Portfolio University Teaching Qualification

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1.1 Vision on education

What is your role as a teacher: what are your responsibilities as a teacher?

My role as a teacher at the university is to contribute to the academic formation of students. I should facilitate and supervise that (mainly young) persons can develop themselves into independent persons with skills, knowledge and an attitude at a high academic level. Assessing whether students reach the level that is required for getting a diploma is also part of my role.

As a teacher, I am responsible for making sure that the teaching activities for this are well organized, and that the level and quality of teaching is good. It is my responsibly that the assessment of students is valid and reliable.

What are your strong points as a teacher?

I am good at assuming the position and perspective of a student at the starting point of the student's learning. When designing a teaching activity, I am good at using the answers to the following questions: What is it that the students do not yet know? What is it that they do not understand? What is difficult or confusing for them? What should I tell them to make sure that they understand why it is important and interesting that they learn the topic and skills of the upcoming teaching activities?

I am good at addressing big and small groups in a manner that creates enthusiasm and curiosity, and in executing teaching activities in a manner where students become active and participate.

I make sure that my education activities are well organized. I am good at creating a situation where it is very clear to the students what they should be doing themselves, and a situation in which the students find the circumstances and materials that are needed for optimal participation in my teaching activities.

I am always looking for, and open to, big or small improvements in my teaching. That also contributes to the fact that I never get bored of teaching. Even when teaching the same course for several years it remains interesting to me.

How did you improve the quality of your teaching?

I have continuously adapted my teaching methods and the way my courses are organized. For this I work from my vision that choices for improving the quality of your teaching should be evidence based. A very central theme that comes forward in evidence-based teaching is that students must be active themselves and most of the improvements that I implemented can indeed be seen as a way to get the students more active. A very clear example is that I started using Peer Instruction for part of my lectures, and I am continuously improving and increasing this.

I have written new study material (Appendix 15) and problem sets (Appendix 8c) when the quality of my teaching was hampered by the fact that the available textbooks do not provide good study material or problem sets (details are provided in this portfolio).

On which points do you intend to improve yourself?

For improving myself as a teacher the challenge lies in reaching a higher level in the limited time that I have available for teaching. I experience that the quality of my teaching is often limited by the simple fact that had a limited amount of time for preparing my teaching activities.
The key to this is not creating more time for teaching in my schedule (not realistic). Instead, improvement can come from having better insight and a more clear vision on the tasks that I need to perform, such that I can do it more efficiently. In addition, improvement can come from using

methods that rely more on student activity and less on preparation by me. The tools, structuring, and ideas for teaching methods that I meet when reading about education and when participating in courses or workshops on teaching provide a basis for this.

For my own teaching, the biggest opportunity for improvement lies in developing a situation where the majority of the students is working the intended number hours on my courses on a weekly basis, all throughout the course (now many students work much less hours most of the weeks that the courses are running, this leads to less development and retention, even when students make up for it by studying hard in the period before passing the exam). The challenge is to do this in a manner that does not create a big workload for me and the teaching assistants, and in a manner that is not in conflict with the principle that the course participants should be treated as mature, independent persons with intrinsic motivation to study.

How have you developed yourself as a teacher?

The way I have developed myself as a teacher is very much in line with the description for further development and improvement above here. For my very first teaching activities I already followed courses on how to teach, and these already put me on the track of evidence-based teaching. At age 18-19 I was working part-time at the tutor center of a university in the USA, for which I got training. During my PhD research I was teaching assistant in a course on solid state physics, for which I took a course on how to teach tutorial sessions (also referred to in section 2).

In what way will you keep on developing yourself?

I am actively monitoring developments in the areas of new teaching methods, evidence-based learning, online learning and ICT-supported learning. I will use the information I get from this for developing and improving myself as a teacher, and the teaching activities that I carry out.

Which aspects of teaching appeals to you the most?

The intellectual challenge to coach students as good as possible in mastering new knowledge and skills.

The interaction with students, where I notice that they are motivated to learn more and get deeper understanding. The interaction with students where I notice that they learn and develop themselves due to my teaching.

