ikke blev gjort til en leg men bare var videnskab*	Science	Preconceptions and prior knowledge

2.6 Obstacles when conducting this research:

Throughout the research of this study, the pandemic of Covid-19 made the teaching and interaction with the students more difficult, since a face mask had to be worn, when interacting with the students. Most importantly, the module was supposed to be taught in an additional class but because of the lockdown, students were sent home. Interviews were also conducted via. phone to minimize risks.

Chapter 3 Results

The following section presents findings from the implementation of the module, students' responses to the questionnaire, student interviews and analysis. First, the findings from the implementation of the "Super Yeast" module are presented. Secondly, the students' responses to the questionnaire are presented through

figures and tables. After the presentation of the quantitative data, the context in which the interviews were conducted is described. Finally, the findings from the analysis of the student comments and interviews are presented.

3.1 Findings from implementing the "Super Yeast" module

In class observations:

Activities and content of the module fitted with time schedule

An important aspect of developing the "Super Yeast" module was that it reflected the schematic structure of the Danish gymnasiums, making it easy to apply for other teachers. Therefore, it was important to assess if all the learning activities in the "Super Yeast" module could be completed satisfactory within the time restrictions of one module. In all the six classes, students completed the learning activities within the time frame of 90 minutes. In some classes, one module was equivalent to 100 minutes, still the duration of the learning activities of the "Super Yeast" module was found to be adequate.

Students met the instructional learning outcome of the module:

In all classes, all student groups finished their experiments and met the observable learning outcome of producing a graph, representing their results (see Appendix 6). All the student groups were able to relate their graph with the growth curve of the textbook in the *Forklar* phase, meeting the condition and degree of the instructional learning outcomes. In the module following the "Super Yeast" module, students, from three of the classes, were asked by their teacher to explain a similar growth curve, as presented for the students in the *Forlæng* phase. Students were able to name the different growth phases of the curve but having more difficulty in explaining what happens on a cellular level in the phases. The students were explaining the growth curve from the textbook in relation to their experiment and included their experience in their explanations. Some student groups did not finish their videos, which is a part of the observable learning outcome, and many of the student groups did not share their videos. In all the student groups, a person was filming but several students did not understand that they should answer questions while filming. Some groups preferred to answer the questions in writing instead. One student was observed sharing their video with their friends on the social media platform Snap Chat. Some student groups ask would ask for more time to finalize editing their videos.

Students' had a pre-existing understanding of the growth of yeast and the factors influencing cellular growth

In all classes, students showed an understanding of the growth of yeast as something which requires time and could be influenced by different factors. In the *Forudsætning* phase, students would suggest all the factors which were available for testing in the *Forsk* phase: pH, amount of sugar and temperature (see Appendix 6).

Students would also suggest other factors influencing the growth of yeast. When asked to elaborate their responses, student would often explain their suggestions in relation to their experience with using yeast as a rising agent. In all classes, students would suggest respiration, revealing that students know that metabolism is somehow connected to the growth of cells (see Appendix 6). Even so, that connection between bubbles, growth and metabolic processes were not completely clear to students. They had difficulty in explaining how bubbles could reflect an estimation of the growth of yeast cells.

Students' pre-existing perception of experimental work became evident in the Forsk phase

Students showed a pre-existing knowledge and perception about how to conduct experiments. Through the *Forsk* phase, many student groups asked if there was a controlled experiment, they could compare with. Often students would ask if they should repeat their experiments to increase validity of their results.

Most of the students chose to investigate temperature's influence on the growth of yeast

Despite the students suggesting many different factors influencing the growth of yeast, many of the student groups chose to investigate temperature's influence on the growth of yeast especially how a low temperature influences the growth of yeast. In one class, almost all the student groups investigated temperature's influence on the growth of yeast, despite students being introduced and showed all the different materials available. When asked why, students said it was easy or that their choice was affected by other student groups. Baking soda was the factor fewest students were choosing to investigate. Students were also told that it was not clear how the baking soda affects the growth of yeast, which might have discouraged them from investigating that variable.

Student participation

If students were actively participating in the activities varied throughout the module. Students were observed to specifically engage and participate in the *Forudsætnings* phase and in the *Forsk* phase. There was a "busy classroom" atmosphere when students were conducting their experiments, especially when setting them up. The student groups who would observe few or no bubbles, were more disengaged through the *Forsk* phase but the video engaged them to some extent during the 20 minutes of counting. It varied between classes how much students participated in the classroom discussions. Students participated more actively in the classroom discussions after they had completed their experiment, when they were asked to share their findings of their experiment and relate it to the growth curve of the textbook.

Students tried to find a "correct" answer

Several students were asking if their observed number bubbles were "correct". Similarly, a student group whose graph followed the growth curve of the textbook would describe their graph as "correct" or "really good". In the *Forlæng* phase, it was important to address that student graphs did not necessarily follow the

growth curve of the textbook, since the students could have inhibited growth e.g., lowering the pH or temperature of their yeast cultures. Students could place their own graph on the growth curve from the textbook and argue why they have placed their graph in a specific growth phase. Thereby, maybe diminishing students' perception of the growth curve from the textbook as the "correct" result.

Experiences in supporting students through formative feedback

It was difficult not to give any explanations to the students in the *Forudsætningsphase* when they ask for answers, especially when being behind the time schedule but instead supporting them in constructing their own knowledge. The "transition" phases, before and after the *Forsk* phase, were the moments when students needed the most instructions to help them to set up and finish their experiments. Some students needed help to formulate a hypothesis and students needed to be allocated time to formulate a hypothesis before starting to set up the experiment. After feedback through the student interviews, I tried to start the *Forsk* phase with the students formulating and writing their hypothesis on the Padlet prior to conducting their experiments. That provided great feedback and insight into the learning process of the different groups. It also provided the opportunity to guide students that needed help formulating a hypothesis. It was also useful in preparing the *Forklar* phase, giving a better overview of the students' experiments. The *Forklar* phase could be prepared while getting feedback through the dialogue with the students when circulating between student groups in the *Forsk* phase. It became apparent what the students found difficult and therefore could be addressed when discussing students' findings in the *Forklar* phase for example some student groups needed assistance to note their observations in Excel or LoggerPro and to design a graphic representation reflecting the relationship between number of bubbles and time.

Conclusion of the findings from implementing the module:

Students already had a pre-existing knowledge and ideas about what can influence the growth of cells. They understood growth is a phenomenon happening over time. Furthermore, they have a pre-existing of experimental work and the scientific method, which also influenced their understanding of the learning activities of the "Super Yeast" module. Students needed support to set up their experiments but also to formulate hypothesis. When choosing a factor to investigate, the majority of the students chose to investigate temperature. All student groups managed to produce a graph reflecting their experiment. Several student groups did not share their video and needed more time finishing editing them. The videos may not have been a tool supporting students' experimental work. Students could relate and place their graphs on the growth curve from the textbook. Moreover, students incorporated their observations and experiences from their experiment when explaining the growth curve from the textbook.

3.2 Results from the Survey

The questionnaire was distributed by providing students with a weblink and students responded the questionnaire via. their phones. Three of the classes were responding to the questionnaire in the week following the "Super Yeast" module. In total, 133 students responded to the questionnaire. The averaged time students spent answering the questionnaire was 2 min, which might reflect students answering the questionnaire in class in the last part of the module. A total of 377 comments were added to the students' responses with an average of 37.7 comments per question. The first statement "Jeg synes, *modulet om gærs vækst var interessant"* (I found the module about the growth of yeast interesting) had 88 comments being in the highest number of comments. The following section presents the students' responses to the statements in the questionnaire, providing an overview of how students had experienced the "Super Yeast" module. There were not found any evident variation in the responses across the classes, therefore the following section outlines the responses of all the classes collectively.

Did students find the "Super Yeast" module engaging and interesting?

To investigate to what extent, students perceived the module "Super Yeast" as interesting, students were asked to what extent they agreed with the statement "*Jeg synes, modulet om gærs vækst var interessant"* (I found the module about the growth of yeast interesting). A total of 63% of the students responded, "To a high extent" and "To a very high extent" (See Figure 3). Only about 1.5% of the students responded that they found the module about the growth of yeast interesting "to a low extent" or "to a very low extent", whereas 35% of the students responded the module being interesting "to some extent" (see Figure 3). In the comment section, 88 students responded to the question "*Hvad var interessant*" (What was interesting) (See Table 10).

Figure 3. Bar chart illustrating the percentage of student responses

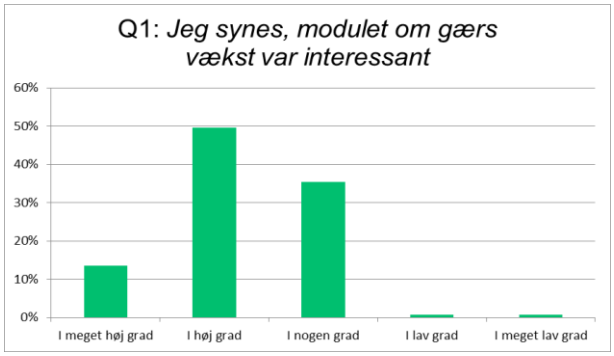


Table 10. Percentage of student responses to Q1

Q1: *Jeg synes, modulet om gærs vækst var interessant*

Answer Choices	Responses	
I meget høj grad	14%	18
I høj grad	50%	66
I nogen grad	35%	47
I lav grad	1%	1
I meget lav grad	1%	1
Hvad var interessant?		88
	Answered	**133**
	Skipped	**0**

In the "Super Yeast" module, the learning tasks were contextualized by using a fictional case. Despite the case being fictional, appx. 61% of the students responded that they were engaged by working with a case "to a high" or "to a very high extent. Around 32% reported that they were engaged "to some extent" by working with a case". Around 8% responded that they were engaged "to a low extent" (See Figure 4). Additionally, 45 students added a comment in the comment section (See Table 11).

Q2: *Jeg blev engageret af at arbejde med en case*

Answer Choices	Responses	
I meget høj grad	20%	26
I høj grad	41%	54
I nogen grad	32%	42
I lav grad	8%	10
I meget lav grad	0%	0
Kommentar		45
	Answered	**132**
	Skipped	**1**

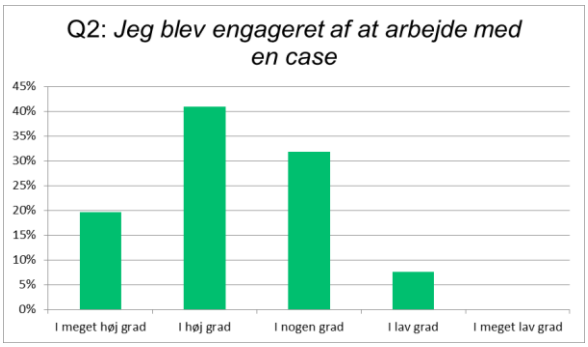


Table 11. Percentage of student responses to Q2

Figure 4. Bar chart illustrating student responses to Q2

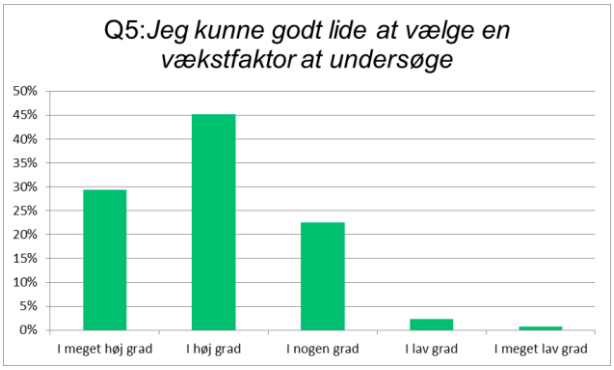
The biggest change in the redevelopment of the experimental exercise *Forsøg med gær* (Hansen *et al.* 2012) was letting students choose their own variable to investigate. When asked to what extent students liked choosing their own growth factor, 74% of the students, responded that they liked choosing their own growth factor "to a very high extent" and "to a high extent" (see Figure 4). 23% of the students answered that they liked choosing their own growth factor "to some extent", whereas 3% of the students responded that they liked choosing their own growth factor "to a low extent" and "to a very low extent" (see Figure 5). 36 students added a comment in their response (see Table 12).

Table 12. Student responses to Q5

Q5: *Jeg kunne godt lide at vælge en vækstfaktor at undersøge*

Answer Choices	Responses	
I meget høj grad	29%	39
I høj grad	45%	60
I nogen grad	23%	30
I lav grad	2%	3
I meget lav grad	1%	1
Kommentar		36
	Answered	**133**
	Skipped	**0**

Figure 5. Bar chart illustrating student responses to Q5



How did the students respond to the structure of the 6F model?

In the questionnaire, students' responses to different aspects of the 6F model was collected. Collectively, 64% of the students responded that they liked learning the theory, behind the experiment, after they had conducted the experiment by themselves "to a very high extent" or "to a high extent" (See Figure 6). A third of the students responded, "to some extent" and 6% of the students responded that they the structure "to a low extent" and "to a very low extent". 32 students added a comment to their response (see Table 13).

Figure 6. Bar chart illustrating the percentage of student responses to Q6

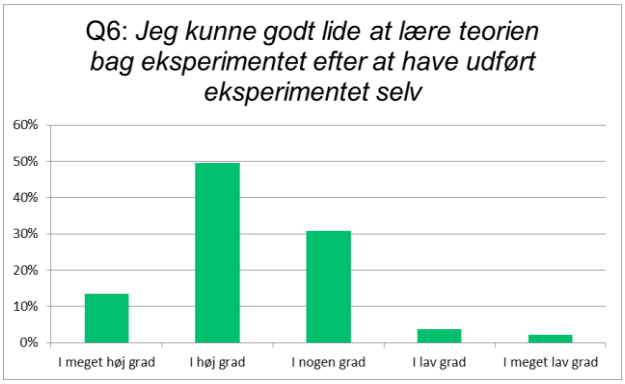


Table 13. Percentage of student responses to Q6

Q6: *Jeg kunne godt lide at lære teorien bag eksperimentet efter at have udført eksperimentet selv*

Answer Choices	Responses	
I meget høj grad	14%	18
I høj grad	50%	66
I nogen grad	31%	41
I lav grad	4%	5
I meget lav grad	2%	3
Kommentar		32
	Answered	**133**
	Skipped	**0**

The level of difficulty of the learning activities and content appeared to have been suitable, across all classes and levels of biology. When asked to what extent students agreed with the "Super Yeast" module being more difficult than other biology teaching, 3% of the students reported that they find the module more difficult "to a very high extent" and "To a high extent" and 20% of the students found the module more difficult "to some extent". Around 2/3 of the students, reported that they found the "Super Yeast" module more difficult "to a low extent" and "to a very low extent" (see Figure 7). In the comment section, 48 students had responded to the question "Hvad var sværere?" (What was more difficult) (see Table 14).

Figure 7. Bar chart illustrating the percentage of student responses to Q3

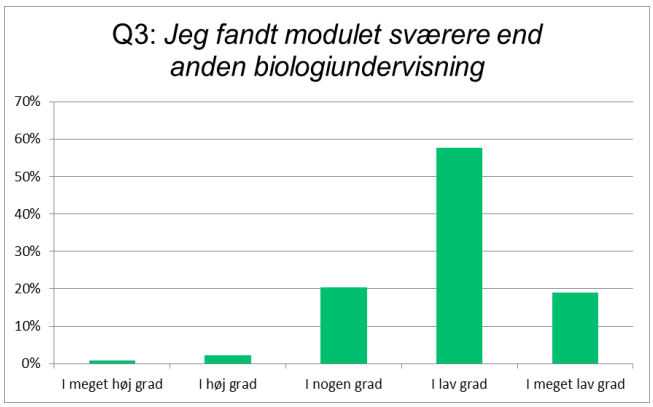


Table 14. Percentage of student responses to Q3

Q3: *Jeg fandt modulet sværere end anden biologiundervisning*

Answer Choices	Responses	
I meget høj grad	1%	1
I høj grad	2%	3
I nogen grad	20%	27
I lav grad	58%	76
I meget lav grad	19%	25
Hvad var sværere?		48
	Answered	**132**
	Skipped	**1**

The students' responses indicated that student had a positive attitude towards working with inquiry-based experiment with 77% of the students responded that they agreed with the statement "Jeg kunne godt tænke mig at arbejde på same måde med andre emner i biologi" (I would like to work in a similar way with other topics in biology) "to a very high extent" and "to a high extent" (see Figure 8). Contrary, 3% of the students reported that they agreed with the statement to "a low extent" and "to a very low extent", whereas 20% of the students responded that they would like to work in a similar way "to some extent" (see Figure 8). In the comments, 24 students had added a response (see Table 15).

Figure 8. Bar chart illustrating the percentage of student responses to Q10

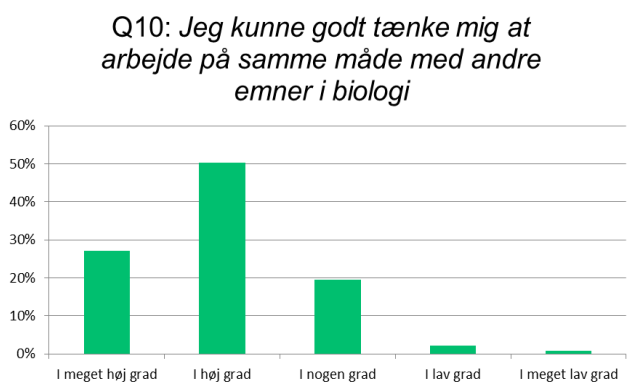


Table 15. Percentage of student responses to Q10

Q10: *Jeg kunne godt tænke mig at arbejde på samme måde med andre emner i biologi*

Answer Choices	Responses	
I meget høj grad	27%	36
I høj grad	50%	67
I nogen grad	20%	26
I lav grad	2%	3
I meget lav grad	1%	1
Kommentar		24
Answered		**133**
Skipped		**0**

According to the students, how much did they learn from the "Super Yeast" module?

When asked to their learning outcome of the "Super Yeast" module, 78% of the students agreed "to a very high extent" and "to a high extent" that they had a better understanding of the growth of yeast after participating in the module. Only 2% of the students reported that they agreed with having a better understanding "to a low extent". Moreover, 20% of the students, responded that they had a better understanding "to some extent" (see Figure 9). Furthermore, students responded that they have found the instructions understandable, when asked to what extent they agreed with "Jeg forstod instruktionerne" (I understood the instructions) 85% percent of the students agreed with the statement "to a very high extent" and "to a high extent". Only 2% of the students understood the instructions "to a low extent", with none of the students reporting that they understood the instructions "to a very low extent". 14% of the students understood the instructions "to some extent" (see Figure 10). In the comment section, 27 students had written a response (see Table 16 and 17).

Figure 9. Bar chart illustrating the percentage of student responses to Q4

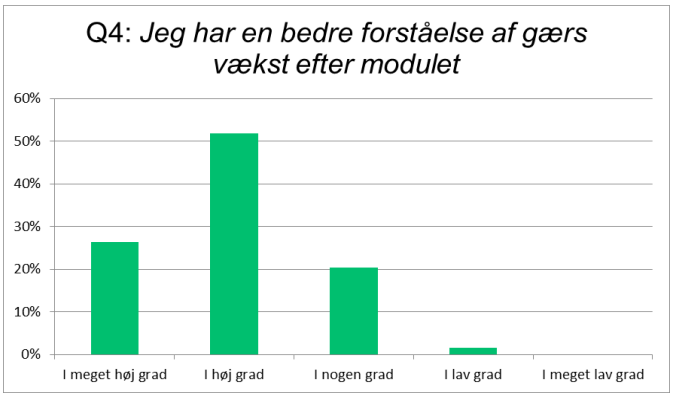


Table 16. Percentage of student responses to Q4

Q4: *Jeg har en bedre forståelse af gærs vækst efter modulet*

Answer Choices	Responses	
I meget høj grad	26%	35
I høj grad	52%	69
I nogen grad	20%	27
I lav grad	2%	2
I meget lav grad	0%	0
Kommentar		27
	Answered	**133**
	Skipped	**0**

Figure 10. Bar chart illustrating the percentage of student responses to Q7

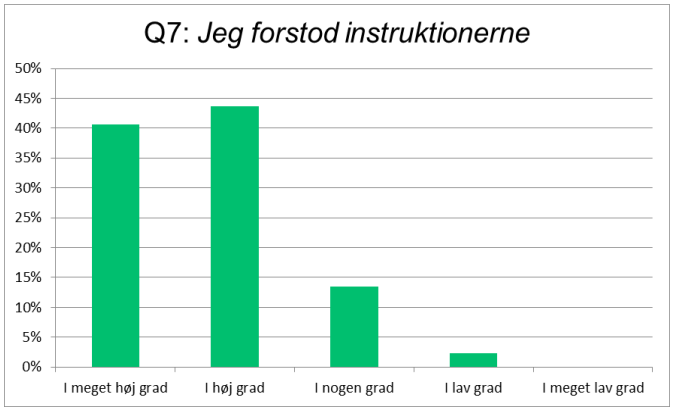


Table 17. Percentage of student responses to Q7

Q7: *Jeg forstod instruktionerne*

Answer Choices	Responses	
I meget høj grad	41%	54
I høj grad	44%	58
I nogen grad	14%	18
I lav grad	2%	3
I meget lav grad	0%	0
Hvad var svært at forstå?		27
	Answered	**133**
	Skipped	**0**

Did students experience their acquired knowledge about the growth of yeast as useful in other contexts?

Students' responses differed between the statements" Jeg kan bruge min viden om gærs vækst i anden biologi undervisning" (I can use my knowledge about the growth of yeast in other biology teaching) and "Jeg kan bruge min viden om gærs vækst udenfor gymnasiet" (I can use my knowledge about the growth of yeast outside of the gymnasium). Only 2% of the students responded that they could use their knowledge about the growth of yeast in other biology teaching "to a low extent", whereas 28% of the students responded that they could use their knowledge about yeast outside of the gymnasium "to a low extent" and "to a very low extent" (see Figure 11 and Figure 12). 62% of the students, responded that they agreed "to a very high extent" and "to a high extent" that they could use their knowledge about yeast in other biology teaching, whereas 35% of the students agreed "to a very high" and "to a high extent" that they could use their knowledge about yeast outside of the gymnasium (see Figure 11 and 12). Similarly, 36% and 37% of the students responded that they agreed with being able to use their knowledge about the growth of yeast "to some extent" in other biol-

ogy teaching and outside of the gymnasium (see Figure 10 and 11). Respectively, 24 and 26 students had written a comment to the two statements (see Table 18 and 19).

Figure 11. Bar chart illustrating the percentage of student responses to Q8

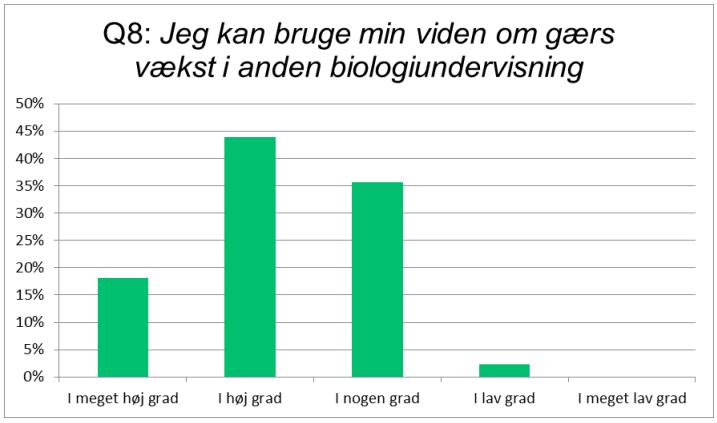


Table 19. Percentage of student responses to Q8

Q8: *Jeg kan bruge min viden om gærs vækst i anden biologiundervisning*

Answer Choices	Responses	
I meget høj grad	18%	24
I høj grad	44%	58
I nogen grad	36%	47
I lav grad	2%	3
I meget lav grad	0%	0
Kommentar		24
	Answered	**132**
	Skipped	**1**

Figure 12. Bar chart illustrating the percentage of student responses to Q9

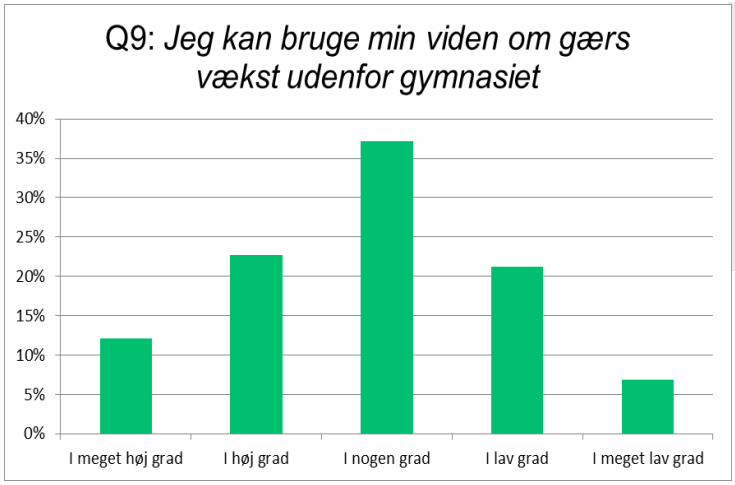


Table 20. Percentage of student responses to Q9

Q9: *Jeg kan bruge min viden om gærs vækst udenfor gymnasiet*

Answer Choices	Responses	
I meget høj grad	12%	16
I høj grad	23%	30
I nogen grad	37%	49
I lav grad	21%	28
I meget lav grad	7%	9
Kommentar		26
	Answered	**132**
	Skipped	**1**

Summary of the findings from the Survey

Based on the students' responses to the questionnaire. Around two-thirds of the students found the "Super Yeast" module interesting to a high extent. Similarly, around two-thirds of the students were engaged by working with the case of Strain 323 to a high extent and three-quarters of the students liked choosing their own variable to investigate. In relation to the structure of the module, appx. two-thirds of the students responded that they liked having the theory behind the experiment presented after having conducted the experiment themselves. Moreover, only 3% of the students' found the "Super Yeast" module more difficult than other biology teaching to a high extent. Additionally, students' responses reflected a positive attitude towards working with other biological topics in a similar way, with appx. two-thirds of the students stating that they

would like to work in a similar way to a high extent. Additionally, appx. two-thirds of the students reported that they had a better understanding of the growth of yeast, after participating in the module. Variations were found in the students' perception of the usefulness of their knowledge about the growth of yeast. Appx. two-thirds of the students agreed that they can use their knowledge in other biology teaching to a high extent, whereas about one third of the students responded that their knowledge about yeast was useful to a low extent outside of the gymnasium.

3.3 Interviews

Seven students from different classes volunteered to participate in an online interview. The interviews were conducted online due to safety precautions of Covid-19. The students were interviewed approximately two weeks after participating in the "Super Yeast" module, between the 29th of November to the 15th of December 2020. It was intended that students would be interviewed in pairs but because of technical issues, time restrictions and interruptions, all the interviews were conducted with one student at the time, with some of the students overlapping. Before the interview, students gave permission to be audio recorded for later transcription. One of the interviews were repeated due to technical issues with the audio recorder. The duration of the interviews varied between 23 to 14 minutes. All the interviews, except one, were conducted without picture and video of both the student and the interviewer, resulting in the interview only collecting verbal information, since no body language or facial expression could be observed. The transcription of the interviews can be found in Appendix 4.

3.4 Results from analysis

The following 9 categories were identified from the qualitative content analysis of the student comments and interviews. The categories describing the identified connections in the students' responses revealing how the students' responses to the experimental work were influenced and how they were motivated to engage in the "Super Yeast" module are outlined below. In the following discussion chapter, the findings from the analysis will be discussed using the concepts from the Self-Determination theory.

Experiments compared to other activities

This category was based on the student's responses which reflected their comparison of experimental work with other learning activities. Students reported that they like being activated when conducting experiments instead of more "passive" activities where students "are told" the content they need to learn. Students emphasized experiments as engaging them more than reading and listening, and that doing something active contributes to their learning and engagement. Examples of student responses falling into this category are the following student comments:

> *"The fact that you stood up and was active. It gives more motivation to learn but also a better understanding of what it is that you are doing."* (*Det at man skulle op og stå, og være i gang. Det giver både mere motivation til at lære, men giver også en mere forståelse for hvad man laver*.) (Appendix 3 Student comment 67, author's translation) and
>
> "*It [the Case] is much more fun and motivating to learn about something compared to when you are reading about it*" *(Det er meget sjovere og mere motiverende for at lære noget end hvis man skulle læse om det*) (Appendix 3 Student comment 113, author's translation).

Comments under this category revealed that students were not necessarily more engaged because of an aspect of the "Super Yeast" module but because they were doing something active instead of reading or listening. Generally, it was evident in the responses that students described their experience in the "Super Yeast" module in relation to how they perceive other learning activities and biology as a subject.

Application of knowledge

Throughout the responses it was evident that it was unclear to the students how they could use what they have learned in the "Super Yeast" module. They were uncertain about whether they could apply what they have learned in other biology lessons but mostly in other contexts than school. This tendency might reflect that most of the students just had started in the gymnasium and only worked with one topic in biology at the that time. Still, some of the students' responses reflected that students were able to apply what they have learned in the "Super Yeast" module to other topics taught in biology such as microbiology, beer brewing and bacteria. In relation to their life outside school, almost all the students suggested that they could apply what they have learned in the "Super Yeast" module for baking:

> *"I don't really know what I can use it for besides knowing that I should put my food in the fridge."* (*Jeg ved ikke helt hvad jeg skal brugen den til ud over at vide jeg skal putte mad på køl.)* (Appendix 3, Student comment 299, author's translation).

The uncertainty in the students' responses might reflect the question being unspecific and therefore abstract to the students. However, it noticeable that students' have accommodated a new perception of yeast by participating in the "Super Yeast" module:

> *" It explains many things which you don't really think have anything to do with yeast."* (*Det forklarer mange ting som man enligt ikke tænker over har noget med gær at gøre.)* (Appendix 3, Student comment 274, author's translation).

This quote exemplifies that after participating in the "Super Yeast" module, students could connect biology to things the meet in their everyday. The above leads into the identified category *Preconceptions and pre-existing knowledge.*

Preconceptions and prior knowledge

This category encapsulates what students bring to the classroom and how that influences the way they perceive learning activities and engage. Students' perception of; biology as a subject, what science is, how experiments should be conducted, their previous experiences, pre-existing knowledge, and skills were all found to influence how students perceived themselves as capable of as well as if the activities were interesting and engaging. Moreover, students' responses reflected that they had different learning strategies to achieve the required learning outcome.

