

Catalyzing learning beyond factual knowledge

1. Introduction

I am currently working as a researcher in computational chemistry at the Department of Chemistry, University of Tromsø (UiT). I have studied chemistry and molecular biology (1999-2003) and hold a PhD degree (2004-2008) in the field of computational chemistry. As part of my current position, I have various teaching obligations. I have therefore participated in the local program aimed at obtaining basic competence in pedagogics in order to improve my teaching qualifications. As part of this course, I am here discussing my teaching history and my teaching philosophy. I am fluent in Norwegian, but I am more accustomed to writing in English, and the following text was therefore written in English.

2. My teaching history

2.1 Teaching during my education (school to PhD degree)

My teaching history probably starts in the last years of school (~1997), where I gave extra chemistry lessons to some classmates. I did not reflect much over teaching principles at the time, but I do remember thinking during one lesson, that it is difficult to explain something, which in my opinion is obvious. It made me aware that what is obvious to me does not have to be obvious to someone else and that teaching requires being able to see a problem from another person's point of view.

When I began studying at the University (1999, Århus, Denmark), I continued to help out fellow students, but more on a casual basis. During that time, I was also part of a chemistry show for a few years (2000-2003). We were touring schools to give shows that were meant to stimulate interest in chemistry. We would demonstrate interesting effects (colour changes, small explosions) mostly with easy available household chemicals. Although I would not necessarily classify this as teaching, it did illustrate the power entertainment has in making a subject more approachable.

In 2003, I worked in a crystallography laboratory (Karolinska Institute, Stockholm). There I was given responsibility to teach a student at Master level in various laboratory techniques. The teaching consisted of one-to-one interaction with demonstration of a particular procedure in the lab. I remember enjoying teaching the student. I then went on to pursue a PhD degree in computational chemistry at a different university (Royal Institute of Technology, Stockholm, 2004-2008). Here I was assigned to help out a student at Master level on a theoretical project. Again it constituted mostly in practical demonstrations e.g. of a software. I did not have other teaching duties during my PhD studies. I did help organize some courses, but only at administrative level.

2.2 Teaching after my PhD degree

After obtaining my PhD degree in 2008, I started working as a postdoc at UiT. Here I actively tried to be involved in teaching, although initially I was not formally required to do. In 2012, my postdoc position changed into a temporary researcher position, with 20% teaching duties (in 2014 my position became permanent, still with 20% teaching). A quick overview of regular courses taught at UiT during 2009-2015 are given in **Table 1**.

2.2.1 KJE-3102, Computational chemistry

During 2009-2011, I was giving parts of the lessons in *Computational chemistry (KJE-3102, Master/PhD level)*. I was also designing the majority of computer exercises (9 in total) and was instructor on these exercises. My goal with the exercises was to expose the students to various areas of computational chemistry and to various principles and computational techniques. I did not reflect very much if this was

in alignment with the learning goals the course had overall. With regard to the lectures I gave, I mostly viewed it as 'giving a presentation on something I know something about' and did not reflect much over the learning goals or how I could assure they were reached.

2.2.2 KJE-6004, Physical and inorganic chemistry for teachers

During summer **2012**, I was given responsibility to prepare half of a new course, **KJE-6004**. This is a course in physical and inorganic chemistry for teachers, mainly internet-based but with some teaching occurring on campus during three different gatherings (each 2-3 days). I was responsible for the inorganic chemistry part (7.5 out of 15 points), and I was given free hands on the design. As this was a new course, I had to design the entire content from scratch, including choosing the textbook and subjects to emphasize, making seminar and laboratory exercises, obligatory tests, etc. . As the course is internet-based, I also had to make video lectures for the students. This was also the first time I made exam exercises and corrected these. I used Fronter heavily for the first time, created overview pages, divided the content into 7 subjects, made a video lecture for each, a set of exercises for each, multiple choice tests and obligatory exercises to hand in. I also taught at two gatherings during spring **2013** with additional lectures and computer exercises. In spring **2014**, I taught KJE-6004 for a second time with the same setup, but I also took over as coordinator for the course. This would imply extra duties, for example coordinating different lecturers, booking rooms and finding an external examiner. Both times I taught KJE-6004, the course received very positive feedback.^a

The work on KJE-6004 was inspiring and made me think about teaching in a different way than before. I was now much more occupied by thoughts about quality and of teaching as a form of product, something the students take with them and should be satisfied with. I also came to realize that it is quite important as a teacher to be involved in the design of what is taught.