How do you motivate and activate your students

As detailed further on in this portfolio (see for example Appendices 04a, 04b, 04c, 05), I make very clear what is needed for successfully participating in the course, and what the importance and benefits are of participating in the course. In addition, I choose and organize evidence-based teaching methods which aim at a high level of student activity.

What are the most effective teaching methods in your opinion?

My opinion is that the choice for a certain teaching method should be evidence based (rather than being based on an opinion, tradition or intuition). In this portfolio I will explain that I use Peer Instruction during my hearing lectures because there is scientific evidence that this gives a better learning yield per lecture for the students than a traditional hearing lecture. Similarly, I will explain that I organize tutorials for solving problem sets in such a way that students work themselves at least 90% of the time, again because there is scientific evidence that this gives the optimal learning effect per tutorial session for the students.

How do you introduce your research into teaching?

When including examples in my lectures I often take them from recent research publications or current research activities from my own institute.

In addition, in my lectures I make links to research on occasions where the textbook presents something for a fact while the reality is that the research on this topic is still active and questioning the established theories.

Do you ever read literature about education or pedagogy?

Yes. For example, for introducing Peer Instruction in my teaching I have been reading books and literature on this topic.

I frequently read pieces on evidence-based teaching, and developments in the area of ICT-supported education and online learning. The main sources are *NRC Wetenschap*, *Nederlands Tijdschrift voor Natuurkunde*, *Physics Today, Bulletins from the American Physics Society and the Optical Society of America*, and internet webpages that I can find after being directed to them by any of these sources or by information from workshop or course participation.

I participate, co-organize and present in courses and workshops on teaching, both at the university level and the national level (for example presenting at the 2013 conference of *Innovatiecentra Academisch Bètaonderwijs (ICAB)*, on using Peer Instruction for teaching Quantum Physics, see Appendix 14).

Do you look at the way other universities are teaching your courses?

Yes, I look at the web pages of courses taught at other universities, and frequently have discussions with peers from other universities (Netherlands, USA, Germany, Switzerland, France) on our teaching.

Do you look at things like the Khan Academy or ITunes University?

Yes, to monitor this development in general, and for getting ideas for my own teaching. I also refer students to good internet movies when they are in need of remedying a deficiency on their own. My favorite sources are *YouTube* and *MIT Open Courseware*.

How did you renew your education, using new procedures, activities, Nestor, new media?

As detailed in this portfolio, I use in my lectures Peer Instruction with E-clickers (electronic answering devices for multiple choice questions) with computer administration for supporting it.

For all of my courses I have a webpage (on Nestor, or just a public webpage on the domain of my research group or the education program) for providing all information on the course organization, all study material (besides the textbook), and for providing links to other material on the web.

1.2 Review of the UTQ course

How do you evaluate the UTQ workshops?

2009 – 2014	Individual coaching	Enno van der Laan (and to a lesser extent Henk Hanson)
I am positive about this. It was very focused on, and supportive for my individual needs.		
2009 – 2010	BKO-cursus for FWN (4 mornings excl. preparation) 26-11-2009 07-01-2010 04-02-2010 04-03-2010	Lucie Sierenberg-de Boer Yta Beetsma
In part these 4 mornings were good courses with good exercises. A good example is that I learned there for the first time about, and practiced with structures (various matrices) for designing/analyzing whether an examination is properly testing *all* the learning outcomes of a course. However, in part I found it too theoretical. That is, the distance between the course contents and the direct needs for hands-on improvement of my teaching was in part too large. The most clear example is that we spend time on differentiating between an “aim” and a “goal” in education, in a manner that seemed only relevant for wording used by academic specialists in the field of pedagogy.		
Tuesday 1/2 July 2014	field day writing portfolio.	BKO-team
This was very good very finding the time and concentration for making a big step with writing this portfolio, after having it 50% finished on the corner of my desk for about 4 years. Given that I came in after already participating in BKO-curcus for FWN (above), and with the desire to fully focus on writing the portfolio, I found all of the plenary parts of little use. In addition, the link between the plenary parts and the portfolio writing task was sometimes weak (for example, the discussion of the fact that since 1990 a higher percentage of high school students studies at VWO level).		

