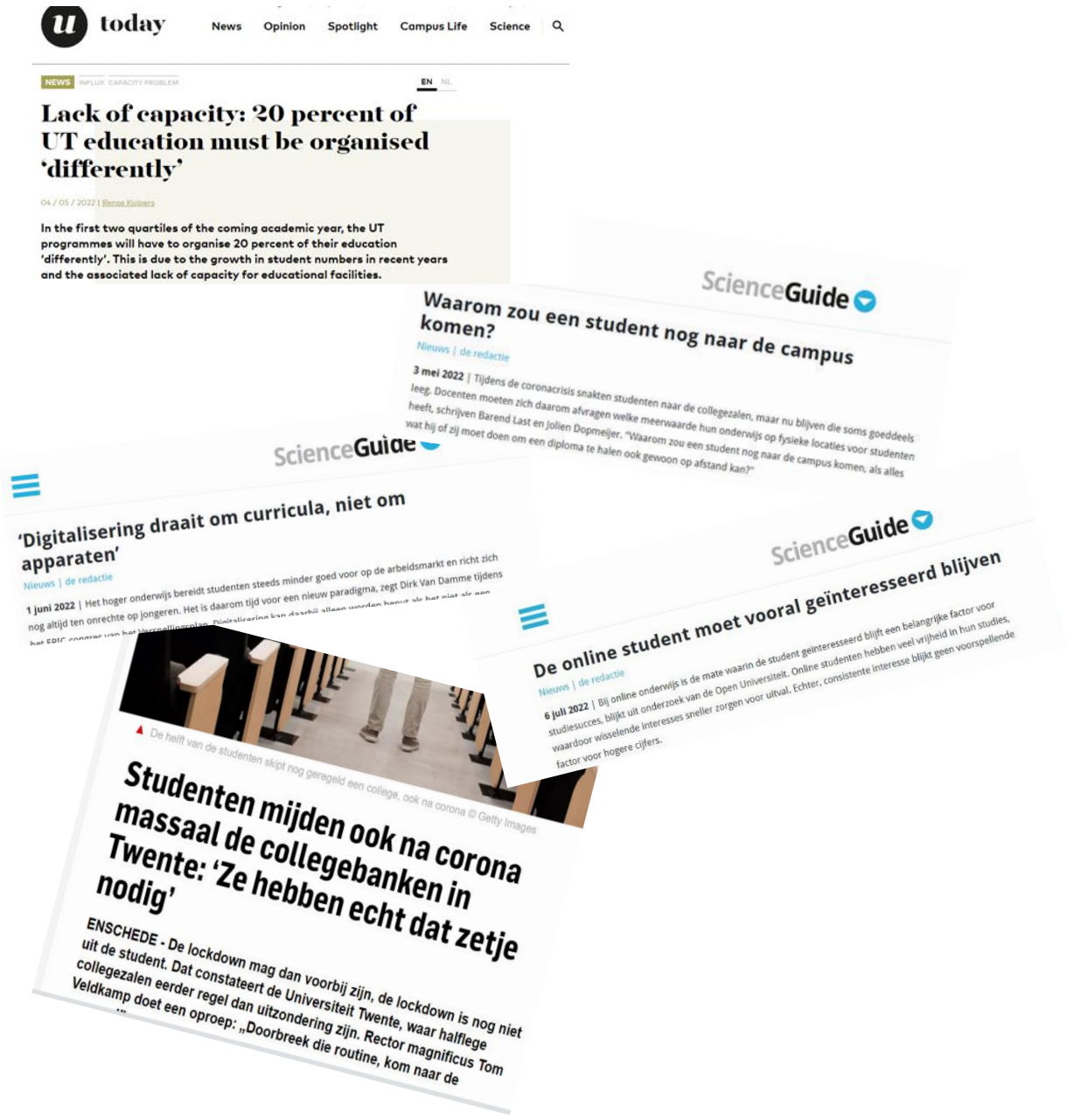
Developing blended learning in chemical education



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Preface and introduction of the definitions used in this research

To give a definition of the concepts used in a study is not obvious for scientist with a background in natural sciences. If we talk about physical quantities they have units, e.g., length is expressed in meters. If we talk about molecules they have a structural formula, the atoms the molecules contain determine their interactions with themselves and the surrounding molecules. In educational sciences we deal with people, interactions between people and their behaviour, this cannot be captured in a unit or a structural formula, therefore it is essential to describe what is meant with definitions as well as possible. This is to avoid misinterpretation.

As a natural scientist on an excursions in the field of educational science this was new to me. Being the only SUTQ participant from the faculty of Sciences and Technology, the lectures, the methods to do measurements and analyse data is conceptually very different from how I normally collect and analyse data.

In this research I use several terms that require a definition. Before I explain the aims, methods and outcomes of my research, I will have to describe what I mean with certain terms.

Blended Learning

The main educational concept that has to be defined is Blended Learning (BL). Since there are different ways to blend, e.g., combining different pedagogies, combination of media and tools employed in an e-learning environment and an integrated combination of traditional learning with web-based online approaches,[1] blended-learning is a rather ill-defined concept.[1] In the current day and age most people will associate BL with being a mix between online and offline learning. The most cited articles on this topic by Graham[2] and Garrison and Kanuka[3] define BL as "learning systems combining face-to-face (F2F) instruction with computer-mediated instruction" and "the thoughtful integration of classroom face-to-face learning experiences with online learning experiences." The nuance difference between these definitions is carefully discussed by Hrastinski,[4] in the article entitled "What do we mean with Blended Learning?"

In this project the definition of Blended Learning will be a combination of the definitions proposed by Graham and Garrison and Kanuka:

The thoughtful integration and combination of classroom face-to-face learning experiences with online learning experiences.

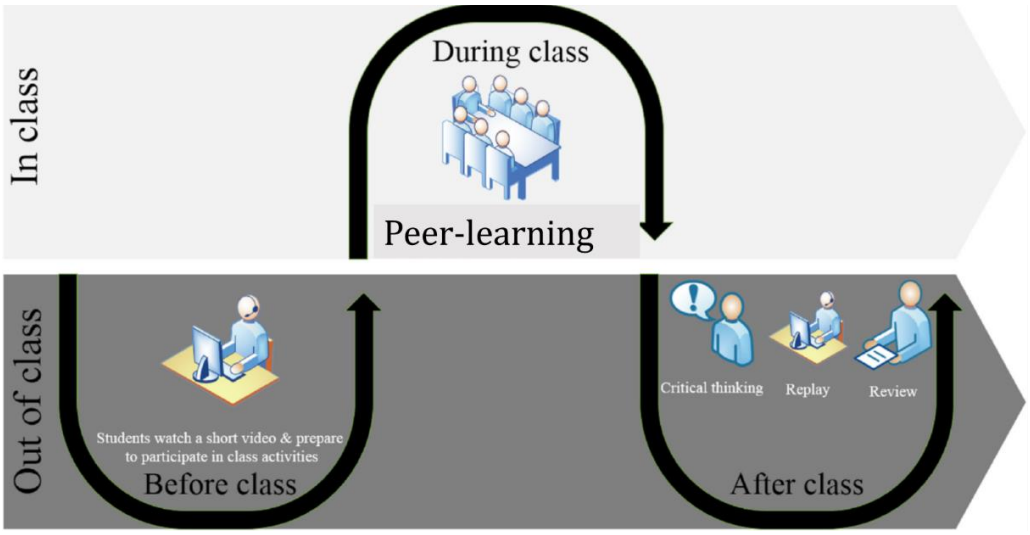


Figure 1: Flipped-Classroom, students prepare at home, during class they make tutorials and take part in a cooperative learning element. After class they reflect. The image is adapted from Munir et al. [5]

Flipped-classroom

According to Staker and Horn[6] there are four different models of blended learning. These are 1) the rotational model, 2) the flex model, 3) the self-blend model and 4) the enriched virtual model. The blended learning model used in this study is the rotational model. This model can be sub-categorised into 4 models and the main sub-model used is flipped-classroom (see figure 1). In this model the online content can be accessed by students remotely on their own time and pace. During the in class, face-to-face session lecturers spend more time directly interacting with students. In this SUTQ project the face-to-face sessions will be in the form of tutorials, a group discussion about a premade assignment and a diagnostic test.

Active learning

Active learning is any instructional method that engages students in their learning process. It requires students to do meaningful learning activities and think about what they are doing. So the key ingredients of active learning are student activity and engagement in the learning process.[7] Several methods of active learning exist. In this research I make use of peer learning.

Peer learning

Peer learning is an educational practice in which students interact with each other to attain educational goals.[8] Peer learning is a form of active learning.

Learning analytics

To get information about the online study behaviour of students learning analytics can be used. The society of learning analytics research gives the following definition of learning analytics: *learning analytics is the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs.*

Chapter 1: Introduction

The Covid pandemic changed the way we teach. In 2020 during the first lockdown all education had to be done online. This had impact on many aspects of teaching and learning, it impacted both teachers and students. Now about two years later we have learned a lot about online education and its advantages and disadvantages. It appears that the majority of the students would prefer blended education, where part of the education is given online and part face-to-face. This gives flexibility to the students, and opens up opportunities for teachers to experiment with quality education. It can also reshape the organisation of education, because less (big) lecture halls are required.

With these opportunities also several challenges can be identified. The most important being that blended education requires a change of role for both the teacher and the student. The teacher becomes a *facilitator of learning* instead of a transmitter of content and a student changes from a receiver of content to a *creator of knowledge*.[9] These changes could be uncomfortable for both parties, e.g., most teachers in the STEM (Science, Technology, Engineering and Mathematics) disciplines took part in teacher-centred classrooms,[10-12] where the main role of the teacher was to transmit content. For effective design of BL courses examples of well implemented courses are desired.

The University of Twente is part of several life-long learning initiatives and offers education to students from outside the university. For instance within the S&T faculty, health professionals follow courses to optimise and/or learn new skills. Another example is the Process Technology (PT) Master for chemical engineers from industry (https://www.utwente.nl/nl/tnw/pt-cursus/). Before the implementation of the Twente Educational Model (TEM) model, courses for the PT programme were scheduled on Mondays or Fridays allowing for the external students to follow the educational programme together with the regular students. In the TEM model this was no longer possible. It was therefore decided (already before the pandemic) to convert all the mandatory courses for the PT programme to blended-learning.

Chemical Equilibria, the course I teach is the first course of the PT curriculum. Together with the other teachers involved in the PT programme, I was quite concerned to convert the course to BL. First of all, in the national student survey the teachers of the courses in the Chemical Science and Engineering programme are evaluated very well because of their approachability. Our concern was that this would be difficult to maintain in blended-learning, when education would also take place online. Interactions between teachers and students, and students and students are important for learning. It has even been shown that lack of learner interactions makes learners drop out.[13,14] Secondly, if part of the education is online it will be asynchronized, this means that it will be challenging to know whether students need help or feedback. For my course in flipped-classroom format it will be very useful to know whether students have well prepared, e.g., watched the online content before they come to the F2F session where they can practise with the theory.

Furthermore learning requires two essential parties, the students and the teachers. Effective learning can only be achieved when both parties are at ease within the educational setting. Going from face-to-face to blended education provides challenges for both parties. These challenges became very clear from a cross faculty survey by Pei et al., held in summer 2020 after the first lockdown. This research shows that both students and teachers see the benefits of blended-learning, because it gives flexibility.[15]

This research also identified that students have more difficulties adapting to online learning,[15] which is of course part of blended-learning. For teachers the report (appendix 1) recommends that: *more allocated time to experiment with online and blended learning is necessary*. For students it is recommended that in the future *more attention has to be given to topics like self-motivation,*

time management and stress prevention. On the topic of study motivation the report states: *Some students indicated that they struggled with online learning and feel "demotivated and disoriented, getting stressed".* Teachers have similar concerns*, it's difficult to reach out to students to motivate and keep them on track.*

The pandemic has caused that education had to be given online. Several educational elements have been developed that worked well and maybe even better than in a classical face-to-face format. It would be reasonable to keep on using this educational material and a logical next step would be converting education to BL. The big question is how to do it in such a way that productive learning environment is created.

BL needs a student-centred pedagogy even more than face-to-face teaching. This presents the opportunity to implement student-centred pedagogies like active-learning. Here students are encouraged by the teacher to be actively engaged in their own learning process. Active learning activities promote higher order thinking skills resulting in deep, rather than superficial learning. If implemented in a good way the learning outcome could increase.[7] Moreover many active learning activities require interactions between students and instructors and students and students. These interactions could prevent the feeling of disconnectedness that students experience in online courses.[14]

Student-centred learning also presents a challenge for the teacher. In a student-centred classroom the teacher's role and identity change.[10] Most (STEM) teachers took part in teacher-centred classrooms.[10-12] Converting their education to student-centred education means for many of them that they will go out of their convert zone. Moreover implementation takes time and dedication and the latter might require prioritisation of teaching over other tasks.[16] These and other more complex barriers currently prevent the implementation of active learning in BL.[12] Having examples of how student-centred learning and/or active-learning can be implemented in their teaching might encourage teachers to implement it.

In addition students want to receive feedback from teachers and when this does not happen within the expected timeframe of the student, they tend to get demotivated.[13,17] On the other hand it cannot be expected from teachers to be available whenever students are studying. Agreements about when interactions between students and teachers occur are therefore desirable.

To overcome these problems it is necessary to rethink how we teach and redesign our teaching. Examples are needed, experiments have to be performed and time needs to be allocated to do this. The most important stakeholders in this process are the teachers, their role needs to change from transmitter of content to facilitator of learning. Teachers therefore will have to change the way they teach, implement new learning elements and evaluate the elements. To do this well it is necessary to step out of your comfort zone and experiment with teaching. In a sense for the teacher it is entering a learning trajectory and therefore the teacher can be seen as a student too. Teachers need to feel empowered to perform this important change in our educational system. Only when teachers are confident that a new way of teaching is working then students can optimally benefit.

Apart from the changing roles of teachers and students in BL learning, the design of BL is a challenging task. According to Boelens et al,[18] there are four key challenges to the design of BL:

1. Incorporating flexibility
2. Facilitating interaction
3. Facilitate student's learning processes
4. Fostering an effective learning climate

These challenges are interlinked and it is difficult to study them individually. From a teacher's point of view, as was stated in the report by Pei et al., it is important to reach out to students (facilitating interactions) to motivate (fostering an effective learning climate) and keep them on

track (facilitate student's learning process). From a student's point of view challenges arise in the form of self-motivation, time management and stress prevention. In addition, two years of (part) online education have changed the student's perspective on university education. The flexibility online education offers, the not having to travel and being able to affordably live at one's parents made students reluctant to come back to the campus. Face-to-face activities with added value for the students have to be designed such that students see the need to come to the university.

Evaluation of the educational experience

When new teaching methods are introduced, the student perspective is very important. For online learning experiences, there are three factors that contribute to the learning experience: 1) convenience, 2) learner characteristics and readiness, and 3) antecedent conditions that may promote teaching quality, but are not directly responsible for it, e.g., these can be teacher motivation and appropriate teacher training.[19]

A theoretical framework that describes student's perceptions of quality in computer mediated communication, such as BL, is called the Community of Inquiry model (figure 2).[20] This model assumes that learning occurs through the interaction of three core elements: teaching presence, social presence, and cognitive presence. Here teaching presence reflects the interaction with instructional tools and learning activities, social presence reflects the interaction with other learners and the cultural aspects of the learning environment and cognitive presence reflects the interactions of the students with the course content.