2.2.3 MNF-6001, Natural science for teachers

In the fall of **2013** and of **2014**, I taught part of a different course for teachers in natural science ('naturfag'), **MNF-6001**. Here I was teaching the equivalent of 5 points out of 15. The subjects were pre-decided (the chemistry of food and cosmetics), but I was given free hands to design my part. I decided on the course literature, created different lectures and seminar exercise sets, identified useful laboratory exercises and was responsible for the exam in my part. I again employed Fronter heavily, creating overview pages and providing links to other useful resources. The course has been evaluated in 2013 and received very positive feedback.^b

The work on MNF-6001 helped me develop as a teacher. Particularly the second time I was teaching the course (2014), I reflected much on what I wanted the students to learn and explicitly stated desired learning outcomes to the students. I think this was helpful, as it allowed them to distinguish between central information (directly related to the desired learning outcome) and other type of information that was meant to provide a context. I also decided to implement other elements, which were beyond the teaching of chemical facts. As the course is on the chemistry of food and cosmetics, several of the substances discussed are compounds that the students might have heard about before, e.g. through the

^a Some of the feedback in KJE-6004 (given in an anonymous questionnaire):

- "Tusen takk for et flott møte med uorganisk kjemi. Det blir mye som jeg tar videre i undervisningen min. Dette var en av de beste emner i studiet."
- "Meget godt fornøyd. Også fint å ha en koordinator (Katrin) som var kontaktpunkt og ordnet med koordinering og ga oss rask og korrekt informasjon. Positivt at kursopplegg var klart før vi begynte, tema for hver samling var klart fra starten av. Fronter ble brukt fra UIT sin side på en meget god måte."

^b Some of the feedback in MNF-6001 (given in an anonymous questionnaire):

- "Forelesere har vært dyktige, rask og god tilbakemelding på oppgaver. Jeg er meget fornøyd med studiet."
- "Dyktige forelesere som kan faget sitt godt! Masse tid til spørsmål og oppfølging av oss studenter. Interessant og spennende tema."

Table 1. Regular courses taught at UiT (2009-2015)

Course	Time ^a	#Students	Student assessment	My involvement	Key words related to content I prepared
KJE-3102 (10p) <i>Computational Chemistry</i>	<ul style="list-style-type: none"> • S 2009 • S 2010 • S 2011 • S 2015 	4 2 5 3	<ul style="list-style-type: none"> • Exercise reports • Oral exam 	Prepared most computer exercises and was instructor on these. Gave some lectures.	<ul style="list-style-type: none"> • Computer exercises • Lectures
KJE-6004 (15p) <i>Inorganic and Physical Chemistry</i> (for teachers)	<ul style="list-style-type: none"> • S 2013 • S 2014 	5 3	<ul style="list-style-type: none"> • Obligatory exercises • Lab rapports • Written exam (4h) 	Taught the equivalent of 7.5 points. Prepared the content, gave lectures, seminars, and video lectures. Course coordinator from 2014.	<ul style="list-style-type: none"> • Progress plan • Pensum plan • Video lectures • Lectures • Seminar exercises • Computer exercises • Fronter tests • Resource pages • Exam set • Coordinator tasks
MNF-6001 (15p) <i>Natural Science</i> (for teachers)	<ul style="list-style-type: none"> • F 2013 • F 2014 	7 6	<ul style="list-style-type: none"> • Obligatory exercises • Lab rapports • Written exam (4h) 	Taught the equivalent of 5 points. Prepared the content of these and gave lectures and seminars.	<ul style="list-style-type: none"> • Pensum plan • Lectures • Seminar exercises • Resource pages • Exam set • Online meetings
KJE-1001 (10p) <i>Introduction to chemistry and chemical biology</i>	<ul style="list-style-type: none"> • F 2014 	Lectures: 230 Seminars: 24	<ul style="list-style-type: none"> • Lab rapports • Written exam (4h) 	Taught 4 of 21 lectures and gave weekly seminars (Aug-Nov).	<ul style="list-style-type: none"> • Lectures • Use of 'clickers' during lectures