How do you evaluate the UTQ-procedure?

I am not very positive about the overall procedure. This is mainly due to the central role and required format of the extensive portfolio that should be written for obtaining the UTQ. In comparison with the UTQ/BKO-course of 2009-2010, and workshops like the ones I did with Eric Mazur (Peer Instruction) and at the ICAB conference, writing this portfolio gave much less added value for the effort it took. Of course, also this writing of the portfolio stimulates reflection on your own performance, and a reflection and more structured thinking on what you now really do when you do your own teaching. However, the writing the portfolio mainly feels as a big administrative hurdle. Given that is has to be a fairly long coherent piece, you can only make a significant step if you fully concentrate on it for some substantial time. I found it very difficult to find a big enough block of time for this in my schedule. In addition, for FWN education there were permanently far more urgent big tasks, and it was in fact the FWN education management that urged me to take care of them and to give priority to it (chairing the curriculum committee, becoming director of master program, supervising its visitation, etc.).

I think that a series of half-day workshops is a better format. Short courses with a very hands-on contents on what a teacher needs or can use for improving one part or aspect of a course. Participants need to prepare homework and prepare and evaluate actual small improvements in their teaching. On the scale of such aspects, the participants can then also reflect on their performance and improvement. Participants should then write a short summary and reflection on it during the last hour of the workshop, and that part can then be added to a portfolio without further editing needs.

At the same time, I should remark that I spent a considerable amount of time on Peer Instruction thanks to the UTQ trajectory. I was already interested in Peer Instruction before 2010, but never spent serious time on it yet for my own teaching. I decided to do it for creating more added value for the time I had to spend on the UTQ trajectory.

How do you evaluate the two day session and the feedback you received?

See also the table above here. During the two day session I got the information I needed but not yet any feedback on my writing.

2.1 (Re)designing courses (competence 1)

Introductory statement
This section 2.1 is written for the course *Quantum Physics 1*, an obligatory course for 2nd year bachelor students in (Applied) Physics and Astronomy. Given the questions that are asked below here, I found it useful to answer with respect to three aspects of (re)designing and improving this course:

1) The general initial design for this course.
2) Changing the contents of this course in reaction to a restructuring of the full bachelor programmes.
3) Improving the lectures of this course (*instructional method* [3]) by introducing Peer Instruction to the lectures, a method for increasing student activity during the lecture.

2.1.1 Goals and Objectives

- *Formulate the goals and objectives of the course, comparable to the description in OCASYS*
- *Be sure to formulate the goals and objectives **S**pecific, **M**easurable, **A**cceptable, **R**ealistic, realizable in the given **T**ime (SMART)*

At the end of the course, the students should be able to use the main concepts of the quantum theory (detailed below here) in a scientific discussion on a conference or in a research situation, when explaining them to fellow students, and they should be able to write a very short essay on it. In addition, the students should be able to solve a problem using the concepts (detailed below here) in quantum physics. Solving a problem involves either the exact calculation or estimation of a physical quantity, and to evaluate the value or expression that is found.

The contents of the course covers the following concepts of quantum theory (as covered in Chaps. 1-5 of the book *Introduction to Quantum Mechanics*, David J. Griffiths [1]): Postulates of quantum mechanics, wave functions, superposition principle, operators, Schrödinger equation, measuring a quantum system, representations (incl. Dirac notation), Hilbert space, Eigenvalues and -states, commutator bracket, time-evolution of quantum systems, Heisenberg uncertainty relation, quantum interference, wave mechanics, tunnel effect, particle in a box, harmonic oscillator, creation/annihilation operators, coupling quantum wells, degeneracy and identical particles, exchange, quantum mechanical treatment of angular momentum and spin (a more detailed list with concepts is available at the website of the course).