Students would often describe the "Super Yeast" module as being *"new"* or *"different"* indicating that the 6F model and inquiry-based way of experimenting were new to them. This led to two types of responses; the ones reflecting the student being more engaged by the different approach and others being less engaged because it seemed less "scientific", theoretical, or serious. Most of the students responded that they were engaged working in a different way from what they were used to. The "typically" biology teaching was described by students as consisting of a lot of concepts and terms:

> *" Well, I think what makes it uninteresting sometimes is if it is a whole new topic and I begin at the beginning, it can seem pretty hardcore because there is so many new terms and a whole new system and you don't understand any of it in the beginning." (Jamen, jeg tror, det der gør, at det er lidt uinteressant nogle gange, hvis nu det er et helt nyt emne og jeg så starter på begyndelsen, så kan det godt virke sådan ret hardcore i forhold til, der er så mange nye termer og et helt nyt system og man forstår intet af det i starten.)* (Appendix 4, Line 567, author's translation).

The students' perception of biology as a subject was found to influence the way they perceived the "Super Yeast" module:

> *"I am not so super excited about biology so that is why my answer is how it is." (Jeg er bare ikke sådan super vild med biologi, så det er blot derfor, mit svar er som det er.)* (Appendix 3, Student comment 62, author's translation).

Contradictory, to the above, students reported that if they did not feel that the understood the content of the module, they would relate that to insufficient emphasis on theory, concepts and terms in the module:

> *"[…] The use of concepts because we did not have time to learn so many concepts in that topic, so it would have been better if we had learned some more and then worked with the experiment"*
> *([…] med brug af begreber, fordi vi nåede ikke at lære så mange begreber i det emne, så i det*

hele taget havde det været bedre, hvis vi havde nået at lære en lille smule mere også lave forsøget […]"(Appendix 4, Line 23, author's translation).

It was evident in their responses that students had a preconception of what is required to understand from an experiment and what it means to work experimentally:

> *"A case seems like an unnecessary addition to an experiment where the connection between theory and experiment should have a greater influence than a case."* (*En case virker som en overflødig tilføjelse, til et forsøg, hvor sammenspil mellem teori og forsøg bør spille en større rolle end en evt. case)* (Appendix 3, Student comment 100, author's translation)

Additionally, to the students' preconceptions of experimental work, students' perception of pre-existing knowledge and competence were affecting their responses to the inquiry-based activities for example formulating a hypothesis independently:

> *"I think most of the students know that it is a working question or what it is that we want to find […] It is more the formulation […] And how you achieve what you want from a hypothesis."* (*[…] Jeg tror, de fleste ved, at det er et arbejdsspørgsmål eller sådan hvad er det, vi vil finde. […] Det er mere selve formuleringen af det. […] Og hvordan man får det, man gerne vil have ud af en hypotese.)* (Appendix 4, Line 62, author's translation).

The above quote exemplifies how students' responses reflected that working inquiry-based with experiments were new and challenging in another way than other biology module. Contrary, many students reported that they found the "Super Yeast" module easier than other biology teaching for example:

> *"I think the exact opposite. She had made it easy to understand for a person who usually find biology difficult."* (*Jeg synes lige netop det omvendte. Hun havde gjort det nemt at forstå for en person, som normalt har svært ved biologi.)* (Appendix 3 Student comment 132, author's translation).

This quote exemplifies many of student responses describing the module as "more simple" and "easier to understand" compared to other biology modules. This can be related to the reduced emphasis on acquiring concepts. Moreover, some students expressed that they found it exciting to learn something new about things from their everyday life which change their preconceptions:

> *" I thought the most interesting thing was to learn about why a dough containing yeast rises when you do not normally think about such everyday stuff"* *(Jeg synes at det mest spændende var at lære om hvorfor en dej med gær i hævede da man*

normalt ikke tænker over sådanne hverdags-ting) (Appendix 3, Student comment 54, author's translation).

This quote exemplifies several of the students' responses expressing how they found it interesting discovering how yeast is a living organism whose growth can be influenced by different factors.

Social learning

Seeing how the different factors influenced the growth of yeast from the other student groups' experiments and results were one of the aspects of the "Super Yeast" module students would often highlight as engaging and interesting for example:

> *" I like when the others in the class get some completely different results and then compare them because there is usually somebody who gets some crazy results." (Jeg kan godt lide når andre i klassen får nogle helt andre resultater end en selv, og dernæst sammenligne dem, fordi der plejer at være nogen der får nogen skøre resultater.)* (Appendix 3 Student comment 190, author's translation).

The above quote reflects that it was important to the students to share their results with the other students' results and that the other students' results are of just as much interest to the students than their own experiments. Additionally, student reported that sharing results, resulting in a greater learning outcome:

> *" It was interesting that everybody was doing different investigations, then you'll learn more in a short time" (Det var interessant at alle lavede forskellige undersøgelser så man lærte meget på kort tid)* (Appendix 3, Student comment 12, author's translation).

Some respondents suggested that sharing the groups' hypothesis would have been a good support for them to formulate their own hypothesis:

> *"And then you could write all the groups hypothesis on the black board. Then everyone could see what the class was investigating together" ([…] også kunne du skrive alle gruppernes hypotese op på tavlen. Så alle kunne se, hvad vi som klasse samlet undersøger.)* (Appendix 4, Line 51, author's translation)

There were no indication, in the responses, of students finding it more confusing to see other experiments and results, contrary students expressed that it made the experiment more fun:

> *" I think it was fun that you could have your own focus but compare with the others afterwards". (Jeg synes det var sjovt at man kunne have sit eget fokus også sammenligne med andre bagefter.)* (Appendix 3 Student comment 192, author's translation)

Despite students expressing interest in other students' results, none of the students reported that they had shared their videos of their experiments internally in the group or to other groups. Still, there was indication of the video as activity contributing to the group work by some students describing it as "cosy". Generally, there was no indication of the video contributing to students' engagement but rather that it contributed positively to their group work becuase every group member had an assigned task. Students responded that the assigned tasks provided an overview of the experiment as well as leading to concentrated group work. Furthermore, the assigned task led to all group members contributing to the group work:

> *"It was very cosy that everyone in the group had a task. I often feel, in the science subjects, that those who can understand it takes the lead while the others sit and do not understood anything."*
>
> (*Det var meget hyggeligt at alle i gruppen havde en opgave. Jeg føler tit i naturfag, at det er dem, der kan finde ud af det, der tager teten og de andre sidder og ikke har fattet noget af det.)* (Appendix 4, Line 28, author's translation.).

According to the students, the assigned tasks in the groups led to inclusion. Students also reported that having to choose their own growth factor led to groups discussions about how the different factors could influence yeast and what might happen if they designed their experiment in a certain way:

> *"[…] That you have to sit and talk to each other about "what if you do this?" or "What about this?". That made really good sense to me that you talked about what you thought would happen with the different things […]"*
>
> *([…] at man selv skal sidde og snakke med hinanden om "kunne man gøre sådan her?" eller "hvad med sådan her". Det synes jeg gav virkelig god mening, at man fik snakket om, hvad man tænkte ville ske ved de forskellige ting […].)* (Appendix 4 Line 103, author's translation).

The quote illustrates how the students were working inquiry-based with a question through discussion and emphasising the importance of the social aspect of motivating students to engage. Students' responses revealed that their choice of growth factor was influenced by what the other student groups had chosen and what have seemed "obvious" to them.

Autonomy

Student responses revealed that the most interesting and engaging aspect of the "Super Yeast" module was that they could choose their own variable to investigate. Some students reported that it led them to reflect and discuss in groups what they wanted to investigate, contrary to when the teacher instructed them. It was also evident that having a choice was new to the students, reflected in the student responses reporting that it was difficult to work independently and having the responsibility to choose what should be investigated, Never-

theless, none of the students expressed that working independently influenced their engagement or motivation negatively. Despite being new and different, students reported that making decisions by themselves made them wanted to work more:

> *"[…] I also think that it was, that you could decide what should happen, which made it more exciting. That is, that you wanted to work a little bit more because you weren't just following an instructional learning material."*
>
> *(Jeg synes også, det var, at man selv lidt skulle bestemme, hvad der skulle ske, gjorde det lidt mere spændende. Altså, man ville arbejde lidt mere, fordi man ikke bare havde sådan en journal, man skulle følge.)* (Appendix 4, Line 452, author's translation).

Similarly, to the above quote, other students expressed that it benefitted them not having an instructional learning material to follow:

> *"It works fine having a little bit of control over the experiment then you don't stress and fiddle with everything being according to the instructional learning material."*
>
> *(Det fungerer fint med at have lidt kontrol over forsøger selv, så man ikke skal stresse og fumle med at alt skal være lige efter forsøgsvejledningen)* (Appendix 3, Student comment 311, author's translation).

Despite having an experimental set up to follow and having been assigned an individual task, students would describe the *Forsk phase* of the "Super Yeast" module as being "freer" and that they experienced more control and influence on experiment, which were often emphasised as the most interesting and exciting aspects of the module. Additionally, students stated that choosing their own variable to investigate made them feel that they were a greater part of the teaching. Moreover, having students choosing their own variable also made the experiment interesting to students who reported that they already had a pre-existing knowledge about the content:

> *"I had been taught about many of the things before but that is why it was interesting to choose your own growth factor."*
>
> (*Mange af tingene havde jeg haft om før, men det var også derfor det var interessant at man selv kunne vælge vækstfaktor)* (Appendix 3, Student comment 161, author's translation).

Throughout the student responses, it was evident that it had an impact on their engagement being able to choose the variable, which they were curious about. However, responses and observations indicated that the students' choices were affected by what the other groups had chosen as well as some students responses indicating that they might be driven by confirming their hypothesis:

" It makes it more exciting to change the experiment and then have the hypothesis confirmed, I think."

(*Det gør det mere spændende at ændre på forsøget og så få bekræftet nogle hypoteser, synes jeg.)* (Appendix 3 Student comment 189, author's translation).

This quote indicates that some of the students chose a variable they could foresee the outcome of and thereby resulting in a conformation of their hypothesis. Moreover, the quote indicates that for experimental work to be interesting, hypothesis should be confirmed. The responses did not reflect how students would perceive their choice of variable if the experiment did not confirm their hypothesis.

Learning by doing

It was apparent in the student responses that it was important for students having concepts visualized and that they had an increased understanding when they could apply their knowledge to something concrete. This was sometimes directly written in the student comments but also reflected when students often used the verb "at se" (to see) when describing something as interesting. This revealed that *to experience* something is important for students' interest:

" That it is in some way alive and it grows."

(At det på en måde er levende og det vokser)

(Appendix 3, Student comment 5, author's translation).

Similarly, students reported that they acknowledged the potential of their videos as notes because it provided them with the opportunity to re-watch the experiment. Nevertheless, none of the students had shared their videos with each other.

Students stated that having the growth curve presented after conducting their experiments increased their understanding because they could relate their own experience and results:

"Yes, I think so, then you can comprehend it. That is, you experience something first and then it is put into a model afterwards - ah this was this, that happened and that was like this and because of that."

(Ja, det synes jeg, så man ligesom kunne tænke sig til det. Altså det der med, at man først oplevede noget, også få sat det ind i en model bagefter - nåh det var det, der skete og det var sådan her og det var derfor.) (Appendix 3, Student comment 430, author's translation).

Furthermore, students would express that they were more interested and willing to listen when they could compare their results to the growth curve, which follows the students expressing that it was motivating and engaging to test and relate concepts to something in "reality", Even with the learning and motivational poten-

tial of "learning by doing", students would also report the activity of the "Super Yeast" module required more focus and was challenging:

> *"There were a lot to remember and in relation to the results you should continuously reflect upon what have gone wrong and what could be different."*
>
> *(Der var meget man skulle kunne huske og ift. resultaterne så skulle man hele tiden tænke over hvad der var gået galt eller hvad der kunne være anderledes)* (Appendix 3, Student comment 118, author's translation).

The above quote reflects the importance of guidance in inquiry-based experimental work. Throughout the analysis, students' responses often reflected guidance in different ways influencing their perception of the module.

Guidance

It was evident that guidance influenced students' responses to having a choice, working with a case and video as well as their perception of the learning activities when they had an experience of not fully understanding the content and the activities of the "Super Yeast" module. Students expressed that they needed clear guidance and support in choosing a growth factor and formulating a hypothesis but also to know *when* they could influence the experiment. Though, most students responded that it was manageable if they could ask the teacher. Still, it was very evident among the responses that especially practical instructions were important for the students. Moreover, guidance in connecting the different activities of the modules especially the *Forsk* and *Forlæng* part of the module was important in the students' responses. Students' recognized several ways they have been given guidance and they both emphasized the case and the video questions as helping them focus on what to reflect upon in their experimental work and what to include in their video. Nevertheless, most of the students had not understood that the video questions should be included in the video and sometimes they have not even noticed the questions, which might be explained by the time instructions were given.

Structure

The structure of the 6F model was generally found to make sense for the students and help them understand their experiments and relate their results to the growth curve of the textbook:

> *"I liked learning something, then doing something and then understanding it."*
>
> *(Ja, jeg kunne godt lide at lære noget, så lave noget og så forstå det)* (Appendix 3, Student comment 307, author's translation).

Accordingly, some students expressed that the structure helped them focus. Even so, some students would report that they would prefer having the theory (growth curve) behind the experiment presented before conducting their experiments lead to a better understanding of the growth curve. Additionally, some students found it problematic to align the different phases of the module:

> *"I think the topic was interestingly enough but there was not really enough time to learn about it - therefore it was mostly a lot of info which we didn't fully understand."*
>
> *(Jeg tror det var et interessant nok emne, men der var ikke rigtig tid til at lære nok om det - derfor var det mest bare en masse info vi ikke nåede at forstå fuldt ud.)* (Appendix 3, Student comment 59, author's translation).

Similarly, it was apparent from the student responses that some students were missing alignment in the presented case in *Fang* phase.

Case was engaging/not engaging.

Several student responses reflected that they had difficulty in connecting the case with the other activities and many students forgot the case while working in the *Forsk* phase. Moreover, the case of Strain 323 was conflicting with what students believed to be scientific:

> *"I would prefer if it wasn't made into a game but just science."*
> (*Jeg ville foretrække hvis det ikke blev gjort til en leg, men bare var videnskab.)*
> (Appendix 3, student comment 97, author's translation).

Contrary, other students found the case exciting because learning was combined with play. Often, students emphasized the case as the most exciting and interesting aspect of the module and students reported that the case was engaging them by providing the experiment with purpose and a problem made their learning outcome more useful:

> *"[…] a little more exciting and a little bit closer even though it is not real but that we thought, okay what is happening here, or something. Also, that we got something political science related. I thought that was nice. I think sometimes that, when you are in biology and physics class and like that. Then I think it can be like "okay what can I use this for" kind of. So, I think it was good to include the outside world."*
>
> *(ja lidt mere spændende og lidt mere tættere på, selvom den ikke er rigtig, men at man ligesom tænker okay, der sker det her, eller sådan noget. Også det her med, at vi fik lidt samfundsfagligt også. Det, synes jeg, var ret rart. Jeg synes nogle gange, når man har de der bio-*

> *logi og fysik og sådan noget, så synes jeg godt, det kan blive sådan "okay, hvad skal jeg bruge det til" agtigt. Så jeg synes, det var godt at bringe noget ud fra omverdenen ind i det)* (Appendix 4, Line 442, author's translation).

In addition to providing meaning, students explained that the case made them curious and gave them a focus and understanding when working with the hypothesis in the *Forsk* phase.

Teacher

The last category identified includes the student responses which emphasize the importance of an engaged teacher which communicates clearly through simple instructions.

Chapter 4 Discussion

4.1 Interpretation of results

To what extent are students' responses to experimental work affected by choice

Students responses to experimental work was greatly affected by having a choice. By having a choice, students felt a sense of control and influence which resulted in an increased experience of autonomy. The increased experience of autonomy was affected by students' perception of competence with some of the students perceiving the experimental work as being more difficult than other experimental work because they experienced an increased responsibility and independence in the experimental task. This confirms the findings of Wood (2019) which highlights students' self-perceived competence influencing their motivation and engagement to a greater extent than their experience of autonomy. Still, most students responded positively to having an influence and that it made them more motivated to engage in the experimental work. Moreover, the findings reflected that students felt more included in the learning context. By becoming an active part of the learning environment, students' experience of relatedness was linked to a feeling of being valued and acknowledgment which would result in students being more inherently motivated with positive implications of their learning outcome and well-being. It can be interpretated that by experiencing their behaviours as being less externally regulated they would have an increased *internal perceived locus of causality*, meaning students experiencing that their behaviour was originating from themselves, making them increasingly self-determined (Ryan and Deci, 2000; Niemiec and Ryan, 2009). This increased self-determination was exemplified in students stating that having an influence and not having to follow an instructional learning material made them want to work more and that they "actually had to think about what would happen". These examples can also be an indication of students having internalized the experimental work due to an increased experience of autonomy.

Giving students a choice benefitted the often-challenging task of teaching a group of students which have different pre-existing knowledge about a given topic. Students already having pre-existing knowledge or

experience with the experiment might be bored and less engaged in the experimental work. By giving students the choice to choose the variable they wanted to investigate, students had the opportunity to choose something they were curious about and thereby motivating them to engage in the experimental work. Interestingly, students would often choose to investigate the influence of temperature on the growth of yeast. Findings suggested that the students' choice were affected by what the other students were doing and what will give a successful outcome. Some student groups chose to investigate a variable they could not foresee the effect of such as baking soda, but it is the researcher's interpretation that students' perception of a successful outcome is to have their hypothesis accepted and not rejected. Hence, choosing a variable is influenced by how certain the students are of the results confirming their hypothesis. This could be explained by students being schooled in replicating results which confirms an instructional learning material, but this argument cannot be validated based on the findings from this study. Nevertheless, students reported that having to choose their own variable to investigate required them to reflect, think and discuss internally in their groups, indicating students were engaged by choice. Also, students reported that they felt relieved not trying to replicate the experimental outcome in an instructional learning material, thereby indicating that by giving students an influential choice in their experimental work will reduce the experience of external regulation and thereby leading to a more inherent motivation to engage in the experimental work.

It was surprising to what extent choice affected student responses to experimental work, despite the *"Forks"* phase of the "Super Yeast" module was a rather closed inquiry with students having to choose from a set of presented options and being assigned specific tasks. This finding can be related to students not being used to having an influence in their experimental work - having a so called "newness" factor but also that students need instructions and guidance to feel competent and autonomous. It was also evident that the motivational potential of choice depended on the extent the teacher and learning context supported their autonomy. This finding corresponds to 1) SDT theory which states that students can only have an experience of autonomy in autonomy-supporting environments and that students' need to have an experience of competence to feel autonomous, and 2) findings of other studies emphasising the teacher's educational style and ability to support students, influence students self-perceptions of competence and autonomy as well as motivation and engagement (De Loof *et al.*, 2019; Wood, 2019).

To what extent are students' responses to experimental work affected by working with a case

Student responses to experimental work was to some extent affected by a case. Responses revealed that students found that the fictional case of Strain 323 provided meaning, focus and purpose guiding them in their experimental work, which potentially had given them an experience of competence and autonomy. An important aspect of the experience of autonomy and internalization is that students accept the rationale of an activity e.g., when the teacher is presenting a task (Niemiec and Ryan, 2009). Thus, it appears that the case

promoted an internalization of the experimental work. Moreover, students found it engaging and motivating being able to relate their experimental work to the outside world and thereby given the experimental exercise relevance in relation to their interests for political science and baking. This indicates that by framing the experimental work using "real-life" problems, students can better "translate" what they learn into their own perception of the world. The world outside school is not categorised into different subjects and therefore it is the researcher's belief that the case helped the students to translate the concepts from the "Super Yeast" module into something which fits into their perception of the world and thereby give them an additional reason to engage in the experimental work besides an external factor such as a potential exam. As a result, students' experience of relatedness and competence could have been increased leading to students potentially being more inherently motivated to engage in the experimental work with positive impacts on their learning outcome and experience. However, many students did not remember the case during their experimental work and expressed difficulties in connecting the case with the other phases of the 6F model. Therefore, alignment and connection between the different activities influenced how and if a case affected students' response to experimental work.

If students are not able to connect the different learning activities, students might not accept the rationale of an activity for example a case, since it is an important aspect of the internalization of a task and for students experience of autonomy (Niemiec and Ryan, 2009). Moreover, Students' acceptance of the rationale of the case was found to be influenced by their preconceptions of experimental work and science. If the case conflicted with their preconceptions of what science is, they would not find the case engaging, and result in a negative perception of the learning activities. Contrary, in the responses of students who had an experience of not feeling competent in biology, the case had affected their responses to experimental work in a positive way resulting in an experience of feeling more competent. The less emphasis on finding a correct answer can be a possible explanation for this, leading students to feel more competent and autonomous. Nevertheless, what experiences, pre-existing knowledge and preconceptions students bring to the classroom were found to be important in their responses to working with a case.

To what extent are students' responses to experimental work affected by using videos as notes

It was not apparent that the video contributed to the students learning and engagement. None of them have shared it afterwards and many of them had not understood the instructions. This can be due to the time and way the instructions were giving. Another possible explanation is that the students were not given enough guidance and that the videos were not used in any of the other activities of the module. This might have affected how students have attributed meaning to the task and thereby them not internalizing the task but just filming because they were told to do so. Some findings suggested that students had led them to some discussing but it was apparent that the assigned video questions were difficult to include in the videos due to noise

in the classroom. Moreover, the students reported that they did not have enough time to finish their videos and that might explain why not all groups forwarded their videos. Despite the video not influencing the students' responses to experimental work, students acknowledge the potential of using videos in their documentation of experimental work. Additionally, a few responses indicated that the video contributed to relatedness by students having positive responses documenting their experience and communicating it to each other. Furthermore, students were observed being creative with their videos by adding music and filters. This creativity could potentially have affected student responses to experimental work, but this was not reflected in the responses.

How and to what extent can the application of the 6F model motivate students to engage in experimental work in biology in the Gymnasium?

The findings of this study indicated that the 6F model can make students more inherently motivated to engage in experimental in biology. To answer *how* the model can motivate students and *to what extent* it was evident that students' responses had to be understood in relation to the students' perception of biology as a subject. From the student responses it was evident that biology is a subject consisting of many terms and concepts. Despite most of the students just having started in the gymnasium, students would often describe reading and listening being less motivating. Some students also stated that they did not find biology as interesting as other subjects and that they did not perceive what they learn in biology as useful to them.

The importance of experience

It was evident that students are motivated to learn when they are active, experiencing, and visualizing concepts. Therefore, the *Forsk* phase of the 6F model has a potential to motivate students to engage in experimental work but also to acquire biological concepts and terms. However, student responses suggest that just by being active and not having to read or listen, students were more engaged but that this positive impact could not be attributed to the 6F model. Still, findings from the analysis reflected that it was important to students to understand *why* and *what* they had experienced for them to be motivated and engaged in the learning activities, which supports the argument that to motivate students to engage in experimental work in a considerable way it is not enough to activate students through experiments as an alternative to reading. Rather it appears that it is important when motivating students to engage in experimental work that the students are supported in connecting their experiences with the concepts or theory which they have to learn. This is according to several studies highlighting that students do not accommodate terms, concepts and understanding only by engaging in inquiry-based activities (Kruse, 2013). The teacher must scaffold and structure the IBSE teaching so the students can focus their attention on relevant aspects and to reduce complexity for the students (Kruse, 2013). This confirms the importance of a *Forklar* phase following a *Forsk* phase (Madsen, Evans and Bruun, 2020). Additionally, the case of Strain 323 was for some students helping them reduce the complexity and focus throughout the module, as well as making the experimental work more re-

latable to them. This finding indicates that the structure of the 6F model can potentially increase the students experience of competence and autonomy by guiding them in their learning process.

Moreover, having the *Forklar* phase after the *Forsk* phase students reported that it made the experimental work more simple for them as well as more interested to learn the theory because they could relate the growth curve from the textbook to their own results and use the theory to explain their findings.

The importance of alignment

It is necessary that the students can connect the different phases of the 6F model for the structure to have a positive effect on students' motivation to engage in experimental work. If the connection between the phases is clear to the students, the structure of the model will guide students and help them focus on the learning outcome as well as potentially making the topic more interesting. If students fail to connect the different phases, students might not be able to connect their experience with the concepts and theory they need to learn and they will not perceive the learning activities as meaningful and valuable to them. Findings indicated that some students had trouble connecting the different phases of the 6F model which can be an explanation for why some students expressed that they preferred to work deductively when doing experimental work. Students not having a previous experience with experimental work structured through the 6F model can also be an explanation. It is also a possibility that students just prefer to have the theory presented first for them to feel competent and thereby motivated to engage in the experimental work.

The importance of teacher guidance in motivating students to engage in experimental work

For students to connect their experiences with theoretical concepts and to experience alignment between the different phases of the 6F model it was evident in this study that the guidance of the teacher had a significant influence. Students generally responded positively to not being provided with an instructional learning material, but they also added that it was because they had access to other types of guidance especially through the teacher. Moreover, findings from this study indicated that students internalized the experimental work, thereby being more self-determined, when they were giving alternative type of guidance than an instructional learning material. Therefore, the structure of the 6F model can provide an alternative to instructional learning materials with positive influence on the students' motivation to engage in experimental work.

The findings of this study underline the importance of the teacher facilitate the learning activities and support the students feeling of competence and autonomy, similar to other studies investigating students' motivation and engagement e.g., De Loof *et al.* (2019) and Wood (2019). The 6F model can help the facilitation of competence and autonomy-supportive experimental work with the continuous emphasis on feedback throughout the model. Even so, it is a difficult task to provide students with all the support they need to feel competent and autonomous especially when they do not have experience with experimental work structured by the 6F model. However, findings of this study revealed that students expressed the importance of the so-

cial interactions with their peers just as important in how they were motivated to engage in the experimental work as their teacher.

The social aspect of the 6F model and how it motivates students to engage in experimental work

A surprising outcome of the analysis was how important the social aspect of the module was to the motivation of the engagement of the students. The motivational aspect of the social interactions between students have not been emphasized in the studies included in this thesis, in which the student-teacher relation has been emphasized as being the most influential (De Loof *et al.*, 2019; Wood, 2019). Findings revealed that one of the most interesting and engaging aspect of the "Super Yeast" module was to see the different results from all the student groups. The analysis suggests that by sharing hypothesis and results, students' experience of relatedness was increased. Relatedness facilitates the process of internalization because students will be more dispositioned to internalize tasks and knowledge in relation to others with whom they feel connected too and in contexts where they feel they belong (Niemiec and Ryan, 2009). The facilitated group work where all members had an assigned task increased inclusion, increased students experience of belonging in the social context. Furthermore, it is the researchers' interpretation that by structuring the experimental work as a problem which the class collectively was going to solve, students perceived their contribution and results as valuable and thereby facilitated the process of internalization and motivating to engage. All the phases of the 6F model are supporting sharing and discussion of ideas and experiences, thereby supporting the students experience of relatedness as well as providing the teacher with feedback which can help the teacher's facilitation of an autonomy and competence supportive learning environment.

The preconceptions, self-perceived competence and pre-existing knowledge of students influence how students are motivated to engage in experimental work

The analysis revealed that students' experience, self-perceived competence, and preconceptions determines the way they are motivated to engage in experimental work. It influences how they attribute meaning and value to an activity and thereby to what extent they internalize the experimental work. Results showed that the case and reduced emphasis on theory could conflict with student's preconception of what it means to work scientific and experimentally resulting in them attribute less value to the activity because it might be contradictory what they have been taught. Students' limited experience with working inductively and more exploratively can also undermine their experience of competence because they might not be able to apply the learning strategies they are used to. Consequently, all the above influences the extent in which they are motivated to engage in the phases of the 6F model.

However, the above can actually be addressed in the 6F model because all the phases of the model are based on students' pre-existing knowledge which is expressed through the continuous feedback throughout the model but especially in the *Forudsætnings* phase (Madsen, Evans and Bruun, 2020). By incorporating stu-

dents' pre-existing knowledge and preconceptions of the topic, it is more likely students will identify the learning activities valuable to them and thereby internalize the experimentally work resulting in them being more inherently motivated and self-determined. This was exemplified in this study by student reporting that their perception of yeast had changed and from an everyday item to a biological organism. Thereby indicating that students experience biology as something being relevant to their everyday lives and not just something relating to school. Therefore, the findings of this study indicate that the structure of the 6F model holds a potential to change students' preconceptions, because the model has the students' pre-existing knowledge as a starting point for all the learning activities, resulting in the model having a potential in making the students more inherently motivated to engage in experimental work in biology and a potential to change the students' perception of the how to do experimental work in biology.

4.2 Limitations of results

These results have several limitations. The biggest limitation of this study is the personal bias resulting from the same researcher developing the module, teaching, collecting data and conducting the analysis and conclusions. Throughout the research, the researcher has been aware of the personal bias. Even so, the validity of the findings of the qualitative content analysis would have been improved if it would have been possible to compare the findings from the same data by another researcher (Erlingsson and Brysiewicz, 2017). Similarly, it was evident that the students were giving more positive response especially during the interview for example:

> *"Yes, it was completely clear, it was our mistake. It was really good. It worked really well."*
> *(Jo, det var helt tydeligt, det var vores fejl… Det var rigtig godt… Det fungerede rigtigt godt)*
>
> (Appendix 4, Line 527, author's translation)

This quote illustrates how a student was withdrawing potential criticism during an interview. Through the teaching of the module, a positive relation was built between the researcher and the students which resulted in the students giving less negative feedback because they were aware of the researcher having developed the module. This exemplifies how an interview is a social meeting between two individuals and therefore the outcome of the interview would also be influenced by the relationship between the interacting parties. Even so, the findings are still applicable despite the potential of students expressing more excitement than if another researcher had conducted the interviews. Furthermore, the conducted interviews were varying in terms of wording of the questions, number of respondents and length. More consisted and structured interviews would have led to generalizations from the data being more valid. Nevertheless, the purpose of the interviews was to validate and expand the data collected from the Survey with the objective of having students sharing describing their experience in their own words.

When interviewing, the researcher already had a preconception about what have happened in the class leading to the students' responses being perceived in a different way and put into a context. This bias also applies to the transcription. One way this was reduced was the researcher not being able to see the students during the interview and therefore the researcher does not know which school the student attends. Contrary, non-verbal information is sometimes more informative than verbal communication and therefore validity of the responses could have been increased by collecting the non-verbal information from the students (Cohen, 2007, p. 144) Yet the objective of the analysis was not to find any latent meaning in the students' responses but to apply summative coding and thereby reading the students responses literally.