^a(S = spring, F = fall)

media. I see it therefore also as my role to activate the students to reflect on information they obtain through the media or the internet and to apply critical thinking in this context. This has become even more important, since the amount of easily available information on the internet has exploded. It is now possible to find information on almost any subject in seconds – but most of this information will be written by non-experts (often the author is unknown) and might contain significant misconceptions. In MNF-6001, I incorporated an exercise, in which students were supposed to critically evaluate two videos about a chemical compound found in food. The videos have opposite messages regarding the toxicity of the compound in question, and the students were asked to evaluate the video authors and their intentions. This exercises hopefully activated the students to reflect over authors and intentions also in other contexts. This implies a transferable skill, which also should enhance autonomy in their learning. The need of critical thinking is also relevant because the concept of learning has changed drastically during the last decades. Bransford *et al.* write¹: “As Nobel laureate Herbert Simon wisely stated, the meaning of ‘knowing’ has shifted from being able to remember and repeat information to being able to find and use it”.^c Interestingly, this quote appears to have been made in 1996, before the internet era. Finding information is thus no longer a very difficult task, the difficulty rather lies in being able to separate relevant information from the enormous amount of internet ‘noise’.

^c Throughout the text, italics indicate verbatim quotes

2.2.4 KJE-1001, Introduction to chemistry and chemical biology

During the fall **2014** I started teaching parts of **KJE-1001**, a 10-point course in general chemistry. I taught weekly seminars (from August to November) and 4 two-hour lectures out of 21. This course is particularly challenging because of its size (230 students in 2014) and composition of the student body (these are from a variety of different study programs: geology, biotechnology, pharmacy, chemistry, lecturer, and several more). This means that the students have very different backgrounds and very different focuses. It is also a course on the first semester, which means that the students are not yet accustomed to university and in what ways university differs from school.

Teaching KJE-1001 was a very valuable exercise, because I had to try to explain chemistry to students that did not yet know the 'language' of chemistry. It was thus also my duty to help the students to learn this language. In the lectures of KJE-1001 I also tested out different teaching strategies such as:

- Use of 'clickers'. I used b.socrative.com to ask multiple choice questions to the students (with instant anonymous feedback), with 3-4 questions for a 2-hour lecture. My goal was primarily to activate the students, but also to test if important concepts had been understood. After one question a student said (translated to English): "*Now I really learned something*", which was a very good feedback.
- Use of small video sequences (from youtube.com) on different subjects. This was meant to give a break in the lecture monologue or illustrate some point more explicitly.
- I tried where possible to put information in historical context, e.g. give the names and pictures of those that came up with a given concept and the year it happened. I believe that historical anchor points might help to structure information in the brain. In some cases I would at the beginning of the lecture show a short video featuring e.g. a relevant chemist (which would be mentioned during the lecture), in order for the students to be able to form a picture of who that person was.

In the seminars of KJE-1001 I had 24 students, which I divided into 6 groups. Each group was assigned 1-2 exercises to prepare for the week after to show on the blackboard. Each seminar consisted of 2 hours, of which the students used one hour to work on the exercises (and ask individual questions) and one hour was used to go through exercises at the blackboard. After a student presented at the blackboard, I would sometimes ask the student an additional question (an example of a question could be: "If this compound was a gas and not a solid, would your answer still be valid?"). In most cases the students had difficulties to answer, showing me that they did not yet have the ability to transfer their knowledge from one situation to a slightly different context, and the learning outcomes were thus not as 'deep' as desired. However, due to a lack of time, I would typically not be able to go into depth with such issues.

2.2.5 Student project

During 2009 I was helping out a student on a theoretical research project for some weeks. This was at Bachelor level, but was not a Bachelor project. This was one-to-one teaching, where I would help the student to run calculations aimed at rationalizing the geometries of a certain class of complexes. The scientific content of the project was not designed by me but by another person at the department, who had also assigned me as the project instructor. Sadly, the project was not very successful, i.e. it produced very little scientific results and little learning in the student. It might be important to note that the student had originally wanted to perform a project in the laboratory, but was not given permission to do so. Her motivation for the theoretical project was low, which she stated clearly. According to Biggs, an unmotivated student simply is not responding to the teaching methods that work for the more academic students.² Biggs further implies that changing the teaching methods can improve the learning outcome. Perhaps, if this student had been allowed to perform an experimental project, illustrating the same principles as the theoretical project, her learning outcome would have been better. According to Barr and Tagg, in a learning paradigm, one should apply '*whatever learning experience works*'.³ However, this view does not

take into account the limitations that one faces in everyday teaching. For me, as the assigned instructor on a project formally supervised by someone else, it was not possible to make any significant changes.