An example of cognitive presence is having (online) discussions. For such discussions there are four levels of cognitive presence connected to the learning outcomes: triggering, exploration, integration and resolution/application.[21-23] During the triggering event the key questions/ issues in the discussion are identified. In the exploration phase the opportunities and challenges are discussed. During the integration phase recommendations and conclusions are drawn from the discussion. In the resolution/application phase the lessons learnt from the discussion are applied.[23]

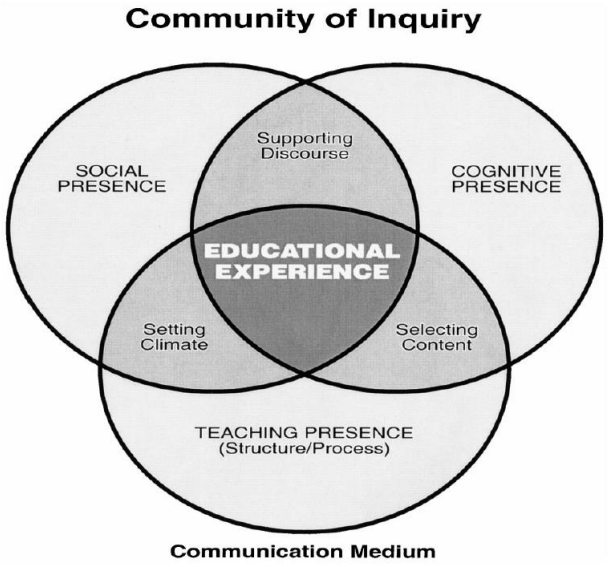


Figure 2: Community of Inquiry model as, proposed by Garrison et al.[20]

The Community of Inquiry framework is translated into a survey that is used to measure educational experience.[24] This survey consists of 34 questions divided over Teaching Presence, Social Presence and Cognitive Presence. There is a debate in literature whether Learner Presence should be added to the Community of Inquiry model.[25] Learning Presence reflects the student's

self-regulation including factors like motivation, behaviour and development. It is also argued that peer facilitation should be included in the social presence element.

The framework is criticised because teaching presence in an online context is far more than delivering lectures as is done in face-to-face classes. The online world provides an increased richness in ways students and teachers can interact and online learning material is available and used. To narrow down the pedagogical and technological elements connected to this richness of teaching methods in a single concept called teaching presence does not give the insights it could give.[19]

Therefore in addition to the Community of Inquiry model, seven distinct factors that describe student's perception of online quality. These factors that all contribute to the educational experience are:[19]

1. Instructional Support, refers to the perceptions of the students regarding the techniques the teacher uses for input, rehearsal, feedback and evaluation.
2. Teaching Presence, refers to the perception of the student regarding the quality and timeliness of communication in lectures, directions and individual feedback including encouragement.
3. Basic Online Modality, refers to the use of learning management system including grading, navigation methods and announcements
4. Social Presence, refers to the perceived quality of student-student interactions, e.g., shared learning and collaboration.
5. Online Social Comfort, refers to the ability of the instructor to create an anxiety free productive learning environment.
6. Cognitive Presence, refers to how students experience whether they are stimulated by the learning material and the instructor to reflect deeply and critically think about the learning material.
7. Interactive Online Modality, refers to the high end uses of online tools and functions.

Learning analytics

Whenever a student interacts with a learning management system, videocall software or another online environment intended for studying, the student leaves a digital footprint. Learning analytics is the process of using these data sources to study and ideally improve teaching and learning. It has for instance been shown that learning analytics can help to support students in BL,[26] can be used to unveil learning strategies in a flipped classroom[27] and can predict the success of students in online courses.[17]

Depending on the data gathered, different levels (see figure 3) can be achieved.[28] Using learning analytics at the descriptive level will provide information about what happens in the teaching and learning environment. The diagnostic level covers the factors relating to the performance of students and their behaviour. At the predictive level specific types of analysis are applied using machine learning algorithms. At the perspective level a prediction model is used to guide and direct the students on an individual level.

Depending on these levels different rules concerning the privacy of data will apply. At the lowest two levels it is not necessary to collect the data concerning the online study behaviour per individual student. The more this online study behaviour is correlated to the actual learning outcome per student, the more personal data are needed.[29] When one wants to collect these data one should be careful not to breach the General Data Protection Regulation (GDPR). Even for collecting data at the lowest levels explicit permission of the students is required before data can be collected.

With this in mind it is important to consider how one would like to use the learning analytics data. In the research by Pei et., teachers indicated that it is difficult *to motivate students and keep them on track.*[15] Currently knowing whether students accessed the online content or not may already be a great tool for a teacher to get insight in whether the students are on track or not. In this way learning analytics is used in a descriptive manner e.g., the teacher will know from the learning analytics data whether the students in flipped-classroom setting come prepared to the F2F sessions.

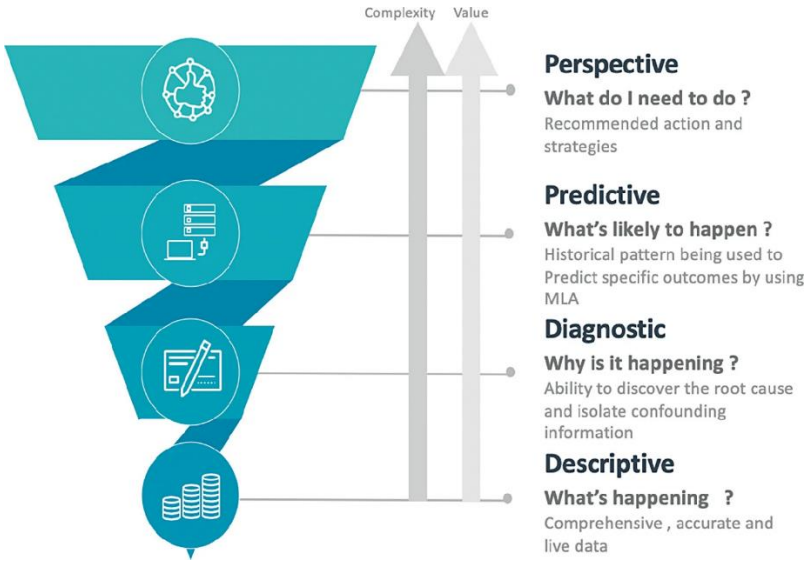


Figure 3: Levels of learning analytics as discussed in[28]

If data are collected on a student population level and not on an individual student level, the teacher will more or less have the same data as when students are present in the lectures. In the latter case there is no guarantee that students present at the lectures are actively participating. It is not uncommon that students show up, sit in the back, open their laptop and play videogames or are more engaged with each other than with the learning content provided by the teacher.

At the University of Twente, there is not a lot of experience in using learning analytics as tool to obtain information about the online learning behaviour of students. The learning management system of the University of Twente, Canvas, provides the possibility to collect data. TELT has developed an award winning dashboard tool that can be used in Canvas to follow the study behaviour of students. In this SUTQ project I will make use of this tool.

There are six different indicators that can be studied using learning analytics: 1) learner-related, describing the learner's background, 2) action-related, giving information about the actions of the learner, 3) content-related, reflecting the interactions of the learner with the content, 4) context-related, giving information about where and when the learning takes place, 5) result-related, presenting the information about the learning outcomes and 6) social-related, reflecting the social interactions between the individuals present in the learning management system.[30]

Currently there is not a lot of knowledge on what are the relevant data that can be collected and how these data could be interpreted. Moreover a lot of personal information about the learners is difficult to access because of the strict GDPR rules. Since this is one of the first courses where learning analytic is used as a tool, the main focus will be on using it on a descriptive level. The focus will therefore be on action-related, content-related and context-related indicators.

Learning communities

The report of Pei et al., showed that during the first lockdown in 2020 students felt *"demotivated and disoriented, and were getting stressed."* For students it was therefore recommended that: *more attention has to be given to topics like self-motivation, time management and stress prevention need more attention in the future*. In order to tackle this issue, it is important to understand why students felt anxious.

Most students are adolescents, they belong to the age group between 10-25. This age group has unique requirements concerning social interactions. In general this group has a stronger sensitivity towards social belonging. Where interactions with friends are (becoming) more important than those with parents. These interactions are crucial for their personal and emotional development.[31] During the Covid 19 pandemic this age group experienced social and emotional difficulties that can associated to mental health problems.[31]

From the start of our lives, we humans develop a sense of belonging. This is important for our well-being. [32] Belongingness has strong influence on emotional and cognitive processes.[33] To belong is important for the overall learning experience and satisfaction.[34] A way to achieve a sense of belonging in learning is through learning communities.[35] In a productive learning community students will feel a sense of belonging and therefore less isolated and more motivated to work. Peer-learning, where students interact with other students to attain educational goals,[8] could be a good basis for a learning community. In this SUTQ project I will experiment with peer-learning activities during the F2F sessions.

Focus of this research and research questions

For making my course available to both first year BSc students and first year MSc students from industry it was decided by the educational management that the format should be Blended-Learning. Within this format flipped-classroom is chosen where students study online and apply what they have learned in the classroom. In order to be able to facilitate the learning process of the students as best as possible as a teacher it is important to understand the online learning behaviour of the students. In addition order get the best learning experience the online and offline content need to be balanced. This provides the opportunity to design and test peer-learning activities with the aim to enhance the learning outcome and experience.

In this SUTQ project I will therefore focus on ***how to support and facilitate the learning process of first year BSc students in a BL course on Chemical Equilibria?***

During this SUTQ I will try to answer the following research questions:

1. How can one use learning analytics data to better understand how students learn in an online learning environment?
2. What kind of learning analytics data are required to influence the online learning behaviour of students?
3. How does the incorporation of face-to-face peer-learning elements affect the learning outcome and motivation of the students?

Learning innovations

In this SUTQ research two types of learning innovations will be considered. The first one is making use of a learning analytics dashboard in Canvas. The second innovation is implementation of peer-learning elements in the F2F sessions.

Stakeholders

Apart from the 2021-2022 cohort of CSE students there are several stakeholders. Several teachers of CSE have been involved in the development of the BL PT course. The results of my research

will be interesting for the other teachers in the PT-course as well as other teachers that would like to convert their teaching to BL.

Linlin Pei has been involved as an educational specialist in the development of the PT-course. She recently started a PhD trajectory and is currently defining her research project. This SUTQ will be related to her research. I will therefore collaborate with Linlin Pei to avoid too much overlap.

André ten Elshof is the OLD of CSE, I have had a discussion with him about my SUTQ and I will keep him in the loop.

Peter Groothengel from TELT is one of the responsible people from TELT who is implementing the dashboard to follow learning analytics in Canvas. He or one of his colleagues will help me to setup the dashboard in module 4. Since this will be one of the first modules in which this dashboard will be used I can help them with improving and testing this new Canvas application.

The whole UT community that is interested in Blended-learning and using learning analytics.

Structure of this report

For this SUTQ research first a research plan was written, this plan can be found in the next chapter and will have some overlap with this introduction chapter. Some adjustments had to be made to this research plan, because the learning analytics data did not have the right time resolution to answer the original research question. In chapter 3 the methodology will be discussed. The outcome of learning analytics part (chapter 4) and the peer-learning part (chapter 5) will first be discussed separately followed by a chapter with an integrated discussion(chapter 6) where the seven factors of student's perception on the quality of online education will be addressed. Chapter 7 will include the concluding remarks and recommendations. This report will be concluded with 10 tips for setting up a course in blended learning. These tips are based on the research and my personal experiences setting up a course in BL.

Chapter 2: Background of the course, baseline data and initial research plan

The research in this project will focus on a BL course on Chemical Equilibria (3,5 EC) intended for first year Bachelor students that are enrolled in the Chemical Science and Engineering program (CSE), for them the course is scheduled in module 4. I am the main teacher in this course and during the tutorials one of my PhD students helps me. This course is the first course mandatory for the Process Technology (PT) Master for chemical engineers from industry. So there are two different groups of students with different backgrounds, the BSc students, typically 50-60 and the PT students, currently 1-5 per year, but a growth of the student number is anticipated. The PT students have signed-up for this Blended-Learning program and know on forehand what is expected from them.

For the BSc students this will be the first BL course they encounter. In my experience from talking to students that failed the first exam in 2021, a different attitude is required. There are several skills students will need to have or will have to develop in order to successfully participate in a blended learning course. These skills include organisation, discipline, time-management, skills in using technology to support their learning process and self-efficacy to control their own learning processes.[18] As a teacher you would like to be able to support and facilitate their learning process.

This SUTQ project focusses on ***how to support and facilitate the learning process of first year BSc students in a BL course on Chemical Equilibria?***

Based on the report by Pei et al., I hypothesise that interactions between the teacher and the students and the students and students are important for the motivation of the students and will contribute to keeping the students on track. I have been teaching Chemical Equilibria since 2015. From 2015-2019 it has been given in a F2F format in a colstruction way where lectures were followed by tutorial session. On average 80% of the students would attend the lectures and 70% of the students would stay for the tutorial session. In the first lecture in general all the students that were enrolled would come. In general most students that frequently attended the F2F sessions would pass the exam.

The intention was to convert the course Chemical Equilibria to BL in 2020, but that year it was converted to fully online because of the first lockdown. There was a clear difference in approach between 2020 and 2021. In the first year the course was held online, i.e., the students could watch minilectures and pencasts and could work on the tutorials themselves. A clear weekly schedule was made with time allocated to contact the teachers for questions or help with the tutorials, but only a few students sought help. No online meetings were planned and the examination was completely adjusted to an online format. In 2020 the interactions between the teacher and the students were very minimal. However, I observed that when open questions were asked during the exam the students used more, and their own language in their answers, compared to exam answers in previous years. An explanation for this observation was that the students could better focus on the short minilectures of maximum 15 minutes in comparison to live lectures of 45 minutes and could rewatch the content if required.

In 2021 I tried to interact with the students in different ways. Before every self-study session and online tutorial an online moment was scheduled via Teams. Attendance reports of these meetings are available and the number of students that were attending these meeting can be found in table 1. During these meeting the webcams of the students were always turned off. Questions were mainly asked in the chat. I also tried to interact with the students via anonymous surveys per topic in Canvas. Via these surveys they could ask questions to me and I answered them during the online contact moments.

The final three tutorial sessions were converted into group discussions and could be held on campus (F2F), this was very much appreciated by the students. During these sessions I could test one peer-learning educational element that I designed for the BL course that should have started in 2020. This will later be explained in more detail.

Date	Online activity	# participants
20-Apr 2021	Contact moment before self-study	47
21-Apr 2021	Online tutorials	35
22-Apr 2021	Contact moment before self-study	27
28-Apr 2021	Online tutorials	25
29-Apr 2021	Contact moment before self-study	13
04-May 2021	Online tutorials	20
06-May 2021	Online tutorials	16
18-May 2021	Contact moment before self-study	11
27-May 2021	Online question hour	9

Table 1: students participating in online activities, data from the Teams attendance reports (2021)

In table 1 can be seen that the number of participants decreases in time and that the average number attending the online education is much lower than the percentage of students that participated in the F2F sessions in the years before COVID (personal observation during the lectures, no data were collected about student attendance in these years). This can be explained by several things but are most likely a combination of lack of motivation and falling behind schedule. From the years the course was taught F2F also a decrease in the number of participants was observed, but in general about 70-80% of the students that did the exam came to the F2F sessions. Lower attendance in the F2F sessions correlated with exams (of other courses) scheduled the day after the F2F session or the Open Nederlandse Chemie Sportdagen (always held in the Ascension day weekend). However a decrease in participating students from 47 to 11 students was not observed in the F2F class. In 2021 many students passed the course, but the average seemed a bit lower than in other years. It is difficult to compare the exact average grades because, apart from the fact that students in 2021 followed the course online differences between cohorts cannot be excluded. In the years 2015-2019 also not many students would come to the question hour, so 9 students in 2021 is not an anomaly.

The concepts that are learned in chemical equilibria are important for the whole curriculum of Chemical Science and Engineering. That's why it is the first course in the PT master for students from industry. For students it would be beneficial if they understand and remember these concepts, it is essential pre-knowledge. From the data in table 1 it cannot be concluded that the students did not watch the minilectures and made the tutorials, it could be that they studied in their own time. In general this is not a problem, but as a teacher you cannot help them, advise them or discuss with them when you don't know what they are up to.