Another limitation of this study is the inclusion of only one motivational theory. Andersen and Krogh (2018) states that it is not adequate to base ones understanding of student motivation on a single motivational theory. Since motivational research is an extensive field of research with several definitions of motivation and different aspects of the learning context being emphasized as important for student motivation, the scope of this thesis only includes one relevant motivational theory.

Throughout the work with writing this thesis the researcher discovered and learned many aspects of the students and how they are motivated to engage in the learning activities in gymnasium, as well as how the activities of the "Super Yeast" module could be improved. Therefore, it would have been interesting and exciting to incorporate these findings and experiences into a further development of the "Super Yeast" module.

Conclusion

This study found that students in the Danish gymnasium perceive biology as a subject which consist of many concepts and terms. Students stated that they prefer to learn by being active and experience the concepts they need to learn. Furthermore, it was possible to facilitate this way of learning by redeveloping an existing instructional learning material by applying the structure of the 6F model. Both the social interactions of the 6F model and the different contributions of the student groups were contributing to the investigation of the growth of yeast were found to be important for student motivation since it contributed to their feeling of relatedness and increased their interest and learning outcome that the. It was apparent that students' experience of autonomy, relatedness and competence were increased by allowing students to choose which variable they were interested in investigating. By giving a choice students felt more included in the learning environment and independent in their experimental work which potentially has made students more self-determined and inherently motivated. When being presented with the theory students could relate their experiences to the learning material, which according to the students made them more interested in learning the theory because it explained their experiments. At the same time students' limited experience with inquiry-based work and the structure of the 6F model made some students feel less competent and autonomous by working more independently. This finding emphasises the importance of guidance in inquiry-based teaching and in the students' motivation to engage in experimental work. By introducing a fictional case in the *Fang* phase of

the 6F model, students felt they had a focus, purpose and meaning to their experimental work which were engaging and guiding them. Also, the case made the students perceive the learning outcome as more useful and related to other subjects.

Findings also revealed that if the 6F model conflicted with the students' preconception of what science and experimental work is, the 6F model would not have a positive influence on students' motivation to engage in experimental work. Similarly, if students could not connect the different phases in the 6F model or their experiments with theory, the structure of the 6F model would undermine the students' feeling of competence, which emphasise the importance of alignment between the 6F phases.

However, it is evident from this study that the 6F model has the potential to make students more inherently motivated and self-determined to engage in experimental work in biology. The findings also demonstrate that smaller adjustments in the facilitation of experimental exercises have an effect. Furthermore, there are indications of the 6F model can change students' perception of experimental work in biology.

For further research and teaching:

To address the limitations of only applying one motivational theory to assess and increase student motivation and to assist teachers in unfolding the motivational potential of IBSE teaching practices, Andersen and Krogh (2020, 2018) have developed the CARTAGO framework. CARTAGO is an acronym for the combined concepts of motivational concepts, which the framework includes: **C**ompetence, **A**utonomy, **R**elatedness, **T**ask-value, **A**ttributions, **G**oal **O**rientations (Krogh and Andersen, 2020, p. 254). Having a framework of motivational concepts gives teachers an overview of motivational concept as the opportunity of sharing and discussing their experiences and perceptions of student motivation in IBSE (Andersen and Krogh, 2018) and other teaching practices. Additionally, the framework can be used as a tool to analysis the dynamics of student motivation in IBSE teaching practices and other instructional teaching material (Andersen and Krogh, 2018). This combination of theoretical concepts and concrete recommendations, in the CARTOGA framework, makes motivational theories relevant in education and it emphasises how student motivation should be an ongoing focus in teaching practices and future research. On this note, this thesis will end by rooting for future research and projects focusing on the development of applicable research-based resources, which can inspire and guide teachers to implement inquiry-based activities which supports students' motivation within the context of the Danish Gymnasium.

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Images:

Image 1: Front page: Image from one of the students’ video 2020.

Image 2: Micropia (2020) *Saccharomyces cerevisae - life in beer, bread and wine*. Available at: https://www.micropia.nl/en/discover/microbiology/saccharomyces-cerevisiae/ (Accessed: October 2020).

Image 3: Figure from Hansen, N. S., Hestbech, G., Hulgard, K., Kahl, I., Madsen, C. V., Marcussen, L., Marker, H. (2012) ’Forsøg med gær - illustration af det kontrollerede forsøg’, *Biologibogen (Ibog)*. Århus: Systime A/S. Tilgængelig på: https://bio.systime.dk/index.php?id=276 (Accesed: 14 oktober 2020).

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Smith, B. (2020) *myBSlife - Pizza Dough in the Dumpster Anyone?!??!*. Avaiable at: http://mybslife.ca/pizza-dough-in-the-dumpster-anyone/ (Accessed at: October 2020).

Appendix 1

Presentation for teaching the ”Super Yeast” module


Saccharomyces cerevisiae
Strain 323

Program

- Introduktion til Strain 323
- Undersøgelse af Strain 323
- Deling af resultater
- Anvendelse af resultater

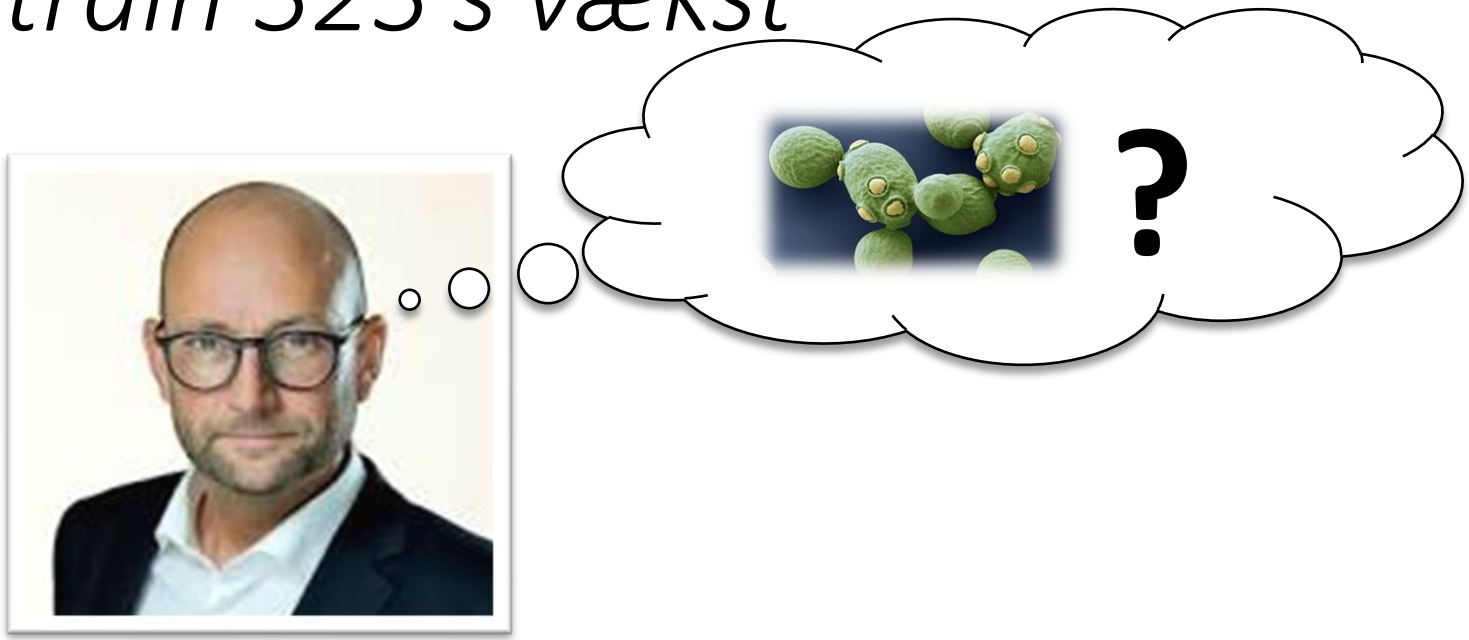
Efter modulet kan i:

- ✓I kan undersøge mikroorganismers biologi vha. eksperimenter.
- ✓I har viden om, hvilke faktorer, der påvirker mikroorganismers vækst.
- ✓I har produceret en video og en grafisk repræsentation af gærs vækst.
- ✓I kan rådgive andre om, hvordan man undersøger mikroorganismer videnskabeligt.

Strain 323 – super hæveren!!!!

Jeres opgave:

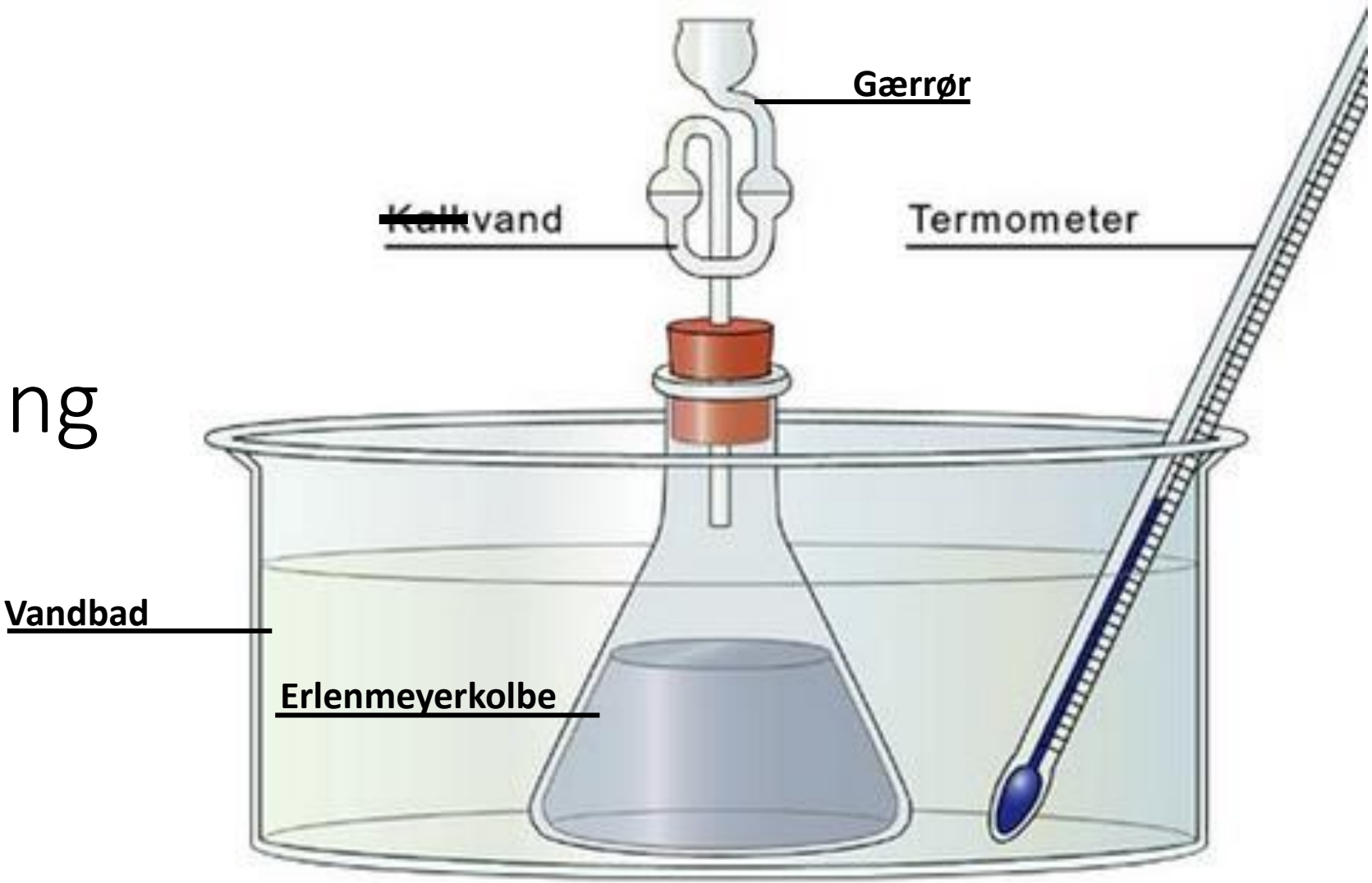
Rådgive fødevareministeren om hvilke faktorer, der kontrollerer Strain 323's vækst



Hvad påvirker gærs vækst?

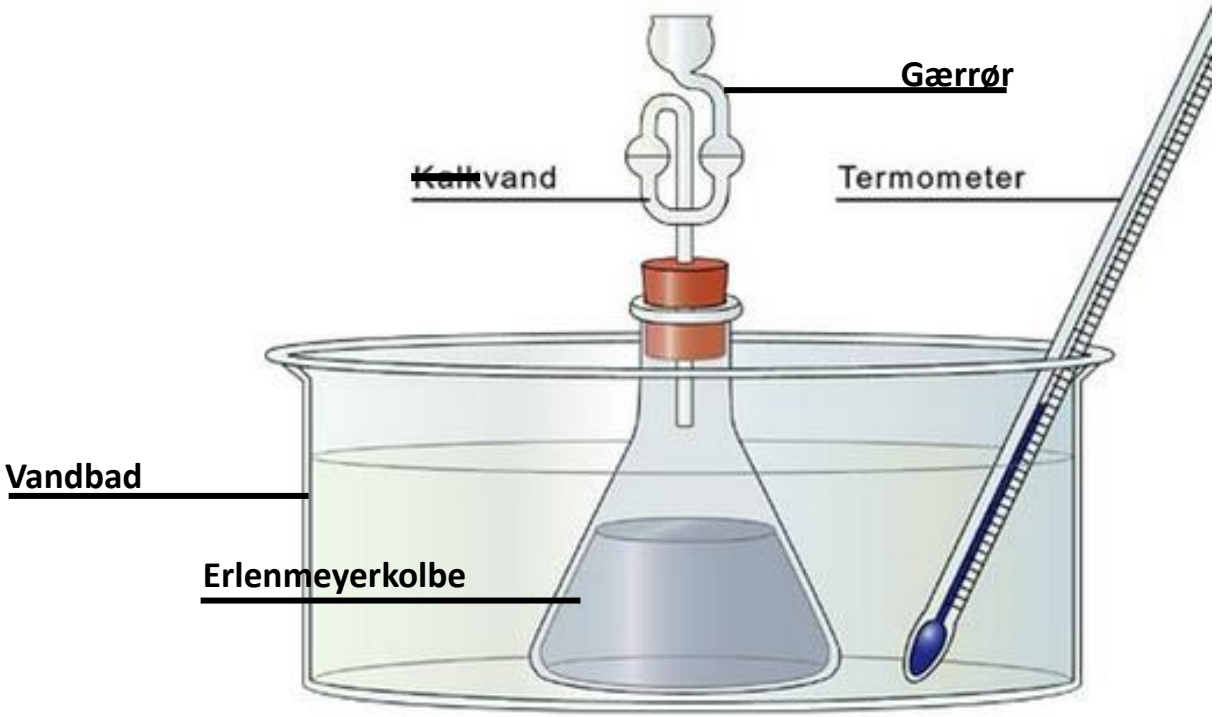
https://padlet.com/carolinegram/2iahr1q1so74vw0t

Forsøgsopstilling



Gruppeopgaver

1. Tæller bobler
2. Producerer 2 min. video
3. Taster data ind i loggerpro/excel
4. Styrer tiden



Fremgangsmåde

1. Beslut jer for hvilken vækstfaktor(er) i vil undersøge i jeres forsøg.
2. Bland **20 g gær, 150 ml. vand 15 g sukker** i erlenmeyerkolben.
3. Opsæt eksperimentet efter forsøgsopstillingen.
4. Fyld **vand i gærrøret**.
5. Efter **3 min. start** med at tælle bobler.
6. I skal notere **bobler for hvert minut** fx 1 min. = 10 bobler, 2 min. = 5 bobler osv.
7. Indtast data for hvert minut i **Loggerpro**.
8. Efter **20 min.** stopper i tællingen.
9. Lav en **graf** over jeres data og del via. **Padlet** link

Video

Jeres noter

Film ikke hinanden

Max. 2 min.

Besvar spørgsmålene:

- Hvorfor laver i jeres forsøg?
- Hvilken vækstfaktor(er) undersøger i?
- Hvad er jeres hypotese?
- Hvordan undersøger i jeres hypotese?

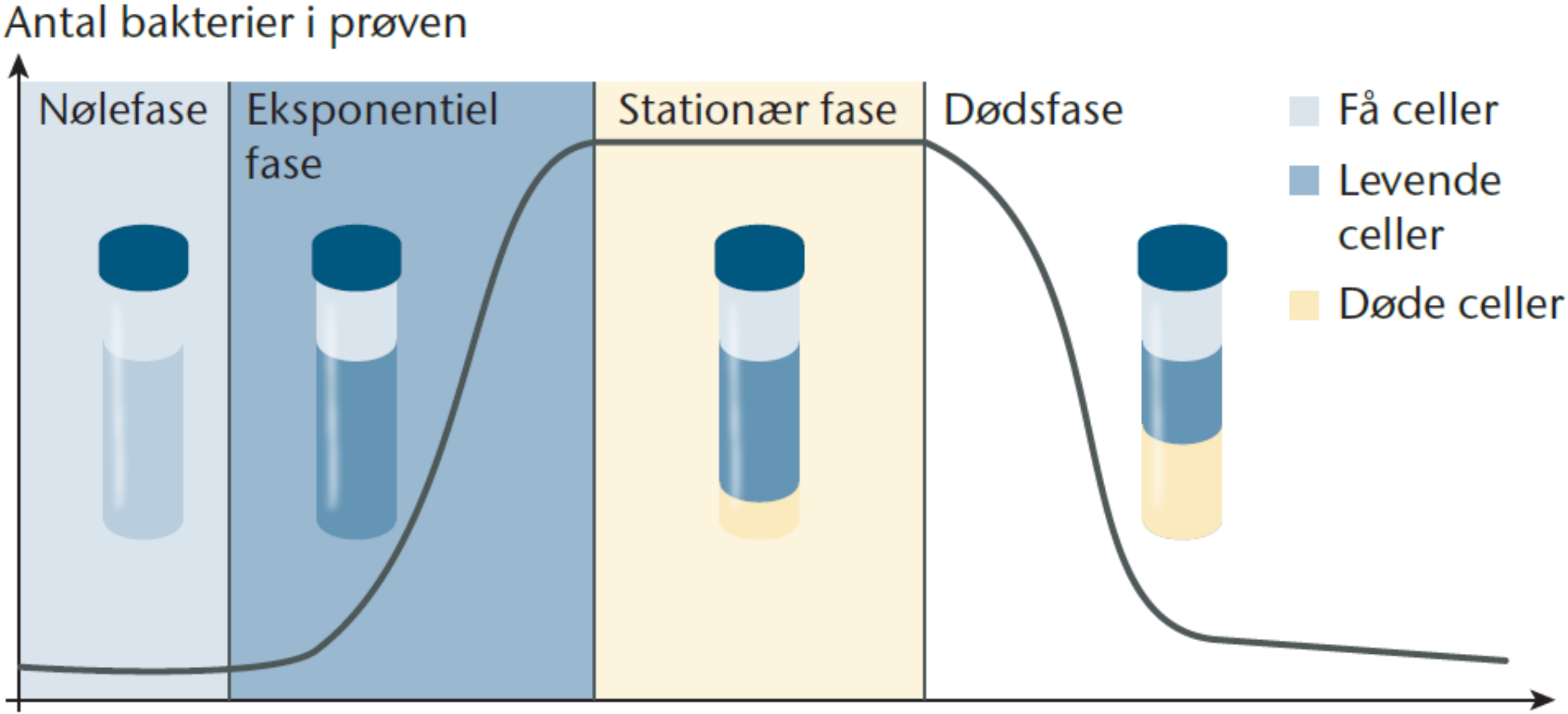
Link til deling af grafer

https://padlet.com/carolinegram/2iahr1q1so74vw0t

Link til deling af videoer

https://wetransfer.com/

Send til caroline.gram@hotmail.com


Antal bakterier i prøven
Nølefase
Eksponentiel fase
Stationær fase
Dødsfase
Få celler
Levende celler
Døde celler

Opsamling:
Hvad kan vi fortælle fødevareministeren?

Interview?

Appendix 2

Qualitative content analysis of interviews

Nr.	Meaning unit	Coding 1	Coding 2
1	Meget unødvendig information i starten.	Case, Owerwhelm	Case was engaging/not engaging
2	Info bagefter. Reaktion spændende bagefter.	Structure	Structure works/do not work
3	Se andres vækstkurver.	Social	Social learning
4	Se udbytte og hvor ens kurve passsede på vækstkurven.	Relate/Application	Learning by doing
5	Interessant og anderledes. Har ikke prøvet at vælge før.	Interest, New, Influence	Autonomy
6	Ikke nok tid til at forstå emnet. Ville gerne vide mere inden at skulle vælge variabel og formulere hypotese.	Time, Understanding, Support, Independence	Guidance
7	Ville gerne have forstået mere og flere begreber inden forsøg.	Understanding, Support	Guidance
8	Sjovt og anderledes forsøg. Godt at alle fik en opgave. I naturfag er det dem, der kan finde ud af det, der tager teten.	Fun, New, Social, Subject	Social learning
9	Alle følte sig som en del af gruppen.	Inclusion	Social learning
10	Opgaver hurtigt fordelt.	Social	Social learning
11	Bedre forståelse af vækstkurve ved at have prøvet selv først.	Experience, Structure	Learning by doing
12	Svært at lave en hypotese. Har ikke så meget øvelse.	Support, Method, Past	Guidance/suggestion
13	Lærer kan vise eksempler på hypoteser.	Teacher, Support	Guidance/suggestion
14	Lærer tydeliggøre at man skal starte med at lave en hypotese.	Teacher, Support	Guidance/suggestion
15	Lærer kan skrive alle gruppernes hypoteser på tavlen.	Teacher, Support	Guidance/suggestion
16	Elever kan vælge et emne også kan lærer hjælpe med formulering af hypotese.	Teacher, Support	Guidance/suggestion
17	Har ikke så meget erfaring med formulering af hypoteser.	Past, Method	Preconceptions and prior knowledge
18	De fleste ved, at det er et arbejdsspørgsmål. Det er formuleringen og hvordan man får det man vil have.	Method	Preconceptions and prior knowledge
19	Ikke brugt eller delt video i gruppe.	Video, Usefullness	Social learning
20	Tænkt over indhold i video.	Video, Understanding, Active	Guidance
21	Hyggeligt at filme.	Video, Relatedness	Social learning
22	Sjovere hvis vi kunne filme imens og alle i gruppen var med.	Video, Social	Social learning
23	Svært at svare på videospørgsmål undervejs.	Video, Support	Guidance
24	Troede spørgsmål skulle besvares efter.	Video, Time	Guidance
25	Svært at indtale spørgsmål efter eksperiment, fordi der ikke var nok tid.	Influence	Structure works/do not work
26	Det var godt selv at få noget at skulle have sagt i forsøget.	Influence	Autonomy
27	Skulle selv reflektere over, hvad vil være spændende at ændre.	Active	Autonomy
28	Fik tænkt mere.	Active	Autonomy
29	Ikke mere forvirret. Havde noget at skulle have sagt i forsøget.	Influence	Autonomy
30	Skulle snakke med hinanden om sine tanker om muligheder og udfald.	Social, Active	Social learning
31	Mere tydelighed om hvordan forsøget stilles laves og stilles op.	Teacher, Method, Support	Guidance
32	Tvivl om opsætning.	Method	Guidance
33	Mange skulle spørge om noget på samme tid.	Teacher, Support	Guidance
34	Klare og tydelige praktiske informationer.	Practical Support	Guidance
35	Tydeligt hvornår man selv skal komme med noget kreativt og vælge selv.	Support Independence	Guidance
36	Fedt at teste, det vi lærer i virkeligheden.	Experience	Learning by doing
37	Eksperimenter altid sjove fremfor kun læsning og teorigennemgang.	Alternative, Experiment	Experiments compared to other activities
38	Glemte case.	Case	Case was engaging/not engaging
39	Fokuserede mere på eksperiment og resultater.	Emphasis, Case	Case was engaging/not engaging
40	Case gjorde ikke en forskel.	Indifference	Case was engaging/not engaging
41	Mere frit og fedt selv at vælge.	Independence, Influence	Autonomy
42	Anderledes med mange forskellige resultater til sammenligning.	Different Factors, Social	Social learning
43	Diskuterede i gruppe om hypotese.	Social, Active	Social learning
44	Øvelse i formulering af hypoteser og eksperiment fra anden undervisning.	Past	Preconceptions and prior knowledge
45	Valgte vækstfaktor fordi det var "oplagt".	Past, Choice	Preconceptions and prior knowledge
46	Hvad andre vælger har indflydelse.	Social, Choice	Social learning
47	Valgte vækstfaktor ud fra nysgerrighed på udfald.	Curiosity, Choice	Autonomy
48	Hvis man ved noget konkret om en faktor vil man være mere tilbøjelig til at undersøge den.	Competence, Choice	Preconceptions and prior knowledge
49	Video er bedre dokumentation end tekstnoter.	Video, Usefullness	Learning by doing
50	Kunne bruge tekstnoter og video.	Video, Usefullness	Suggestion
51	Fedt at se ting man har lavet, så behøver man ikke huske og man har noget konkret til databehandling.	Video, Usefullness	Learning by doing
52	Videospørgsmål var ikke tydelige og ikke inkluderet i video.	Video, task unclear	Guidance
53	Ikke delt video i gruppen.	Video, Usefullness	Social learning
54	Lærer kunne have vist vækstkurve både før og efter forsøg.	Teacher, Support	Structure/suggestion
55	Elever er mere interesserede og lytter mere når de kan sammenligne vækstkurven med deres resultater.	Relate, Application	Learning by doing
56	Lettere at relatere, når man sammenligner.	Relate	Learning by doing
57	Fedt at arbejde praktisk. Husker bedre og giver noget mere end ved læsning.	Experiment, Alternative	Experiments compared to other activities
58	Opgavetildeling i grupper resulterede i koncentrerede arbejde.	Social, Active	Guidance
59	Fedt at alle havde noget at lave.	Social, Inclusive	Social learning
60	Alle ville tage tid.	Social, Choice	Social learning
61	Samlet op på gæring efterfølgende i gruppen.	Social, Application	Social learning
62	Gik godt i efterfølgende test.	Application	Understanding
63	Har fået en bedre forståelse, hvilket er rigtig fedt.	Understanding	Understanding
64	Mere frit og fedt at arbejde uden forsøgsvejledning.	Indenpendece	Autonomy
65	Mindre seriøst uden forsøgsvejledning.	Science	Preconceptions and prior knowledge
66	Man kan selv styre mere uden forsøgsvejledning.	Independence, Influence	Autonomy
67	Det kan være svært at huske alle instruktioner.	Support, Method	Guidance
68	Godt at alle grupper præsenterede deres forsøg og man kan diskutere resultater og fejlkilder.	Social	Social learning
69	Svært at koncentrere sig i sidste modul.	Time	Guidance
70	Lærer skal tænke over hvor meget teori at inkludere afhængigt af tid på dagen.	Teacher, Theory	Guidance
71	Mængde af teori var passende i modul.	Theory	Structure works/do not work
72	Modul federe end normalt.	Subject	Additional information
73	Første gang arbejde eksperimentielt.	Past	Preconceptions and prior knowledge
74	Forsøg er det fedeste i biologi.	Experiment	Experiments compared to other activities
75	Lærer havde god entusiasme og god til at aktivere.	Teacher	Teacher
76	Engageret lærer giver engagerede elever.	Teacher	Teacher
77	Kan ikke huske case.	Emphasis, Case	Case was engaging/not engaging
78	Det var spændende at man kunne se, at det var en vild gær, i stedet for bare at få det fortalt.	Visualization, Experience	Learning by doing
79	Det var mere spændende selv at kunne påvirke forsøget.	Influence, Exciting	Autonomy
80	Fik formuleret en hypotese.	Method	Additional information
81	Det gav mening selv at lave en vækstkurve først også sammenligne.	Structure	Learning by doing
82	Video var meget godt.	Video	Learning by doing
83	Så video efter timen, men ikke delt den i gruppen.	Video, Application	Social learning
84	Kan ikke huske videospørgsmål.		Additional information
85	Fik svaret på videospørgsmål.	Video question included	Additional information
86	Spørgsmål hjalp med at vide, hvad videoen skulle indeholde.	Video question, Support	Guidance
87	Det er nemmere at se videoen end at læse.	Video, Usefullness	Learning by doing
88	Fokuserer mere på forsøg og resultater.	Case, Emphasis	Case was engaging/not engaging
89	Skiftes til arbejdsopgaver. Kedeligt at tælle bobler i 20 min.	Social, Method	Social learning
90	Lærer skal have entusiasme og tænke over om elever er med.	Teacher	Teacher
91	Hvis man bliver tabt i starten, er det svært at komme ind i modulet igen.	Support	Guidance
92	Lærer skal være sikker på at alle er med, og ved hvad de skal gøre.	Support, Teacher	Teacher
93	Let at spørge lærer.	Teacher, Support	Guidance
94	Modul var spændende, fedt, anderledes end normalt, mere simpelt, nemmere at forstå.	Exctiting, New, Understanding	Additional information