2.3 Summary of my teaching history

2.3.1 Teaching repertoire

As my teaching history illustrates, I have experience in a variety of teaching types (lectures, seminar, video lectures, computer exercises, laboratory exercises, individual projects at different levels, etc.). I have used a variety of tools, such as Fronter, clickers, multiple choice tests, short video sequences made by others and video lectures, which were made by me. For several courses, I have been fully responsible for the content and design of the part I taught (determining the focus, choosing the book, making relevant exercises) and for one course I was coordinator. I have taught small classes (1-2 students) and big classes (230 students).

2.3.2 Assessment experiences

Table 1 sums up how the *summative* assessments have been performed in courses that I have taught. I have been part of preparing and assessing the written exams in KJE-6004 and MNF-6001, as well as interacting with the external sensor in these courses. In my opinion, a summative assessment at the end of a course is essential, because it is an important motivation for students to learn. Of course there sometimes is the danger that the students focus too much on the exam and not on understanding the subject in general. In the spring semester of 2015, I will take part in giving the oral exam in KJE-3102 and in the fall semester of 2015, I will participate in preparing the first digital exam at the Institute of Chemistry.

In courses where I have taught seminars, I have made the students answer small exercises at the blackboard in order to evaluate their understanding during the course. The intention of these is to provide a form of *formative* feedback. Also Fronter tests were employed in several of these courses (KJE-6004, KJE-1001) in the same manner in order to make the students aware of their current level of understanding. For the smaller courses (KJE-6004, MNF-6001), I provided written formative assessments to the students in connection with correcting reports on obligatory assignments and computer exercises. I put emphasis on providing the students with feedback promptly and timely, giving them the ability to readjust their learning prior to the final exam (see also Rust for a discussion on feedback⁴).

An element that I have less experience with is in letting students take part in the formative assessment of their fellow students. It has been pointed out that many teachers experience that students do a poor job in peer-assessments,⁵ but I would like to reflect upon, how it can be implemented in the courses I teach. My motivation is that I believe that experience with peer-assessment will improve the students' self-assessment, as also discussed by Allern.⁵

2.3.3 Development as a teacher

My teaching history has given me broad versatility as a teacher. I have developed during these years, from a very content-based approach to reflecting on learning outcomes and alignment of course activities, also including skills beyond factual knowledge in the teaching. This development is illustrated in Table 2.

Table 2. Personal development as a teacher

Time	What I focused on	My teaching activities	Classification
2009	What I know	Lecturing on what I know	} <i>Content-centered</i>
	What students should know	Aligning course elements with desired outcomes	
2012	How students learn	Including activities meant to enhance learning	} <i>Learning-centered</i>
2014	Education beyond factual knowledge	Including activities such as critical thinking	

3. My teaching philosophy

Here I will discuss my view on teaching and learning in higher education. To give a very brief initial outline, my thoughts about learning and teaching can be summarized in two central points:

- Teaching approaches should be flexible and should be guided by concepts and principles, for which there is sound support that they function.
- An academic education should not only promote factual knowledge, but also concepts beyond this such as critical thinking and ethical behaviour.

In the following, I will discuss aspects related to these two points. Firstly, I will point out some central principles that have been proposed to be important for teaching and learning in higher education. These principles are then related to my own teaching. Second, I will discuss elements of academic education beyond factual knowledge, with special emphasis on concepts that are important to me, such as critical thinking and ethical behaviour.

3.1 Teaching – what works?

The quality of teaching will depend on various factors such as the principles employed in the teaching, the qualifications of the teacher, and the material employed. In the following, I will briefly discuss theoretical aspects related to these points and relate them to own teaching.

3.1.1 The principles

The task of teaching would be facilitated if it was possible to identify one method of teaching that clearly is superior to all other methods. However, there is no such universal teaching method. As Bransford *et al.* note,¹ sometimes we need a screwdriver and sometimes we need a hammer. It is not possible to ask which one of these is a better tool. Instead, one might try to define a toolbox of possible approaches or principles to learning and teaching that have been shown to work well.