Talking to other teachers about their experience with online education, the conclusion is that as teachers we don't have any clue about what the students are doing online and when they are doing it. In F2F classroom you know who is attending the lectures and tutorials and synchronisation occurs naturally. Especially in the colstruction format where lectures are followed by tutorials. To achieve the best learning outcome in a blended learning course it is important that the planning of the teacher and the students are more or less synchronised. For instance if tutorials are scheduled on a certain topic, the students should have studied the theory before the tutorial session, because then the best learning experience will be achieved. The

problem is that currently we teachers have no idea when students study online and what triggers can be used to influence their study behaviour.

The focus of this SUTQ project is to investigate how to support and facilitate the learning process of first year BSc students in a BL course on Chemical Equilibria. The format of Chemical Equilibria in 2022 will be Flipped-Classroom (see figure 1). The students have to study the theory at home, by watching minilectures and pencasts, and/or by reading the textbook. The obtained knowledge is used in a F2F classroom in the form of tutorials and an assignment. The best learning experience will be achieved when the students have studied the theory at home and use the theory during the tutorials when answering questions, work on problems together, explain to each other how to answer the questions and confirm their answers or ask questions to the teacher.

In order to be able to support/facilitate the learning process as a teacher I would like to have insight in whether and when they have studied the theory. From the data in table 1 it can be concluded that as a function of time, less students have participated in the online contact moments. This does not necessarily mean that the students did not study. It could also be that they decided to plan the self-study differently, because of exams or preparation for lab work. Since the minilectures and pencasts are available online, knowing whether students have seen this online content will be a first indication of whether they come to the tutorials prepared. In addition if students do not show the intended study behaviour one would like to influence this.

Depending on the time resolution of the data in the dashboard, it could be possible to investigate whether sending out announcements affects the time at which students excess the online content. Woodward et al., studied the effect of four different engagement strategies: 1) No engagement, 2) sending an email reminder, 3) emails with "Video Reminder" in the subject line and 4) emails with direct link to the homework. As can be seen in figure 2, the engagement strategies have an impact on the behaviour of the students. If you make their life as easy as possible they will do their homework.[36]

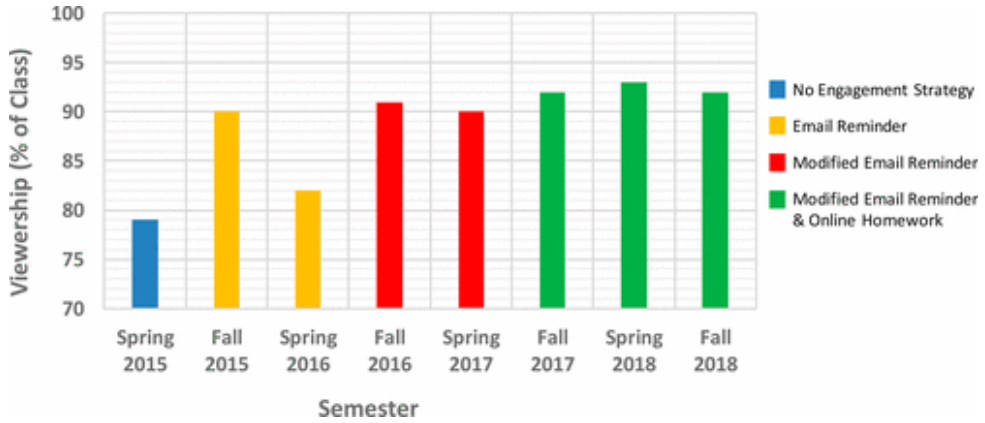


Figure 4: Impact of engagement strategies on pre-lecture video viewership. The timing and subject lines of e-mails were consistent throughout the semesters for the modified e-mail reminders.[36]

If possible, I will use a similar strategy as Woodward et al., where I will send email reminders or announcements in Canvas, before the scheduled self-study moments and measure the viewing behaviour of the students. Here I will compare sending emails with and without links to the Canvas page containing the minilectures to study whether there is a correlation between sending the links and students following the links. In this part of the study I will use anonymised data extracted from Canvas, via the recently developed dashboard in Canvas.

The research question I aimed to answer was:

1. What is the effect of sending Canvas announcements/emails on the moment at which students access online study material?

As could be read in the introduction this research question was revised and split up in two (research question 1 and 2). The dashboard was just ready in time for my module and the time resolution was not good enough to answer this question. To answer this question the dashboard should have provided me with the number of unique student viewers per hour, these data were not accessible in the current format of the dashboard. In the methodology chapter the dashboard and the data that could be collected will be discussed.

Assignment 1

One of the expectations of BL is that if it is implemented in a good way it will lead to active learning, in this learning pedagogy students are actively involved in their own learning process.[37]

The research question I aim to answer is:

2. How does the incorporation of a newly developed peer-learning element affect the learning outcome of the students?

To answer this question (in the plan this is question 2 and in the final research this is question 3) I will test a new method to encourage active learning via peer instruction[38] or collaborative learning, this also encourages students to interact with each other and with the teacher. An easy way to motivate students is to give them credits when they actively work on assignments. Personally I don't like this you get a cookie if you jump approach. Whether they do an assignment or not, is the responsibility of the student. What I think is important is that they learn from the assignment. In order to achieve this I developed the following strategy:

- They make the assignment at home (time will be allocated to do so)
- In subgroups in the presence of a teacher/tutor, the students have 45 minutes to explain to each other how to complete the assignment. I won't give them any answers, I will only give them tips. I have tested this approach in 2021 in during the group discussion sessions and I was surprised how actively the students participated, the answers were provided in 2021, in 2022 I won't provide them, but when they have specific questions they can come to the office hours (online and offline), that I will schedule during the self-study.
- They can bring the completed assignment as reference material to the exam. If they want to do so they will have to hand it in after the exam, so I can check whether it only contains the answers and it is not a cheat sheet.
- During the exam I will make a similar question where they will have to use the same approach as in the assignment. I will evaluate whether they make the question better than similar exam questions used in previous years. In addition I will make an exam question where they have to apply the same approach in a different situation/context.
- After the exam the students will be interviewed by Linlin Pei. She will use this interview for her own research, but will incorporate questions about the assignment
- Based on the outcome of the exam and interview a Canvas survey will be send to the students with some additional questions.

If possible I could use the Canvas dashboard on learning analytics to study when the students start working on the assignment (when did they download it, did they do it at the time slot I assigned?) In principle the theoretical background, needed to complete the assignment will be discussed in the first 2-3 weeks, the assignment will (most-likely) be discussed in week 5. I will send them an announcement that they can start the assignment in week 4 and allocate time in that week in the self-study schedule (the exact planning may vary depending on the scheduling of the course, normally the timetables for module 4 are known in January). I will monitor if the students open the assignment at the allocated timeslot.

Chapter 3: Methodology

Designing the course

Learner convenience contributes to a positive learning experience.[19] A well organised leaning management system will help to achieve this. The University of Twente uses Canvas as learning management system. During the first lockdown in 2020, when the complete course on Chemical Equilibria was online the Canvas Module was designed such that everything could easily be found. This was done with the student's wellbeing in mind.

The first page was a module overview containing the topics and links to the weeks of the module. This overview of the course in 2022 can be found in figure 5. The weeks in figure 4 are linked to the respective weeks. Following this link you'll get to figure 6 and 7. First per week the learning goals were displayed, followed by a program for that week (figure 6). In this schedule it is also indicated whether it is an in person or online activity. Following the link for the online activities will lead you to a Teams meeting. During every online self-study the teacher was available, both online and in person.

How do you get started?

There are several tasks for each of the weeks of the module, all listed below. Every week is linked to its own page, with detailed information about the learr information about the tutorials can be found on this page.

Week	Topic
Week 1 25/04-29/04	Recap Thermodynamics
	Introduction to Chemical Equilibria
	Gibbs Free Energy
Week 2 02/05-06/05	Chemical Potential
	Phase Equilibria
	Mixtures and Solutions
	Colligative Properties
Week 3 09/05-13/05	Colligative Properties
	Chemical Equilibria
	Discussion assignment 1
	Acids &Bases
Week 4 16/05-20/05	Diagnostic test
	Exam
Week 11 06/07	Re-exam

Figure 5: Designed Module Overview page on Canvas

Week 1 (April 25- April 29)

Learning goals:

At the end of this week a student should be able to:

- to apply multivariate calculus in thermodynamics.
- Explain what a dynamic equilibrium is
- investigate or differentiate the Gibbs Free energy as a function of p and T.

Week overview/ detailed planning

Date	Hour	Activity	online/in person	extra information
April 26	6	Introduction lecture	In person	
	7-9	Self-study: Recap Thermodynamics	online self study teacher available for questions online and in CR4207	link to online meeting
		Introduction to Chemical Equilibria		
		Gibbs Free Energy		
April 28	8-9	Tutorials: Multivariate Calculus Gibbs Free Energy and Gibbs Helmholtz relation.	tutorial in person	

Figure 6: Designed planning per week on Canvas

The detailed task overview (figure 7) gives an overview of all the different tasks. This can be reading the book, watching pencasts or minilectures (the link will open a vimeo page), tutorials (the link will open the tutorial exercises) or a feedback quiz, which links to an anonymous survey that can be used to ask specific questions about the minilectures and pencasts.

Task Overview

Topic	Task	
Recap Thermodynamics	Book:	Atkins 10: 3D, Multi-variate calculus (109-111) Atkins 11: 3E
	Mini lectures/ pencasts:	Pencast: Maxwell relations
		Pencast: Fundamental Equations and total differentials There is a small mistake in the pencast can you spot it?
	tutorials:	Multivariate calculus Short answers Answers tutorials Tutorial slides
	Feedback quiz	Recap Thermodynamics
Introduction to Chemical Equilibria	Mini lectures/ pencasts:	Mini-lecture 1: Dynamic Equilibria
		Mini-lecture 2: Gibbs Free Energy and Spontaneity

Figure 7: Designed detailed task overview on Canvas

The process of data collection in detail

The data collection through this project is based on three sources:

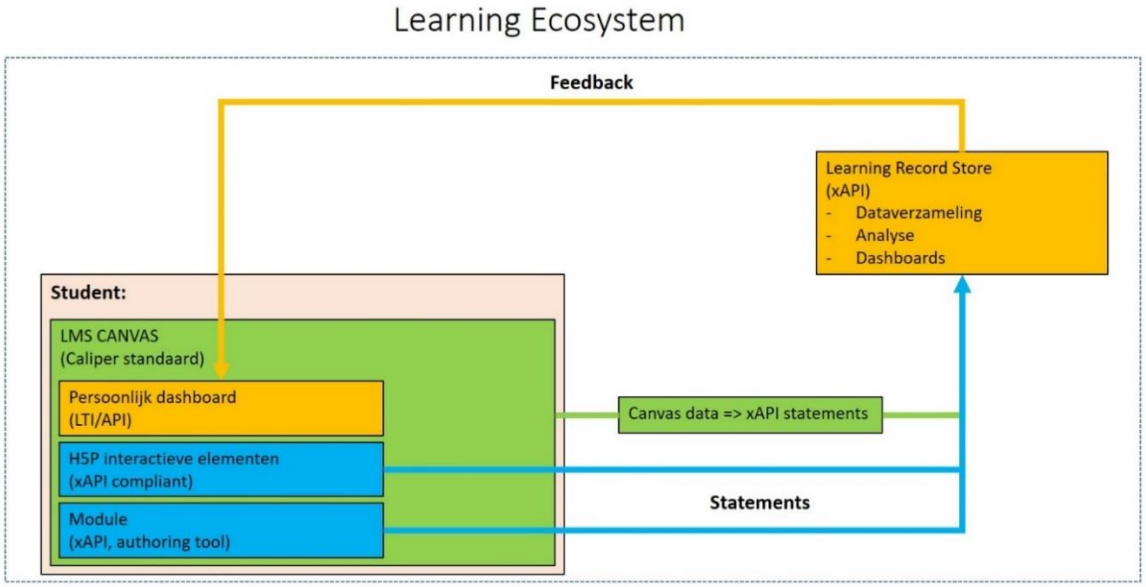
- H5P interactive content creator;
- Dominknow ONE, authoring module for content creation;
- Canvas LMS, for hosting content and discussion platform.

All these sources where able to use the xAPI international standard for collection of learning data. This was very important, because the xAPI standard was the foundation of this project.

When students used the educational content which was created in one of the three sources (H5P, Dominknow and Canvas), the generated data was send in realtime to the Learning Record Store (LRS). For the Canvas data it was necessary to place a translation script between Canvas and the LRS. This was needed because Canvas wasn't able to produce xAPI data from itself. The script was put in place so Canvas data was translated to xAPI data.

The Learning Record Store collected all the data and processed this data into dashboards for students and teachers. These dashboards where send back to Canvas so it was accessible for students and teachers in Canvas to get insight in the learning process of the education module. The schematic overview of this process can be found in scheme 1.

Scheme 1: Schematic overview data collection



Dashboard

Because for the Canvas data it was necessary to place a translation script between Canvas and the LRS the Canvas course I designed was integrated in a new interface. Students could launch the interface with the "launch course button" (figure 8a). This opens the menu displayed in figure 7b. Where students could access the course overview and the weekly program, of which figure 8 shows how this looked like for week 1.

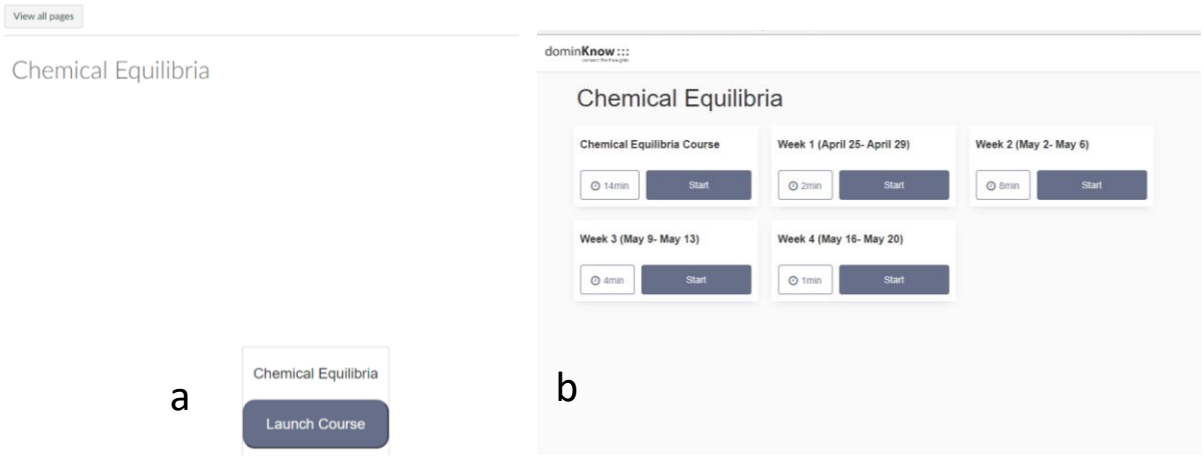
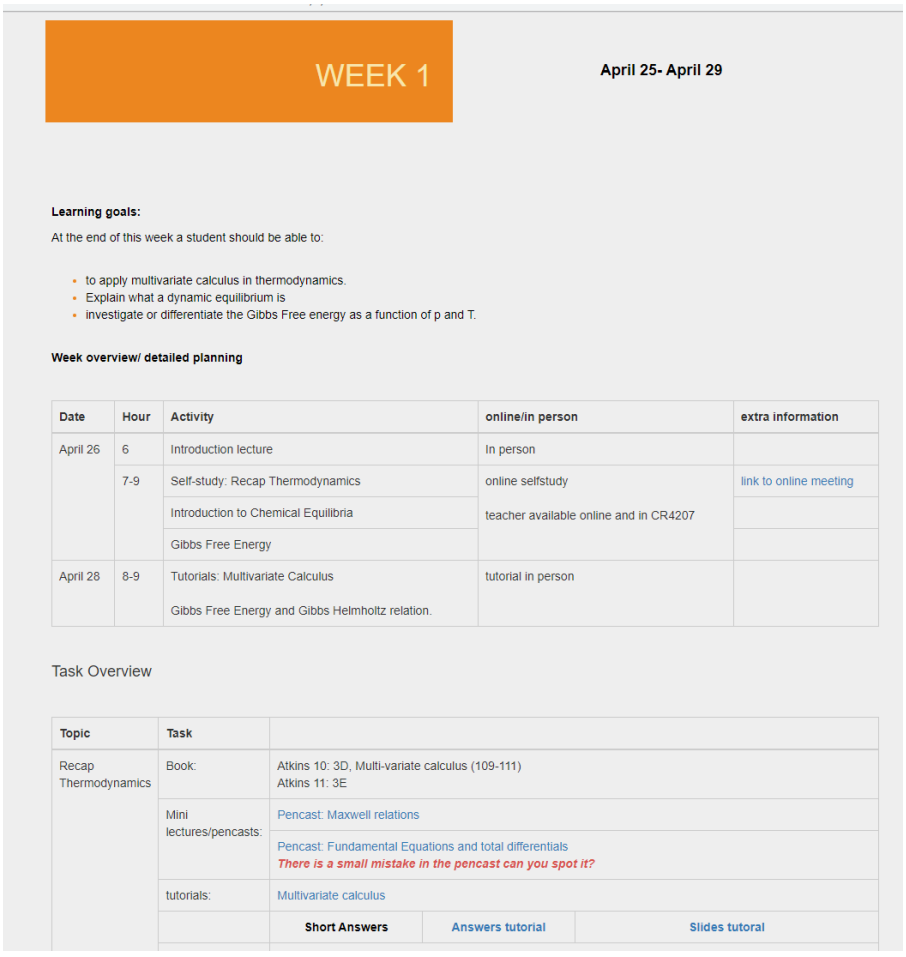


Figure 8a: launch button Built-in Canvas module that was connected to the dashboard. 8b: starting page build-in dashboard.