2.1.2 Embedded in the curriculum

- *Explain how the course fits into the curriculum of the bachelor/ master.*

The course is an obligatory course in the first quarter of the second year of the bachelor programs in (Applied) Physics and Astronomy.

- *Explain the contribution of this course within the bachelor.*

The course provides the first systematic teaching in quantum physics. Knowledge of, and skills for using quantum physics are a fundamental and essential contribution to the formation of the students in the bachelor programs (Applied) Physics and Astronomy.
In particular, knowledge and skills in the area of quantum physics are prerequisites for subsequent courses on atomic physics, solid state physics, physics of fundamental particles, and advanced quantum physics, and also for the participation in research activities in physics.

The concepts that must be treated in the course are specified in the overall plan of these bachelor programmes, and –in particular– in relation to preparing the students for participating in the courses *Quantum Physics 2* and *Solid State Physics*.

- *How does this course fits in the faculty's vision on education?*

In accordance with main points in the faculty's vision on education:

- The course aims to contribute to the formation of students in (Applied) Physics and Astronomy at top level in the world, with modern and innovative teaching that supports the faculty's goal to excel in teaching.
- The format of the bachelor course is designed to be suited for teaching to a group of more than 75 students.
- The structure and organization of the course aims to be very motivating for the students, and aims to provide students with a structure that is suited for their level of independence, such that at least 80% of the participants will pass the course.
- The course includes modern topics and examples to create enthusiasm among students for participating in the course and the full bachelor programme. This should improve the performance of students in the program and have a positive influence on the enrolment of new students in the Physics bachelor programs.

2.1.3 Starting level

- *What is the basic knowledge a student should have at the outset of this course?*

The basic knowledge that the students should have is the contents of the following courses of the 1st year of the bachelor program in (Applied) Physics (or equivalent):

Calculus 1, 2, 3 (in particular mathematics with complex numbers, integration, differentiation, differential equations, Taylor expansions)
Linear algebra
Mechanics & Relativity 1 and 2

In addition it is advised that the students have a basis in (as provided by other courses in the first year):

Description of wave phenomena
Mathematics of the Fourier transform

2.1.4 Learning activities / design of the course

- *Explain why the course will be redesigned.*

I initially designed the course from scratch for the year 2004-2005. That year I was teaching it for the first time, and there were a set of requests and complaints from the teachers of follow-up courses that made clear that using a different book and a full redesign of the course was needed. I started with using the book by Liboff [2].

For the year 2007-2008, the contents of the course was changed to include a part that used to be in *Quantum Physics 2* (angular momentum, 1 week study load in the course), since the teacher of *Quantum Physics 2* (also using evaluations) felt that *Quantum Physics 2* was too full.

Starting per year 2009-2010, I changed several of the lectures to the format where I used Peer Instruction.

Per study year 2011-2012, the contents of the course was strongly modified, and the course started using a different book (by D. J. Griffiths [1]). This was needed after the re-structuring of the bachelor programme, where part of the students would no longer study the follow-up course

Quantum Physics 2. Consequently, the course *Quantum Physics 1* had to become an independent course that covered all bachelor Quantum topics in reasonable depth, and *Quantum Physics 2* became a course of more in-depth treatment and methods (instead of two courses that covered the full range of topics in sequence).

- *What is the general design the course?*

Teaching method and instructional form
The design (and for the most part the choice for a *teaching method* [3,4]) is simply based on the approach that the required contents should be treated in 8 weeks. Further, the overall organization of the bachelor programme defines the situation that the format should be two lectures per week (2 x 45 min each) and two tutorials per week (also 2 x 45 min each), and no practical (but related topics come back in the parallel course *Introduction to Programming and Numerical Methods*). While the bachelor programme would probably allow me to setup the course with very different teaching methods (that is, deviate from the traditional pattern with lectures and tutorials), I see no clear need for this and I lack the time and manpower for this.