Pettersen has defined seven principles of relevance to teaching and learning.⁶ Loosely translated to English, these are:

- P1.** *Activation of previous experience, knowledge and competence.*
- P2.** *Development of flexible and functional knowledge bases.*
- P3.** *Development of metacognitive competence and self-regulated learning.*
- P4.** *Teaching and learning based on problem situations and cognitive conflicts.*
- P5.** *Learning and teaching connected to authentic tasks and contexts.*
- P6.** *Learning and teaching with emphasis on participation, challenge, and support.*
- P7.** *Learning and teaching with focus on articulation, richness, and elaboration.*

Most of these principles are self-explanatory, but might still warrant some discussion. The first principle (**P1**) implies identifying what students know when they enter class. This can help to identify proximal zones of development – i.e. at what level students currently are and what level they can reach given proper assistance (this relates to theories by Vygotskji, as discussed e.g. by Dysthe and Igland⁷). Previous knowledge might influence learning, as also emphasized by Bransford *et al.*: if children come to class thinking the earth is flat, and they are then told that it in fact is round, they might picture a pancake and not a sphere (see [1] and references therein).

P2 points out that students need a rich body of factual knowledge. Although knowledge has become very easily accessible, according to Pettersen, there is a misunderstanding to think that knowledge and learning now is reduced to only being competent in *finding* knowledge, rather than in *acquiring* detailed knowledge.⁶ Both aspects are relevant in current academic educations.

P3 is important especially in higher education where a large part of the learning activity is self-regulated. Learning occurs to a large extent outside class and without direct supervision. Self-regulation is also a concept that is very important for courses that are taught over the internet.

P4 and **P5** relate to the course content and are essential to motivate students to learn. As also Biggs points out, *“Motivation is a product of good teaching, not its prerequisite”*.² In order to motivate students, the teaching should activate students’ curiosity (for example by presenting conflicting cases) and also provide tasks that appear authentic. However, it can be pointed out here that teaching based on problem situations and authentic tasks requires adequate preparation of the course material. The material plays a central role in all teaching, and in particular in courses taught over the internet, the material will to some extent have to mediate teaching principles that otherwise are taught through direct interaction. Interestingly, Pettersen writes that everything the teacher brings to the teaching situation – material, exercises, evaluations, feedback – are artefacts that can mediate the teachers professional authority.⁶ It should further be kept in mind that course material needs to be prepared with the learning outcomes of the course in mind; this is a concept that typically is ascribed to Biggs.² In order to reach learning goals, content, exercises, and assessment form should be aligned. This might appear as an intuitive concept, and might explain why Biggs’ concept of alignments has been widely adopted in higher education. However, teaching strategies focusing too much on alignment have been criticized for various shortcomings, especially regarding educational elements beyond factual knowledge.⁶ Thus, if other elements, such as critical thinking, are desired, they need to be explicitly included as learning outcomes. This is a point further discussed in section 3.2.

P6 and **P7** regard the participation of the student in the teaching situation. Not any activity is meaningful in this context, but beneficial activities include those where the student can test his/her own knowledge and understanding against that of the teacher. Articulation (**P7**) is an interesting point in this context: it is first when the student has to articulate his/her opinion on a given subject that it becomes apparent if he/she truly understood the concept.

The principles by Pettersen are only some of the concepts that have been indicated as important for learning in higher education. A number of other concepts can be indicated. For example, also Chickering and Gamson operate with 7 principles for good teaching, which according to them are based on common sense as well as on *“50 years of research on the way teachers teach and students learn”*.⁸ Chickering and Gamson write that *“Good practice in undergraduate education...”*

- C1.** ... encourages contacts between students and faculty.
- C2.** ... develops reciprocity and cooperation among students.
- C3.** ... uses active learning techniques.
- C4.** ... gives prompt feedback.
- C5.** ... emphasizes time on task
- C6.** ... communicates high expectations.
- C7.** ... respects diverse talents and ways of learning.

These principles overlap somewhat with Petersen’s principles, but add additional perspectives. For example, several of the points by Chickering and Gamson put emphasis on the interaction between teacher (faculty) and student in form of contact (**C1**), feedback (**C4**) and expectation (**C6**).

Interestingly, none of the principles given by Peterson or by Chickering and Gamson relate to the qualification and factual knowledge of the teacher. Undoubtedly, the quality of the teaching will correlate with the qualifications of the teacher. For example, Bransford *et al.* have defined some requirements that good teachers need to possess: teachers need to have *“in-depth study of the subject area themselves”*, need to *“understand the relationships between information and the concepts that help organize that information”*, and *“must have a grasp of the growth and development of students’ thinking about these concepts”*.¹ By having an understanding of how students learn a given task, appropriate teaching strategies

can be chosen. Also Barr and Tagg support this view as they note that in a learning paradigm (which focuses on learning outcomes), it is understood that it requires more than an expert to elicit learning in students.³ Biggs has conceptualized this by describing 3 different categories of teachers.² A teacher at level 1 focuses on what the student is. The teacher's responsibility is to know the content and express it clearly, but lack of learning is ascribed to deficiencies in the student. A teacher at level 2 focuses on what the teacher does and is occupied by teaching strategies. At level 3, the teachers still masters a variety of teaching techniques (in addition to the content) but also focuses on what the student does.² The views by Bransford and Biggs are similar and indicate that a teacher requires both factual knowledge as well as knowledge about teaching strategies and activities that will promote learning within a given subject.