WEEK 1

April 25- April 29

Learning goals:

At the end of this week a student should be able to:

- to apply multivariate calculus in thermodynamics.
- Explain what a dynamic equilibrium is
- investigate or differentiate the Gibbs Free energy as a function of p and T.

Week overview/ detailed planning

Date	Hour	Activity	online/in person	extra information
April 26	6	Introduction lecture	In person	
	7-9	Self-study: Recap Thermodynamics	online selfstudy	link to online meeting
		Introduction to Chemical Equilibria	teacher available online and in CR4207	
		Gibbs Free Energy		
April 28	8-9	Tutorials: Multivariate Calculus Gibbs Free Energy and Gibbs Helmholtz relation.	tutorial in person	

Task Overview

Topic	Task			
Recap Thermodynamics	Book:	Atkins 10: 3D, Multi-variate calculus (109-111) Atkins 11: 3E		
	Mini lectures/pencasts:	Pencast: Maxwell relations		
		Pencast: Fundamental Equations and total differentials *There is a small mistake in the pencast can you spot it?*		
	tutorials:	Multivariate calculus		
		Short Answers	**Answers tutorial**	**Slides tutoral**

Figure 9: Translated Course overview and task overview in Built-in Canvas Module that was connected to the dashboard.

For this course, the learning analytics dashboard that was only available to the teacher. An impression of this dashboard is given in figure 10. For this course the dashboard contained the following items:

- Total video sessions: how many times students clicked on the video.
- Number of unique viewers: from how many IP addresses the video was accessed.
- Video sessions over time: average views over time
- Total duration of videos watched: how much time of a video is watched on average
- Files viewed: how many students viewed which file
- Assessments launched: how many students clicked on which assignment
- Graphs of viewers per frame of the pencasts and minilectures

Figure 10: Impression of the teacher's dashboard.

Possibilities for students to interact with teacher

Students want to interact with and get feedback from the teacher. In a flipped-classroom synchronised and asynchronized learning occurs. It is important to communicate to the students how the teacher can be reached and is available, especially regarding the online learning. For this course the self-study sessions were scheduled for the students. This does not mean that students have to study then, but in this way it is ensured that the schedule allows for self-study. During the course the teacher could be reached/contacted in the following ways:

1. **Panic button:** On every Canvas page a panic button can be found (see figure 5). This button links to the email address of the teacher.
2. **Feedback quiz:** Every topic in Canvas has its own feedback quiz. This is a survey where students can anonymously ask questions to the teacher.
3. **Contact hours:** During the online self-study the teacher was available on Teams and in the office. Students could approach her when they had a question.
4. **Tutorials:** Every topic has an online learning component and an offline learning component. The latter in the form of tutorials where students make exercises. During the tutorial sessions a teacher and a PhD student are present to help the students.

Possibilities for students interaction through peer-learning activities

Apart from tutorial sessions, where students in general work together to solve a problem and where the teacher is present to guide them to the correct answer, also two peer-learning activities were implemented. Assignment 1 was especially designed for this SUTQ research and the second is a diagnostic test, which was already implemented in the course. Since the students were going to be interviewed by Linlin about learning communities, this gave me the opportunity to analyse the diagnostic test as a peer-learning element. Below a detailed description of assignment 1 and the diagnostic test are given.

Assignment 1

In assignment 1 students were given data from a research paper and via several questions they were asked to extract certain information from these data. An important aspect of assignment 1 is that the data have to be plotted in a certain way to extract the information asked for. In the course there are similar situations where this same approach can be used to extract information from a data set. In the exam it can be tested whether the students are able to apply this procedure in the situation of assignment 1 and in a new situation. With other words if we consider Bloom's taxonomy I can test whether students are able to apply the knowledge and whether they gained the next level of understanding and analyse data in a new context.

Assignment 1 is designed as a group discussion. The students have to prepare the assignment at home. During the discussion the students explain to each other how to obtain the right answer. The teacher is present during the discussion, and may give tips or hints, but will not provide the answer. Students are allowed to bring the completed assignment to the exam as reference material, but will have to hand it in with the exam, so that teacher can check whether it solely contains information about assignment 1. The procedure is explained in the F2F session and on Canvas (see box 1).

Assignment 1 will be evaluated at three different ways: at the exam the exam question(s) about the situation of assignment 1 and the new situation where a similar approach is used will be evaluated. Linlin Pei will interview the students about how they experienced assignment 1. Finally a Canvas survey will be sent to all students to ask more students for their experience and specific questions can be implemented based on the interview results.

Box 1. Description of Assignment 1 on Canvas

Assignment 1, the rules of the game:

Assignment 1 is a group discussion, you can use it as reference material during your exam, but there are some rules if you want to do this:

1. For this assignment the participants of the course will be divided into 3 groups, students stick to the assigned group.
2. Before the scheduled discussion session you (try to) make the assignment
3. During the discussion you (the students) explain to each other how to get to the right answer.
4. The teacher will help in the discussion, but will not give you the answers.
5. During the exam you bring assignment 1 as reference material, but you'll have to hand it in (so the teacher can check it is not used as a cheat sheet)

(6. If you want the assignment back for the re-exam, you can pick it up in office CR4207)

Diagnostic test

At the end of the course the students have the opportunity to participate in the diagnostic test. They get three representative exam questions that they have to prepare before the F2F session, if they have not prepared the test they cannot join. Their answers are collected at the start of the F2F session and redistributed, so the students get the answers from a peer. Then the teacher explains how the questions can be answers and the students correct the work from their peer. In general students will ask several questions about how they should grade a certain answer.

This peer-learning element was already implemented before 2020, but it could not be used when the course was held online (in 2020 and 2021). Before the pandemic I had some very good experiences with this way of going through exercises with students. This SUTQ provided a good opportunity to ask students about their experience with this way of teaching.

Evaluation of Assignment 1

The effectiveness of the peer-learning activities will be evaluated in three ways. First of all exam questions will be asked that connect to the peer-learning assignment. The method in assignment 1 can be used in different situations. In the exam it will be tested whether the students can apply their knowledge in a known and a new situation. Second, Linlin Pei will interview the students about their experience during the peer-learning activities. Finally the students will be asked to fill in an anonymous survey in Canvas.

Chapter 4: Results on learning analytics

Part 1: Keeping track on Student's online learning

In teaching there are always two parties, the teacher(s) and the student(s). In Blended-Learning the traditional role of a teacher shifts from a transmitter of content to a facilitator of learning. In BL, especially in flipped classrooms, part of the learning of the students has to be done by self-study in an online environment. This change in role and the lack of control of whether the students are studying or not is uncomfortable for many teachers. This also came out of the survey by Pei et al where teachers indicated that *it's difficult to reach out to students to motivate and keep them on track.*

To make a good connection between online and offline learning it is important that the students are on track, i.e., it makes sense that students first study and then practise with the study material than the other way around. To be more specific for Chemical Equilibria, the course is designed such that students first study the online theory i.e., minilectures and pencasts in which equations are being derived and then practice with the theory during tutorial sessions. Before 2020 this was achieved by making use of the Colstruction where in the first two hours the theory was discussed by means of a lecture, followed by two hours of tutorials. In this way for me as a teacher I had a good idea who was actively participating in the course and with what aspects the students had problems.

For teachers it would be useful to get a better idea when and what students are studying online. Having this knowledge could be useful for many instances, e.g., to know whether the students have viewed the online study material before participating in the tutorials and to get an insight in what topics the students find difficult. For the latter I hypothesis that the more difficult topics are reviewed again before the exam. I heard a student mention once that they used this approach. This knowledge could be useful for course improvement and could be cross-referenced with exam results.

What kind of data can learning analytics provide?

In the original plan I proposed to study "What is the effect of sending Canvas announcements/emails on the moment at which students access online study material?" I assumed that this question would be rather straightforward to answer. I proposed this question before I knew what the teacher's dashboard would look like. The dashboard was ready one day before the start of the course and the data I would need to answer the original research question were difficult to extract. Therefore I had to rethink the research questions, based on the data that were available.

Figure 10 gives an overview about all the different data that were available to me. From these data it is not possible to extract the information about whether students can be encouraged to start their online learning by sending out announcements. So the original research question could not be answered. Therefore the original research questions discussed in chapter 2 were amended to:

1. How can one use learning analytics data to better understand how students learn in an online learning environment?
2. What kind of learning analytics data are required to influence the online learning behaviour of students?

Table 2: overview of the mini-lectures

Mini-lecture	self-study planned on	students watch on average about x % of the video	unique viewers	Least Amount of views per frame	Total viewers	Total/ unique viewers	Least viewers/ unique viewers
Mini lecture 1: Dynamic equilibrium	April 26	52.75	47	43	98	2,08	0,91
Minilecture 2: spontaneity	April 26	44.84	47	13	114	2,43	0,28
Minilecture 3: mini lecture 3 G as function of p and T	April 26	46.16	44	33	107	2,43	0,75
Mini lecture 4 chemical potential 1	May 2	44.95	49	41	149	3,04	0,84
mini lecture 5 chemical potential 2	May 2	47.78	48	30	120	2,50	0,63
Mini lecture 6 phase equilibria	May 2	46.60	45	41	143	3,18	0,91
Mini Lecture 7 Ideal Solutions	May 3	58.76	45	30	95	2,11	0,67
Mini lecture 8 Colligative properties	May 4	44.36	46	36	153	3,32	0,78
Mini lecture 9 chemical equilibria	May 9	36.95	45	21	138	3,06	0,47
Mini lecture 10 Le Chatelier's Principle	May 9	46.04	41	12	78	1,90	0,29
Mini lecture 11 Acids and Bases	May 12	50.11	44	35	104	2,36	0,80
Mini lecture 12 buffer solutions	May 12	47.82	43	13	93	2,16	0,30
Mini lecture 13 titrations	May 12	41.84	43	24	117	2,72	0,56

1. How can one use learning analytics data to better understand how students learn in an online learning environment?

To answer this question it is important to understand how the collected data can be interpreted. This is not straight forward. If one would only use the percentage of the movies watched it appears that students only look at 50% of the content. This is a puzzling result, why would students only watch 50% of a video? To understand what it possibly happening, more data need to be considered. Fortunately there is also information about the total number of viewers and the unique number of viewers. The ratio between those numbers give you the number of times movies are watched. This gives a different interpretation the total number of times something is viewed, for most videos is more than twice. Further information that is available is the viewers per frame for every movie. From these diagrams, the least number of viewers can be determined. This is almost always observed at the end of a minilecture and indicates that student stop watching before the end of the movie. All these numbers can be found in table 2, for the minilectures and table 3 for the pencasts.

Looking at these data, the most likely explanation is that students watch the movie once, but pause or scroll back to parts that caught their attention. There is difference in how they watch the pencasts, where formulas are being derived and how they watch the minilectures. The minilectures show stripy patterns, indicating rewatching certain parts intensively. An overview of these viewing patterns can be found in appendix 2 for the pencasts and in appendix 3 for the minilectures. For the minilectures it can be determined what students find interesting. In appendix 3 screenshots of the movies corresponding to the highest amounts of viewers can be found. In general, students rewatch parts where equations are being explained and graphs are being presented.

Students asked for the ppt files of the minilectures and explained to me that they had to scroll back and forth all the time. This student feedback confirms the behaviour previously described.

2. What kind of learning analytics data are required to influence the online learning behaviour of students?

Figure 3 gives an overview of the four levels of learning analytics. In this research learning analytics had been used on a descriptive level. The data that were obtained are useful to get an idea whether the students are taking part in the online lectures and whether they are accessing the other online learning content e.g., downloading the answers for the tutorials. As a teacher of a course that only lasts for four weeks, this information is sufficient to know whether the students are on track.

In the original research question I wanted to investigate the effect of sending our announcements on the on the moment at which students access online study material. In work by Woodward et al[36] it was shown that sending out announcements influences the students. This kind of information would allow teachers to use learning analytics on a diagnostic level. This level covers the factors relating to the performance of students and their behaviour.[28]

Unfortunately these data were not available in the dashboard. They are hidden somewhere in the content, but currently it is difficult to show them in the dashboard. In my opinion having data showing per hour how many students access online content would be very useful information for the teacher. It will provide even better data about the time at which students access the online information and whether students come prepared to the tutorial sessions or that (part) of the students are not on track. If this information would be available the behaviour of the students can be studied and information about the student cohort performing can be extracted.

In addition to have data about the time at which students access what topic will also be useful to identify topics students find difficult. I think it is reasonable to assume that students will re-view the perceived difficult online content when preparing for the exam. With this knowledge a teacher could include some extra exercises/reference material/ additional explanations on these topics to help students prepare for their exams. In that sense I argue that action-related, content-related, and context-related indicators[30] are the most useful to have access to as a teacher, for a course that is part of a larger module. This kind of data will also help to check whether the students connect different aspects within the module. To be more specific, during the electrochemistry practical part of the module, the students have a practical on acids and bases. The theory about this topic is discussed in my part, about chemical equilibria. In the dashboard it could be observed that in the week of this practical, students revisit the online lecture material on acids and bases. It would be interesting to see if they use it to prepare for the experiment or when they analyse the experiment.

The UT is very strict with the GDPR regulations and it will be extremely difficult to obtain data on the individual student level. I argue that as a teacher within a module one does not need this information. In a module you only work with the students for a maximum of 10 weeks in this

short period this detailed information is not necessary, unless you are carrying out a very detailed educational science related experiment. This detailed student information could on the other hand be useful to study-advisors who follow students throughout their studies.