Appendix 2

Qualitative content analysis of interviews

Nr.	Meaning unit	Coding 1	Coding 2
95	Spændende at få lov til at prøve selv og eksperimentere med forskellige ting.	Independence, Experience	Autonomy
96	Formulerede en hypotese.	Method	Additional information
97	Man kunne tænke sig til vækstkurven. Man oplever først noget også får sat det ind i en model bagefter. Forklarer hvorfor det var sket.	Relate, Application, Understanding	Learning by doing
98	Byttede arbejdsopgaver, så man ikke skulle tælle i 20 min.	Method, Social	Social learning
99	Den fiktive case gjorde det lidt mere spændende og tættere på.	Case, Relate	Case was engaging/not engaging
100	Rart at have omverdenen og noget samfundsfagligt med. Det man lærte føltes mere brugbart end normalt i biologi og fysik.	Relate, Relevance, Subject, Usefulness	Case was engaging/not engaging, preconception
101	Rart at kunne spørge lærer. Billede af opstilling hjalp.	Support, Teacher, Method	Guidance
102	Det at man selv bestemte, gjorde det mere spændende.	Influence, Excitement	Autonomy
103	Man ville arbejde mere uden en forsøgsjournal.	Independence, Engagement	Autonomy
104	For lidt tid til færdiggøre video.	Video, Time	Structure works/do not work
105	Rart at have video til rapportskrivning for at se hvad der skete.	Video, Usefullness	Learning by doing
106	Skrev videospørgsmål ned grundet klassestøj.	Video, Written questions	Additional information
107	Mere tid vil have gjort videoen mere brugbar.	Video, Time	Structure works/do not work
108	Har ikke delt videoen i gruppen.	Video, Usefullness	Social learning
109	Manglede forståelse for cellulære processer - hvor gæren gjorde som den gjorde.	Understanding	Guidance
110	Få forklaret hvorfor tingene skete efter forsøget.	Understanding, Structure	Guidance
111	Sjovt og interessant fordi det var nyt.	Fun, Interesting, New	Doing experiments compare to other activities
112	Stort spring fra andet undervisning.	Connection	Preconceptions and prior knowledge
113	Case skabte meget nysgerrighed.	Case, Curiosity	Case was engaging/not engaging
114	Casen var sjov og søgte efter information på google.	Case, Fun, Curiosity	Case was engaging/not engaging
115	Kunne godt lide selv at få lov til at tænke over og diskutere hvilke faktorer man skulle vælge og udfald.	Influence, Independence, Active, Social	Autonomy
116	Det er kedeligt, hvis alle laver det samme, selvom det er interessant at undersøge variation ift. fejlkilder.	Experiment	Social learning
117	Det er mere interessant, at se de forskellige hypoteser og resultater, når alle har forskellige udgangspunkter.	Social, Different Factors	Social learning
118	Mangler teoridel til at disktutere vækstkurve.	Theory, Understanding	Guidance
119	Vækstkurven før forsøg vil give bedre mening i sammenligning, fordi den var ny.	Structure, Understanding	Guidance
120	Svært at følge med i gennemgang af vækstfaser.	Overwhelming, Teacher, Understanding	Guidance
121	Videoen fungerede ikke. Misforstod opgaven.	Video, Task unclear	Guidance
122	Opgavetilding i grupper gav mere overblik over forsøget.	Socail, Support	Guidance
123	Det var kedeligt at filme.	Video, Boring	Additional information
124	Svært at overskue at filme og det var kedeligt at filme bobler.	Video, Boring	Guidance
125	Fik formuleret en hypotese.	Method	Additional information
126	Forsøgsvejledning vil have givet et bedre overblik over eksperimentet.	Method, Support	Guidance, Structure works/does not work
127	Har ikke delt videoen i gruppen.	Video, Usefullness	Social learning
128	Fik svaret på videospørgsmål, men ikke i videoen. Videoen blev kasseret.	Videoquestion noted	Additional information
129	Andres videoer blev gode og var brugbare til en evt. eksamen.	Video, Usefulness	Learning by doing
130	Biologi indeholder mange termer, der gør det kompliceret og overvældende og aldrig interessant at læse om.	Subject, Theory, Overwheltmin	Preconceptions and prior knowledge
131	Biologi bliver spændende, når man ved det.	Subject, Interest, Understanding	Preconceptions and prior knowledge
132	Efter at have læst meget, er det lettere at forstå de nye emner og det er mere interessant.	Understanding, Interest	Preconceptions and prior knowledge
133	Kan rigtig godt lide at lave forsøg i biologi. Påviser de teorier man læser. Kan bruge det til noget.	Experiment, Relevance, Application	Experiments compared to other activities
134	Lærer skal forklarer vækstfaser før forsøget for at eleven får en bedre forståelse.	Teacher, Support, Structure, Understanding	Guidance

Appendix 3

Qualitative content analysis of students comments

Nr.	Comment	Coding 1	Coding 2
Q1	***Jeg synes, modulet om gærs vækst var interessant***		
1	At få lov til at undersøge gær med et eksperiment og relatere det til en problemstilling	Experiment, Relate	Learning by doing
2	Det var interessant at finde ud af gærs vækst	Solution	Learning by doing
3	Det var sjovt at se hvordan gæret reagerede med forskellige faktorer	Different factors, Experience	Learning by doing
4	Det var hyggeligt at lave forsøg	Experiment	Experiments compared to other learning activities
5	At det på en måde er levende og det vokser	Living	Learning by doing
6	Jeg synes hele ideen om den her made-up case var det mest spændende	Case	Case was engaging/not engaging
8	Det var spændende at lære om vækst, og fedt at udføre et forsøg, som kunne illustrere vores nye læring.	Topic, Experiment, Visualize/Experience	Learning by doing
9	Der var meget der skulle spille rigtigt ind for at få nogle nyttige resultater	Task	Guidance
10	hvordan gær kunne vokse.	Living	Learning by doing
11	at lave et forsøg. og at samle fælles op.	Experiment, Sharing/Social	Experiment compared to other activities, Social learning
12	det var interessant at vi fik lov til at designe vores eget forsøg.	Influence	Autonomy
13	Det var interessant at alle lavede forskellige undersøgelser så man lærte meget på kort tid	Different factors	Social learning
14	Det var interessant at udføre et eksperiment	Experiment	Experiments compared to other activities
15	At lærer noget nyt om gær	New	Preconceptions and prior knowledge
16	Hvilke forskellige faktorer der kunne påvirke plantens vækst	Different factors	Social learning
17	At vi lavede forsøg og at det ikke bare var bogligt	Experiment, Alternative	Experiments compared to other activities
18	Det var interessant, at man fik lov til selv at lave forsøget, så vi selv var indeover det, og at vi selv kunne styre, hvad vi arbejdede med	Influence, Independence	Autonomy
19	at forskellige faktorer kan have en så vigtig påvirkning	Different factors	Social learning
20	Det var interessant at lave et nyt slags forsøg	New	Structure works/not work
21	At man selv skulle lave forsøget	Independence	Autonomy
22	At lave forsøget	Experiment	Experiments compared to other activities
23	at lære	Learning	Additonal information

24	vi fik meget af vide, og caroline var god til at forklarer processener	Learning, Teacher	Guidance
25	Det at lave gruppe arbejde, i stedet for at sidde og lytte.	Social, Alternative	Social learning
26	At lære om ting man selv kender fra dagligdagen.	Learning, Everyday life	Preconceptions and prior knowledge
27	at lære om gær	Learning	?
28	Jeg syntes at forsøgsopstillingen og de forskellige faktorer, bare selve det at lave forsøget var meget interessant, da vi selv fik lov at vælge hvilke faktorer vi undersøgte.	Task, Different factors, Influence	Structure, Social Learning, Autonomy
29	det var lidt kedeligt at tælle bobler men det virkede godt med det der i starten hvor man skulle skrive noget om gær på den der online notepad ting.	Task, Social	Learning by doing, Structure
30	At sætte vores observationer ind i excel i en graf	Task	Learning by doing
31	Generelt sejt at se hvor mange bobler den udled	Living, Experience	Learning by doing
32	At vi også fik lov til at lave noget	Independence/Influence	Autonomy
33	Det var spændende at se, hvordan gær blev påvirket forskelligt, alt efter nogle forskellige faktorer	Different factors, Experience	Learning by doing, Social learning
34	At finde ud af hvilke påvirkninger, der er på respirationsprocessen, hvis man bare ændrer nogle få ting.	Solve, Different facors	Learning by doing
35	At finde ud af hvilke vækstfaktorer spiller en rolle i gærs vækst	Different factors, solve	Learning by doing
36	Det var spændende at kunne perspektivere det til virkeligheden.	Relate, Case	Case was engaging/not engaging
37	At man forstod det man lavede	Understanding	Guidance
38	Jeg synes det var interessant at udføre forsøget dog var det ikke ny viden for mig.	Experiment, Past	Experiment compared other activites, preconceptions and prior knowledge
39	Jeg synes hun var god til at forklare og lære fra sig. Det var nemt at forstå og opgavebeskrivelsen var sjov. Generelt bare en god time 10/10 :)	Teacher, Understanding, Case.	Guidance
40	Det var spændende at se hvordan et hverdagsprodukt, som gær, fungerer og historie delen var sjov	Everyday life, Case, Experience	Learning by doing, Case was engaging/not engaging
41	Ja, jeg syntes at Caroline var god til at forklare selve processen og hvordan vi skulle udføre forsøget	Teacher	Guidance
42	Synes det var spændende at lærer - et simpelt forsøg og simpelt koncept, men det var meget rart	Learning	Addtional information
43	Det var interessant at se hvordan væksten af boblerne ændrede sig	Living, Experience	Learning by doing
44	det var spændene formidlet	Teacher	Guidance

45	Ka ik sætte ord på det, hun gjorde det bare virkelig spændene og interessevækkende	Teacher	Teacher
46	selve forsøget	Experiment	Learning by doing
47	jeg fik ny viden	Learning, New	Preconceptions and prior knowledge
48	det var interessant at vi alle undersøgte forskellige vækstfaktorer, så der var mange forskellige resultater	Different factors	Social learning
49	At observere udviklingen	Experience	Learning by doing
50	Dygtig underviser og spændende emne. Det var fedt at det var en konkret fiktiv problemstilling!	Teacher, Relate	Teacher, Case was engaging/not engaging
51	At man fik lov til selv at bestemme hvad man ville undersøge. At der var forsøg som understøttede det vi havde lært	Influence, Experience.	Autonomy, Learning by doing
52	- At undersøge forsøgets udfald, og efterfølgende evaluering.	Experiment, Social?	Learning by doing, Social learning
53	Jeg synes at væskt var interresant fordi at det er spændende at lærer om hvordan mikroorganismer formere sig og det der har effekt for hvordan de udvider sig	Living	Learning by doing
54	jeg synes at det mest spændende var at lære om hvorfor en dej med gær i hævede da man normalt ikke tænker over sådanne hverdags-ting	Everyday Life	Preconceptions and prior knowledge
55	Du var rigtig god til at kort forklare hvad vi skulle, men så man forstod det, hvorefter vi selv måtte arbejde, så ikke det blev kedeligt - rigtig godt.	Teacher, Independence	Guidance, Autonomy
56	Jeg syntes altid det er interresant at lave forsøg, men at stå og tælle bobler i 20 minutter var lidt nederen, men det var jo bare en del af forsøget man ikke kunne undgå.	Task, Experiment.	Experiment compared to other activities, Learning by doing
57	Jeg kunne godt lide det, vi lavede og måden, vi lavede det på. Det var sjovt at lave et eksperiment, hvor vi selv måtte bestemme, hvad vi ville undersøge.	Influence, Task.	Learning by doing, Autonomy
58	Jeg kan godt lide at det var et anderledes forsøg som jeg ikke har lavet før. jeg kunne også godt lide at man selv havde meget kontrol over hvad man lavede mede forsøget, altså at man selv kunne vælge sin vækstfaktor.	New, Independence/Influence	Structure, Autonomy,
59	Jeg tror det var et interessant nok emne, men der var ikke rigtig tid til at lære nok om det - derfor var det mest bare en masse info vi ikke nåede at forstå fuldt ud	Understanding, Teacher	Guidance, Structure
60	måden vi lavede forsøget på	Task	Structure
61	Jeg syntes det var interessant at høre noget om hvordan det foregik og hvad der skulle til for at der ville være vækst.	Learning	Additional information, Learning by doing?

62	jeg er bare ikke sådan super vild med biologi, så det er blot derfor, mit svar er som det er.	Subject	Preconceptions and prior knowledge
63	Jeg synes at forsøget var interessant og selvom der ikke altid skete vanvittigt imens vi talte bobler så gav det en ret god forståelse af hvordan bakterier lever.	Experiment, Understanding	Learning by doing
64	synes det var intrasaandt man kunne konkludere noget ud fra de forskellige forsøg som grupperne hver især. så det var rart at man havde forskellige resultater og derfor kunne se foreskellene.	Different factors, social	Social learning
65	det var interessant selv at få gær til at vokse	Independence, Living	Learning by doing
66	Jeg synes det var interessant at se hvordan gær ændret sig efter hvad man ændret i forsøget	Living, Experience.	Learning by doing
67	Det at man skulle op og stå, og være i gang. Det giver både mere motivation til at lære, men giver også en mere forståelse for hvad man laver.	Experience, Active	Learning by doing
68	Jeg synes at det spændende selv at kunne vælge hvilken faktor man ville ændre.	Influence	Autonomy
69	Jeg synes at det var interessant, at vi sad og selv arbejdede med noget, i stedet for bare at sidde og lytte	Experience, Independence, Alternative	Experiment compared to other activities
70	Du var super fedt at lave nogle praktiske øvelser og det gav en bedre forståelse af celler og vækst.	Experiment	Experiment compared to other activities
71	at følge processen i eget forsøg, men også at se de andres resultater, og dermed kunne finde ud af hvilket faktorer der spillede en rolle på hvilken måde.	Social, Different Factors	Learning by doing, Social learning
72	Det var interessant at arbejde med et forsøg, og ligesom have et formål med hele modulet	Experiment, Structure, Purpose	Structure
73	at man selv kunne få lov til at lave forsøg og man selv fik lov til at bestemme hvad man ville undersøge	Independence, Influence	Autonomy
74	At vi fik lov til selv at eksperimentere	Independence, Experiment	Autonomy
75	Det var interrresant at få viden om hvordan de forskellige tilstande påvirkede gær	Different Factors	Social learning
76	Fedt at arbejde med et forsøg, hvor man på forhånd følte at man havde en forståelse af forsøget, og man efterfølgende kunne se de føromtalt processer.	Experience, Understanding	Learning by doing
77	At vi havde lov til at designe vores eget forsøg og kunne vælge hvad vi ville undersøge uden, det blev for uoverskueligt. Jeg forstod det også vældig godt.	Influence, Understanding	Autonomy
78	At hele modulet var bygget om omrking et forsøg. Og derfor gave det meget mening og interessant	Structure	Structure

79	Det var interessant at vi selv gik lov af afprøve det	Influence	Autonomy
80	At eksperimentere	Experiment	
81	Det var sjovt at der var en "case" så det var både leg men også læring	Case	Case was engaging/not engaging
82	Jeg synes at det var interessant at være i feltet og arbejde i stedet for bare at sidde og lytte. Jeg føler at man lærer mere, når man rent faktisk laver et eksperiment og får det visuelt forklaret.	Experiment, Alternative, Experience	Learning by doing
83	sjovt eksperiment god case	Case, Experiment	Additional information
84	Forsøget	Experiment	Learning by doing
85	at få lov til at designe et forsøg selv	Influence	Autonomy
86	Det var interessant selv at udføre eksperimenter med gærs vækst	Experiment, Indenpendence	Learning by doing
Q2	***Jeg blev engageret af at arbejde med en case***	**Coding 1**	**Coding 2**
87	Det var lidt Random at det ikke fandtes i virkeligheden, men meget sjovt!	Fun	Case was engaging/not engaging
88	Jeg tænkte ikke rigtig over det, havde nok været lige engageret hvis der ikke var en case	Indifference	Case was engaging/not engaging
89	Det kunne helt klart godt have været en større faktor, og blive gjort en større del af opgaven. Nu havde du jo selvfølgelig kun 1 modul	Alignment, Emphasis	Structure
90	Casen var ikke helt tydelig nok	Emphasis	Structure
91	casen var ik så tydelig	Emphasis	Structure
92	Dybden i casen manglede lidt	Emphasis	Case was engaging/not engaging
93	Glemte lidt alt om casen	Emphasis	Case was engaging/not engaging
94	Jeg synes det var sjovt nok at vi havde noget at lave	Purpose	Case was engaging/not engaging
95	Ja! det er fedt, at hun gjorde forsøget til et "problem"	Relate/Problem	Case was engaging/not engaging
96	Der var et formål til forsøget, så det var noget værd at lave det.	Purpose	Case was engaging/not engaging
97	Jeg ville foretrække hvis det ikke blev gjort til en leg men bare var videnskab	Science	Preconceptions and prior knowledge
98	Jeg glemte lidt casen i selve forsøget, men huskede på det igen da vi talte om det	Alignment	Structure

99	Jeg syntes ikke at sammenhængen mellem case og forsøg var særlig tydelig. Jeg forstod ikke helt sammenhængen. Men jeg kan godt lide tanken om at arbejde med en case- men måske kun hvis casen er mere realistisk og relevant.	Alignment, Relevance	Structure, Case was engaging/not engaging
100	En case virker som en overflødig tilføjelse, til et forsøg, hvor sammenspil mellem teori og forsøg bør spille en større rolle end en evt. case	Science	Preconceptions and prior knowledge
101	Det var sjovt nok fordi at man følte man havde et mål	Purpose	Case was engaging/not engaging
102	Jeg syntes ikke det var så nødvendigt at arbejde med en case.	Indifference	Case was engaging/not engaging
103	Det var sjovt, fordi det blev sat i en sammenhæng. Dog var det ikke, fordi jeg tænkte så meget over det, da vi lavede opgaven.	Alignment, Relate/context	Case was engaging/not engaging, Structure
104	Det at der kom et "real life scenario" gjorde så vi fik følelsen af at vi rent faktisk kunne bruge det vi lærte til noget.	Context, Purpose/Useful	Case was engaging/not engaging
105	Når vi lavede forsøget tænkte vi ikke så meget over casen, da den heller ikke havde så stor en betydning for selve forsøget men det gav mening i sammenhæng med det vi læste	Emphasis	Structure
106	jeg synes det er inspirerende at arbejde med en case i stedet for kun at lytte.	Alternative	Experiment compared to other activities
107	Jeg synes det var spænende at arbejde med en case istedet for at arbejde ting i bogen	Alternative	Experiment compared to other activities
108	Det var sjovt at lave noget anderledes, selvom casen ikke var virkelig gav det noget mere engagement til at lave øvelsen.	New	Case was engaging/not engaging
109	det gav os mere motivation, og vi blev mere interesserede i hvad der skete, og kunne begrunde hvorfor det skete.	Interest, Understanding	Case was engaging/not engaging

110	Det gav en ide om hvad man skulle tænker over undervejs	Support	Guidance
111	jeg tror ved at man satte en case om blev man mere omfattet og forstået omkring hvordan og hvad man ville undersøge	Support	Guidance
112	Man blev meget engageret fordi hele timen handlede om det og man blev sat godt ind i tingene	Support, Structure	Guidance
113	Det er meget sjovere og mere motiverende for at lære noget end hvis man skulle læse om det	Alternative	Experiment compared to other activities
114	Jeg følte at der var et mål man kunne gå efter og opklare.	Purpose, Solve	Case was engaging/not engaging
115	det var sjovt at have noget som man skulle løse og arbejde med	Solve	Learning by doing/ Case was engaging/not engaging
Q3	***Jeg fandt modulet sværere end anden biologiundervisning***	**Coding 1**	**Coding 2**
116	Jeg synes ikke det var så svært ift normalt biologi. Normalt biologi er tit meget tavleundervisning og svare på spørgsmål	Subject	Preconceptions and prior knowledge
117	Jeg synes det blev forklaret godt, og det var let at forstå. Jeg skulle dog lige helt forstå fremgangsmåden	Teacher, Method	Guidance
118	Der var meget man skulle kunne huske og ift. resultaterne så skulle man hele tiden tænke over hvad der var gået galt eller hvad der kunne være anderledes	Method	Learning by doing
119	Vi laver ikke mange forsøg, indtil videre, så når vi selv bliver sat til at lave et forsøg skal man lige forstå hvordan det skal forgå	Past	Preconceptions and prior knowledge
120	Det var lidt mere avanceret	Method?	Additional information

121	Det var sværere selv at skulle tage ansvar for hvad der skulle undersøges	Independence	Autonomy
122	Det er ikke noget man er vant til så det var både sjovt og svært	New, Fun	Preconception and prior knowledge
123	At det var selvstændig	Independence	Autonomy
124	Forklaringerne var bedre	Teacher	Guidance
125	Der var ikke så meget teori, at forstå. Det var ikke så komplekst igen, men meget sjovt	Understanding, Theory, Fun	Structure
126	Det var ikke specielt udfordrende, men meget sjovt	Fun	Addtional information
127	Det var simpelt nok til at jeg kunne forstå det, men samtidig stadig lærte noget nyt	Learning	Guidance
128	Synes forsøget var meget let til værks og let forståeligt, end måske nogle af vores andre biologitimer.	Understanding, Subject	Guidance
129	Det var et meget passende niveau til en 1g klasse	Understanding?	Additonal information
130	Det var simpelt at forstå så man kunne godt være med og det er godt	Understanding	Guidance
131	Har en god viden om emnet fra tidligere	Past	Preconception and prior knowledge
132	Jeg synes lige netop det omvendte. Hun havde gjort det nemt at forstå for en person, som normalt har svært ved biologi.	Teacher, Subject	Guidance, preconceptions and prior knowledge
133	Jeg syntes at gær og vækst er meget mere interessant end celler f.eks	Transfer, Subejct	Preconceptions and prior knowledge
134	Jeg synes ikke det var svært at forstå. Det var lettere end en normal time	Subject	Preconceptions and prior knowledge
135	synes ikke det var et svært forsøg, men mere noget hvor man skulle holde meget fokus	Method	Learning by doing
136	Jeg syntes det var meget nemmere fordi vi ikke skulle arbejde med så mange svære begreber. Jeg synes altid at undervisningen er nemmere at forstå hvis der også er forsøg	Subject, Experiment	Preconception and prior knowledge, Experiments compared to other activities

137	nu har vi ikke haft meget biologi undervisning endnu men jeg synes at det fungerede fint og var ikke for svært eller nemt	Past	Preconceptions and prior knowledge
138	Der var mange vange underemner man skal have styr på som "fotosyntese, respiration, celler osv." hvilket gjorde det sværere.	Method, Transfering	Preconceptions and prior knowledge
139	Jeg fandt modulet spænende, da det var et interessant forsøg.	Experiment	Learning by doing
140	Man kan jo sige at det var sværere på den måde at vi rent faktisk var fysiske og ikke bare sad og lyttede.	Method,Active, Alternative	Experiments compared to other activities
141	Det var mere forståeligt end de normale bio timer - sværhedsgraden var god/passende	Subejct	Preconceptions and prior knowledge
142	Jeg synes ikke det var specielt svært men snarere lærerigt.	Learning	Addtional information
143	Det var ikke svære det var mere spændende og det gav en bedre forståelse af hvad der faktisk skete og hvad der var med til at påvirke gæringen	Understanding, Excitement	Learning by doing
144	det var sværere på en anden måde end de andre moduler	Method? Subejct	Preconceptions and prior knowledge
145	jeg synes ikke det var sværere, fordi at vi fik lov til at arbejde selv med noget i hænderne. Det synes jeg giver mere potentiale til at udvise sine egne evner, og finde svar, stedet for at skulle sidde stille og lytte i lang tid. Det gjorde det lettere at forstå fordi vi fik lov at bruge vores viden i praksis	Independence, Active, Alternative, Experience	Experiments compared to other activities, Learning by doing
146	det var meget som de andre timer, men man lærte meget på kun en time	Learning	Additional information
147	Jeg syndes det var let at forstå, og godt forklaret	Teacher	Guidance
148	jeg synes at modulet lænede sig meget op af de andre biologi moduler. Det var måske en	Transfering, Experiment	Preconceptions and prior knowledge, experiments

	smule nærmere da de meste af modulet gik ud på at kigge på forsøget og tælle bobler.		compared to other activities
149	Jeg følte ikke at det var voldsomt svært at lave det, men man fik stadig lært en hel masse.	Learning	Additional information
Q4	***Jeg har en bedre forståelse af gærs vækst efter modulet***	**Coding 1**	**Coding 2**
150	Er stadig lidt i tvivl om hvorfor	Understanding	Guidance
151	vores forsøg gik lidt i vasken	Method	Guidance/preconceptions and prior knowledge
152	Der var ikke særlig meget teori	Theory	Structure, preconceptions and prior knowledge
153	Vidste ikke at de kunne overleve uden ilt og det var det der gjorde at der blev skabt alkohol.	Learning	Learning by doing
154	Jeg har lært, at en lav pH-værdi har en negativ påvirkning på gærs respiration	Learning	Learning by doing
155	Altså jeg vidste allerede lidt, men jeg har stadig lært noget nyt	Learning	Preconceptions and prior knowledge
156	Jeg lærte meget	Learning	Additional information
157	Jeg har helt klart fået en bredere forståelse end før.	Learning	Additional information
158	Jeg har lært at syre mindsker vækst	Learning	Additional information
159	Jeg har fået en langt bedre forståelse med de forskellige faktorer er påvirker gær	Different factors	Learning by doing
160	Vil sige at det var godt forklaret og nemt at forstå, jeg har dog ikke fået en bedre forståelse da jeg vidste alt i forvejen	Teacher, Understanding, Past	Preconceptions and prior knowledge
161	Mange af tingene havde jeg haft om før, men det var også derfor det var interessant at man selv kunne vælge vækstfaktor	Past, Influence/Independence	Preconceptions and prior knowledge, Autonomy
162	jeg har lært ret meget om gærs vækst	Learning	Additional information
163	Jeg vidste ikke rigtigt noget om gær andet end det skal hæve når man bager med det, så nu ved jeg meget mere.	Learning	Preconceptions and prior knowledge

164	Jeg kendte ikke rigtig noget til gærs vækst før modulet, så jeg mener helt klart at jeg lærte noget.	Learning	Preconceptions and prior knowledge
165	Jeg vidste ikke rigtig noget om det før men det gør jeg nu. Det gav et godt visuelt eksempel på det for mig	Learning, Experience	Preconceptions and prior knowledge, Learning by doing
166	Det gav en bedre forståelse	Understanding	Additional information
167	jeg synes jeg lærte en masse	Learning	Additional information
168	Jeg ved hvordan man kan ændre på gærets vækst ved fx. tilsætte mere glukose	Learning	Additional information
169	meget lærerigt	Learning	Additional information
170	Helt klart! Det var godt forklaret og øvelsen gav mening.	Teacher, Method	Guidance
171	jeg forstå nu hvad der sker, og hvorfor, samt hvilke faktorer der spiller en rolle.	Understanding, Different Factors	Additional information
172	ja jeg har helt klart en bedre forståelse af gærs vækst, da vi arbejde med stoffet på mange forskellige måder	Understanding, Method	Structure
173	jeg forstod det bedre efter forsøget	Understanding, Method	Learning by doing
174	Jeg har lært meget om, hvilke faktorer, der spiller ind i gærs vækst.	Different Factors	Additional information
175	Jeg endte med at forstå det godt	Learning	Additional information
176	Havde ikke noget ide om gærs vækst og har fået en lang større forståelse for det nu	Learning	Preconceptions and prior knowledge
Q5	***Jeg kunne godt lide at vælge en vækstfaktor at undersøge***	**Coding 1**	**Coding 2**
177	Det var sjovt selv at vælge hvad der interesserede en	Influence, Fun	Autonomy
178	Det var fedt selv at kunne vælge, hvad man ville kigge på, men der blev kun kigget på temperatur, hvilket var lidt nederen	Influence,Different Factors	Autonomy
179	Jeg synes det var meget bedre selv at vølge en faktor, så man kunne vælge den man synes var den fedeste måde at undersøge på	Influence	Autonomy

180	kunne også være fedt, hvis man havde fået tildelt en faktor, så det bliver mere fordelt.	Different Factors	Social learning
181	Det var fedt at kunne bestemme noget selv, som man ville undersøge	Influence	Autonomy
182	Man kan selv styre ens forsøg	Independence	Autonomy
183	Det ville have været meget interessant hvis man kunne have lavet mere end et forsøg og man kunne have mere end et kørende, altså hvor man ændrede på nogle variable	Method	Suggestion
184	Det var lidt svært at finde ud af hvad man skulle vælge, men jeg synes stadig at det gik godt	Influence	Autonomy
185	Ja - fedt man selv kunne bestemme	Influence	Autonomy
186	Synes det gjorde forsøget lidt mere personligt, og at man også selv havde en indvirkning på det.	Influence= internalization	Autonomy
187	det giver en følelse af indflydelse på forsøget	Influence	Autonomy
188	Det var fedt at kigge på hvordan de forskellige faktorer påvirkede den samme type gær. Også det at kunne bestemme mængder selv og lege med det og derefter sammenligne det fælles.	Different Factors, Influence, Social	Learning by doing, Social learning, Autonomy
189	Det gør det mere spænende at ændre på forsøget og så få bekræftet nogle hypoteser, synes jeg.	Method, Excitement	Preconceptions and prior knowledge
190	Jeg kan godt lide når andre i klassen får nogle helt andre resultater end en selv, og dernæst sammenligne dem, fordi der plejer at være nogen der får nogen skøre resultater	Social, Different Factors	Social learning
191	Det gjorde det ret meget sjovere, at man selv kunne påvirke forsøget.	Influence, Fun	Autonomy
192	Frihed en undersøgelse skaber større engagement	Indenpendence, Engagement	Autonomy
193	jeg synes det var sjovt at man kunne have sit eget fokus også sammenligne med andre bagefter	Social, Fun	Social learning

194	det var fint selv at kunne vælge, men ikke noget der gjorde den helt store betydning.	Indifference	Autonomy
195	Det var da spændende at finde ud af hvilken vækstfaktor der havde størst indflydelse på gærens vækst.	Solve, Excitement	Learning by doing
196	Det var sjovt, fordi man kunne vælge en vækstfaktor, hvor man ikke selv umiddelbart kunne regne ud, hvad der ville ske.	Fun, Influence, Curiosity?	Autonomy
197	det er ikke så tit at man selv vælger noget inde for forsøg så det synes jeg var mega fedt	New, Influence	Autonomy
198	Kan godt lide at fokusere på en ting	Method, Focus	Structure
199	jeg kunne godt lide at vi havde et valg af hvad vi gerne ville undersøge	Influence	Autonomy
200	Det var fint at vi kun skulle fokusere på en fordi det gjorde det lettere end at skulle have styr på en hel masse. Det var også fedt at vi så bagefter gik igennem de andres forsøg fordi så fik jeg også en forståelse af hvad deres faktorer gjorde	Method, Focus, Social	Structure, Social learning
201	Jeg tænkte ikke så meget over vores vækstfaktor det var bedst at man kunne sammenligne sign sin data med de andre grupper	Social	Social learning
204	Jeg synes det var spænende at man selv kunne vælge hvilken vækstfaktor man måtte undersøge	Influence, Excitement	Autonomy
205	Så føler man at man selv har et valg	Influence	Autonomy
206	Det var super nice selv at have indflydelse	Influence	Autonomy
207	Det var med til at føle, at vi var en større del af undervisningen	Influence	Autonomy
208	Det var sjovt selv at kunne bestemme eksperimentet, det var bare ærgeligt at vi ikke kunne nå at lave et mod eksperiment såsom høj vs. lav ph-værdi eller høj vs. lav temperatur.	Influence, Method, Understanding/Transfer	Autonomy, Suggestion