3.1.2 Relation of teaching principles to own teaching

As indicated in **P1** above, an optimal learning situation requires that the pre-knowledge of the students in a particular subject is mapped out beforehand. To map out the previous knowledge can be difficult in for large classes, but approach adopted for example in general chemistry (KJE-1001, ~200 students) is to give a multiple-choice test in Fronter prior to the course start to let the students themselves identify at what level they are. Also during the course, two such tests are given, allowing the student to track their own level of understanding and progress. Although there is no individual feedback in this system (only automatically generated answers), this should help the students to identify own weaknesses and improve learning outcomes. Over time I would like to develop tools that allow me to even better map out knowledge that students have before they come to class and use this information to redesign for example the content of a lecture.

Student activity is a central point, relating to principle **C3** by Chickering and Gamson, and **P6** and **P7** by Pettersen.⁶ Only by using knowledge in some way, the student can apply meaning to it. As Biggs writes: "[...] *meaning is not imposed or transmitted by direct instruction, but it is created by the student's learning activities*".² In circumstances where I can influence the content of a course, I have various activities, clickers, seminar and computer exercises, written rapports, multiple choice tests, and group work (see e.g. section 2.2.3). Also articulation of knowledge is very relevant in all settings – only if a student can express a concept with own words is it clear if he/she has understood it well. I have tried to implement this actively by letting students explain something in front of the class or writing about it in a report. In this context, it is also important to give proper feedback and to help the student realize if something was not fully understood. Feedback and proper possibility for students to interact with faculty members is very important in my teaching (principle **C1**). I therefore try to be available and emphasize to the students that they are very welcome to come and ask questions outside class or to send emails, which I answer as promptly as possible.

As touched upon above, the content of a course is of high relevance and mediate the teachers professional authority, also without direct face-to-face interactions.⁶ This is particular relevant when teaching internet courses, where the face-to-face interaction might be absent. I put special emphasis on well-prepared material, statements about learning goals, and timely feedback. In the preparation of the content, I also put emphasis on authentic and conflicting cases (**P4** and **P5**). As briefly mentioned in 2.2.3, providing the students with conflicting material on the same chemical compound and letting them evaluate the implications of this produced a very interesting discussion, with high student participation.

3.2 Academic education – beyond factual knowledge

A student entering University might have has a main goal to master the factual content of a certain subject. The pure mastery of facts will make the student a knowledgeable person, but not necessarily an academically educated one. I will briefly define these terms and discuss their importance in relation to own teaching.

3.2.1 Knowledgeable versus academically educated

What is a knowledgeable person? My thoughts on this are in line with statements by Bransford *et al.* about what is required to be competent in a certain area: “*deep foundation of factual knowledge*”, being able to “*understand facts and ideas in the context of a conceptual framework*”, and the ability to “*organize knowledge in ways that facilitate retrieval and application*”.¹

In my opinion, an academically educated^d person is far more than a knowledgeable person. Solberg makes several important points about what it means to be academically educated.⁹ These include critical thinking, reflection, and the ability to understand the limitations of one’s knowledge. An educated person should be able to see a subject from different point of views, be able to be precise and convincing, be curious, be able to act independently, be able to collaborate fruitfully and see oneself as part of a larger community. According to Solberg an educated person is also humble, behaves ethically, and has integrity.⁹ Of this large (but not exhaustive) list I will discuss further three points of particular relevance to me: Ethically correct behaviour, critical thinking, and the limitation of knowledge.

3.2.1.1 Ethical behaviour

The first aspect of being educated that I want to emphasize is ethical behaviour. Ethical behaviour within a discipline implies a variety of things to me such as not stealing ideas or text from others, not fabricating or falsifying data, correctly referencing the origin of ideas and scientific concepts, not exaggerating the importance of one’s results, not omitting data that does not fit one’s hypothesis, not giving unfair advantages to anyone, treating students/colleagues/applicants with fairness, respect, and integrity,^e and being open and truthful about results and intentions.