Table 3: overview of the pencasts

Pencast	self-study planned on	students watch on average about x % of the video	unique viewers	Least Amount of views per frame	Total viewers	Total/ unique viewers	Least viewers/ unique viewers
Maxwell relations	April 26	52.57	50	55	120	2,40	1,10
Fundamental equations and total differentials	April 26	55.60	46	49	102	2,21	1,07
Pressure dependence of G	April 26	53.51	45	43	90	2,00	0,96
Gibbs-Helmholtz relation	April 26	53.21	44	48	96	2,18	1,09
Clapeyron Equation	May 2	50.05	47	54	134	2,85	1,15
Clausius Clapeyron Equation	May 2	54.33	46	44	125	2,71	0,96
Gibbs Duhem relation	May 3	58.52	45	48	107	2,38	1,07
Chemical potential of a solution	May 3	59.82	45	48	99	2,20	1,07
Free Energy And Mixing Of Gasses	May 3	47.16	43	39	109	2,53	0,91
Free Energy And Mixing Of liquids	May 3	49.71	44	35			0,80
Partial Molar Quantities	May 3	51.45	45	53	112	2,49	1,18
Boiling point elevation and freezing point depression	May 4	35.73	47	43	160	3,40	0,91
Osmotic Pressure	May 4	49.45	46	51	113	2,46	1,11
Ideal Solubility	May 4	53.96	44	49	116	2,64	1,11
Equilibrium constant and standard Gibbs free Energy	May 9	49.74	41	43	100	2,44	1,05
Temperature Dependence Of The Equilibrium Constant	May 9	51.94	42	34	81	1,93	0,81
Going Real 1 Fugacity and fugacity coefficient	April 26	47.93	37	20	61	1,65	0,54
Gong Real 2 Activity And Activity Coefficient	May 3	55.95	30	18	No data		0,60
Going Real 3 Excess functions	May 3	54.37	21	17	No data		0,81

For my research I had to obtain explicit permission from the students to use their data. This costed a lot of effort. First I had to get permission from the ethics committee of the faculty of S&T and let them approve the consent form I was going to use. Then there was a lot of admin getting

the students to sign the form and send the signed forms back to them. In addition they had to give permission for the learning analytics part in Canvas. It would have been easier if the permission to collect data could be integrated in Canvas at the start of the module, or that the students have to give permission on the start of the academic year, for the full year.

My course is one of the first courses at the UT that makes use of learning analytics. Currently it is difficult to predict whether in the future learning analytics will be used in more courses. If together with other teachers I could collect learning analytics data for many years, these data can be used for the predictive or perspective levels of learning analytics. Currently I don't have the ambition to use learning analytics at these higher levels.

For this SUTQ research learning analytic is used on the descriptive level. This allowed me three different indicators.[30] I have studied action-related indicators, the learning analytics data me with some data on when the students studied. It is desired that the time resolution of these data is improved, so teachers will know whether students react on their announcement. I have used content-related data, I could study how students watched the online content. From this I learned that the students watch pencasts and minilectures differently. Finally I know something about the and context-related indicators, where I have observed that the students watched the online content during the tutorial sessions.

The learning analytics provided a lot of information, but currently it is difficult directly to relate it to the learning outcomes. A important question that remains is "What have the learning analytics learned us about the online study behaviour of the students?" The most important finding is that the students watch the online learning material. The pencast they seem to watch in one go, whereas part of the mini-lectures is rewatched and they scroll back to where important aspects are being discussed. This was what I already expected in 2020 during the first lockdown when I observed that students used more and their own language in open exam questions where an explanation was asked. So it could be that providing the content in the form of mini-lectures results in a better learning outcome. However more research needs to be performed to confirm this.

That students like to watch the online content together aligns with Linlin's observation during the interview (see next chapter). Where "the group of students indicated that they like to learn together, also during the self-study. The peer-presence and peer-pressure would help them to be motivated do the self-study. So having a learning space dedicated to the course would be a good idea." This peer-presence aspect during online self-study is an interesting finding and research on this topic is recommended.

To conclude this chapter, let me summarise the main findings on using learning analytics as a tool to 1) better understand how students study in an online learning environment and 2) what kind of learning analytics data are required to influence the online learning behaviour of students. The learning analytics data can provide information about how students watch online videos and how many students have interacted with the online content. The latter data were available as number of unique views and total number of views. The ratio between both gives a good idea whether the students are on track and it can be deduced whether the students come prepared to an offline educational activity. It appears that students watch pencasts and minilectures differently. In general pencasts are watched in one go, whereas parts of minilectures are rewatched.

In order to be able to influence the learning behaviour of the students a better time resolution of the data is required. This would allow for studying the effect of triggers, like sending out announcement and the response of students to this announcement. In addition a better time resolution will help to get insight in which online content the students rewatch before the exam. This information can help the teacher to identify which particular aspects of the course are perceived as being important or difficult and could help to improve or elaborate certain aspects for the next year.

Chapter 5: Results on Peer-learning

When learning occurs (partly) online it is important that students feel a connection with the teacher and their peers. Peer-learning can be used as a tool to build a learning community. In this course there are three different ways in which students learn together. During the tutorial sessions students work together on assignments. For a newly developed peer-learning element students have to prepare an assignment (assignment 1) at home and explain to each other how to tackle the assignment in a group discussion. During the discussion the teacher is present, and helps the students, but does not give the correct answers. The students can bring their completed assignment to the exam as reference material. Finally the diagnostic test is a peer-learning element that I have used for years (not during covid-time). Here students have to prepare three exam questions at home and hand these in at the start of the lecture. They receive the answers from a peer and correct these answers while the teacher explains the exam questions on the board. This session is always very insightful for the students, because they realise that they have to give a full explanation and calculation in order to get the full number of points.

For this SUTQ the focus is on the incorporation of assignment 1 as peer-learning activity and I would like to investigate:

3. **How does the incorporation of a newly developed peer-learning element affect the learning outcome and motivation of the students?**

Since there are other peer-learning elements present within the course these will also be discussed to give a complete overview. A remark I can make about the tutorials is that I was very surprised that so many students attended these and stayed on till the end. Especially because they were mainly scheduled between 15:45-17:30. I also noticed that students were working on their own pace during the tutorials. Some were on schedule and worked together on the tutorials that were on the program for that day. Some lacked behind and were working on previous tutorial sessions. Some students were watching the online content, sometimes together. Some students were asking specific questions to me about the online content. As a teacher I felt like a facilitator of learning continuously adjusting to the individual needs of the students, but these sessions were quite intensive given the variety of problems/questions the students had.

Observation during the discussion of assignment 1

The group discussion sessions were planned on the same day as the symposium of the study association Alembic, it was the intention the split the group up in four subgroups, but because of the symposium I had to split the group up in three subgroups. Doing so the group discussions could be aligned such that the time corresponded to the activities during the symposium and students attending the symposium would only miss one activity. Therefore the group was split up into three subgroups instead of four.

The groups were similar in group size, group 1 having 14 students and group 2 and 3 had 12 students. The way the students approached the discussion varied per group. In group 1 one student took the lead and was standing in front of the whiteboard asking the other students for input. In group 2, students are more hesitant but in the end two students stand up and lead the discussion. The last group was quite hesitant, then two students start explaining things to each other in front of the group and ask for input from the rest of the group. In all groups some students remain quiet throughout the discussion and do seem to actively participate, but seem to be paying attention to what is happening.

Most questions can be answered without a lot of problems, only derivation of some formula's and the plotting of the data require some hints/ tips from the teacher for certain groups. The students find it difficult to judge whether their answer is correct or not. In some cases specific questions are revisited at the end.

Exam

The students were allowed to bring assignment 1 to the exam as reference material. The first observation during the exam was that not all students that participated in the group discussions brought the answers with them as reference material. This presented the opportunity to compare the exam results from the students who brought the assignment to the exam to the exam results of the students who didn't. In table 2 these data can be found. Here the average points, the standard deviation and the average number of points divided by the total number of points are presented.

Comparing the exam results of the two groups of students, it can be seen that the students who brought the assignment to the exam score higher on questions that apply to the same situation as assignment 1. Similar scores are observed for both groups of students when the same approach of assignment 1 has to be applied in another context.

		Students who brought assignment answers (total=21)			Student who didn't bring assignment answers (total=23)		
Question	Max points	Average points	Standard deviation	Average/max points	Average points	Standard deviation	Average/max points
8	3	**2,76**	0,56	0,92	2,65	0,71	0,88
9	4	**3,05**	1,13	0,76	2,50	1,10	0,63
10	4	**3,62**	0,80	0,90	3,28	1,36	0,82
11	3	**2,62**	0,71	0,87	2,20	0,94	0,73
13	4	3,29	1,15	0,82	**3,37**	0,91	0,84
14	2	1,50	0,39	0,75	**1,52**	0,41	0,76
15	3	**2,36**	0,96	0,79	2,35	0,78	0,78

Table 4: exam results, question 8-11, same topic as assignment 1, question 13-15 same approach as assignment 1 but different context/situation

We can consider these findings in terms of the four levels of cognitive presence, a way in which (online) discussions can be connected to learning outcomes.[21-23] In this case the triggering event and exploration phase occur during the group discussion of Assignment 1. That the students reached the integration level becomes clear from the outcome of the exam. The resolution/application level is not reached by the majority of the students, since many of them cannot apply the obtained knowledge in a different context. In terms of Bloom's taxonomy they the students are able to apply their knowledge, but they are not yet in the analysis phase. The challenge for next year will be to get to this stage.

Another observation about the exam is the following: I always calculate the exam results in excel. Normally my excel file contain a lot of 0 where students did not give any answer at all. This year however, there were hardly any 0 in my excel file because the students gave answers/tried to answer most exam questions.

Interview by Linlin Pei

About a week after the exam Linlin interviewed the students. In her research she investigates whether students experience a sense of community and how important this sense of community is for Blended-Learning.

All the students she interviewed experienced that the course had a strong sense of community.

She let students rank the different F2F learning elements that were presented to the students during the course and asked them: Which activities help you to connect with others and learn better? The students indicated that the Diagnostic test helped them best, followed by the supervised tutorial sessions and at the last place was the Assignment 1 group discussion.

The students value the possibilities of BL in terms of more flexible and personalised learning experiences; they can learn more effectively through self-study, the use of Pencasts, and mini-

lectures. In addition, the students are motivated to come to campus. They believe that if they miss the tutorial sessions, they will have problems catching up with the course.

As for the group activities, this is appreciated by the students and they indicate that these encourage one another during the learning process.

The group of students indicated that they like to learn together, also during the self-study. The peer-presence and peer-pressure would help them to be motivated do the self-study. So having a learning space dedicated to the course would be a good idea.

Finally the students expressed a concern about assignment 1. When students do not receive answers from the teacher, they can become frustrated. A more in-depth explanation of assignment 1's motivations is required.

Survey in Canvas (12 students answered)

Based on the findings during the exam and the interview of Linlin Pei a Canvas survey was designed and distributed among the students. Although it is difficult to obtain information about student motivation, such a survey can probe the general impression of the students. More importantly, the finding that students did not bring the assignment to the exam as reference material was surprising and this survey allowed for asking why students did not bring the assignment to the exam. In the interview the students indicated that they did not like it to not get the right answers of assignment 1. In question 4, 5 and 6 I addressed this issue, also in the open questions 8 and 9 the students give their opinion about assignment 1 and other improvements of the course. Below the questions and replies of the students can be found.

Question 1: I did attend the discussion session of Assignment 1

Yes	12
No	0

Question 2: I was motivated to work on assignment 1

Yes	6
Somewhat	6
No	0

Question 3: I enjoyed the group discussion about assignment 1

True	6
Somewhat True	5
False	1

Question 4: It bothered me that I did not get the right answers of assignment 1

True	3
Somewhat True	5
False	4

Question 5: I brought assignment 1 as reference to the exam

Yes	8
No	4

Question 6: If you did not bring assignment 1 to the exam, can you explain why?

Student 5: “I did not think it would really help a lot. I only used the formulas and I don't need more than that.”

Student 6: “too much of a bother for something that would only give me very limited and probably not even completely right information”

Student 8: “I felt confident that I was able to do well on the exam without it.”

Student 10: “I felt like it was unnecessary since i understood what was on my assignment 1 paper and thought it might even take me extra time if i used it as a "cheat sheet"”

Question 7: Because of assignment 1 I could make the exam better

Yes	5
Somewhat	6
No	1

Question 8: Having a group discussion about an assignment is a new teaching format, do you have any suggestions to improve this format?

Student 1: “I think that it wasn't clear enough to everyone that there would be absolutely no input from the teacher. If this was made clear, the students would have had more motivation to try every exercise for themselves.”

Student 2: “Overall, I enjoyed the discussion. I noticed we were struggling because none of us wanted to start at first even though we, as a small study, know each other relatively well. Unfortunately, I do not know how to improve that from a teacher's point of view since I think it is only a matter of stepping outside of one's comfort zone. Though it helped me quite a lot that we were divided into small groups.”

Student 3: “No, it was carried out well. Answers at the end would be nice, but the hints worked alright as well.”

Student 5: “Tell in the end whether the answers were correct or not. Otherwise people will never know, when they are not sure about their answer if it is correct and whether they can take it to the exam. Otherwise you'll fill in wrong answers possibly.”

Student 7: “It is a great way, but for me I would have liked to receive answers even if it was days after.”

Student 8: “I enjoyed the discussion but I think the discussion should be teacher-led. If the students lead the discussion, then they get nervous and unwilling to share their solutions with everyone because they are afraid of being wrong. If a teacher starts the discussion, then there is momentum and slowly everyone shares their ideas and thoughts on the problem.”

Student 9: “Perhaps smaller groups could involve everyone”

Student 10: “maybe feedback at the end would've been nice”

Student 12: “The discussion during assignment one was a bit rocky, because a lot of people were not sure about their answers and therefore did not participate in the discussion. A bit more guidance would have been helpful to remedy this.”

Question 9: Do you have any other comments?

Student 1: “I think that group discussions like assignment 1 are a very good way to teach/ learn. I personally learned a lot from the session. I think that I may also have been lucky with my group as there were multiple people who were engaged in the discussion. I can imagine that in a group where almost everyone is silent, the students will not learn as much.”

Student 5: “Make some tutorial exercises together with the class. Then the students will know how to make certain exercises and which makes the learning easier and more effective. in my perspective because you don't need to ask the teacher every time.”

Student 7: “The online way was different for this course, as the videos were mostly about deriving equations. It would be nice if we prepared beforehand to solve a tutorial and then in class we could solve it together all of us to get an insight of how to solve the questions.”

Student 8: “Assignment 1 was overall a good idea; however, I would not make it a requirement. There are some students that work better and more efficiently by just giving them problems and its detailed solutions.”

Student 10: “thank you for constantly trying to improve our program :)”

The survey was answered by 12 students, who all joined the discussion of assignment 1. Half of them where motivated to work on the assignment and half of them were somewhat motivated. Of the 12 students only they did not enjoy the discussion, 6 enjoyed and 5 somewhat enjoyed it.

Whether or not receiving the answers of assignment 1 did bother a quarter of the students sincerely and four students not at all. Eight students brought assignment 1 to test, and four didn’t. The main reason why they did not bring the assignment to the exam was that they were confident that they could make the exam without assignment 1. One student indicated that they were not convinced that they would have the right answers, so why bother bringing it to the exam.

Of the 12 students, 5 indicated that they could make the exam better because of assignment 1, 6 indicated that having made assignment 1 somewhat helped them during the exam and 1 indicated that it did not help at all.

The most important issue raised when the students were asked about how to improve assignment 1 was that they would appreciate it to obtain answers at the end. This corresponds to the finding of Linlin during the interview that students indicated that they want to know the right answer. This is an interesting finding and almost comes down to the philosophical question what is the truth? It could indicate that the first year BSc students think that all questions have an answer and that the answers can be found in answer sheets. This observation can be further explored. Since this academic year, within the CSE BSc program students are exposed to conceptual modelling from the start (M1). This may also help to think like a scientist and may solve the current observation that students find it difficult to deal with (scientific) uncertainty.