209	det var fedt fordi så havde man mere tid til at fordybe sig i et specifikt område.	Focus, Method	Guidance
210	ja ved at man selv fik lov til at bestemme noget i forsøget blev men også mere engageret i det	Influence, engagement	Autonomy
211	Fedt at fokusere på en enkelt variabel.	Focus, Method	Guidance
212	Men synes også der skal være et normalt forsøg med alle tingene så der var noget at sammenligne med	Method, Transfer, Relate	Preconceptions and prior knowledge
213	Det var sjovt selv at få lov at undersøge de forskellige vækstfaktorer	Indenpendence, Different Factors	Autonomy
Q6	***Jeg kunne godt lide at lære teorien bag eksperimentet efter at have udført eksperimentet selv***	**Coding 1**	**Coding 2**
214	Det er altid fedt at have en baggrunds viden omkring hvorfor ting reagere som det gør	Understanding	Additional information
215	Kan bedst lide at få teorien før man udfører forsøget	Structure	Structure
216	Godt med opsamling i klassen for at sammenligne resultater	Social	Social learning
217	Der blev gået lidt hurtigt over teorien	Teacher, Time	Guidance
218	føler det blev løbet ret hurtigt igennem, da vi nok ikke havde nok tid	Teacher, Time	Guidance
219	Teori er aldrig sjovt	Science, Theory	Preconceptions and prior knowledge
220	Altså ja, for det gør jo at de man lide har lært giver (mere) mening	Understanding	Preconceptions and prior knowledge
221	Selvom det ikke er det mest spændende, så synes jeg det var meget interessant.	Science, Theory	Additional information
222	Vidste det i forvejen	Past	Preconceptions and prior knowledge
223	Det er rart at vide hvorfor der sker de processer som der gør	Understanding	Guidance

224	Kan bedre lige at kende teorien og vide det hele først	Structure, Theory	Structure
225	Jeg ville hellere kende baggrunden for eksperimentet først	Structure, Theory	Structure
226	jeg synes at det giver mening at få teorien bag et forsøg at vide	Theory	Structure
227	Du forklarede godt før forsøget fremgangsmåden, og efter forsøget viste du blandt andet bakterievækstkurven, hvilken var rigitg godt.	Teacher, Structure	Structure, Guidance
228	Det var rart at kunne fokusere på eksperimentet fremfor teorien bag. Eksperimentet gav også ekstra god mening, efter man havde gået teorien.	Structure, Theory, Focus, Understanding	Structure, Guidance
229	Jeg ville fortrække at lære om teorien først også udføre forsøget efter	Structure, Theory	Structure
230	ja det gav derfor bedre mening med det samme	Structure, Understanding	Guidance
231	det er en del af at udføre eksperimentet. så jeg synes det er vigtigt	Science	Preconceptions and prior knowledge
232	Jeg kunne godt lide eksperimentet især efter når man fik en forståelse for eksperimentet	Structure, Understanding	Guidance
233	Nogen gange. Men andre gange er det også vigtigt at kunne forstå teorien bag det, så man kan forstå hvorfor man lige præcis laver noget i et forsøg.	Structure, Understanding	Guidance
234	Ellers havde det været ligegyldigt	Science	Preconceptions and prior knowledge
235	Det gjorde i hvert fald, at hvis man havde spørgsmål, at man så fik dem besvaret	Strcuture, Understanding	Guidance
236	Det gav mening måden den blev forklaret på og tidspunktet.	Teacher, Structure, Understanding	Guidance
237	jeg synes det hele bliver meget mere fangende når man får lov til at bruge sin viden til noget	Engagement, Application	Structure

238	Det var sjovere at vide hvorfor gæret gjorde som det gjorde	Fun, Understanding	Learning by doing
239	ja så man fik en forståelse af hvorfor vi fik de resultater som vi fik	Understanding	Guidance
240	Man vil jo godt forstå hvorfor man har lavet det forsøg som at man har.	Understanding	Guidance
241	Det var rart af få svar på de spørgsmål man havde efter man havde udført eksperimentet	Understanding	Guidance
241	Det var fedt at få teorien efter man havde udført eksperimentet	Structure	Structure
242	Det var bedre når vi gennemgik det på tavlen, istedet for at læse	Alternative	Experiment compared to other activities
243	det var en god måde at forstå det på	Structure, Understanding	Guidance
Q7	***Jeg forstod instruktionerne***	**Coding 1**	**Coding 2**
	Hvad var svært at forstå?		
244	Hun forklarede meget grundigt, hvad vi skulle lave	Teacher	Guidance
245	At man selv kunne vælge	Independence	Autonomy
246	vi blev nødt til at lave forsøget tre gange, Fordi vi ikke læste opgaveformuleringen	Support, Method	Guidance
247	Der var nogle ting, der godt kunne understreges mere. Fx hvornår syren skal i kolben	Support, Method	Guidance
248	Det gik lidt galt et tidspunkt, men tror mere det var pga vores mængde af vores vækstfaktor.	Method	Additional information
249	Hvor lang tid vi skulle bruge	Support, Method	Guidance
250	Det var nemt at forstå. Det hjalp meget at instruktionerne stod skrevet ned, så man kunne læse det igen hvis man havde glemt noget, eller glemt at høre efter	Support, Method	Guidance
251	instruktionerne var nemme at forstå og gå igang med	Method	Guidance

251	Igen, du var rigtig god til at forklare.	Teacher	Guidance
252	det blev forklaret godt	Teacher	Guidance
253	Det eneste var hvor meget sukker man skulle putte i og man selv måtte bestemme	Influence, Practical, Support	Guidance, Autonomy
254	Det var svært at forstå noget af terorien. Jeg har ikke lige noget specifikt. Men for det meste forstod man det.	Understanding, Theory	Guidance
255	Det var let forståeligt og meget velskrevet.	Teacher	Guidance
256	misforstod nogle instrukser ved forsøget	Method, Understanding	Guidance
Q8	***Jeg kan bruge min viden om gærs vækst i anden biologiundervisning***	**Coding 1**	**Coding 2**
257	Det ved jeg ikke endnu?	Uncertain	Application of knowledge
258	ved ikke, måske	Uncertain	Application of knowledge
259	Man kan vælge at perspektivere det til hvilke forhold bakterier trives i, og måske med en smule mere teori om gærceller, med hvordan den er i forhold til andre bakterier.	Application	Application of knowledge
260	Måske kan der drages paralleller	Uncertain	Application of knowledge
261	Altså det tror jeg da	Uncertain	Application of knowledge
264	det ved man aldrig måske får jeg brug for det en dag	Uncertain	Application of knowledge
265	Det er en super god baggrundsviden	Application	Application of knowledge
266	Dog ville det være rart med mere teori om f.eks. hvordan cellerne vokser eller hvad det nu end er der sker	Application, Theory	Application of knowledge
267	Det kommer nok an på hvad vi har om i det andet biologiundervisning	Uncertain	Preconceptions and prior knowledge

268	Ved jeg ikke endnu.	Uncertain	Application of knowledge
269	Jeg forstod ikke emnet nok til at kunne bruge det i en anden sammenhæng	Understanding, Application	Application of knowledge
270	Det gav helt klart en bedre forståelse af selve processen	Understanding	Application of knowledge
271	Ja, det gav en bedre forståelse af celler og vækst.	Application, Understanding	Application of knowledge
272	jeg synes emnet var meget vigtigt og centralt, så ja	Application, Relevance	Application of knowledge
273	ja det var en god introduktion til det	Application	Application of knowledge
274	Det forklare mange ting som man enligt ikke tænker over har noget med gær at gøre	Everyday Life, Understanding	Preconception and prior knowledge
275	Ift. andre mikroorganismer.	Application	Application of knowledge
276	Det kan sammenlignes med bakteriers vækst	Application	Application of knowledge
277	Vi lærte meget om hvad påvirkede gær osv. hvilket gjorde det nemmere i andre biologitimer	Different Factors, Connection	Application of knowledge
Q9	***Jeg kan bruge min viden om gærs vækst udenfor gymnasiet***	**Coding 1**	**Coding 2**
278	Ved bagning	Everyday Life	Application of knowledge
279	Ved ikke hvad jeg skal bruge det til	Uncertain	Application of knowledge
280	hvis man skal bage brød	Everyday Life	Application of knowledge
281	Elsker at bage derhjemme, behøver jeg sige mere	Everyday Life	Application of knowledge
282	Muligvis	Uncertain	Application of knowledge

283	Ved ikke lige hvad jeg kan bruge det til, måske når jeg bager:))	Everyday Life, Uncertain	Application of knowledge
284	Måske, ved dog ikke hvad jeg skulle bruge det til	Uncertain	Application of knowledge
285	Det tror jeg ikke helt, jeg kommer til, men stadig nyttig information.	Useless	Application of knowledge
286	hvis jeg bager	Everyday Life	Application of knowledge
287	Hvis man vil have et job enten inden for naturfag eller måske madlavning så ja	Everyday Life, Subejct	Application of knowledge
288	Ved ikke rigtig hvad man kan bruge det til andre end at bage brød men det jo også godt	Everyday Life, Uncertain	Application of knowledge
289	Det kan jeg jo helt sikkert godt, men jeg kan ikke lige komme i tanke om nogle tilfælde andet end når jeg bager.	Everyday Life	Application of knowledge
290	når man skal brygge øl er det vigtigt at vide processerne bag	Everyday Life	Application of knowledge
291	Sikkert ikke.	Useless	Application of knowledge
292	Bage	Everyday Life	Application of knowledge
293	Måske	Uncertain	Application of knowledge
294	det kan man vel når man laver mad	Everyday Life	Application of knowledge
295	Det kan jeg ikke forestille mig	Useless	Application of knowledge
296	Jeg kan bruge det hvis jeg skal lave brød eller kage	Everyday Life	Application of knowledge
297	vil tiden vise	Uncertain	Application of knowledge
298	til at lave brød	Everyday Life	Application of knowledge

299	Jeg ved ikke helt hvad jeg skal brugen den til ud over at vide jeg skal putte mad på køl.	Everyday Life, Uncertain	Application of knowledge
300	helt klart, ift. husholdning og bedre forståelse af processer generelt	Everyday Life	Application of knowledge
301	Når man bager	Everyday Life	Application of knowledge
302	Det ved jeg ikke endnu.	Uncertain	Application of knowledge
303	Hvis man laver ølbrygning derhjemme eller andet lignende	Everyday Life	Application of knowledge
Q10	***Jeg kunne godt tænke mig at arbejde på samme måde med andre emner i biologi***	**Coding 1**	**Coding 2**
304	Fedt med eksperiment og teori samtidig	Structure, Experiment, Theory	Structure
305	det var ok sjovt	Fun	Additional information
306	jeg kan godt lide at lave eksperimenter	Experiment	Experiments compared to other activities
307	Ja, jeg kunne godt lide at lære noget, så lave noget og så forstå det	Structure, Method	Structure
308	Ja det motiverer en lidt mere, da der er noget man kan forholde sig til	Relate	Learning by doing
309	Synes det var spændende at lave noget i stedet for at læse.	Alternative, Active	Experiments compared to other activities
310	det var et sjovt og spændende	Fun	Additonal information
311	Det fungerer fint med at have lidt kontrol over forsøger selv, så man ikke skal stresse og fumle med at alt skal være lige efter forsøgsvejledningen	Influence	Autonomy
312	Ja fordi det er simpelt at forstå og man husker det	Understanding	Guidance
313	flere forsøg	Experiment	Experiments compared to other activities

314	Kan bedre lide at lære noget igennem forsøg end bare at sidde og lytte. jeg synes det gav en meget bedre forståelse for emnet	Alternative, Active	Experiments compared to other activities
315	Det interesserer mig ikke så meget i forhold til mat eller samf	Subject	Preconceptions and prior knowledge
316	Det kunne være fint en gang i mellem, men ikke alle moduler	Method, structure?	Additional information
317	ja det var en god måde at arbejde på	Method	Additional information
318	Det var en sjov måde at arbejde med det på	Method, Fun	Additional information

Appendix 4

Transcriptions of interviews

1. Interview 29/11/20

Var det en positive oplevelse

R1: Meget information til at starte med, som måske var unødvendig.

Var casen unødvendig?

R1: Ville høre info bagefter. Fakta om reaktionen ville have mest spændende bagefter. Gennemgang af forudsætningsfasen kunne være bedre bagefter.

Hvordan synes du det var, at få vækstkurven præsenteret til sidst?

R1 Det passede fint, så kunne man også se, hvad de andre havde fået af forskellige vækstkurver.

Synes du, det var fint at putte sin egen kurve på vækstkurven fra bogen?

R1: Ja så man selv kunne se, hvad man havde fået ud af det og i hvilken del af vækstkurven ens egen kurve hørte til. Det passede rigtigt godt med, at du viste den bagefter.

Hvordan fungerede det for dig at have et valg ift. at kunne vælge det, du ville undersøge?

R1: Det var interessant, det har vi ikke prøvet før. Jeg har i hvert fald ikke prøvet før at kunne vælge, hvad jeg ville undersøge indenfor et forsøg, så det var meget interessant og anderledes ift. hvad der plejer at ske indenfor forsøg. Så det var ret godt.

Gjorde det, at du havde mere lyst til at lave forsøget, eller var det mere forvirrende?

R1: Selve emnet havde vi nok ikke i lang nok tid til at kunne forstå opgaven og tingene, i mit tilfælde. Det havde været bedre at have lært lidt mere om emnet først, så man forstod, hvad det var, man gerne ville undersøge lidt mere.

Så du følte, at det var lidt som om at prøve noget af, som du ikke vidste, om ville virke?

R1: Ja

Var det svært at formulere en hypotese så?

R1: Ja, det var lidt.. med brug af begreber, fordi vi nåede ikke at lære så mange begreber i det emne, så i det hele taget havde det været bedre, hvis vi havde nået at lære en lille smule mere også lave forsøget, men det kan jeg godt forstå, hvis der ikke var tid til, når du var her.

R2 kommer ind i interviewet.

Var modulet en positiv oplevelse for dig?

R2: Jeg synes, det var sjovt og et lidt anderledes forsøg. Det var meget hyggeligt at alle i gruppen havde en opgave. Jeg føler tit i naturfag, at det er dem, der kan finde ud af det, der tager teten og de andre sidder og ikke har fattet noget af det.

Var det det at alle fik en opgave eller videoen?

R2: Det var at alle fik en opgave, så alle følte sig som en del af gruppen.

Hvordan foregik opgaveuddelingen i jeres gruppe?

R2: Det var så fint. Vil du tage det jaja. Det var hurtigt fordelt.

Hvordan synes du, det var, at jeg præsenterede vækstkurven efter forsøget?

R2: Det var sådan okay. Fordi så havde man prøvet det selv først. Det tror jeg gav en bedre forståelse af det efter. Hvis vi havde set den før, havde vi nok været sådan, at vi ikke ville forstå det. Eller det måske ikke rigtig gav mening, men at man havde prøvet det først selv, så tror jeg, det i hvert fald gav bedre mening i min gruppe.

En af grundene til at jeg ikke præsenterede figuren først, var også så i ikke tænkte, at jeres vækstkurve var forkert, hvis nu det ikke lignede, hvilket den jo ikke ville, da i lavede om på den.

Hvordan var det i jeres gruppe at formulere en hypotese?

R2: Ja, det tror jeg ikke rigtigt, vi fik gjort. Jeg synes i hvert fald det er svært at lave en hypotese og det ikke er noget, vi har gjort så meget. Så jeg tror bare, vi gik i igen og glemt at gøre det, der vi nærmest var færdige. Også fik vi det ikke rigtigt gjort.

Har i et råd til, hvordan jeg kan gøre det lidt nemmere at lave en hypotese?

R2: Måske kunne du vise nogle eksempler på en hypotese alt efter, hvad man ændrede på i forsøget. Ikke så de skulle bruge den du viste, men så give et eksempel på at en hypotese, kan være det her.

R1: Måske være tydelig om, at starte med at lave en hypotese også gå i gang med forsøget. Vi havde i hvert fald fuldstændig glemt en hypotese.

R2: Man kunne også inden vi gik i gang med at tage alle materialerne frem, så kunne du sige ”nu skal i finde en hypotese” også kunne du skrive alle gruppernes hypotese op på tavlen. Så alle kunne se, hvad vi som klasse samlet undersøger.

Det var rigtig gode forslag. Jeg spurgte en klasse, der alle sammen havde valgt det samme, hvorfor de havde valgt at undersøge det samme. De svarede, at de havde valgt at det samme, fordi de andre gjorde det.

R2: Ja det sker også nogle gange.

R1: Det kan godt være lidt svært at formulere en hypotese. Så måske også starte med at de vælger et emne også hjælpe dem på vej med, hvad hypotesen kunne se ud. Det er ikke så meget vi har haft om hypoteser. Jeg har i hvert fald ikke haft så meget om dem.

R2: Det har jeg heller ikke.

Jeg synes også, det er rigtigt svært at formulere en hypotese. Så det er måske godt at tage det med. Ville det have hjulpet, hvis jeg havde kaldt det for et spørgsmål i stedet for, så man ikke tænkte åh nej?

R2: Ja, det kunne det måske godt. Jeg tror, de fleste ved, at det er et arbejdsspørgsmål eller sådan hvad er det, vi vil finde. Eller sådan hvad er det, vi regner med, at der kommer til at ske på grund af bla bla. Det tror jeg godt, de fleste ved.

R1: Det er mere selve formuleringen af det.

R2: Ja, det er svært.

R1: Og hvordan man får det, man gerne vil have ud af en hypotese.

Hvordan fungerede videoen for jer, som en slags noteredskab?

R1: Vi har ikke brugt den efterfølgende. Det er kun den person i gruppen, som lavede den, som måske stadig har den.

Okay så i har ikke delt den mellem hinanden?

R1: Nej, men vi var nødt til at tænke over, hvad der skulle filmes. Det var også meget hyggeligt, at der var en, som gik rundt og filmede nogle gange.

R2: Ja, men du sagde, at vi ikke skulle filme hinanden. Altså ansigterne og sådan noget. Det synes jeg måske var lidt øv. Det havde været sjovere, hvis vi havde kunne filme imens vi lavede det, også dem der sad og gjorde eller talte, kunne sige "nu er vi i gang med at gøre det her" imens, så vi ikke skulle tale tingene indover bagefter måske.

R1: Jeg kan godt se logikken i det.

Hvordan synes I, det fungerede med de spørgsmål, der var til videoen?

R2: Jeg synes, det var svært at svare på dem. At skulle svare på dem undervejs.

R1: Var det de der spørgsmål på tavlen?

Ja de spørgsmål, der var meningen, skulle med i videoen, så mens man lavede videoen, skulle man prøve at svare på de spørgsmål, så godt man kunne. Som handlede om, hvad ens hypotese var og hvordan man undersøgte den.

R1: Okay. Vi fik ikke. Vi troede, man skulle svare på dem bagefter.

Det er også helt fint. Det er der også nogle, der har gjort. Det skal bare være som man har lyst. R2 du sagde, det var svært at svare på dem?

R2: Ja, vi ville gerne svare på dem undervejs, men når vi ikke måtte filme hinanden svare på det, så var det lidt svært at skulle sidde bagefter og indtale dem, fordi der var heller ikke så meget tid efter, vi havde lavet forsøget. Det var lidt nemmere at svare på det undervejs, end at skulle svare senere på dagen end dagen efter, fordi der sad man ikke med det i hænderne.

Okay, så jeg skal måske gøre opmærksom på, at man skal svare på spørgsmålene, mens man filmer ligesom med data.

Sidste spørgsmål til R2: Hvordan synes du det var at vælge sin egen vækstfaktor at undersøge?

Det var meget godt, fordi så fik vi sådan lidt selv noget at skulle have sagt i forsøget. Du havde ikke sagt præcis, det man skulle gøre. Man skulle selv lige reflektere over, hvad man gerne ville lave om på og de ting, der ville være spændende at lave om i.

R1: Vi fik tænkt mere over det.

R2: Ja.

Gjorde det dig mere nysgerrig eller mere forvirret?

R2: Nej det gjorde mig ikke mere forvirret. Jeg følte, jeg havde noget at skulle have sagt i forsøget. Og det synes jeg var fedt, at læreren ikke altid laver en præcis step by step guide - gør sådan her og sådan her. Så skal man ikke selv tænke over det. Men det med, at man selv skal sidde og snakke med hinanden om "kunne man gøre sådan her?" eller "hvad med sådan her". Det synes jeg gav virkelig god mening, at man fik snakket om, hvad man tænkte ville ske ved de forskellige ting og sådan noget.

Fedt det var også det, der var meningen!

R2: Det virkede!

Sidste spørgsmål til jer. Nu skal jeg ud og lave det her modul med nogen i morgen og på onsdag. Har i nogle ideer til, hvordan det kunne blive lidt bedre?

R1: Måske være lidt mere tydelig med, hvordan forsøget laves og stilles op. Der var den der tegning, du havde sat op på tavlen, men det vi var i hvert fald en smule i tvivl om, hvad de forskellige var. Altså hvornår det var det ene eller det andet skulle puttes i.

R2: Ja det var vi også.

R1: Der var lidt forvirring, der vi så var begyndt på forsøget. Fordi der var mange grupper, der skulle spørge om noget hele tiden.

Okay, så der skal være nogle mere tydelige instruktioner, sådan praktiske?

R2: Ja. Også fordi (lærerens navn) ikke ville hjælpe, hun bare sad nede i hjørnet. Vi ville også gerne spørge dig, men der var også virkelig mange, der ville spørge dig om noget. Så måske de der praktiske informationer skal være meget klare og tydelige, så der ikke er nogen, der er i tvivl. Det var det, mange havde spørgsmål om.

R1: Vi havde det i hvert fald i folkeskolen stillet op i punkter. Nu tager i det her også putter i det her ned i det der. Jeg ved ikke, om det er for børnevenligt.

Nej nej sådan er det med alle hele vejen op. Også med voksne nogle gange. Man skal nogle gange skære det ud i pap. Der sker også meget på en gang på det tidspunkt i modulet. Alle sammen er oppe.

R1: Også er det tydeligt, hvornår man selv kan komme med noget kreativt. Altså hvornår man kan rykke rundt på temperatur eller hvornår man selv vælger, hvad der skal puttes i det der. Det var måske heller ikke helt tydeligt. Altså hvad det var, der skulle puttes i og hvad man selv kan putte i.

Men det lyder rigtigt godt. Det vil jeg tage med videre. Har i noget at tilføje til sidst? Ellers vil jeg bare sige rigtig meget tak for jeres input. Det har virkelig været brugbare.

R2: Det var da så lidt.

R1: Det er godt.

R1: Det lyder som om, vi kommer med ret meget, men det var altså meget hyggeligt modul. Mere hyggeligt end mange af de andre.

R2: Ja (lærerens navn) moduler er lidt kedelige.

R1: Ja det kan godt være lidt tungt.

R2: Du gjorde det meget godt, vil jeg sige, også i forhold til, at du ikke er uddannet dig som lærer. Så du gjorde det godt.

Tak skal i have. Det er jeg glad for. Det var første gang med jer.

R2: Jeg synes, du gjorde det godt. Også fordi det kan være ret grænseoverskridende at stå overfor en masse unge mennesker, der skal lytte på, hvad det er, man har at sige. Hvordan får jeg dem lige til at synes, at det jeg siger, er interessant. Men jeg synes, du gjorde det.

Nåh men det er jeg glad. Det er jeg virkelig glad for. Det var det, der var hele meningen. Jeg synes også, at i gjorde det godt. Jeg synes, i var rigtigt søde at tage imod og ikke bare tænke "wuhu" vikar også lave helt anarki.

R2: Så var (lærerens navn) nok blevet lidt sur.

Jeg skal faktisk ringe nogen andre op nu, men jeg håber, i får en rigtig dejlig weekend.

R2 og R1: I lige måde.

Og tak for hjælpen.

R1 og R2: Det var så lidt.

2. Interview 29/11/20

Hvordan oplevede I at have modulet? Var det en positiv oplevelse eller? Hvad var jeres indtryk af det?

R3: Det var da meget positivt.

R4: Det var fedt i hvert fald at teste, det vi lærer i virkeligheden.

R3: Lige præcis.

R3: Det er altid sjovt at lave eksperimenter, synes jeg. Så man ikke bare læser bøger eller gennemgår teori.

R4: Jeg er enig.

Hvordan synes i det var at arbejde med en case her i modulet - den her Strain 323?

R3: Øhm.

R4: Strain 323? Hvad var det nu, det var.

R3: Det var en gærcelle ik?

Jo jeg havde ligesom fundet på, at en fiktiv gærtype, der voksede helt vildt.

R3: Ja…

Gav det mening, når man lavede modulet, at det var det i lavede eller glemte i det lidt, mens I var i gang med jeres forsøg?

R4: Jeg tror mere, at vi fokuserede på resultaterne og på selve eksperimentet. Jeg havde nok lidt glemt… eller personligt.. jeg ved ikke med dig R3.. Jeg havde glemt det med Strain 3223. Da man sad og talte boblerne og sad og skrev data ind.

R3: Ja, man tænkte heller ikke, så meget på, at det var en case. Jeg lavede bare forsøget og jeg glemte lidt at det var strain 323. Jeg vidste ikke helt, hvad det var.

Blev det sjovere af det?

R3: Jeg synes ikke rigtigt, at det blev sjovere.

Hvordan synes I det var selv at vælge, hvad I ville undersøge?

R4: Det gør det lidt mere frit, umiddelbart. Det var rimelig fedt, synes jeg.

R3: Der var en masse forskellige resultater, så det kan man jo sammenligne. Selvom alle valgte at undersøge det samme. Eller så er det lidt noget andet end det, man plejer.

Hvordan var det i jeres grupper, at I skulle finde ud af, hvad I ville undersøge og formulere et spørgsmål eller en hypotese?

R4: Vi sad og diskuterede det sammen. Jeg synes, det gik rigtigt godt umiddelbart. Vi forventede, at jo flere isterninger, vil ville komme i, jo færre bobler vil der umiddelbart være.

R3: Det ligger også meget op til det, vi lige har lavet i NV. Så har vi også hovedsageligt formuleret hypoteser og prøvet dem. Det er ikke noget nyt som sådan at formulere en hypotese og lave eksperimentet.

Okay så det var fint nok. Hvordan kunne det være I lige valgte is, hvis det var det, I begge to lavede?

R4: Min gruppe tænkte ”nu laver vi det med is” og da tænkte jeg ”det gør vi da” også endte det med at blive meget sjovt.

R3: Oplagt.

R4: Ja oplagt. Der var også mange andre, der gjorde det også, så vidt jeg ved.

Valgte I efter noget, hvor I vidste, hvad der ville ske, eller valgte I noget, hvor I tænkte, jeg ved faktisk ikke, hvad der vil ske?

R3: Det var nok rimelig sikkert. Mig og min gruppe var nok rimelig sikre. Hvilket man også kunne se på hypotesen,

Hvorfor valgte I at lave noget, hvor i godt vidste, hvad der ville ske med?

R3: Vi var trætte og det var 4. modul. Eller nej det ved jeg ikke helt men ja...

R4: Jeg tror hovedsageligt, at i vores gruppe, vi ikke vidste, hvad der skete. Vi var lidt nysgerrige umiddelbart. Og så tænkte vi, at det var sjovt med is. Så det er oplagt.

R3: Enig

R4 forlader interviewet.

Er temperatur noget mange godt ved, hvordan de skal ændre på? Hvor fx bagepulver eller ph værdien er lidt mere abstrakt. Eller jeg ved ikke, hvordan det opfattes?

R3: Det kan jeg godt forestille mig. Jeg tror, der er mange, der .. hvis de har noget konkret, de ved noget om i forvejen, så vil de være mere tilbøjelige til at lave et forsøg med det.

Ja så det er det der med, at man ikke skal begynde sætte sig ind i, hvordan man begynder at regulere pH-værdien oveni alt det andet?

R3: Ja, det tænker jeg.

Hvordan synes du, det var at lave en video?

R3: Jeg synes faktisk, det var bedre dokumentation end at skrive det ned. Man kunne evt. gøre begge ting næste gang. Det var fedt det med, at man kunne se det, man havde lavet. Så kan man også se det, man har lavet. Man skal ikke huske. Man skal ikke huske det hele i hovedet. Så det man filmer det gør, at man har noget konkret, som man kan bearbejde i sin databehandling senere. Også hvis man filmer resultaterne som man laver i loggerpro. Også lettere i power points eller. Det er også lettere at tage screen shots af den film man har lavet over forsøget.

Gav det mening at skulle svare på de spørgsmål, jeg havde skrevet op imens eller?

R3: Svarer på om modulet var godt eller?

Nej jeg mener, jeg havde lavet nogle spørgsmål, jeg gerne vil have jer til at svare på, som handlede om jeres hypotese og hvordan I undersøgte. Der var fire spørgsmål i alt.

R3: Jeg kan lige se, om jeg kan finde det. Gæringsforsøg. Ja, der. Ja vi har i hvert fald skrevet hypotesen ned, kan jeg se. Jeg ved ikke umiddelbart om min gruppe, har de andre fire. Jeg ved ikke, om de er blevet skrevet ned.

Har I delt jeres video imellem jer efterfølgende eller er det kun den person fra din gruppe, der har videoen?

R3: Der må jeg desværre sige, at jeg tror, det er den person, der har den. Jeg har den i hvert fald ikke, desværre. Jeg ved ikke.

Okay, det er måske en meget god ting at have med og opfordre til.

R3: Ja.

Jeg præsenterede jer for en vækstkurve efter I havde lavet forsøgene også skulle I putte jeres egen ind i. Hvordan synes du det var, ift. for eksempel at jeg viste jer vækstkurven inden i startede jeres forsøg?

R3: Ja men ja. Du viste os efter, også kunne vi sammenligne. Du kunne også have gjort begge ting også vise den før. Der tror jeg knap så mange ville have lyttet og været så interesseret i det modsat hvis man havde kunne sammenligne med noget konkret, som vi selv havde lavet. Vores fulgte umiddelbart fint nok ift. det der med nølefasen, den eksponentielle fase, den stationære fase og den døende fase. Var det ikke det?

Jo lige præcis, nu ved jeg, at jeres klasse faktisk skulle have haft set den (vækstkurven) inden modulet. Nu ved jeg ikke, hvor mange, der kunne huske den, men for nogle klasser er det helt nyt. Men det er fedt, at det bliver mere interessant, når man sammenligner med sin egen graf, fremfor bare at læse om den.

R3: Ja helt klart, man kan sammenligne med noget konkret. Tror også der er mange, der synes, det er lettere at relatere til.

Der er også en grund til, jeg ikke vise grafen først og det er for, at man ikke kan komme til at tænke at man nødvendigvis skal have noget, der ligner på en prik, fordi nu laver I jo faktisk om på det, så det vil se lidt anderledes ud. Hvordan var det i jeres gruppe - tænkte I, at når I blev præsenteret for (vækstkurven), at jeres kurve blev mere rigtigt eller forkert? Kom vækstkurven til at virke som "lærerens svar"?