These concepts are absolutely essential for Academia, but also for society in general. It is often implicitly assumed that students with an higher educational degree are fully aware of what is considered unethical behaviour. However, active teaching of relevant ethical issues often appears to be limited to isolated stand-alone courses, and does not appear to be implemented actively in everyday teaching. That the current approach is insufficient is shown by several studies concluding with essential the same finding: more than 70% of students have at some time engaged in dishonest behavior such as plagiarism.¹⁰ Nadelson concludes that students behavior will be influenced by the environment and the behavior of the instructor.¹¹ Direct information about expected behavior is considered beneficial, because in many cases students are simply not aware of what is unethical.¹¹

3.2.1.2 Critical thinking

There exist different thoughts on what constitutes critical thinking. Stassen *et al.* write that: “*Critical thinking can include the thinker’s dispositions and orientations; a range of specific analytical, evaluative, and problem-solving skills; contextual influences; use of multiple perspectives; awareness of one’s own assumptions; capacities for metacognition; or a specific set of thinking processes or tasks*”.¹² Stassen also points out that faculty members in general appear to want to promote critical thinking, but as they lack training in doing so, they will typically develop their own definition of critical thinking.¹²

I view critical thinking especially as a concept on how knowledge should be approached. Does it makes sense with respect to other knowledge one has? Does it apply in general or might there be exceptions? Could it be incorrect? Critical thinking implies to make conclusions based on (scientifically proven) evidence not on belief. It implies questioning one’s own knowledge and own conclusions and to ensure that one does not only see results that fit a certain hypothesis but also those that do not. Evaluating the source of a given piece of knowledge, such as the author and his/her intentions, also falls under critical thinking, as touched upon above (section 2.2.3).

^d I use the term ‘academically educated’ here as corresponding to the term ‘dannet’ in Norwegian.

^e In this context the [ethical guidelines for supervision at the University of Tromsø](#) are also relevant.

Students should be able to demonstrate critical thinking in particular at higher educational levels (e.g. in a Master's or PhD thesis), where they should be able to critically approach general knowledge in the subject and also their own results and conclusions. However, critical thinking is so essential that it should also be emphasized strongly in undergraduate studies.

3.2.1.3 The limitation of knowledge

Understanding the limitations of knowledge are important. This regards the limitation of the knowledge itself (e.g. knowing what situations a certain scientific law does not describe) and the limitations of ones own knowledge, which can be viewed as a metacognitive skill of high importance. Solberg correctly points out that as we become more and more experts in a particular subject, what we know becomes more and more specialized, and in the end we sit on a narrow spearhead of knowledge.⁹ But in the process we also realize that others are sitting on equal tips,⁹ i.e. we realize that also the knowledge of others (e.g. that of an university colleague) is structured equally. Figure 1 tries to illustrate how my personal knowledge has changed from a broader foundation to a more tip-like structure. There will be some overlap with the knowledge of a fellow colleague, but we will each sit on our specialized knowledge tip.

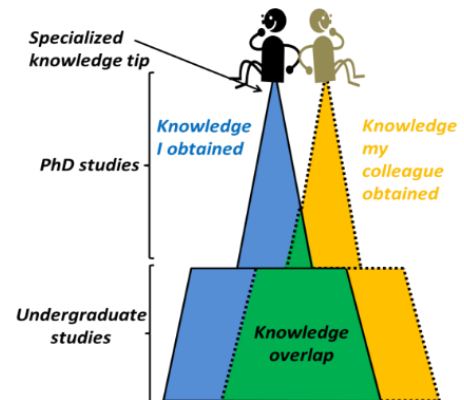


Figure 1. The knowledge tip.

3.2.2 Teaching beyond factual knowledge – relation to own teaching

As an University teacher, I believe I have a responsibility to help students become academically educated (as defined by Solberg⁹) and not just knowledgeable. However, as for example Andersen points out, predefined learning outcomes often focus on factual knowledge or specific skills related to a discipline, implying that concepts such as critical thinking will fall short if only 'aligned' topics can be taken up in a class.¹³ Thus, Bigg's theory of alignment is not sufficient to ensure that students become academically educated. Too detailed constraints on the course content will also hamper the development of independence, creativity, and reflection in the students.¹³ Training elements especially aiming at concepts beyond factual knowledge are therefore essential in higher education. Pettersen touches upon some of this in principle **P3** (Development of metacognitive competence and self-regulated learning), where the students ability to recognize own limitations in knowledge and competence are indicated.⁶ Pettersen emphasizes that "*metacognitive competence is not something one has or does not have. It is something that develops through experience, education, and active training*" (my translation).⁶