Nevertheless, I think that the assignment can be improved by placing it in a better context. I more elaborated explanation about how the data, the students are working with, were obtained will take away some of the concerns raised by the students. In addition, a few days after the discussion of the assignment I could share a link with the students to the article I obtained the data from. The students can then check by themselves whether they got the answer right, but they have to read the paper in order to check this.

Putting the data in context and explaining how the data were obtained may also help the students to use the same approach in a different situation. This will be investigated next module 4 with the aim to get to the resolution stage and a higher level in Bloom’s taxonomy.

Evaluation module 4

After every module a module evaluation survey and a student panel discussion take place. These are combined in a module evaluation report, which is discussed by the lecturers and the students. Personally I have problem with this format and think that the data are less reliable, than the interview with Linlin and survey I held myself. The remarks can be very random and not specific. In opinion the emphasis is on the negative aspects of the module. Moreover the exam of chemical equilibria was end of May, the discussion and evaluation are done Mid-October, this is 4.5 months after the exam.

From the student panel discussion 2 points were raised:

1. The Canvas site sometimes crashed while watching lectures. (During the panel meeting the students confirmed this only happed on one day and was resolved when I contacted Peter Groothengel)
2. The students did not like the tutorials that much, the questions were too hard. When students asked questions they would only get the answers without an explanation

In the survey 4 points are raised that probably apply to my course:

1. More in person lectures instead of pre-recorded lectures and pencasts as a support instead of it being more like a lecture
2. Sometimes, the lecturing in this module maybe relied too much on videos. There are advantages to this, but the video quality was not consistent.
3. Very nice module to follow online!
4. While in general the module seems pretty coherent, the lecture material was not up to standard. For electrochemistry the course was difficult to follow and the practice material was scarce and usually did not include worked solutions to check whether the student has done the practice material properly. Conceptual modelling was also incredibly confusing until the end, and the material provided did not help. *Equilibria was okay*.

During the discussion the following I discussed the tutorials with the students. I suggested to implement peer-learning during the tutorials. Where in the first hour we will discuss a pre-made tutorial question, with the same rules as the diagnostic test. In the second hour students can work on their own pace on where they are in the course. The students liked the idea, so this will be implemented next in module 4, April 2023.

For this SUTQ research I wanted to study whether a newly developed peer-learning element affect the learning outcome and motivation of the students. From the exam, interview with Linlin, a survey and the module evaluation I learned that the students were motivated and enjoyed working on the assignment and having the discussion. For the students it was difficult that they don't got the right answer in the end. This insecurity made some of them decide not to bring the assignment as review material to the exam. Comparing the exam results from students who did bring and did not bring the assignment as review material, it appears that the students who did bring the assignment scored better on a similar exam question than the student who didn't bring the assignment. However since I cannot correlate the interview and survey results to the exam results of a particular student it is difficult to draw a conclusion. To be more specific, in the survey one student 8 said: "I felt confident that I was able to do well on the exam without it." Since student 8 is anonymous I cannot check how well student 8 performed on the exam. Both students groups scored similar when the approach of the assignment was needed in a different context.

To conclude this chapter I would like to come back to the research question. In this research I used F2F peer-learning activities to affect the learning outcome and motivation of the students. For this an assignment was designed and also the other peer-learning activities were evaluated. From the first lockdown we know that students felt *"demotivated and disoriented, and were getting stressed."* This could be prevented if students feel they are part of a learning community. In a learning community students learn together. Peer-learning is a way to achieve this. From Linlin's interview it became clear that the students felt to be part of a learning community

In assignment 1 the student liked explaining to each other how to solve the problem. What did not like is that the correct answers were not provided. For them it seemed very important to know whether they are right or not. Scientists need to be able to deal with this uncertainty. So assignment 1 could potentially be a good way to teach students this. However, the context assignment 1 need to be better explained in order to also include this learning objective.

Chapter 6: General Discussion

In this SUTQ research there are two learning innovations that have been studied. The first one is making use of a learning analytics dashboard in Canvas. The second innovation is implementation of peer-learning elements in the F2F sessions. In the previous two chapters I have discussed them individually. In the introduction I discussed the different ways to evaluate (online) educational experiences. In addition to the Community of Inquiry model, seven distinct factors that describe student's perception of online quality.[19] I will use these seven factors to discuss both learning interventions.

1. **Instructional Support, refers to the perceptions of the students regarding the techniques the teacher uses for input, rehearsal, feedback and evaluation.**

Based on the interviews of Linlin Pei and the survey of assignment 1, the following can be remarked about Instructional Support: Blended-learning was a new format for the students and some had difficulties to adjust to it. In general the students were positive about the different techniques used and liked the discussion session. The students highly valued the diagnostic test as a way of peer-learning.

Points of improvement: the background of the assignment needs to be explained better. This year the students were frustrated that they did not get the right answer, whereas as a scientist you never know whether your answer is right, the answer will only support a hypothesis or not. Communicating this to the students is important.

2. **Teaching Presence, refers to the perception of the student regarding the quality and timeliness of communication in lectures, directions and individual feedback including encouragement.**

There were several ways the students could interact with the teacher:

- **Panic button:** On every Canvas page a panic button can be found (see figure 5). This button links to the email address of the teacher.
- **Feedback quiz:** Every topic in Canvas has its own feedback quiz. This is a survey where students can anonymously ask questions to the teacher.
- **Contact hours:** During the online self-study the teacher was available on Teams and in the office. Students could approach her when they had a question.
- **Tutorials:** Every topic has an online learning component and an offline learning component. The latter in the form of tutorials where students make exercises. During the tutorial sessions a teacher and a PhD student are present to help the students.

The students mainly interacted with the teacher during the tutorials. The feedback quiz was used twice in the first week, in contrary to last year when the course was mainly online then it was used more extensively. During the contact hours I was contacted once online and once a group of students walked into my office because they had a question.

Based on the interviews of Linlin Pei and the survey of assignment 1 the following can be remarked about Teaching Presence: the students valued the presence of the teacher during the tutorials, but did not really need the other methods to contact the teacher. I would like to make the remark here that when the course was online, these other options were values a lot and when there will be MSc students from industry following the course, these may be a good method of teacher-student interactions.

Points of improvement: as a teacher becoming a facilitator of learning I did not realise that encouragement was so important for the students and I will try to improve this in the future. With respect to assignment 1 and the students feeling almost frustrated not knowing whether they got the right answer I hope that explaining the background of assignment 1 in more detail will help the students to feel more confident about their own performance. Within the CSE curriculum we

are implementing conceptional modelling more and more in order to learn students how to think like a scientist. Not knowing whether your result is correct is part of being a scientist, getting use to this will also help students to become more confident about their (experimental) results.

3. **Basic Online Modality, refers to the use of learning management system including grading, navigation methods and announcements**

Based on learning analytics the following can be remarked about Basic Online Modality: the online part should be as clear as possible, a well-organised canvas page is essential for a blended-learning course. I have based my canvas module on the one I made last year and the year before, when the course was fully online. During the student evaluations, the students gave complement about the organisation of the canvas pages within our TEM module.

Announcements are important to remind students that they are supposed to be learning.[36] I used the announcement at the start of each online session. Unfortunately I could not use the learning analytics to study the effect of sending the announcements.

Points of improvement: in my original plan I wanted to study the effect of sending announcements on the behaviour of the students and would have liked to answer the research question: What is the effect of sending Canvas announcements/emails on the moment at which students access online study material? The point of improvement here is not the use of announcement, but to be able to study their effectiveness.

4. **Social Presence, refers to the perceived quality of student-student interactions, e.g., shared learning and collaboration.**

In the survey of assignment 1 the following can be remarks were made about Social Presence by the students:

To the direct question about motivation 6 students answered they were motivated and 6, somewhat motivated. More importantly, there were no students who was *not* motivated.

Student 1: *"I think that group discussions like assignment 1 are a very good way to teach/ learn. I personally learned a lot from the session*. I think that I may also have been lucky with my group as there were multiple people who were engaged in the discussion. I can imagine that in a group where almost everyone is silent, the students will not learn as much."

During the interview the students said the following about social presence "As for the group activities, this is appreciated by the students and they indicate that these encourage one another during the learning process." And "The group of students indicated that they like to learn together, also during the self-study. The peer-presence and peer-pressure would help them to be motivated do the self-study. So having a learning space dedicated to the course would be a good idea."

From this it can be derived that the students enjoyed this new way of working. They like to learn together. Even when doing the online self-study.

Points of improvement: try to include everybody in the discussion. Smaller groups (which was the initial plan) of about 10 students may work better (as suggested by student 9). In addition it might be good to suggest to the students that they are allowed to work together during the online self-study and that if they want, they can book a room to do so.

5. **Online Social Comfort, refers to the ability of the instructor to create an anxiety free productive learning environment.**

From the survey of assignment 1 the following two students commented on Social Comfort:

Student 2: "Overall, I enjoyed the discussion. *I noticed we were struggling because none of us wanted to start at first even though we, as a small study, know each other relatively well.* Unfortunately, I do not know how to improve that from a teacher's point of view since I think it is only a matter of stepping outside of one's comfort zone. Though it helped me quite a lot that we were divided into small groups."

Student 8: "I enjoyed the discussion but I think the discussion should be teacher-led. *If the students lead the discussion, then they get nervous and unwilling to share their solutions with everyone because they are afraid of being wrong.* If a teacher starts the discussion, then there is momentum and slowly everyone shares their ideas and thoughts on the problem."

Student 12: "*The discussion during assignment one was a bit rocky, because a lot of people were not sure about their answers and therefore did not participate in the discussion*. A bit more guidance would have been helpful to remedy this."

Points of improvement: it was the first time that, as a teacher I was organising these discussions. I thought that my role would be observer and that the students would be in the lead. From the feedback of the students it becomes clear that the students need a discussion moderator. Apart from leading the discussion this moderator can try to create an anxiety free productive learning environment.

6. **Cognitive Presence, refers to how students experience whether they are stimulated by the learning material and the instructor to reflect deeply and critically think about the learning material.**

Based on the exam outcome the following can be remarked about Cognitive Presence:

The students who brought assignment 1 to the exam scored better on exam questions connected to assignment 1. All students scored the same the same approach of assignment 1 was required to answer questions in another situation. Connecting this finding to the four levels of cognitive presence[21-23] It can be concluded that the students did not reach the resolution/application level. In terms of Bloom's taxonomy they the students are able to apply their knowledge, but they are not yet in the analysis phase.

Points of improvement: to reach to the resolution stage the context of assignment 1 needs to be improved. One additional question that could be added is, whether this approach can be used in another situation. Then they can discuss about this and explain this to each other.

7. **Interactive Online Modality, refers to the high end uses of online tools and functions.**

Based on learning analytics the following can be remarked about Interactive Online Modality: for the dashboard built-in canvas module was used. Because of this the videos could not be played full screen. When the students indicated that the size of the videos was small it could fortunately be increased. It was also raised by students in the evaluation of module 4 that the platform sometimes crashed.

The way learning analytics is implemented now, means that as a teacher you have to ask someone else to change/correct/update items on your Canvas page. This does not only mean that you have to have everything ready and in place at the start of the module, it also means that you have to give up some freedom and are dependent on another person. This is not an ideal situation.

Points of approvement: it would be great if the dashboard could be just based on the Canvas page of the teacher, then the teacher can make changes themselves and the students can play the videos in a full-screen mode. This may also be a more stable set-up and less likely to crash.

Chapter 7: Concluding remarks and recommendations

Becoming a facilitator of learning

I argued that in order to be able to facilitate the learning process of the students as best as possible as a teacher it is important to understand the online learning behaviour of the students. This will allow the teacher to help the students to remain on track. In addition order get the best learning experience the online and offline content need to be balanced. This provides the opportunity to design and test peer-learning activities with the aim to enhance the learning outcome and experience. This will also increase the sense of belonging of the students and it is expected that students feel that they are part of a learning community. A learning community will make the students feel less demotivated, less disoriented and less stressed.

To conclude this SUTQ report I would like to reflect on how this research has contributed in where I am now, becoming a facilitator of learning, and what I should improve in order to support and facilitate the learning process. In addition to these recommendations I have phrased as 10 tips designing a course in Blended-Learning format. This list can be found on the next page.

To obtain information about the online learning behaviour of students I have made use of learning analytics. I have used the learning analytics on a descriptive level. This allowed study action-related, content-related and context-related indicators. The knowledge that the students were actually watching the mini-lectures and pencasts, assured me that most students were actually on track and participating. For me having this information is important.

During the tutorials the students expressed different needs and this made the tutorials very demanding for the teachers. I think that I have to redesign the tutorial session somewhat and to structure the better. A possible way to do this is to start with a pre-made question connected to the topic of the mini-lectures and pencasts and discussed in the “diagnostic test” set-up. So the students correct work from one of their peers. After this they can work in their own pace on whatever they want.

The students indicated that the peer-learning activities helped them to learn better. Still I think several improvements can be made. From the student feedback on assignment 1, I have a better impression of what the students need from the teacher during such a discussion. As a teacher you have to moderate the discussion. This is new for me and I have learn how to do it. In addition I need to explain how the data of assignment 1 were obtained, to put it in a better context. It will also help to include a question about in what other situation the approach can be used. This will help the students to already think about this themselves and will hopefully lead to the students being able to use the data in a different context. This may help to achieve the resolution/ application level.

Finally, the students need more encouragement. During the diagnostic test, one student explained to Linlin that they wrote encouragement and made drawings on the test as form of encouragement for their peer. I realise that I can do a better job encouraging the students and give them complements once in a while. I expect that encouragement will contribute to a productive learning community.

10 tips for designing a course in Blended-Learning format

Setting up a Blended-learning course can be overwhelming. I have therefore made a list, based on my own experience and this SUTQ research, with ten suggestions to help you get started:

1. Learning Management Systems (LMS)

In blended-learning the online part will always take place via the learning management system, for the UT this is Canvas. It is therefore important to set up your module in such a way that it is easy to use for the students. So it is important to structure it well and that everything can easily be found. This is also essential if you want to implement learning analytics.

2. First meeting in person

For community building, both with the teacher and the fellow students it is important to have the first meeting in person. Consider using an ice-breaking activity, especially when the students have not met before.

3. Plan the online learning activities for the students

Depending on whether your course is a BSc or MSc course I would advise to allocate slots within the UT timetable for students to do self-study. It is up to them whether they study at the allocated time. As a teacher you make sure that there is time enough for the students to study.

4. Teacher presence

Think about when and how you can be reached by the students. In asynchronized learning environments, students can contact you at any time of the day. This does not mean that you have to be available at any time. On the other hand students may become frustrated when they have to wait to long for answers. Expectation management is therefore important and being clear about when and how you are available will help you and the students.

5. Use of announcements

Sending out announcements via the LMS or emails, for instance at the start of an online self-study session will provide motivation and encouragement to students. In these announcements you can remind the students about how you can be reached when they have questions/get stuck.

6. Balance and link online/offline learning activities

Depending on the course you teach, think about what activities can be done online and what activities F2F. In flipped-class room the preferred set-up is studying theory at home and practice with the theory in the F2F sessions. This gives a natural link between the online/offline learning.

7. Implement peer-learning activities

Peer-learning activities are favourable for creating a learning community. These can be implemented both F2F and online. These activities don't have to very complicated, simply asking students to give feedback on each other's exercises/reports is a method of peer-learning.

8. Is learning analytics useful for you?

Think about the possibility of using learning analytics and what kind of information you would need in order to be confident as a teacher and how you can use it to facilitate the learning process.

9. Learning online together

In the interviews with Linlin Pei the students indicated that they would like to have a room where they could do the online self-study together. Having this peer pressure motivates them to complete their online tasks.