Forstår du, hvad jeg mener?

R3: Ikke helt.

Nej det var også bøvlet formuleret. Følte du, at du fik noget ud af at lave forsøget?

R3: Ja det tænker jeg. Jeg synes, det var fedt at udføre det i praksis i stedet for. Selvfølgelig også at sidde og læse om det, selvfølgelig tager det også mere tid, men det giver bare noget mere og man husker det bedre, vil jeg umiddelbart sige. Hvis det er det, du spørger om?

Ja det er så fint. I forhold at I alle sammen fik en opgave i gruppen, hvordan fungerede det i jeres grupper?

R3: Jeg synes faktisk, at det fungerede rigtig godt. Vi sad koncentreret. Så vidt jeg husker, der var en der, der lavede video, en der indtastede data og en der talte bobler også den sidste … det var tid. Ham med tiden, han løb lidt rundt frem og tilbage. Så der var det lidt. Så ham der talte bobler måtte gøre begge ting, hvilket var lidt svært. Ja så måtte jeg også hjælpe ham lidt med det… jeg sad og lavede data og den sidste hun filmede og det er noget man gør, det er man ene om og det er sværere at gøre andre ting samtidig med, hvis man gerne vil gøre det rigtig koncentreret. Men det fungerede umiddelbart meget godt udover der var en der løb lidt rundt.

Der var en der allerede var gået på weekend.

R3: Ja men det var også fedt, fordi vi var firemandsgrupper, så der var fire opgaver, så der ikke er en, der bare sidder og ikke laver noget, tænker jeg.

Ja, lige præcis og det er også netop det, at det godt kan være lidt svært at tælle og tage tid samtidig. Især hvis man vælger fx en høj temperatur, hvor der lige pludselig kommer rigtig mange bobler, så der kan man godt have brug for lidt hjælp. Men det var godt at høre. Hvordan gik den proces med at uddelegere det? Var det okay? Eller var der nogen, der bare sagde, jeg vil gerne det her?

R3: Ja det var… Der var rigtig mange, der startede med at … hvad var det, de ville… jeg ved ikke, hvad de ville… Alle i klassen ville det samme nemlig … jeg kan ikke huske det … jeg tror, det var … jo tog tid. Det var det alle ville! Alle ville tage tid. Men det var egentlig … så var der en i gruppen, der gjorde det. Men det andet er jo lige så svært… Eller tage tid… Du skal selvfølgelig være præcis, det er måske det mindst svære, men at taste data ind er heller ikke så svært… Måske er det, der er svært, er at tælle bobler, hvis du skal være præcis også filme, hvis du skal være koncentreret… men umiddelbart gik det meget godt. Og vi har jo lavet… Vi sad faktisk sammen. Faktisk så har vi afleveret en biologirapport, hvor det her med gæring indgik. Så tror jeg. Jeg tror, det gik. Men jeg har i hvert fald samlet op på det i gruppen, ved jeg.

Hvordan var det at få præsenteret (vækst) kurven igen i jeres test?

R3: Jo det gjorde vi, og det gik rigtigt godt, fordi den kendte man jo.

Det er fedt! Så du føler, at du har fået noget ud af at lave det her. Det har givet bedre forståelse?

R3: Ja i meget høj grad endda. Det er rigtig fedt.

Hvordan var det med de her instruktioner? Fordi jeg valgte jo ikke at give jer en forsøgsvejledning. Hvordan synes du, det fungerede?

R3: Tror det blev meget mere frit. Jeg ved ikke, om det er en god eller dårlig ting, nødvendigvis. Jeg tror, der er mange, der tror, det er mindre seriøst, hvis ikke man har en forsøgsvejledning. Måske… men umiddelbart fungerede det rimelig godt i klassen og man kunne også se, at folk var kommet frem til nogle helt forskellige resultater, så noget fik man da alligevel lavet. Jeg tror, der er mange, der synes det var fedt, at det var mere frit

og at de måtte selv styre, hvad de gjorde - i hvert fald i højere grad, end hvis man havde en forsøgsvejledning, tænker jeg.

Ja hvis man fx blev bedt om "nu skal du sætte den på den her grad" eller sådan noget

R3: Jaja

Var det også til at forstå, når vi skulle gå i gang? Var det okay ligetil eller var det forvirrende eller?

R3: Når man først er kommet i gang, så gik det jo meget fint, men det der er problematisk, i hvert fald for mig, jeg tror også, det var for nogle af de andre altså i min gruppe, det er at man skal lige… Lige meget hvor meget, man følger med, så føler jeg altid, at man misser et par instrumenter, eller hvad man skulle have med. Man skal normalt have 4 - 5 ting med også kan man kun huske 3 - 4 af dem, så må man lige spørge. Ellers var det meget overskueligt, synes jeg.

Okay.

R3: Det var meget rart.

Det er jeg glad for. Hvordan var det med opsamlingen? Som jeg husker jeres klasse, så kunne man godt mærke I var lidt trætte, så jeg var lidt i tvivl om, hvor mange, der var helt med. Nu er de her jo ikke, men følte du, at der blev samlet op på dine resultater?

R3: Ja det gjorde. Jeg følte, at det var godt, at vi spurgte hver enkelte gruppe ift. hvordan de havde præsenteret det, så alle kunne se de forskellige forsøg og få dem forklaret, så kunne man diskutere fejlkilder osv.

Okay

R3: Men det var 4. modul og det er bare sværere at koncentrere sig, desværre.

Det er det for alle. Nu sad der (lærerens navn) og en anden lærer sad og jeg kunne også se at de var lidt væk i deres øjne, fordi alle bliver trætte, det er helt normalt. Jeg er også bevidst om, at det er et lidt hårdt modul, fordi man skal være aktiv og man får ikke nogen pause. Sådan vil jeg også selv have det.

(Begynder at takke og runde af)

Et til spørgsmål til sidst. Jeg skal lave det her modul sammen med en klasse i morgen og på onsdag, også vil jeg høre, om du havde et forslag til, hvordan jeg kunne gøre det lidt bedre? Kunne forberede det på nogen måde?

R3: Godt spørgsmål. Jeg synes umiddelbart, at det fungerer meget fint. Jeg kan nok ikke… Hvis det er i starten… Hvordan skal jeg beskrive det? Afhængigt af, hvornår det er på dagen, så kan man udelade eller tilføje mere eller mindre teori. Hvis det giver mening? Fordi, jeg tror, folk har en højere sandsynlighed for at lære ting mere på morgenen, hvor jeg tror, de vil være… der vil være større chance for, at de vil, huskede et forsøg, hvis de laver det i 4. modul, end hvis de blev præsenteret for en masse teori.

Synes du, der var okay med teori i det modul, jeg havde lavet? Var der for meget eller for lidt?

R3: Jeg synes, det var perfekt, fordi der var ikke så meget, så vidt jeg husker. Der var ikke så meget før, igen der var ikke så meget før forsøget, også var der lidt opsamling og lidt teori bagefter, så vidt jeg husker. Og det fungerede meget godt også nu, hvor det var 4. modul, så det kan jeg i høj grad anbefale måske gøre igen.

Det vil jeg tage med. Tusind tak for hjælpen også håber jeg, du får en god weekend.

3. Interview 1/12/20

Jeg vil starte med at spørge dig om, hvordan du oplevede det med modul, jeg viste dig i - altså det modul om gærs vækst?

R5: Ja, Generelt synes jeg faktisk, det var et rigtigt godt modul og det er en del federe, end det plejer at være, når vi har biologi. Det er første gang vi har lavet forsøg her i gymnasiet, og det synes jeg er det fedeste i biologi. Også synes jeg også, du havde sådan en god entusiasme og var god til at få os i gang med forsøget. Når lærerne er engagerede, så bliver eleverne også, eller det gør jeg i hvert fald.

Fedt, det er jeg glad for. Så du følte altså, at du blev mere engageret af det her modul?

R5: Ja, helt klart.

Det var også det, der var meningen! Så vil jeg spørge ind til de enkelte dele. Kan du huske, at vi arbejdede med Strain 323?

R5: Jeg kan godt huske, at du snakkede noget om det, men jeg kan ikke helt præcist huske, hvad det var for noget.

Okay, så det her med, at jeg havde lavet en fiktiv case, gjorde det, at du blev mere interesseret?

R5: Hvad var det nu, at casen var, kan du huske det? Så kan det være jeg kan huske lidt bedre, hvad det var.

Det var den her gærtype, der hævede helt vildt meget…

R5: Nåh ja, det var der, hvor der var nogen, der havde sådan en kæmpe hævning, hvor det bare var blevet helt vildt stort. Var det ikke det?

Jo lige præcis.

R5: Det synes jeg faktisk, gjorde det lidt mere interessant, det der med at man kunne se i stedet for bare at fortælle, at det var en vild gær, så vise, hvad det var, der var sket. Det synes jeg gjorde det mere spændende.

Okay, kunne du godt forstå, at det var noget, jeg havde fundet på? Fremgik det tydeligt?

R5: Ja, det synes jeg.

Okay godt. Hvordan synes du, det var, at du kunne vælge den vækstfaktor, du gerne ville undersøge?

R5: Det synes jeg var… Det kunne jeg også godt lide, at man selv kunne påvirke forsøget selv. Det gjorde det lidt mere spændende, i stedet for man bare fik at vide af læreren, hvad man skulle.

Ja, i din gruppe, fik i formuleret en hypotese?

R5: Ja, jeg tror… Vi lavede det forsøg, hvor vi puttede en del sukker i. Og der havde vi hypotesen om, at der vil komme en del flere bobler, end hvis man ikke havde puttet så meget sukker i, eller intet sukker i. Det var i hvert fald noget lignende det.

Okay, lavede i hypotesen før eller efter forsøget eller imens?

R5: Det gjorde vi før.

Så når i så havde lavet forsøget, hvordan var det for dig at få præsenteret vækstkurven efter forsøget - altså den her fra bogen, som jeg viste jer?

R5: Nåh den der med de forskellige faser, der var?

Ja

R5: Hvad mener du med, hvordan det var for mig? Hvad er det helt, du mener?

Altså nu kan man jo forestille sig, at jeg fx også kunne have vist jer den inden forsøget og gav det mening for dig først at få den vist, efter du havde lavet dit eget forsøg? Og lavet din egen vækstkurve?

R5: Ja det gav fin mening, synes jeg, så man ligesom selv kunne få den lavet først, også kunne man bagefter sammenligne den med den, du havde med. Det, synes jeg, fungerede fint.

Hvordan synes du, det var at lave en video?

R5: Det, synes jeg, egentlig også var okay. Det, synes jeg også, var meget godt.

Har din gruppe efterfølgende delt videoen mellem jer?

R5: Ja, vi så den efter timen.

Men du har den ikke selv nu?

R5: Nej jeg har den ikke.

Fungerede det med de spørgsmål, jeg havde skrevet op til jer, som I skulle have med?

R5: Ja, hvad var det for nogle spørgsmål, der var? Hvad var det?

Jeg havde stillet jer nogle spørgsmål. Sådan noget med: "Hvad var jeres hypotese? "Hvordan vil i undersøge den?" Fik I dem med i jeres film?

R5: Ja, det gjorde vi.

Det gjorde det nemmere at lave en video?

R5: Ja, at man ligesom vidste, hvad den skulle indeholde. Det gjorde det. Det er også fedt, når man laver en video, så kan man måske se tilbage på det, hvis man senere hen skal bruge noget fra det forsøg, eller et eller andet.

Du føler godt, du kan bruge den igen senere fx hvis du skal til eksamen?

R5: Ja, præcis præcis. Så kan du lige se tilbage på hvad var det helt præcist, der skete der. Det gør det nemmere at se det i stedet for at læse om det.

Tilbage til casen. Du sagde, det gjorde det lidt mere interessant at høre om det i starten. Gav det så mening til sidst, når jeg stillede jer det sidste spørgsmål om, hvad I ville rådgive fødevareministeren om?

R5: Nej lige det kan jeg ikke huske.

Okay, som jeg hører det, du siger… nu er det ikke for at putte ord i munden på dig… men at du starter med at se den case, og synes det er meget sjovt, men så går det lidt i baggrunden, når man går i gang med at lave forsøget?

R5: Ja det vil jeg nok sige, det gjorde lidt. Så fokuserer man mere på forsøget og resultater og sådan noget.

Nu gav jeg jo jer hver en arbejdsopgave. I din gruppe hvordan blev de fordelt ud?

R5: Altså det med at der var en, der skulle filme, en der skulle tælle bobler og sådan noget? Er det, det du mener?

Ja

R5: Det skiftes vi lidt til, fordi det godt kunne blive lidt kedeligt at sidde i 20 minutter og tælle de bobler der, så vi skiftede lidt rundt.

Så du fik simpelthen prøvet alle opgaverne?

R5: Ja altså. Ja, hvad var det, opgaverne var? Var det ikke sådan at filme, tælle bobler og indsætte dataen? Var det ikke det?

Jo også kunne man styre tiden for at hjælpe den, der talte.

R5: Nåh ja, det gjorde ham, der indtastede dataen samme tid. Ja så jeg fik prøvet det hele.

Nåh men så har jeg faktisk kun et sidste spørgsmål tilbage. Jeg skal faktisk undervise i det her modul igen i morgen, så jeg vil høre, om du havde nogle forslag til, hvordan jeg kunne gøre det lidt bedre for den klasse, jeg skal se i morgen?

R5: Lige umiddelbart, så har jeg ikke noget, jeg tænker, kunne være bedre. Men bare behold en god entusiasme og tænke over ting. meget over det her med, om eleverne er med, fordi hvis man bliver tabt i starten, så er det svært at komme ind i modulet igen, det synes jeg i hvert fald.

Hvad mener du med, at man bliver træt?

R5: Nej tabt. Du bliver tabt i løbet af undervisningen, hvis ikke du følger med i starten. Så vær sikker på at alle er med og er med på, hvad de skal gøre?

Ja okay, så har jeg faktisk lige et spørgsmål. Bare af ren interesse. Nu har jeg ikke taget en forsøgsjournal med i det her eksperiment. Var det okay tydeligt for dig, hvornår du skulle gøre hvad?

R5: Hvornår man skulle lave en hypotese, hvornår man skulle udføre forsøget, eller?

Ja og hvordan man måske skulle sætte det op?

R5: Ja, det, synes jeg, var ret tydeligt. Ellers var det let lige at spørge dig eller vores anden lærer.

Tak, jeg har faktisk ikke mere, så medmindre du har et eller andet, du har lyst til at sige, så synes jeg, at det var rigtigt fedt at høre dit input.

R5: Ja selvfølgelig, jeg håber, du kan bruge det til noget.

Det kan du tro, jeg kan.

4. Interview 1/12/20

Jeg vil gerne starte med at spørge dig, hvordan du oplevede at have gær modulet sammen eller blive undervist af mig?

R6: Jamen, jeg synes, det var fedt og jeg synes, at det var spændende og lidt anderledes, end hvad vi plejer. Det var lidt mere simpelt, synes jeg. Det var nemmere at forstå.

Ja fedt, hvad var mere spændende?

R6: Jeg tror, at vi fik lov til at prøve selv, og at vi fik lov til at eksperimentere med de forskellige ting ift. hvad der ville ske og sådan noget.

Ja, så jeg hørte, at det engagerede dig at vælge din egen vækstfaktor?

R6: Ja.

I din gruppe, fik I formuleret en hypotese?

R6: Det synes jeg, vi gjorde. Vi havde om, hvordan det ville påvirke med syre. Og der var vores hypotese sådan, at vi tænkte, at det ville svække respirationen.

Når I så havde lavet det her forsøg, hvordan fungerede det for dig at få præsenteret vækstkurven fra bogen, efter du havde lavet forsøget?

R6: Altså efter vi havde lavet forsøget, hvordan vi så aflæste, eller hvad?

Jeg ved ikke, om du kan huske, at efter I havde lavet forsøget, så viste jeg et billede af en vækstkurve med nogle forskellige faser på, også spørger jeg, om du godt kunne lide at få præsenteret vækstkurven på det tidspunkt af modulet?

R6: Ja, det synes jeg, så man ligesom kunne tænke sig til det. Altså det der med, at man først oplevede noget, også få sat det ind i en model bagefter - nåh det var det, der skete og det var sådan her og det var derfor.

Jeg gav jer nogle forskellige arbejdsopgaver i gruppen, hvordan blev de fordelt i din gruppe?

R6: Altså, vi var… Jeg tror, vi var 3… 4. Vi havde (navn på elev) med virtuelt, så han kunne ikke rigtigt være med fysisk, men vi skiftes to personer med at tælle de der bobler. Så var der en, der satte hele forsøget op og skrev ned samtidig med. Når vi så ikke talte, så vi byttede vi.

Okay så I byttede nogle gange?

R6: Ja, det synes jeg fungerede meget godt, sådan så man ikke sad bare i… hvad var det 20 min?... og bare sad og talte.

Jeg havde jo også lavet en fiktiv case, som var den her nye gærtype. Fungerede det for dig? Gjorde det det mere interessant for dig?

R6: Ja, det synes jeg. At vi ligesom også med de der billeder med "super gær", eller hvad det hed. Også at vi ligesom, at vi lidt mere... hvad hedder det sådan noget… ja lidt mere spændende og lidt mere tættere på, selvom den ikke er rigtig, men at man ligesom tænker okay, der sker det her (utydelig sætning), eller sådan noget. Også det her med, at vi fik lidt samfundsfagligt også. Det, synes jeg, var ret rart. Jeg synes nogle gange, når man har de der biologi og fysik og sådan noget, så synes jeg godt, det kan blive sådan "okay, hvad skal jeg bruge det til" agtigt. Så jeg synes, det var godt at bringe noget ud fra omverdenen ind i det.

Det er jeg glad for, det var også det, der var meningen. Nu gav jeg jer jo ikke nogen forsøgsjournal. Normalt får man jo, eller i hvert fald da jeg gik i skole, får man normalt sådan en forsøgsjournal, hvor der står, hvad man skal gøre og sådan noget. Nu fik I ikke det udleveret, hvordan var det, synes du?

R6: Altså, jeg synes, det var fint, men jeg synes også, det var rart, man lige kunne spørge jer, hvad man så lige skulle gøre, hvis man lige kom væk fra det. Eller hvis der var noget, vi ikke forstod, også fordi jeg synes selve… altså, du havde jo det der billede med af opstillingen, det hjalp ret meget. Jeg synes også, det var, at man selv lidt skulle bestemme, hvad der skulle ske, gjorde det lidt mere spændende. Altså, man ville arbejde lidt mere, fordi man ikke bare havde sådan en journal, man skulle følge.

Hvordan var det at lave en video?

R6: Det, synes jeg, var fint nok. Det var lidt sådan...øh… Vi var kun tre i gruppen, der faktisk kunne være med, men jeg synes, det fungerede okay, men jeg ved ikke… hvis vi havde haft lidt mere tid eller lavet det over to moduler, så kunne videoen blive bedre, fordi vores var sådan lidt hurtigt i starten. Men det er også meget rart at have bagefter, hvis man skal skrive en rapport om det, at man ved, hvad der skete og at man faktisk kan se det.

Fungerede det med de spørgsmål jeg havde skrevet til jer, som I skulle prøve at svare på i videoen?

R6: Altså, vi fik ikke rigtigt svaret på dem i videoen, fordi der var lidt klassestøj og sådan noget, men jeg tror, vi fik dem skrevet ved siden af videoen. Også igen hvis man havde haft længere tid, så havde vi kunne svare på dem med en voice over.

Jeg synes, at hvis vi havde haft flere moduler, så synes jeg, det kunne have været … to moduler eller et længere modul… så tror jeg, at videoen kunne have være lidt mere brugbar, men jeg synes stadig, den er rar, hvis man skal skrive rapport om det senere hen, at man ligesom har den og kan se det.

Har I delt videoen mellem jer bagefter?

R6: Ikke endnu faktisk, men det kan vi gøre senere hen.

Men så har jeg faktisk ikke så meget mere. Jeg har et spørgsmål. Nu skal jeg faktisk undervise i det her modul i morgen, også tænkte jeg, om du måske havde et forslag til, hvordan jeg kunne gøre det en smule bedre?

R6: Jeg tror at, måske kunne man lige præsentere, hvad det nu… jeg kan ikke huske, hvad det var … miose eller mitose… jeg kan ikke huske forskellen… måske lige præsentere de stadier i det, der skete. Så man ligesom vidste lidt og forstå det bagefter. Ligesom kunne fornemme, hvad der skete og hvorfor det gjorde som det gjorde det der gær.

Okay så hvorfor der bliver mere af det?

R6: Ja, men bare sådan… Jeg synes, du forklarede det rigtigt fint, men hvis man skulle gå mere dybden med det. Jeg ved ikke, om det giver mening?

Jo det giver meget god mening. Skal jeg forstå, at du godt kunne tænke dig at have haft det før forsøget?

R6: Mmh. Nej, jeg synes, det der med at vi først lavede forsøget og vi så så de der faser bagefter, det synes jeg, fungerede helt vildt godt, men at man måske lige kan få forklaret… Jeg ved ikke, hvordan jeg skal sige det, men sådan… selve… vi har jo lige haft cellebiologi… altså ligesom hvad der skete indeni cellen før det eller efter, men man ligesom fik det forklaret, så man var afklaret med, hvad der skete og hvorfor og sådan noget.

Okay, ja men det giver god mening. Har du andre ting, der falder dig ind eller?

R6: Nej, jeg synes, det var rigtig godt. Simpelt at forstå og sådan noget.

Det er jeg glad for. Jeg synes også, I var rigtig og tog godt imod mig, selvom jeg ikke er jeres normale lærer, kan man sige. Så vil jeg bare sige, rigtig mange tusinde tak for din tid her.

R6: Det var så lidt.

Også håber jeg, du får en rigtig god aften.

R6: I lige måde.

5 Interview 15/12/20

Hvordan oplevede du modulet om gærs vækst?

R7: Jeg synes, det var meget sjovt, interessant, fordi at vi jo ikke har haft om det før og i forhold til, at vi lige har haft om immunsystemet, så var det et ret stort spring, synes jeg - at gå fra det til det andet. Så jeg synes, det var meget interessant at lære noget nyt.

Hvordan synes du, det var at arbejde med den her case Strain 323?

R7: Den kunne jeg virkelig godt lide. Jeg synes, det var sindssygt godt fundet på. Jeg var jo en af de elever, der bare sad på google og prøvede at finde ud af, hvad det egentlig er, men det var jo ikke noget som helst, det var bare noget, du havde fundet på. Så det synes jeg egentlig fungerede rigtig godt. Det skabte meget nysgerrighed, ikke kun hos mig men også hos andre.

Blev du egentlig lidt ærgerlig, da du fandt ud, at det ikke var helt rigtig ved at google?

R7: Både og - det var virkelig sjovt, synes jeg, at jeg havde siddet så langt tid og brugt tid på det, som egentlig ikke fandtes. Jeg vil ikke sige, det var ærgeligt, det var mest sjovt.

Hvordan synes du, det var selv at vælge den vækstfaktor, du havde lyst til at undersøge i dit eksperiment?

R7: Det kunne jeg egentlig godt lide, så får vi jo selv lov til at tænke, kan man sige - også diskutere i forhold til hvilken vækstfaktor, man har lyst til at arbejde med og hvilke resultater der kommer ud af det.

Fungerede det at alle havde lavet noget forskelligt? Man kunne også have lavet det samme også kunne man se, hvad de andre havde fået med den samme vækstfaktor?

R7: Jeg synes, det vil være lidt kedeligt, hvis alle lavede det samme, men selvfølgelig det kunne også være interessant også se, om der alligevel sker forandringer i forhold til - det gør der jo helt sikkert. Der kan jo altid være sådan nogle fejlkilder eller et eller andet. Men jeg synes, det var mere interessant at se, hvad der sker i forhold til, når vi har forskellige udgangspunkter og hypoteser også se de resultater, der kommer ud af det.

Hvordan var det at få præsenteret vækstkurven fra bogen, efter du havde lavet dit forsøg?

R7: Det var … Altså det var fint, men man kunne godt have præsenteret det før, synes jeg, fordi så havde vi både den teoridel, som kræver, at vi kan diskutere vækstkurven. Det havde givet meget bedre mening i forhold til at sammenligne vores egen med den. Også fordi, at der var ingen af os, der havde fået undervisning i det før, så vi var ret blanke i forhold til de faser.

Så der var også noget i forhold til, hvordan jeg fik samlet op på de faser?

R7: Det var meget godt. Men det var bare lidt svært at følge med.

Hvordan fordelte i jeres arbejdsopgaver i din gruppe?

R7: ja, hvordan gjorde vi det… Der var en, der optog, så var der en, der sagde… der var en, der satte tingene på plads fra forsøget, og så var der en, der sagde, hvad vi skulle gøre. Det eneste jeg ikke sådan rigtigt synes fungerede, det var selve videoen. Den var ret mærkelig, vi optog i 15 minutter. Men det var også vores egen fejl, vi havde ikke læst op på, hvor lang tid vi egentlig skulle optage i forhold til hvad.

Så det var ikke helt tydeligt, hvad videoens formål var måske?

R7: Jo, det var helt tydeligt, det var vores fejl… Det var rigtig godt… Det fungerede rigtigt godt…

Hvordan fungerede det at have arbejdsopgaver i gruppen?

R7: Nårh de sidste i forhold til hypotese?

Nej, altså hvordan fungerede det at have en opgave pr. mand i gruppen?

R7: Nåh på den måde. Det fungerede virkelig godt. Det kunne jeg rigtig godt lide. Så fik vi et større overblik over selve forsøget. Jeg fik godt nok den kedeligste del, men jeg synes alligevel, at den var virkelig fed.

Hvad var det egentlig, der gjorde den kedelig?

R7: Det var bare, det der. Også på grund af at samtidig havde jeg seks andre virtuelt i anden hånd. Så jeg havde en computer her og (elevnavn) telefon, som vi åbenbart ikke har kunne sende alt det, vi har optaget. Jeg ved ikke … jo det var kedeligt. Også skulle jeg optage i et kvarter ik'. Det var ret kedeligt at optage de der bobler i så lang tid.

Var det fordi, der ikke skete så meget eller?

R7: jaaa… men hos os var det faktisk den, hvor der skete mest, men det startede bare ud ret langsomt. Så kom der slet ikke nogen bobler, også skulle vi vente i ret lang tid, også på grund af, at vi lavede den fejl, hvor vi optog i et kvarter - det skulle jo kun være i to minutter. Så jeg tror mere, det var på grund af vores fejl.

Fik I formuleret en hypotese i jeres gruppe?

R7: Ja det gjorde vi. Det var et eller andet i stil med.. i takt med at.. hvis vi putter mere gær, så vil der kommer flere bobler agtigt.

Ja, vil du gerne have haft en forsøgsjournal til den her øvelse?

R7: Jaaa.. det var vil jeg egentlig gerne. Det gør det meget lettere i hvert fald at få det her overblik over, hvad det er, vi har gang i. Men (lærerens navn) gav os jo også en dagen før.

Har i delt videoen mellem jer, efter I har været færdige med det her forsøg?

R7: Nej, jeg har aldrig set den her video igen. Men jeg optog i et kvarter.

Fik I også svaret på de spørgsmål, som jeg havde skrevet op, der skulle indgå i videoen?

R7: Ja, dem fik vi svaret på.

Også i videoen?

R7: Ikke i videoen. Den blev ret mærkelig. Videoen har jeg aldrig set igen.

Så vil du bruge videoen, hvis du fx skulle til eksamen i den her øvelse?

R7: Nej, nej jeg vil aldrig bruge den video. Jeg har set andres videoer og de blev faktisk ret gode og der var også nogle af dem, hvor de faktisk havde besvaret de der spørgsmål i videoen. Og dem kunne jeg godt finde bruge på at bruge, hvis jeg skulle op til eksamen.

Ja okay, det her spørgsmål er en lille smule abstrakt, men hvad er interessant biologi undervisning for dig? Altså hvornår er biologi interessant?

R7: Uh.. jeg synes egentlig biologi er meget interessant. Jeg synes, det er sindssygt spændende, hvad der sker i vores krop. Jeg synes aldrig, det er interessant at læse om det, fordi det har så mange termer og det er ret kompliceret, men jeg synes altid, biologi bliver spændende, når man ved det. Eller når man kender til det. Eller når man måske selv underviser i det. Det kan jeg forestille mig er ret sjovt. Men at læse om det, kan godt være ret ikke særlig interessant.

Så du siger, at det ligesom bliver interessant, når man har forstået det? Jeg hører dig sige, at det ikke er så interessant at læse om det?

R7: Jamen, jeg tror, det der gør, at det er lidt uinteressant nogle gange, hvis nu det er et helt nyt emne og jeg så starter på begyndelsen, så kan det godt virke sådan ret hardcore i forhold til, der er så mange nye termer og et helt nyt system og man forstår intet af det i starten.

Okay, så det kan godt virke lidt overvældende?

R7: Ja, også synes jeg egentlig, at efter jeg har læst ret meget, så synes jeg også, at jeg har lettere ved at forstå de nye emner og det gør det også mere interessant.

Nu er biologien jo læren om alt det levende, men hvis nu man tænker, at der både er noget, der hedder biologisk viden, som du siger, eller man kan se nogle film, eller man kan bare gå udenfor og kigge, også er der det biologi, der er i gymnasiet. Hvornår er det biologi, der er i gymnasiet mest interessant? Hvilke situationer er det?

R7: Det, jeg synes, der var rigtig spændende i gymnasiet, det var der, vi begyndte at beskæftige os med der her celler og i forhold til immunsystemet, det, synes jeg, var sindssygt interessant. Altså når der kom virus ind i vores krop, hvad er det for nogle processer og hvad er det, der sker. Hvordan tackler vores immunsystem de her fremmede celler. At få en forståelse for det, det synes jeg, var ret spændende i gymnasiet. Jeg kan også huske for to år siden, hvor vi beskæftigede vi os med, hvordan en celle er opbygget og sådan nogle ting, hvor man går helt i dybden med, hvordan de ser ud… de er så små… og vi ved det faktisk godt. Det synes jeg er ret sejt… spændende… bare sejt. Og antistofopbygning og sådan nogle ting, hvor man går helt ned i de helt små dele og ser, hvad der sker. Også sådan noget som, når man prøver at lave forsøg i biologi. Det kan jeg også rigtig godt lide. Hvor man påviser, at de teorier, man har læst, faktisk er rigtige. Altså, hvor man kan bruge det til noget.

De emner, du sagde, er også rigtig spændende og fascinerende. Det er jo alt sammen noget, der på en måde handler om os selv. Det her er et lidt ledende spørgsmål, men er det fordi, at du føler, at du også lærer noget om dig selv?