In my teaching, I try to actively incorporate elements that will foster learning beyond factual knowledge, in particular in relation to the three points indicated above (3.2.1.1 to 3.2.1.3). The first point, ethical behaviour is a concept that is of very high importance to me. Although aspects related to this are easily implemented in teaching on individual projects, it is less obvious how to do so in a lecture in front of 230 students. In my own teaching I adopt three principles:

- Leading by example
- Clearly stating expected (ethical) behaviour
- Taking actions if unethical behaviour is apparent

The first point involves for example correctly referencing material employed in the teaching. The second is particularly important, as many students appear utterly unaware of what is unethical.^f For home assignments I clearly state that any copy-pasting off the internet is not allowed and students that do so have to rewrite assignments. Nadelson points out that if students are held accountable and are aware that misconduct has consequences, then this has a positive effect on their behaviour.¹¹ I have repeatedly sent back assignments and even PhD theses where I noticed plagiarized content. However, I think that more concerted efforts, involving the faculty as a whole, might be beneficial.

An essential metacognitive skills involves being able to see the limitations of own knowledge and competence.⁶ I believe it is equally important to know the limit of the knowledge itself. In all teaching situations I try to convey to students that the knowledge presented should not be taken as an absolute truth. Any knowledge might at any time become subject to revision. In particular in my field, computational chemistry, we operate very much with models. Models are for example computational approaches (guided by physical principles) that reproduce certain experimental results and therefore can be used to rationalize these. However, it should always be remembered that any result depends on the model it was produced with. I try to make this particularly apparent by letting student apply different models to the same problem to make them realize that answers will differ; there is not necessarily one correct answer. When writing reports, I also ask students to critically evaluate sources of knowledge and to reflect on how credible these sources are – this is an aspect that is related to critical thinking.

3.4 Concluding remarks

In this text, I have discussed my view on teaching and learning in higher education. Firstly, I have discussed practical pedagogic principles that have been shown to work well in higher education, and these were related to own teaching. However, equally important as practical principles that promote factual knowledge are concepts beyond, such as ethical behaviour. For some of these concepts it is far less obvious how to implement them in everyday teaching at University level. Although I have developed some approaches and implemented them in my teaching, this is an aspect that I wish to reflect on and develop much further during the coming years.

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- ⁸ Chickering, A. W.; Gamson, Z. F. (1987) «Seven principles for good practice in undergraduate education», *AAHE Bulletin* 39(1), 3-7.

^fAn illustrative example concerns a PhD thesis I examined in 2013. The thesis contained large amounts of verbatim copying from various textbooks. The student was given the possibility to rewrite the thesis, and 10 months later I received the new version together with the information that the updated text successfully had passed a test with plagiarism software. However, surprisingly, the text was almost the same as before. Instead of rewriting the thesis, the student had replaced 3-4 words in each sentence with synonyms (e.g. *increasing* became *expanding*). This was sufficient to fool the plagiarism software, but it did not change the fact that the original text and the concepts therein were stolen. Obviously, the student had not understood, what she had done wrong.

⁹ Solberg, M. (2010), "Om akademisk dannning med utgangspunkt i Kants *sensus communis* og 'Hva er opplysning?'" from *Festskrift til Hjørdis Nerheim i anledning 70-årsdagen*. Unipub forlag 2010, p. 51-68.

¹⁰ Iorgaa, M.; T. Ciuhodarub; S.-N. Romedeac (2013) "Ethic and unethical behavior during academic years", *Procedia - Social and Behavioral Sciences* 93, 54 – 58

¹¹ Nadelson, S. (2007). "Academic Misconduct by University Students: Faculty Perceptions and Responses". *Plagiarism: Cross-Disciplinary Studies in Plagiarism, Fabrication, and Falsification*, 67-76.

¹² Stassen, M. L. A.; Herrington, A., Henderson (2011), L. «Defining critical thinking in higher education» in *To Improve the Academy: Resources for Faculty, Instructional, and Organizational Development, Volume 30*, eds. Judith E. Miller, James E. Groccia.

¹³ Andersen, H. A. (2010), "Constructive alignment' og risikoen for en forsimplende universitetspædagogikk", *Dansk Universitetspædagogisk Tidsskrift* (9).