10. Encourage the students

Giving encouragement and conformation to the students when you notice they are working by themselves/contribute to discussions is important for creating a productive learning environment/learning community.

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Appendix 1

Recommendations for Improvement as concluded from the study: ***Impact of Covid-19 in education at UT – Opportunities and Challenges. Online learning and teaching experience survey repor***t by Linlin Pei (CES), Raisa van der Vegt (CES), Henk van den Hengel (TNW), Ben Betlem (TNW) July 2020

1. **Long-term online education strategies**
   The survey results clearly show the needs from the faculties to explore and experiment with online and blended learning further. To support these initiatives and promote innovational education, our university needs to look beyond the Covid-19 crisis and create long-term strategies for future-proofed university.

2. **Continuous support for teachers**
   Next to developing a long-term strategy, the university needs to focus on the support infrastructure. Teachers reported that they would like to receive didactical and technical support in the future, but they also highly value the opportunity to exchange experience with their colleagues. More allocated time to experiment with online and blended learning is necessary.

3. **More attention needed for students**
   Students who experienced problems with online education didn't always receive the support they needed. If the university wants to put more effort in online and blended learning, topics like self-motivation, time management and stress prevention need more attention in the future.

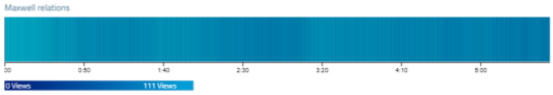
4. **Quality of online education**
   In the past few months, the implementation of online education was focused on the digitalization of course content and substitution of traditional classroom activities. In the coming months, support for better interaction and communication requires more attention to deliver high quality education.

5. **Devices for teachers**
   The survey results show that teachers were not always equipped with the right devices to teach online. Our university should investigate how they can improve their service to provide the necessary equipment to teachers (e.g. not only make frequently requested devices like tablets and drawing pads available through the LISA self-service portal, but also promote this service within the different faculties and programmes).

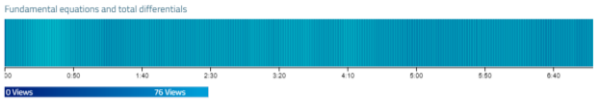
6. **Platform for social interaction**
   The university should investigate the possibility to adopt or develop a social platform where students can easily connect with each other and their teachers (e.g. Discord). The already existing channels (Canvas, Skype, e-mail, etc.) do not seem to fulfil this need, but Microsoft Teams might prove to be a possible solution for this.

Appendix 2: Pencasts

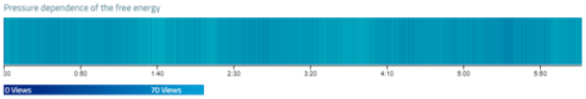
Maxwell Relations



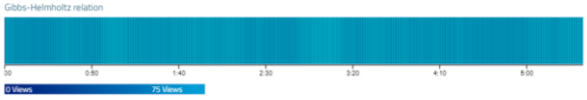
Fundamental Equations And Total Differentials



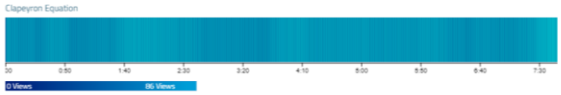
Pressure Dependence Of The Free Energy



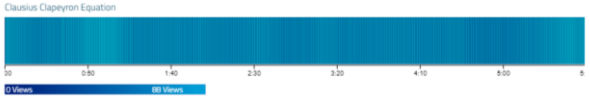
Gibbs-Helmholtz Relation



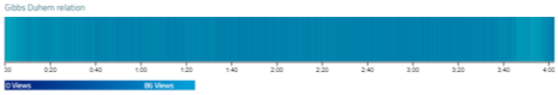
Clapeyron Equation



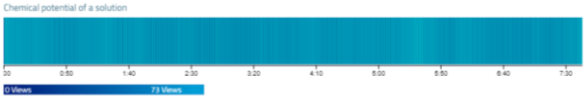
Clausius Clapeyron Equation



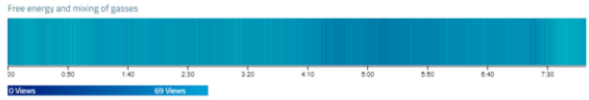
Gibbs Duhem Relation



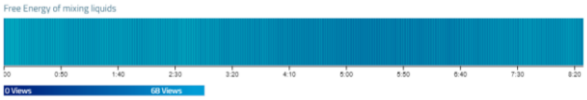
Chemical Potential Of A Solution



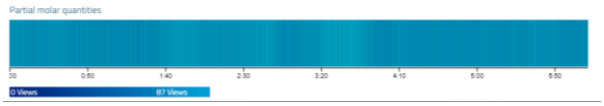
Free Energy And Mixing Of Gasses



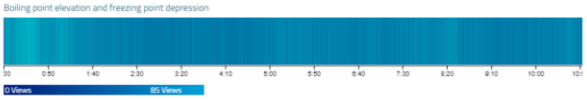
Free Energy Of Mixing Liquids



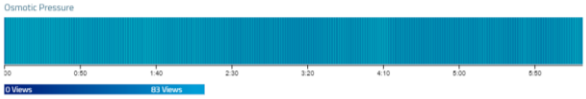
Partial Molar Quantities



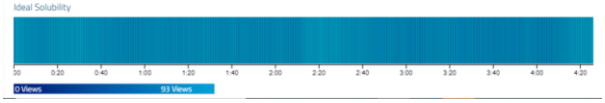
Boiling Point Elevation And Freezing Point Depression



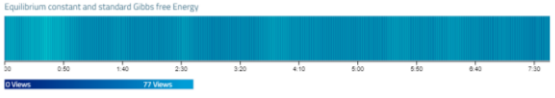
Osmotic Pressure



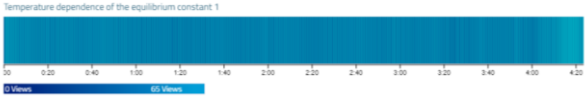
Ideal Solubility



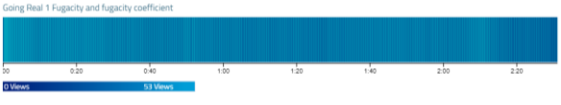
Equilibrium Constant And Standard Gibbs Free Energy



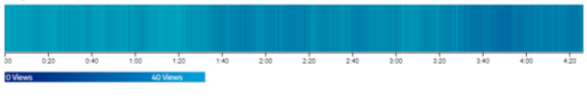
Temperature Dependence Of The Equilibrium Constant 1



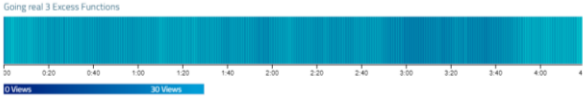
Going Real 1 Fugacity And Fugacity Coefficient



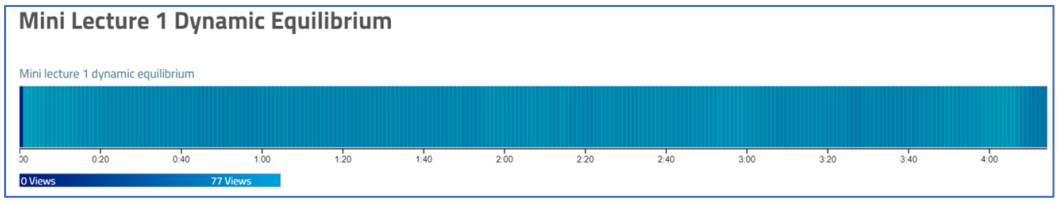
Gong Real 2 Activity And Activity Coefficient

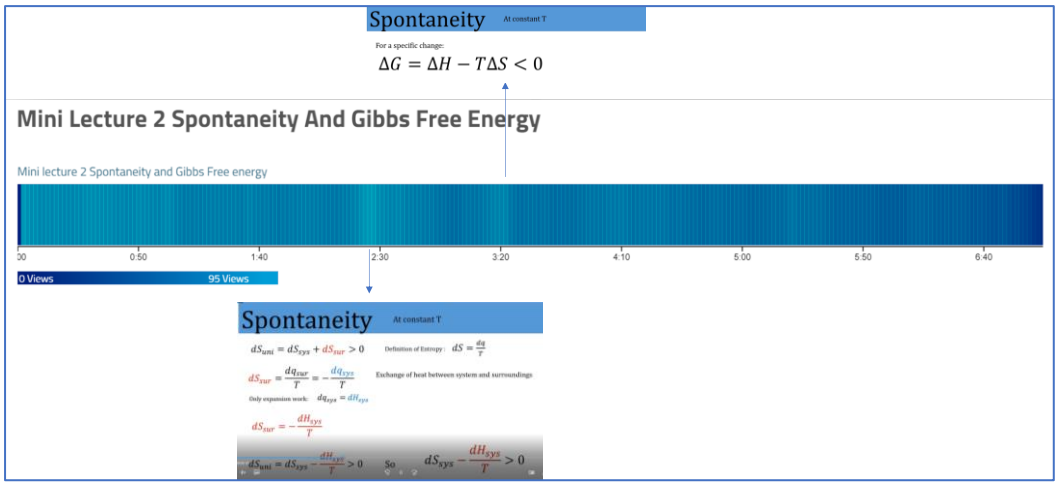


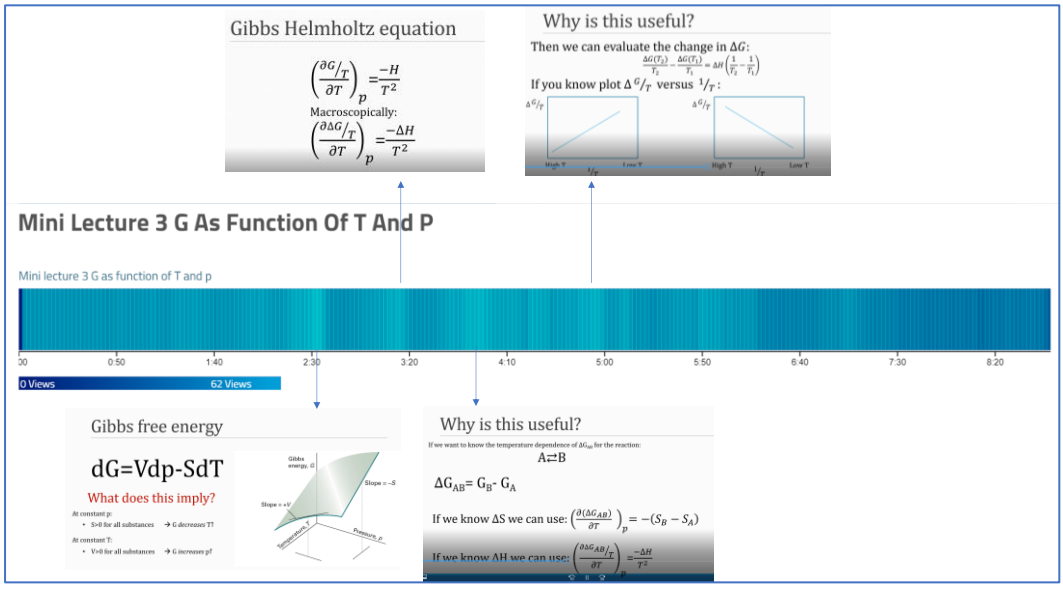
Going Real 3 Excess Functions

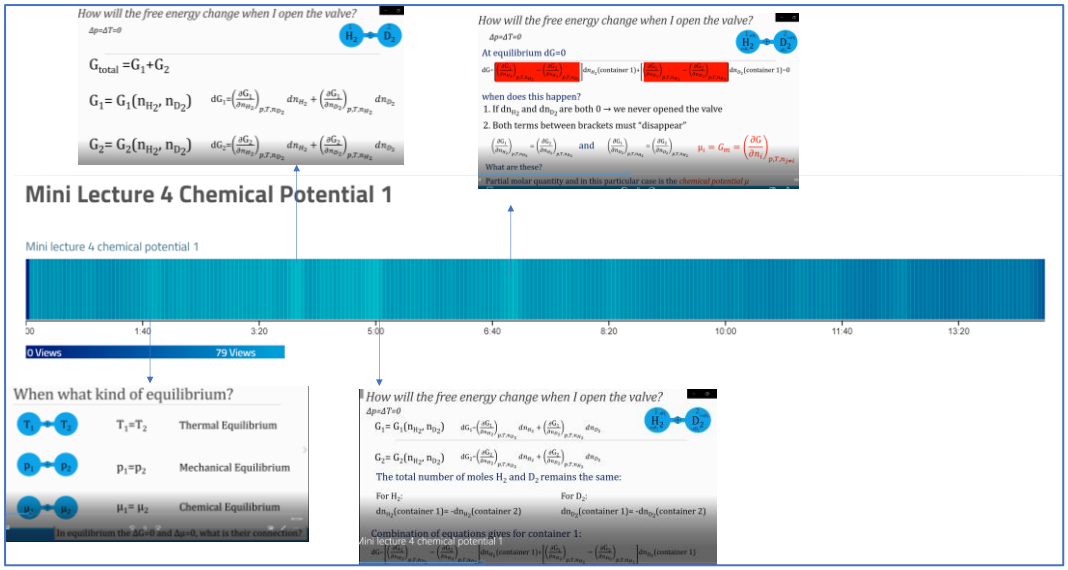


Appendix 3: Minilectures








How will the free energy change when I open the valve?
$G_{total} = G_1 + G_2$
$G_1 = G_1(n_{H_2}, n_{D_2})$
$G_2 = G_2(n_{H_2}, n_{D_2})$
How will the free energy change when I open the valve?
At equilibrium dG=0
when does this happen?
1. If dn_{H_2} and dn_{D_2} are both 0 → we never opened the valve
2. Both terms between brackets must "disappear"
What are these?
Partial molar quantity and in this particular case is the chemical potential μ
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Mini lecture 4 chemical potential 1
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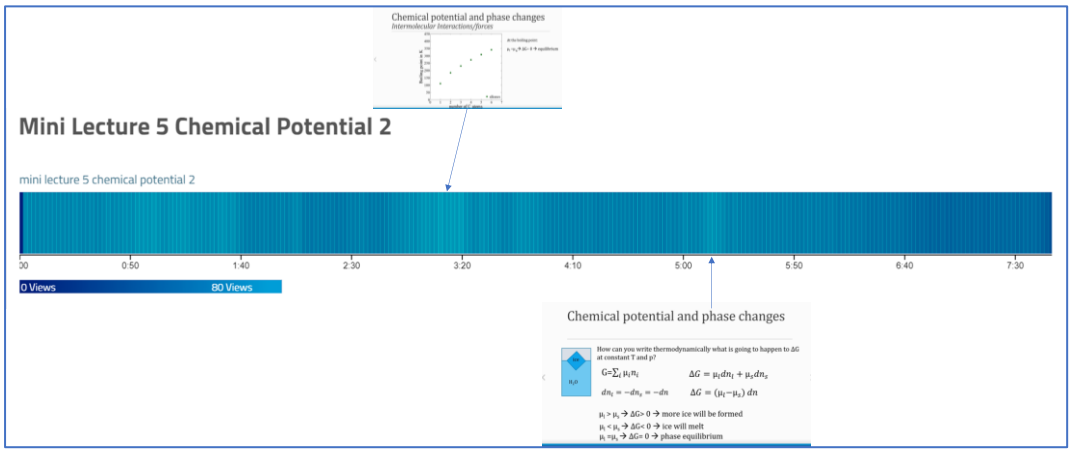
When what kind of equilibrium?
$T_1 = T_2$ Thermal Equilibrium
$p_1 = p_2$ Mechanical Equilibrium
$\mu_1 = \mu_2$ Chemical Equilibrium
In equilibrium the ΔG=0 and Δμ=0, what is their connection?
How will the free energy change when I open the valve?
The total number of moles H_2 and D_2 remains the same:
For H_2:
For D_2:
Combination of equations gives for container 1:


Chemical potential and phase changes
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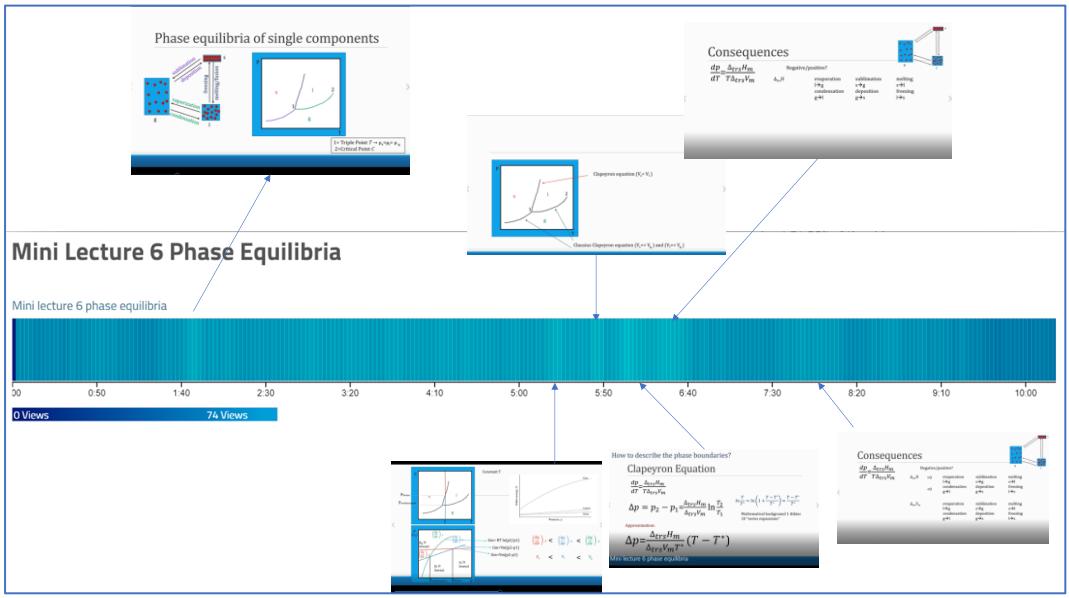
Chemical potential and phase changes
How can you write thermodynamically what is going to happen to ΔG at constant T and p?
$G = \sum_i \mu_i n_i$
$\Delta G = \mu_l dn_l + \mu_s dn_s$
$dn_l = -dn_s = -dn$
$\Delta G = (\mu_l - \mu_s)\, dn$
$\mu_l > \mu_s \rightarrow \Delta G > 0 \rightarrow$ more ice will be formed
$\mu_l < \mu_s \rightarrow \Delta G < 0 \rightarrow$ ice will melt
$\mu_l = \mu_s \rightarrow \Delta G = 0 \rightarrow$ phase equilibrium


Phase equilibria of single components
Consequences
Mini Lecture 6 Phase Equilibria
Mini lecture 6 phase equilibria
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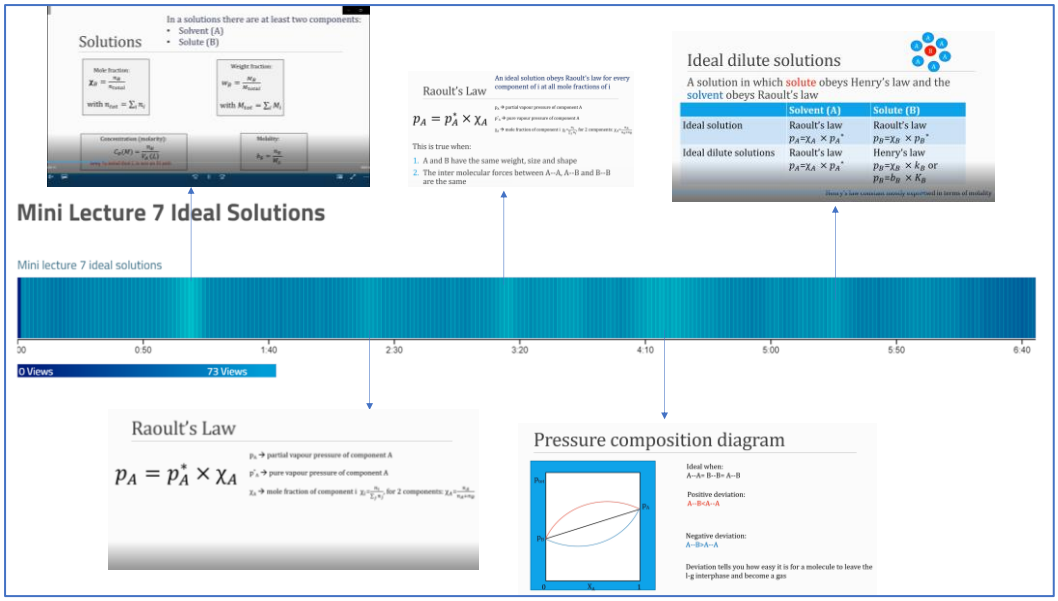
How to describe the phase boundaries?
Clapeyron Equation
$\Delta p = p_2 - p_1 = \frac{\Delta_{trs}H_m}{\Delta_{trs}V_m} \ln\frac{p_2}{p_1}$
Approximation:
$\Delta p = \frac{\Delta_{trs}H_m}{\Delta_{trs}V_m T^*}(T - T^*)$
Consequences


Solutions
In a solutions there are at least two components:
Solvent (A)
Solute (B)
Raoult's Law
$p_A = p_A^* \times \chi_A$
This is true when:
1. A and B have the same weight, size and shape
2. The inter molecular forces between A–A, A–B and B–B are the same
Ideal dilute solutions
A solution in which solute obeys Henry's law and the solvent obeys Raoult's law
Solvent (A)
Solute (B)
Ideal solution
Raoult's law
$p_A=\chi_A \times p_A^*$
Raoult's law
$p_B=\chi_B \times p_B^*$
Ideal dilute solutions
Raoult's law
$p_A=\chi_A \times p_A^*$
Henry's law
$p_B=\chi_B \times k_B$ or
$p_B=b_B \times k_B$
Mini Lecture 7 Ideal Solutions
Mini lecture 7 ideal solutions
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1:40
2:30
3:20
4:10
5:00
5:50
6:40
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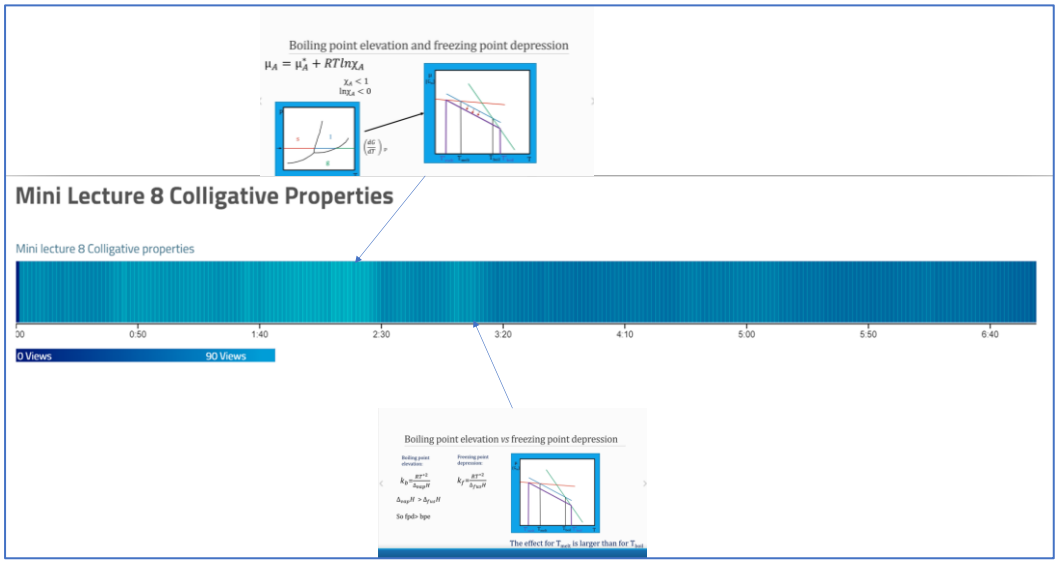
Raoult's Law
$p_A = p_A^* \times \chi_A$
Pressure composition diagram
Ideal when:
A–A= B–B= A–B
Positive deviation:
A–B<A–A
Negative deviation:
A–B>A–A
Deviation tells you how easy it is for a molecule to leave the l-g interphase and become a gas


Boiling point elevation and freezing point depression
$\mu_A = \mu_A^* + RT\ln\chi_A$
$\chi_A < 1$
$\ln\chi_A < 0$
Mini Lecture 8 Colligative Properties
Mini lecture 8 Colligative properties
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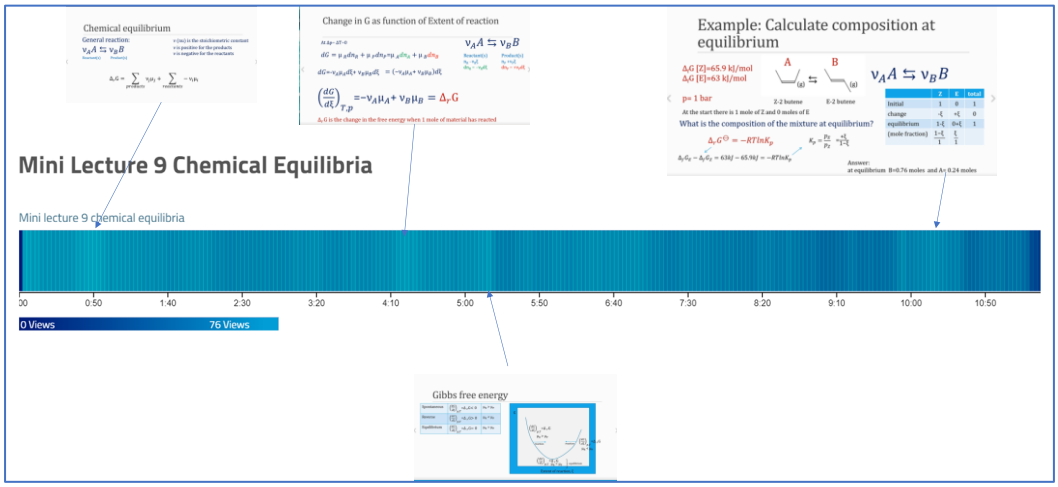
Boiling point elevation vs freezing point depression
So fpd> bpe
The effect for T_{vap} is larger than for T_{sol}


Chemical equilibrium
General reaction:
$\nu_A A \leftrightarrows \nu_B B$
Change in G as function of Extent of reaction
$\nu_A A \leftrightarrows \nu_B B$
$\left(\frac{dG}{d\xi}\right)_{T,p} = -\nu_A\mu_A + \nu_B\mu_B = \Delta_r G$
Example: Calculate composition at equilibrium
$\Delta_f G$ [Z]=65.9 kJ/mol
$\Delta_f G$ [E]=63 kJ/mol
p= 1 bar
2-2 butene
E-2 butene
$\nu_A A \leftrightarrows \nu_B B$
What is the composition of the mixture at equilibrium?
$\Delta_r G^\ominus = -RT\ln K_p$
$K_p = \frac{p_E}{p_Z} = \frac{\xi}{1-\xi}$
Mini Lecture 9 Chemical Equilibria
Mini lecture 9 chemical equilibria
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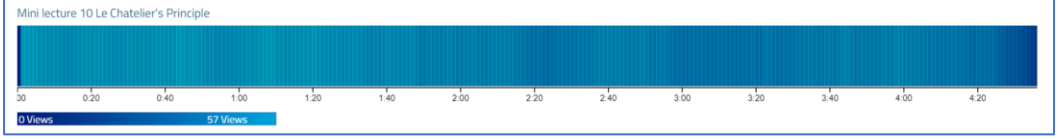
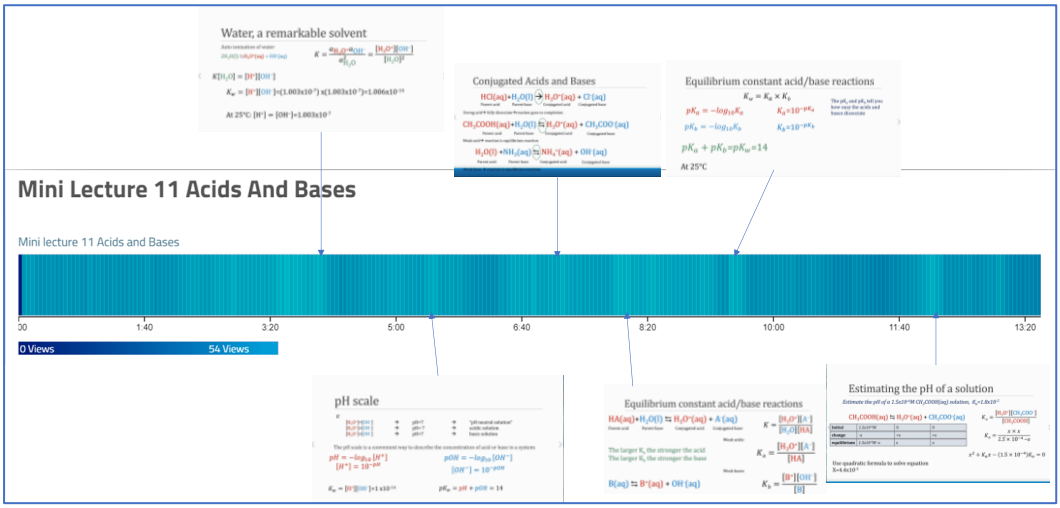
Gibbs free energy

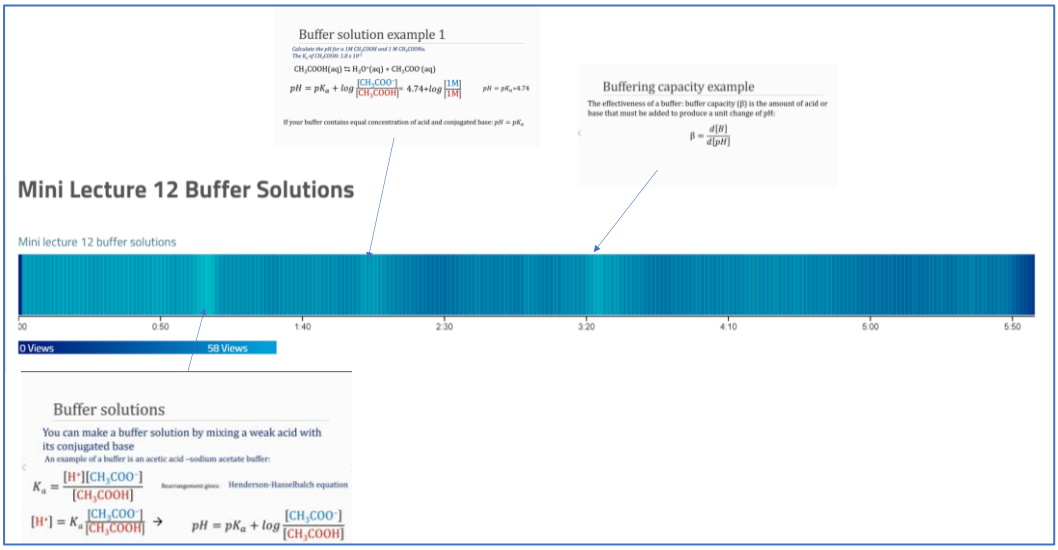
Mini Lecture 10 Le Chatelier's Principle



Mini Lecture 11 Acids And Bases



Mini Lecture 12 Buffer Solutions



Mini Lecture 13 Titrations