R7: Ja, jeg føler, jeg lærer rigtig meget. Jeg vil ikke sige om … jo mig selv… altså i forhold til min krop. At jeg har en forståelse af, hvad der sker fx hvis der er en, der nyser... Eller i hvert fald hvad der kan ske ik', hvis han har en eller anden bakterie, som min krop aldrig har set og netop overgår i vores krop og vi kan også bruge den senere i forhold til immunsystemet, når man har en forståelse af det, så ved man jo også, hvor alvorlig

coronavirus er, hvis man også indstuderer det og ser hvad den her SARS gør ved vores krop. Så på den måde kan man bruge.

Ja, interessant. Det kan jeg godt forstå. Jeg har lige et sidste spørgsmål. Hvis jeg skulle undervise i det her modul igen, hvad synes du så, jeg kunne gøre bedre?

R7: Jeg synes egentlig, du gjorde det rigtig godt. Jeg synes ikke rigtig, at der var noget, du kunne … jo i forhold til de der faser og det der tidspunkt, men måske putte dem før forsøget, så vi har en forståelse. Men ellers synes jeg, det var sindssygt godt, jeg kunne virkelig godt lide det… Og så synes jeg ikke, du skal fjerne den der, du selv havde med.

Jeg skal ikke fjerne casen?

R7: Ja, casen. Den skal du ikke fjerne Det var sindssygt fedt… godt … sejt.

Okay, tusinde tak for dine svar. De er rigtigt brugbare.

R7: Selvfølgelig.

Appendix 5 Reflections

Date and time: 2/12/20. 9.55 am. 2nd module. 90 min.

Elected course Biology B, 2G, 3G and 4G students

What went well?

- Despite the limited time, all the groups conducted the experiments and produced their own growth curves.
- The students exhibit a good understanding of growth and growth curves.
- Some of them even looked like they enjoyed the experiment.
- They were nice and friendly, and I felt comfortable teaching the class.
- It worked well giving the students time to formulate a hypothesis and write it in the Padlet.

What could be better?

- No explaining in the *Forudsætning* phase.
- If possible, try out the technical equipment before the classes starts.
- Only two groups send me their video. I have a suspicion that the students did not finish their videos because that usually inhibits them from sending their video to me.

Things I should change?

- Incorporate time for the students to formulate a hypothesis and ask them to share it on the Padlet
- Do not explain concepts and terms in the *Forudsætnings* phase - very difficult when they ask!
- Explain the phases in the growth curve by focusing on how the environmental factors affect the growth of yeast cells.
- Try to include the students as much as possible in the *Forlæng* phase because they are tired and usually blank in their eyes, in that part of the module.
- The students should not have access to another version of the experiment because it confuses them.

Notes:

- Started the class after 5 min. because of problems with connection to the smartboard.
- It was a bit turbulent to start the class, directly after arriving. Difference from other gymnasium, where I had spent time in the classes and knew the teacher and students better.
- The teacher had given students a link to the original instructional material on https://bio.systime.dk/index.php?id=276. This created confusion with one of the groups because they noticed the difference between my instructions and the instructions on the instructional material.

***Forudsætning* Phase:**

- Because of the delay I explained in the *Forudsætnings* phase.
- The students had more knowledge about growth and were referring to previous experiments they had done.
- The students mentioned concepts including enzymes, mitosis, respiration, pH, temperature, moisture (CF. Padlet from the module)
- They showed understanding that time is required to observe growth (most classes had this understanding)
- Often the students would use their observations from baking e.g. it takes time before you can see your dough rising or it is bubbles that make a dough rise.

***Forsk* Phase**:

- The student groups chose a variety of growth factors to investigate (Cf. Padlet), contrary to other classes where the student groups chose one of the variables.
- Due to the feedback from the student interviews, I had decided to start the *Forsk* phase with the students formulating and writing their hypothesis on the Padlet prior to conducting their experiments. That worked well, and it also provided with great feedback and insight into what the thought process was in the different groups. I also had the opportunity to guide the students that needed help formulating a hypothesis. It also helped me prepare the *Forklar* phase because I had a better overview of the students experiments. In the further development of my module, I would incorporate this step. Depending on the students and their experience, teachers can decide to spend time explore what a hypothesis is and help the students with formulate one.
- The students had a good workflow and even with the reduced time to conduct their experiments, they produced some good results.
- It was evident that the students were used to making experiments. One group did not need any further instructed but completed the task by themselves.
- Other groups needed more help to understand the instructions.
- The students seemed like they had more experience with formulate hypothesis.
- A group questioned (like the other classes) how their experiment could say anything without anything to compare it to.

***Forklar* og *Forlæng* phase:**

- When presented to the growth curve from the learning materials, some students could recognize it and had knowledge about the different phases.
- One student argued that the optimal growth would be in the stationary phase because the number of cells would not change. I tried to make them understand that the stationary phase is when the number of living cells, equals the number of dead cells. I forgot to say that the stationary growth is caused by a limitation of the growth of the yeast cells. This would have been an important point and helped the students to understand that the optimal growth conditions are under the exponential phase.
- The students were able to place their graphs on the growth curve.
- Students showed a good understanding of the experiment and how growth can be expressed as bubbles. They could also explain their experiments and how their chosen variable affected the growth of the yeast cells.

Data and time: 20/11/20. 1st module. 100 min.

Mandatory Biology C, 1G Students

What went well?

- All groups completed their experiments and produced a graph.
- 5 groups sent a video.
- Most groups worked concentrated and in silence.

What went wrong?

- I felt I "lost" the class in the *Forklar* and *Forlæng* phase
- I did not seem that I managed to make them interested.
- Forgot to ask about interviews.

What to do better next time?

- More energy from my side
- Try and see if you use the get the students' graphs more in the *Forklar* and *Forlæng* phase.

Other observations

- The class was kind of quiet.
- The class have not seen the growth curve before.
- A girl filming the temperature after the end of the experiment, even though it was not her chosen growth factor - curiosity?

- The teacher said that the students would have to write a mini report/journal based on the experiment.
- One of the students said "relax" to me as a response to me encouraging them to upload their graphs.
- In general: the "transition" phases in the module e.g. cleaning up from the experiment, sharing the results etc. takes quite some time for the students. I spend the most energy when giving them instructions and making them execute the instructions. Activity this point in the module.

Date and time: 20/11/20. 3rd module. 100 min.

Mandatory Biology C, 1G Students

What went well:

- All students conducted their experiments and produced a graph and a video.
- Students mentioned all the factors in the *Forudsætningsphase.*
- Students groups chose to investigate many different factors.
- All the activities were completed within the time frame.
- I had good discussions about the experiment with the students during the *Forsk* phase.

What went wrong:

- One student group had trouble working in the *Forsk* phase. They were unfocused and had to set up the experiment several times. Their teacher was helping them focusing.
- Students did not really seem to understand the instructions of the video questions.
- Not sure if students know that their graphs would not necessarily follow the growth curve from the textbook since they have experimented with factors which might have reduced the growth of yeast.

What can I do better?

- I was explaining many concepts in the *Forudsætningsphase* - explain less because it can turn into a theory session and that I have the right answers.
- Supporting the group who had trouble focusing but it is a difficult balance because other groups needed assistance.
- On the other hand, groups had a good workflow during the *Forsk* phase and managed to answer the questionnaire at the same time.
- Have students share their hypothesis on the Padlet.
- I might be nudging the students to much in the hypothesis phase.
- Be careful not to interrupt students.
- I might introduce the video question in a different way and in a different time in the module - I introduced them in the *Forsk* while the students were counting.

Other observations:

- Students suggesting *milk* as a factor influencing the growth of yeast. Indicates that the students use their pre-existing experience of yeast. Someone had put a recipe on.
- Students copy-pasting knowledge from the internet in the *Forudsætnings* phase.
- Two groups decided to write answers to the questions instead of filming.
- Students discussing the experimental set up according to what they do when they bake.

Reflection

Data and time: 12/11/20. 3rd module. 90 min.

Mandatory Biology C, 1G Students

What went well?

- All students finished their experiments and produced a graph representing their results.
- All groups participated.
- I assume all groups produced a video - four videos were sent to me.
- The students seemed enthusiastic about their video and experiments.
- The activities were carried out within the time schedule.
- The students seemed to understand the growth curve in the Forklar phase.
- They understood the case.
- The students seemed to understand the growth curve presented in "Forklar"
- They understood the case.

What went wrong?

- Students were confused about how to start their experiments. They had to be the practical instructions several times.
- Several groups did not understand that the questions for the video should be included in their video.

What could be better?

- Discuss with the students: "What are we measuring?" "Why are we counting CO2 bubbles?".
- Ask the students the following the Forklar phase:
    - Do you accept your hypothesis?
    - What would you do if you were repeating the experiment (maybe look at the pictures from the case)?
- Video guidelines on paper so I do not have to switch between slides.
- Remember to emphasize that Strain 323 is a fictional case.

- Activate the students.
- Clarify that the video questions must be included in their videos.
- Be specific about what the students are measuring and that they must observe the bubbles in the gærrør.
- There might be a knowledge gap in how the cells allocate energy - is all the glucose turned metabolized into CO2 bubbles?

***Forudsætning* phase:**

The students had knowledge about a lot of growth factors, which potentially could influence the growth of yeast. I did not have to mention a growth factor or suggest an alternative. Students also suggested time as a factor. It is necessary to observe growth over time. I managed to ask the students to elaborate their suggestions and how they would test the specific factor.

***Forsk* phase:**

- Students ask if they should repeat their experiment - how can we say anything from an experiment if it is not validated - asking about control experiment. I told them that all the groups were making an experiment and that we were going to compare results.

Student's work:

- The factors are relative: what is high temperature? What is a lot of sugar?

Data and time: 13/11/20. 1st module. 90 min.

Mandatory Biology C, 1G Students

What went well?

- All groups produced nice results and graphs.
- Activities were carried out according to the time schedule.
- The students had some good reflections about hypothesis, variables, control experiments and why it is critical to compare the experimental results.
- The students participated more actively in the class discussions after they had completed their experiments - they could participate with their observations and results?

What went wrong?

- Be more prepared before class, instead of arriving right at the start of the module.
- Demonstrate the experimental set up to the students.
- Some students did not understand that they should only do one experiment.

- The students were shy/careful in the *Forudsætnings* phase - they wrote suggestions on the Padlet but were a bit reluctant to explain why.

What could be better?

- Take more time to present the different opportunities/growth factors for the students.
- Ask the students how you measure the different growth factors, suggested in the *Forudsætnings* phase.
- Give the students some time to formulate a hypothesis e.g. how can one vary the pH value of a solution? How will that affect the growth of the yeast cells?
- 15 g sugar = 1 tablespoon.
- *Forlæng* phase: more bubbles = more yeast cells? Glucose => respiration => growth.
- Prepare the *Forklar* phase when I talk with the student groups during the *Forsk* phase.

Date and time: 18/11/20. 4th module. 90 min.

Mandatory Biology C, 1G Students

What went well?

- All groups accomplished to design an experiment and produce a graph and video.
- One group produced a graph reflecting a rate instead of an number of bubbles. They had bubbles pr. min. as the dependent variable at the y-axis and the temperature as the independent variable at the x-axis. They designed an experiment with a varying temperature but also managed to construct a graph reflecting their experimental set up. Another group wanted to change the temperature as well, but they did not reflect it on their growth curve. I tried, by asking them questions, what the problem was with only having bubbles on the y-axis and minutes on the x-axis and therefore not reflecting the varying temperature. It did not seem to make sense to the group. They kept answering that the person reading their graph should just see their video and then they would understand. While explaining one of the students just got up and left.

What went wrong?

- Unfocused class - I found it difficult to keep them focused and attentive.
- The *Forklar* and *Forlæng* were not as I would have liked it to be.
- Most of the groups chose low temperature as their experimental variable, despite them suggestion all the different growth factors in the *Forudsætning* phase - this made it more difficult to do comparison of their results and explain different growth factors to them.
- It was evident that it was the last module of the day.

What could be better?

- How to inspire students to choose different variables and design different experiments but not instructing them?

Notes:

- Baking soda: what happens? Does it make the yeast solution more acidic or alkaline? And does it increase the amount of CO2 bubbles?
- In all the *Forudsætning* phases, the students suggested many different growth factors, influencing the growth of Baker's yeast. In many classes, some students would not elaborate their suggestions. The fear of having made a wrong suggestion, might have been holding them back.
- Despite all the classes suggesting all the factors, available to experiment with in the module, they mostly decided to experiment with temperature. Very few groups chose factors like, the amount of yeast, pH, and sugar. I am not sure about the reason for this. I asked one the classes, why most of the groups have decided to do an experiment with low temperature. One said "It was easy" another said that their choice was affected by what the other groups have chosen.
- Obvious in the *Forudsætning* phase that the students had worked with osmosis in the previous class - a lot of them suggested salt.
- Knowledge gap: does all the sugar get respired or does some of the energy goes to cell growth, mitosis or stored? How can we say that growth equals CO2 bubbles? We must assume that there is a correlation between CO2 bubbles and growth of the yeast cells. The students work with these questions the module following my module. The students were given the figures from their textbook including the growth curve, I presented for the students. Students were asked to explain the figures to each other and then share their explanation with the whole class. The teacher corrected the student's explanations of the figures. When explaining the growth curve, I observed that the student I was talking with, mostly knew the correct names for the growth phases but it was more difficult for them to explain what happened in the individual phases. I observed them referring to their experiment from the yeast module, when explaining the growth curve.
- The three 1G classes were given a test the following week of my module. The test was a finalisation of their Cell Biology course. Growth was included in the test - maybe a growth curve?

Appendix 6

Padlets

Hvad påvirker gærs vækst?

[redacted]

CAROLINE GRAM 8. NOV 2020, 11.28

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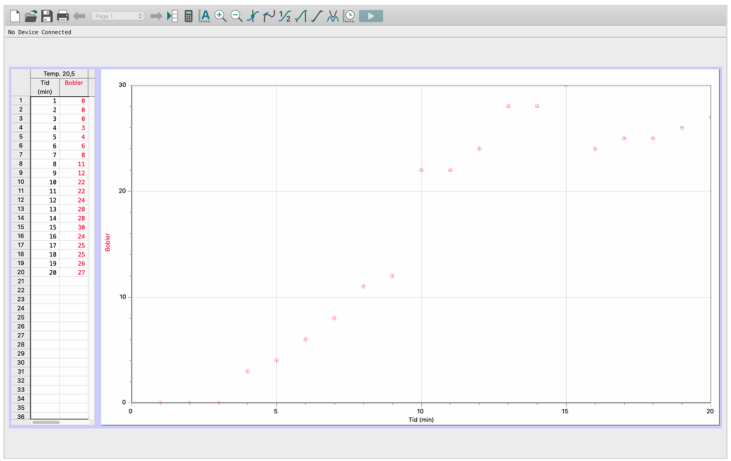
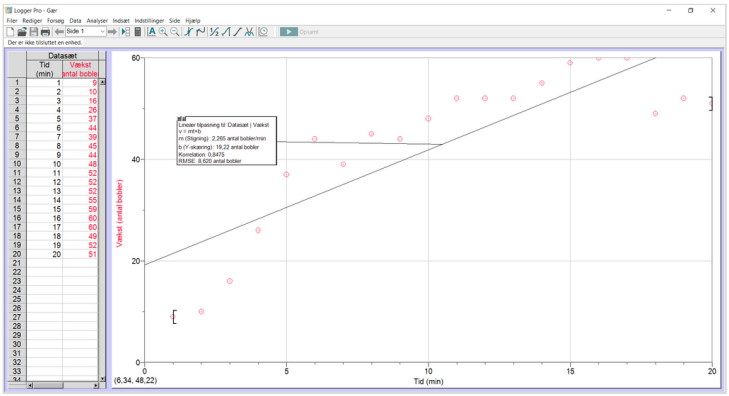
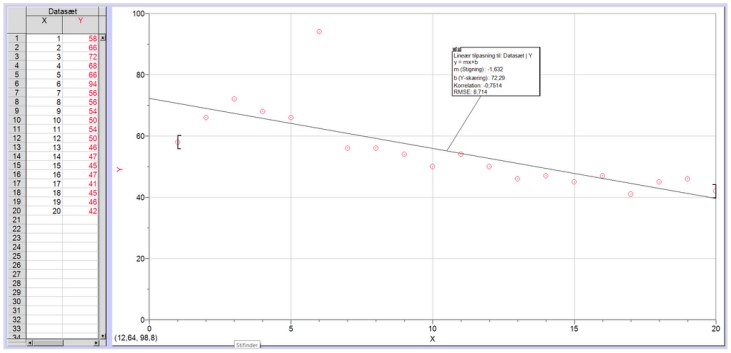
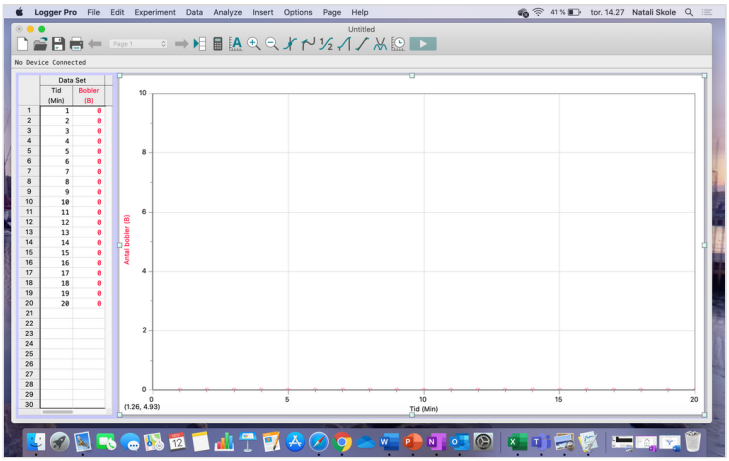




Lav temperatur

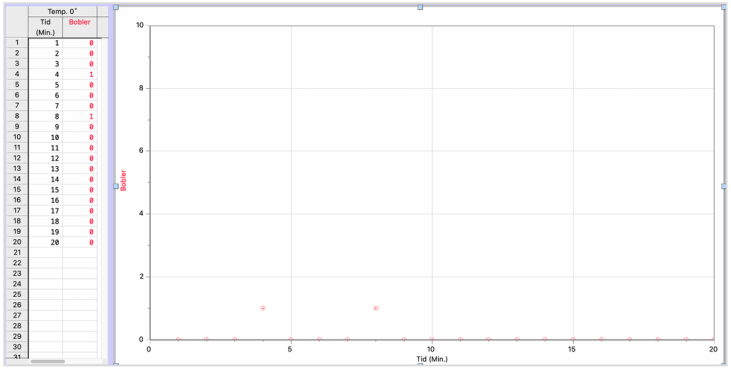
Høj temperatur

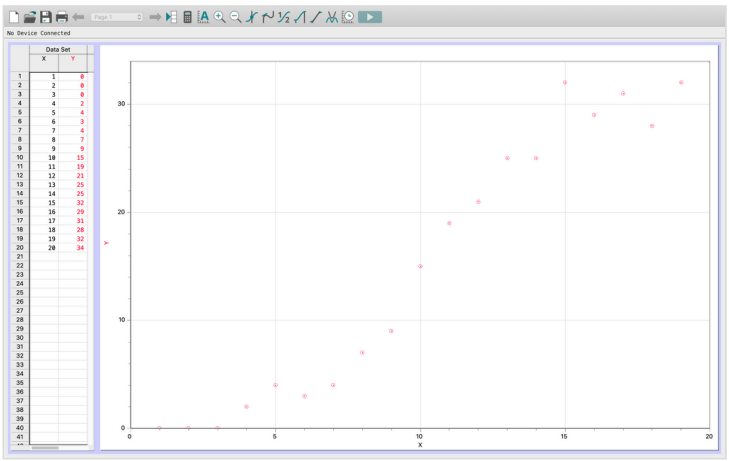




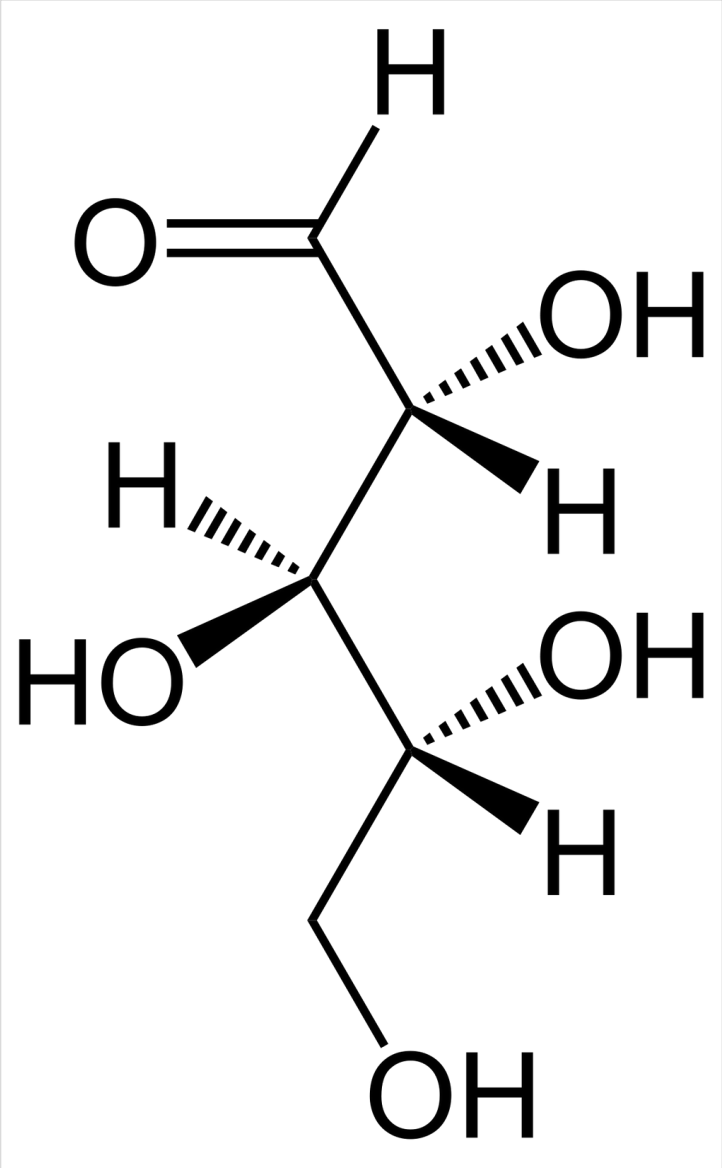
ved 50g sukker

Temperatur: 0 grader





konstant temperatur



adgang til rette næringsstoffer

Ilt

Temperatur
Glukose
ph værdi

- En passende temperatur
- En passende PH-værdi
- Tiden mellem to celledelinger
- Næringsstoffer
- Plads

Fugt

* Mineraler

* Temperatur (varme)
* Tid
*Næringstoffer

temperatur, fugt, ilt

Glukose
Gærtype
Mængde
Temperatur
Fugt
Respiration?- luftens iltindhold? Aerob/anaerob

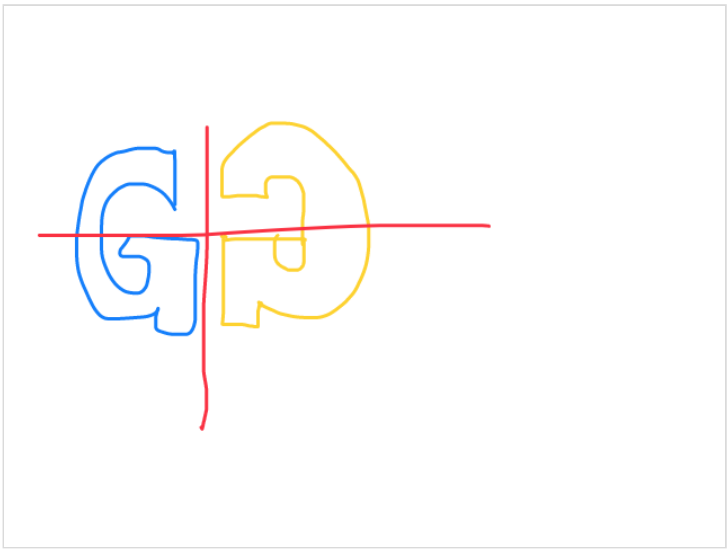
Luft

Vand

Temperatur

temperatur

næringstoffer



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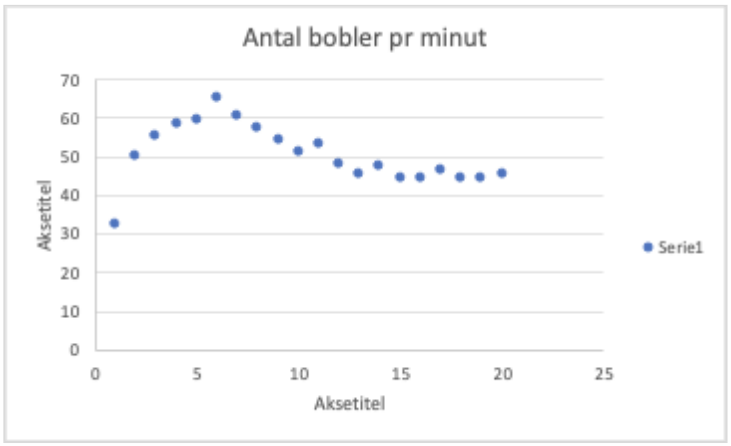
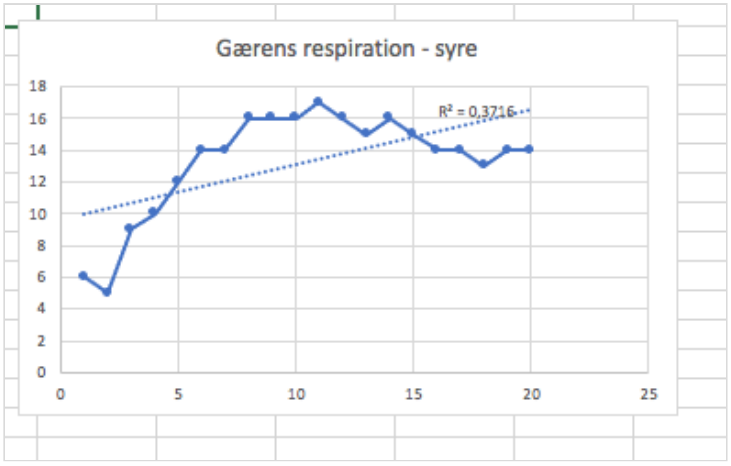
Hvad påvirker gærs vækst?

CAROLINE GRAM 17. NOV 2020, 18.41

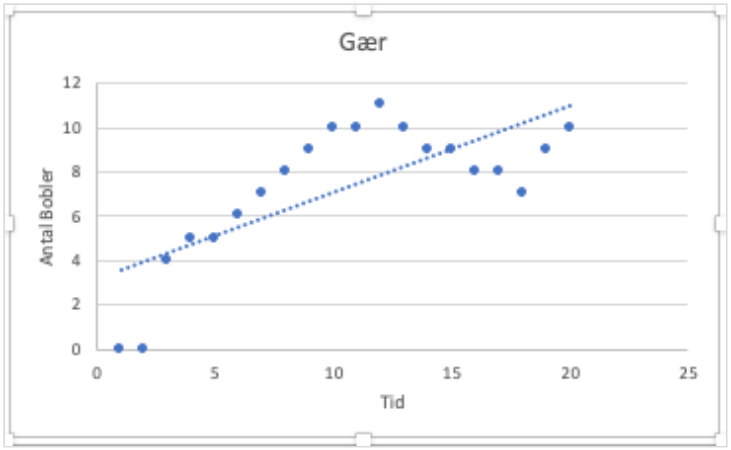
Tilsat mere sukker





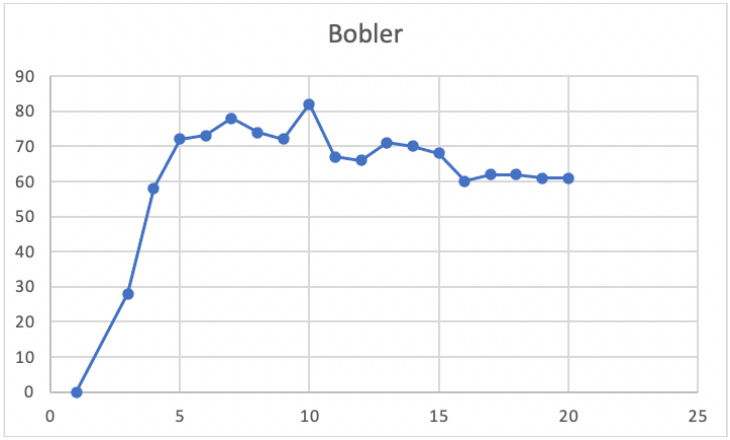
Koldt vand.

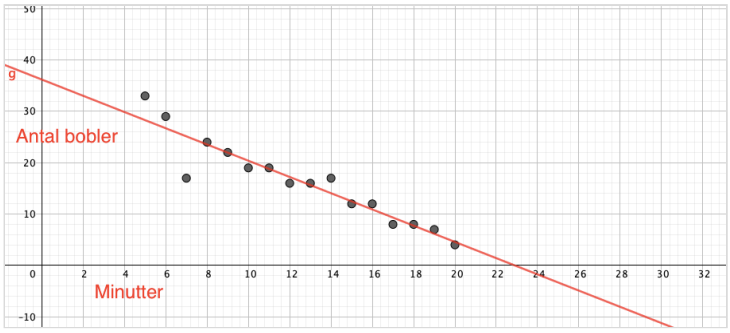
Nye isterninger i ved 12 minutter



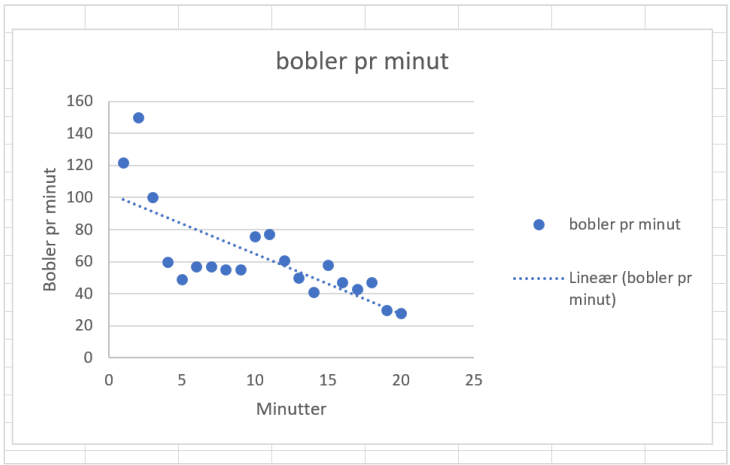
Ekstra sukker

Vi ville se, hvad der sker, når respirationsprocessen bliver påvirket med ekstra tilføjet sukker.

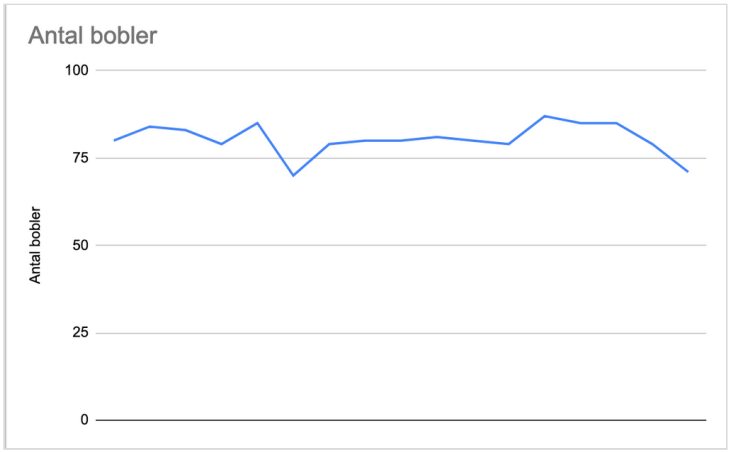




Vi undersøgte hvordan høj temperatur(60-50 grader) påvirker gærs vækst



om gæren er mindreårig



vibes

gærheden

CO2

pH-værdi

Hvor gammel gæren er

Lufttemaparaur

mængde af gær

disakkarider (sukker)

Tid

h2o

(Lun) temperatur

Fugt

Lunkent vand

mængden af gær

sukker

temperaturen

Fugt

Varme

Temparatur

Gærs vækstfaktorer

Tid, sukker, salt, vand, temperatur, swag, pH-værdi

aktiveres med vand

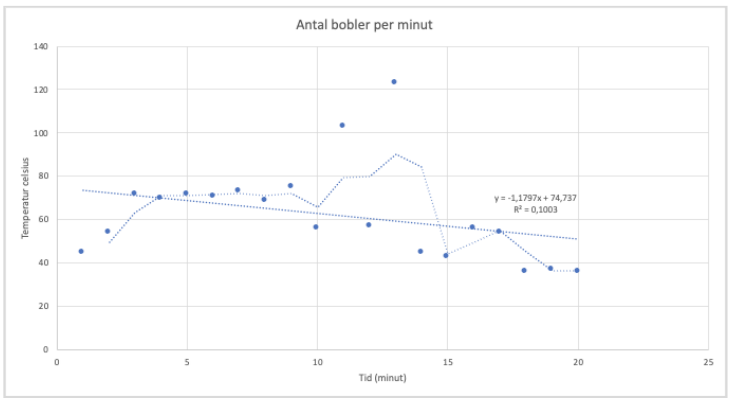
temperatur

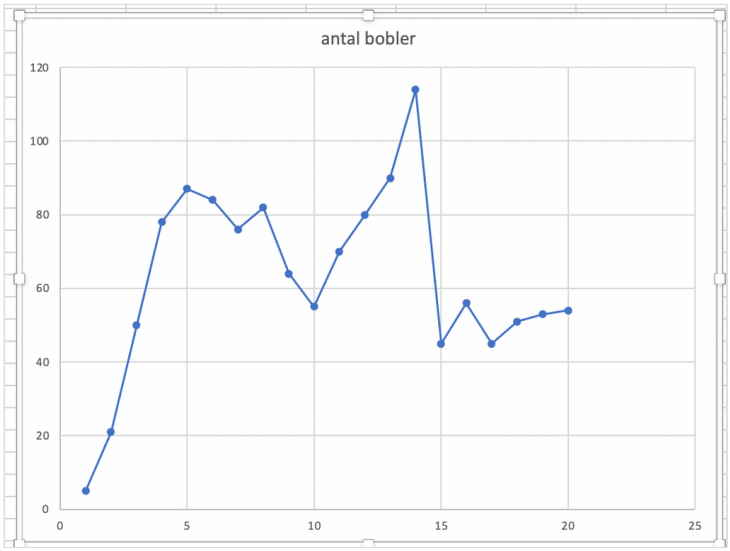
****

Hvad påvirker gærs vækst?

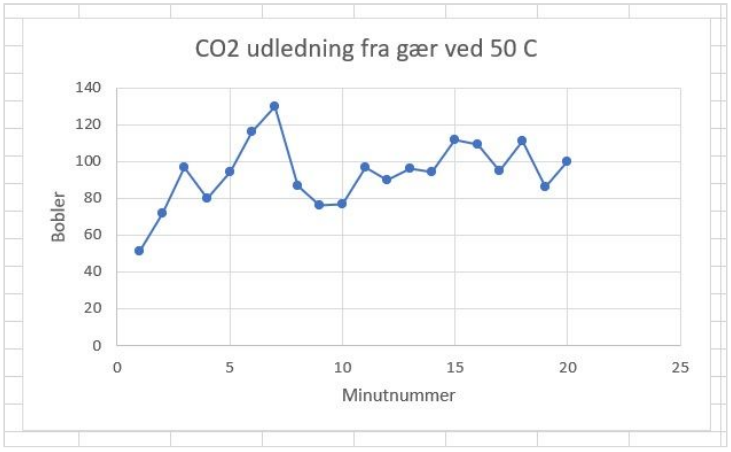
CAROLINE GRAM 17. NOV 2020, 18.41

Lavere pH værdi

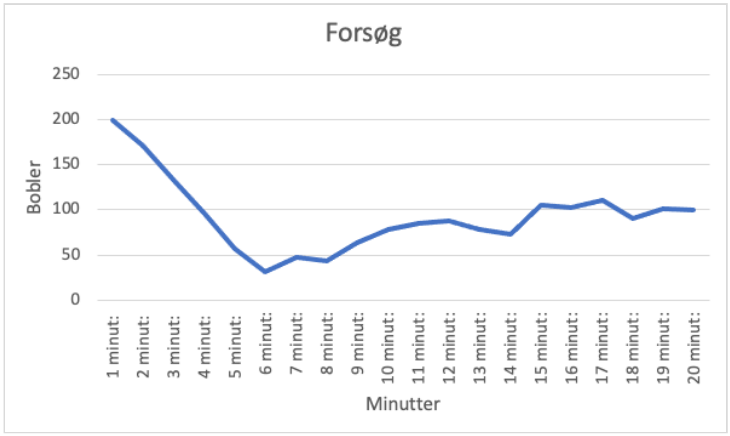




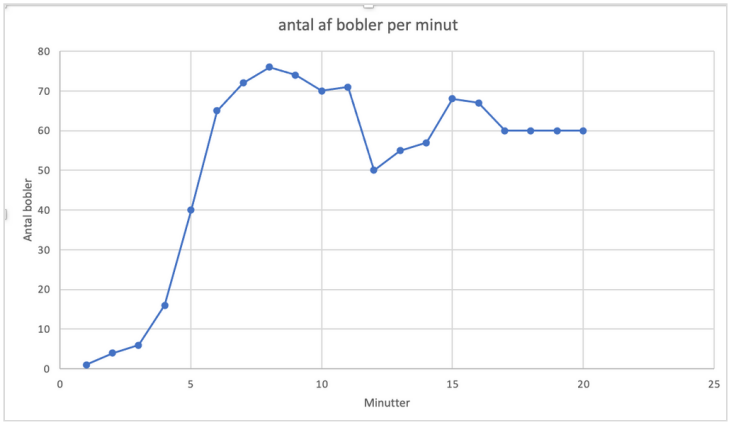
50 grader



Afprøvet med bagepulver



20g gær, 15g sukker, stuetemperatur



Større mængde sukker

Gærcellers vækstBiologi C, B og A + Biotek A.Gærcellers vækst forløber eksponentielt. Det betyder, at gærceller fordobler deres antal for hver generationstid (dvs. den tid, der er mellem to celledelinger). Væksten forløber på denne måde, fordi gærceller deler sig ved mitose, hvor en celle altid deler sig til to. En gærcelle bliver altså til to celler gennem første generationstid. Dernæst deler de to celler sig til fire igennem anden generationstid, de fire celler deler sig derefter til otte osv.

Abiotiske faktorer

Luft
Temperatur

Derudover skal cellerne bruge energi for at kunne respiraer

ph værdi
næringstoffer

Temperatur, fugt, vand/væsker, næringstoffer, bagepulver, salt, sukker, mælk, ilt(O2),

Varme, ilt, sukker

Temperatur
Ilt
tid

væske

ilt

sukker

Væske,

Hvad påvirker gær

temperature, fugtighed, ilt, vand, organisk martiale

O2, temperatur, sukker, væske.

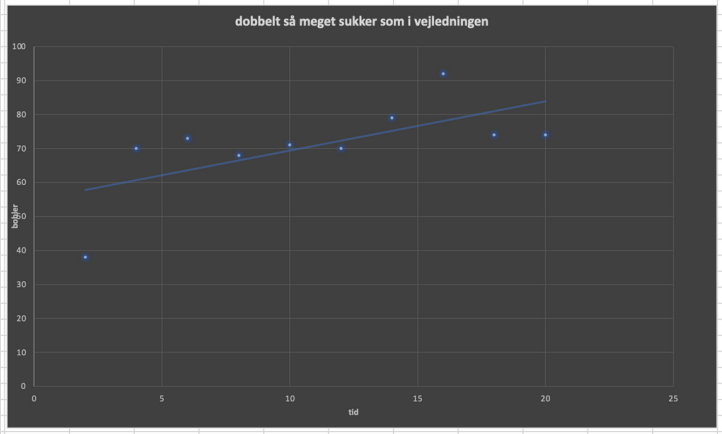
❋❋❋❋❋❋

Hvad påvirker gærs vækst?

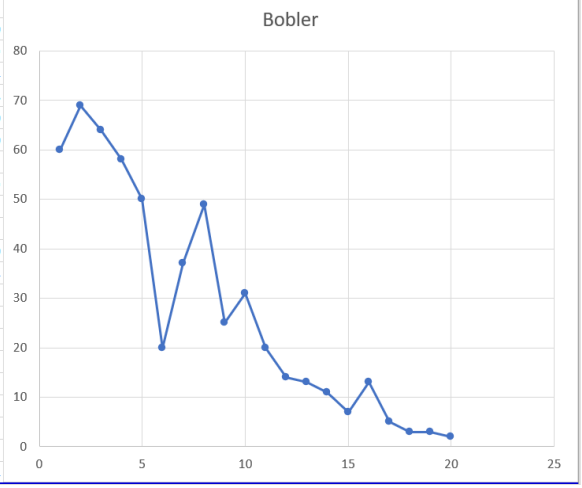
CAROLINE GRAM 12. NOV 2020, 21.29

dobbelt så meget sukker end i vejledningen

tid	2	4	6	8	10	12	14	16	18	20
bobler	38	70	73	68	71	70	79	92	74	74

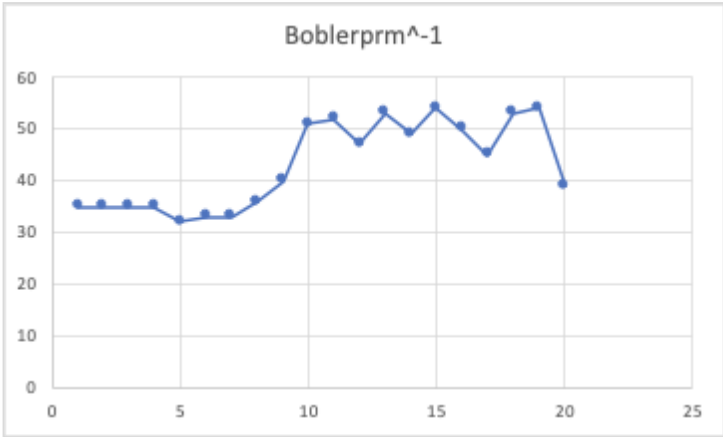


Minutter	Bobler
1	60
2	69
3	64
4	58
5	50
6	20
7	37
8	49
9	25
10	31
11	20
12	14
13	13
14	11
15	7
16	13
17	5
18	3
19	3
20	2
Sum	554

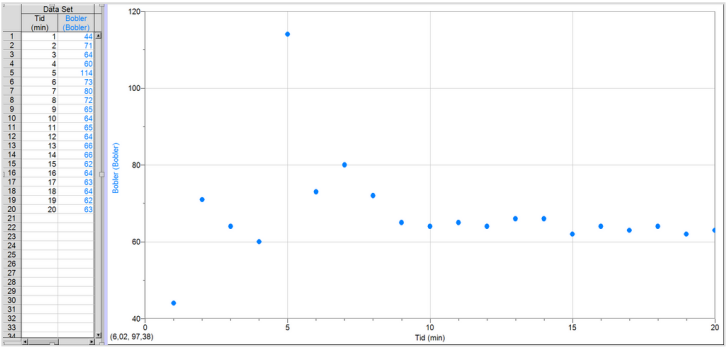


Gær i isvand

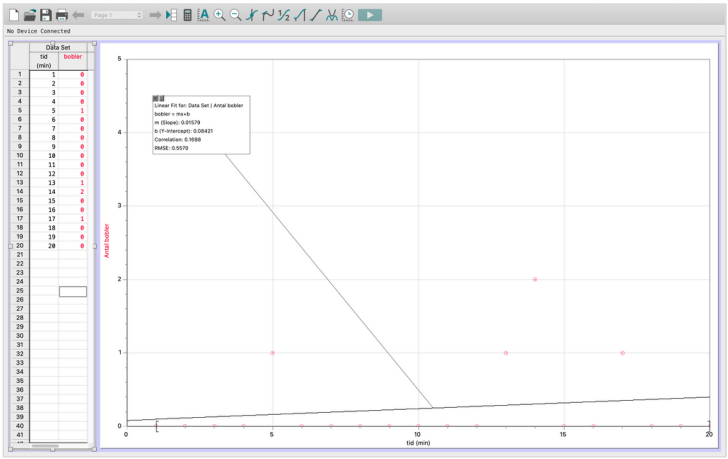
Forsøg med bagepulver



4 skefulde sukker

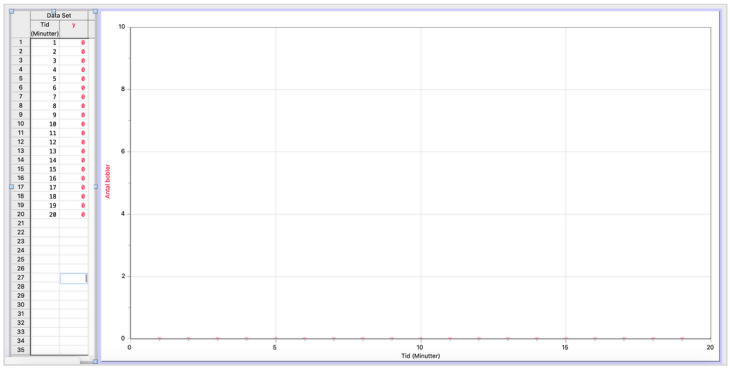


forsøg med syre(eddike)



Vi forventer at væksten vil være en del mindre kogende vand end i stuetemperatur da kogende vand vil dræbe cellerne

Test af temperatur (isvand)



salt

salt

salt

salt

tid

Nødvendige næringssttoffer

Bakterier

omgivelser

Bakterier

Sukkerstoffer

PH-Værdi

salt

Fugtighed

Iltmængde

H2O

Luftfugtighed

Fugtighed

Glukose

temperatur

Glukose

Temperatur

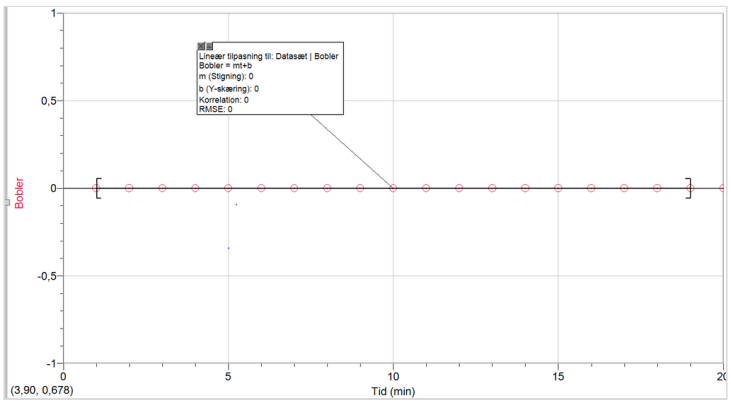
Temperatur

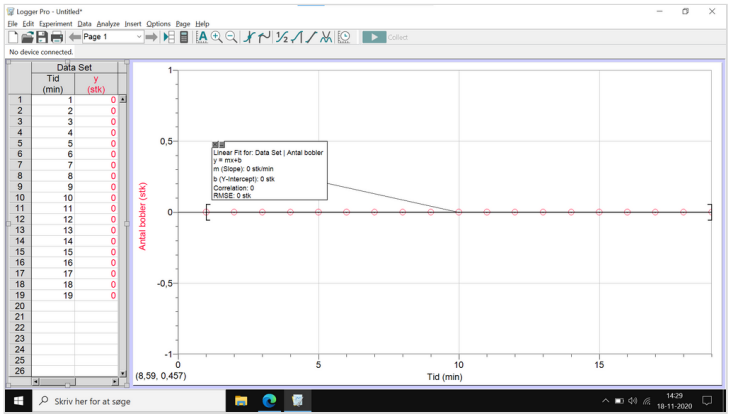
****

Hvad påvirker gærs vækst?

[redacted]

CAROLINE GRAM 17. NOV 2020, 18.29





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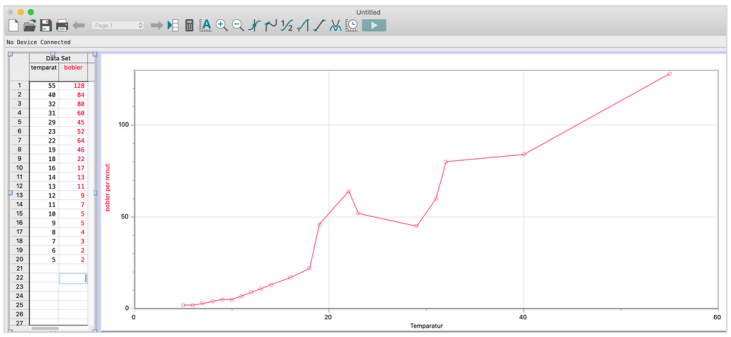
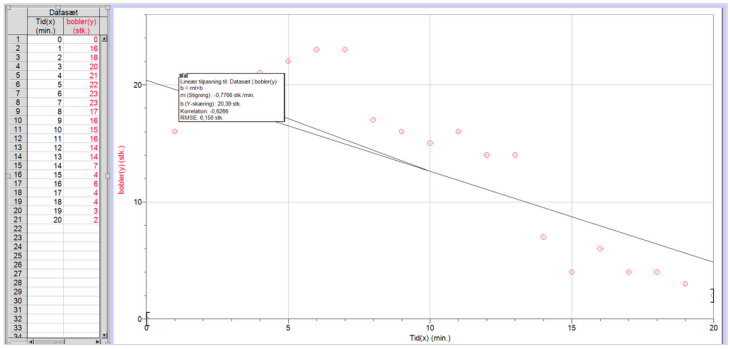
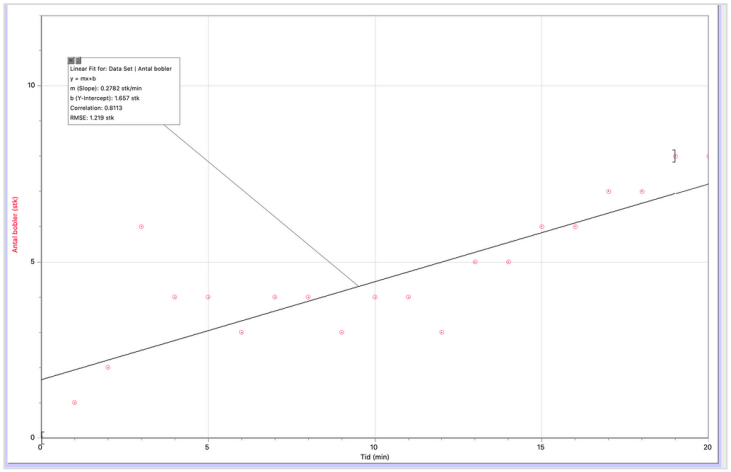
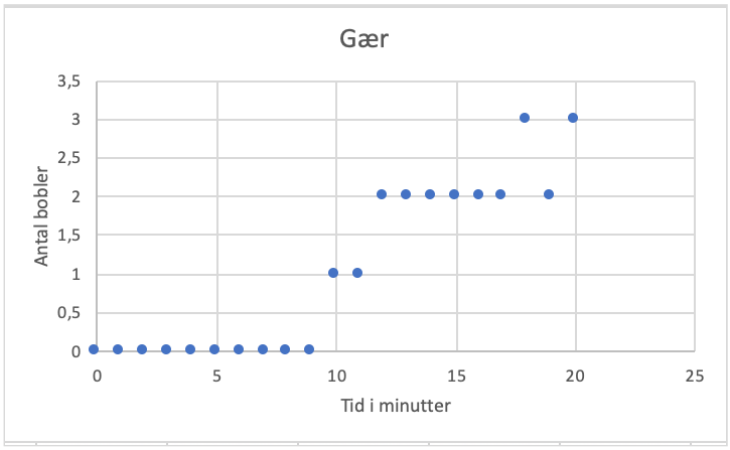








vandmængde

adgang til de rette næringstoffer
alkoholmængde

Tid

Omgivelser
Temperatur
Sukker
Alkoholmængden
Tid
pH-værdi

PH-værdi

Salt mængde

temperatur

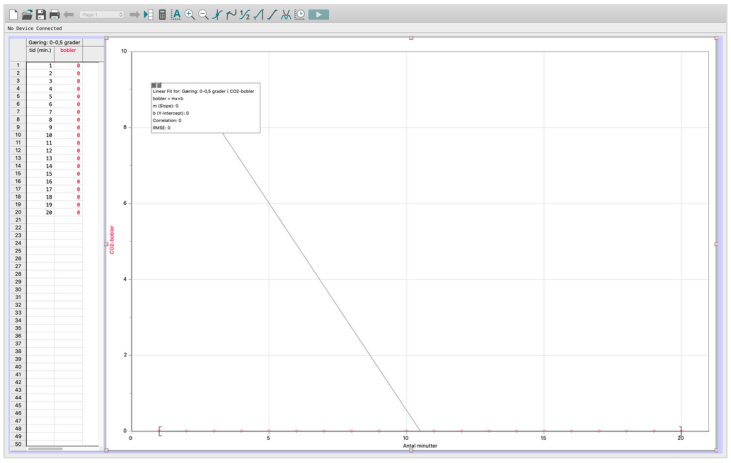
reber

Sukkemængde

Vandmængde

Gruppe 7: Gæring med is

Hypotese: Eftersom forudsætningerne, altså 0-0,5 celsius grader, for væksten er så lave, som de er, forventer vi få eller ingen CO2-bobler.



Temparatur
ph værdi
mængden af sukker
mængden af salt
tid
friskheden

Temperatur

Temparatur

sukker

Temperatur
mængde af sukker
mængde af salt
PH-værdi
tid

temperat

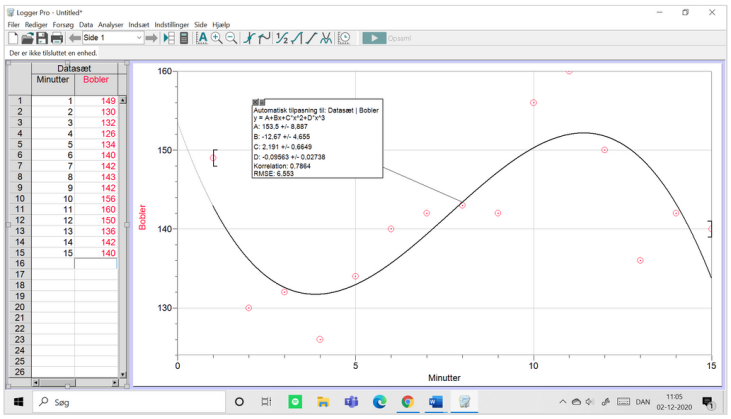
Temperatur

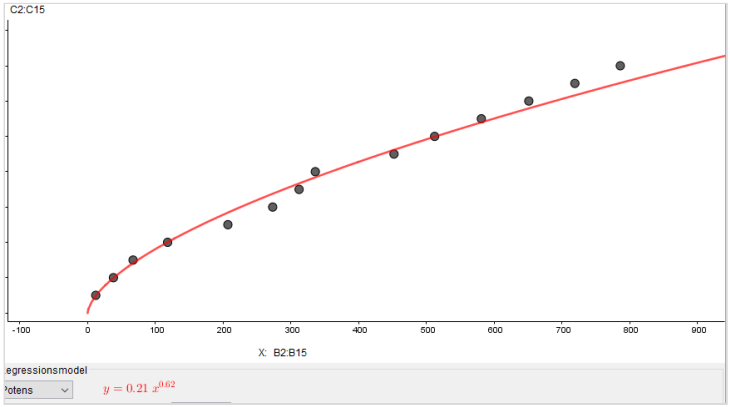
Vandmængde
mængden af tid
Alkoholmængde
Friskheden af gæren
Blandingen
Mængden af gær
Mængden af andre vækststoffer
Næringsstoffer
Saltmængde

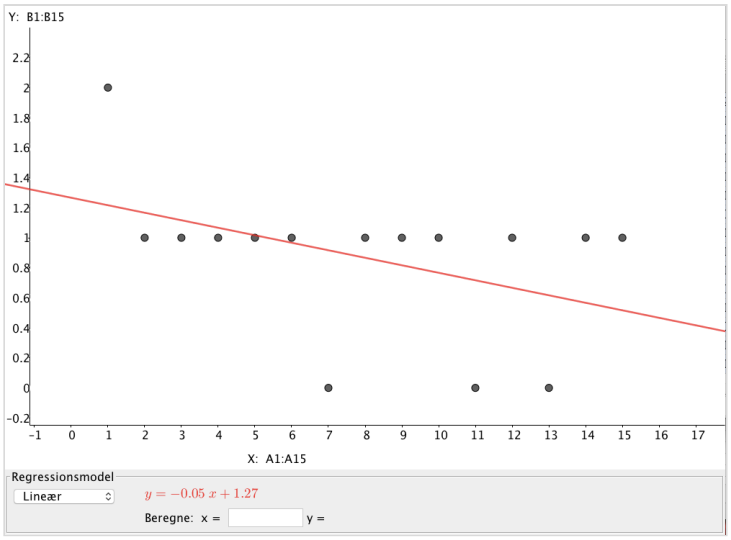
****

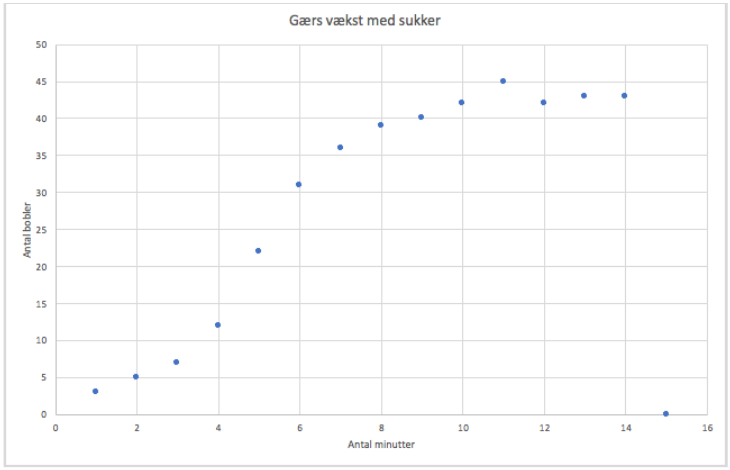
Hvad påvirker gærs vækst?

CAROLINE GRAM 23. NOV 2020, 14.29



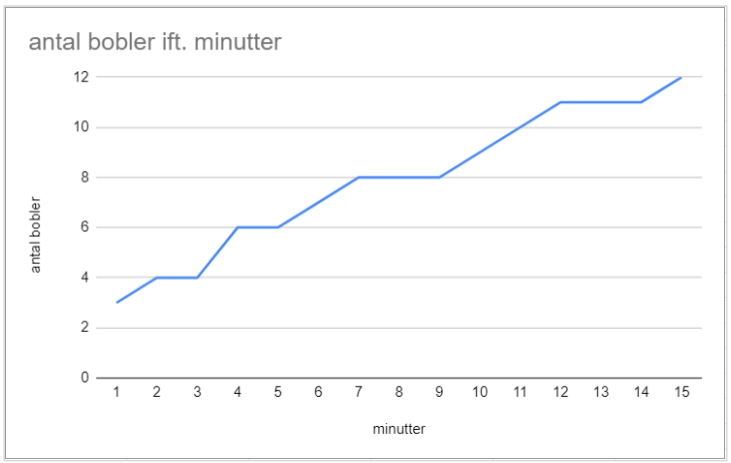






vi tror hvis man tilføjer mere gær, vil det hemme veksten af gærceller

Gruppe 4



HYPOTESE

Vi har en ide om at gærens reaktion vil være bedst omkring de 30-40 grader.

Hypotese: Vi vil gerne afprøve hvordan gæren reagerer med meget sukker. Vi har en hypotese om at gærcellerne vil blive mere aktive og vokse hurtigt

Hypotese: Vi vil gerne teste gærs vækst ved sur pH-værdi, bliver den mon hæmmet?

Hypotese: Vi har en hypotese om at gær vokser bedst i bestemte forhold. Fx vil dens vækst være hæmmet i salt, men vil derimod vokse bedre i det varme, da det vil sætte gang i væksten. Ydermere vil det også vokse bedre i edikt, da det er en syre, som vil gå ind og ændre på pH-værdien

Sukker? Salt?

Temperatur

konkurrence

at det er den eneste bakterie der er/sterilhed

Temperatur, næring

Luftfugtighed

Temp.

Øhm luft

Næringstoffer, ph-værdi

den har noget den kan spise

Luftfugtighed måske?

temperatur, pH-værdi, næring og plads

Temperatur, fugt, næringsstoffer

temperatur, tilstand/form, koncentration/densitet

PH-værdi

Temperatur, pH-værdi og enzymer

❋❋❋❋❋❋