Sequencing content
The design with respect to *sequencing content* [4] is *structurally based* for the most fundamental structure of the course. I on purpose choose the systematic approach to start with the postulates of quantum physics. I find this course a suitable moment for the students to learn that in fact any theory in physics is based on postulates, and that they learn how that works out. All the later lectures are then with reference to these postulates. This appears in two forms:
1) The contents (lectures and problems) show how well-known basic equations and phenomena are a very direct consequence of the postulates.
2) For phenomena and equations that are new for the students but core material for the students to know after the course (for example, angular momentum, identical particles), this is presented and investigated as consequences of the postulates.

Working this out at weekly level, the sequencing content is not strictly structurally based. Instead, to display relations between topics and alternative views, individual lectures are *conceptually based*. Further, lectures can in fact work out as *learning based*, since I often ask students (also at the start of each lecture) whether there are questions, or requests for what the students want me to lecture about. This should then of course still have relation with the prescribed theme (students must have read the book) and problem set of the current or previous week. I then improvise, while in fact using material that I have at hand from the weeks around it and previous years.

Weekly planning based on 8 main themes and problem sets
I divided the required contents into 8 parts, that are in turn the basis for the two lectures for that week. In addition, for each week I developed a related problem set (in part problems from the book, but for the most significant part self-written problems, see Appendices 08a-08d). These form the basis for the two tutorial sessions in a week. The related contents of the book (for Griffiths [1] Chaps. 1-5) is specified in parallel, where we skip parts of Chapter 2 in the first weeks to finish those in week 8. This has the advantage that the students can work with interesting concepts and tools early in the course (to avoid getting stuck in a rather algebraic part of the book). Where the book is incomplete, I provide extra handouts that I in part wrote myself (a chapter on identical particles, see Appendix 15).

- *How did you construct the course? What is the relationship between lecture, seminar, lab periods etc.?*

See above. To be more specific, the way of interacting with the student during the lectures and the contents of the lectures assume that the students can and do read the book. The lectures are used to treat the topics at a more conceptual level, to discuss points that are confusing, and to do concept exercises (Peer Instruction questions). In addition, a significant part is spent on discussing related research activities and modern applications.

The tutorials are organized in a manner that is based on the evidence-based vision that the students get most out of it when they spend >90% of their time at the tutorial at trying to solve hard problems. I give very specific instruction to the teachers of the tutorials to adhere to this way of teaching (Appendix 03).
The problem set is related to the contents of that week, and is in part further illustrating applications of quantum physics. For another part, the problems are designed to confront the students with the conceptual meaning of the theory in the book, for cases where this will probably be overlooked by most students when only reading or hearing about it. I developed my own problem set because the problems in the text book are for the largest part too superficial in forcing the students to think about, and work with the physical meaning of the theory (often they do not go beyond superficial mathematical tricks). In addition, the problem set (and concept questions during the lectures) and the way of working during the tutorials sets the students on track to meet the learning outcomes of the course: the problems ask the students to reason, to calculate, estimate, and evaluate answers, and to apply a systematic approach of working while solving the problems (Appendix 05).

- *How did you deal with the limiting conditions of the course like number of students, number of study points, number of available lectures, rooms for seminars, labs etc.*

The course was designed to function well with respect to the boundary conditions provided by the programme (number of meeting hours etc.) and the number of students. To be specific, I always check that the work load for the students should be 140 hours for the full course (5 ECTS) and this defines in how much depth the topics of each week can be worked out. In addition, as an example for the lectures, Peer Instruction is well suited for enhancing student activity for group sizes 10 to 400 students.

- *Relate the chosen activities to the indicated goals and objectives. Give arguments why you feel these activities will help achieve the desired learning results.*

As in part already stated in the above: the required knowledge (conceptual topics) are all covered in the 8 week program. In terms of skills and attitude (the student can reason, discuss, calculate, estimate, evaluate, etc., and is critical towards accepting final answers), these are all addressed during Peer Instruction sessions in the lectures or while working on the problem set during the tutorials. The argument why these activities will help for meeting the desired results is simply: the students are directly and actively training exactly what the course aims to achieve.

- *Which literature did you choose as background for his course? Why did you make this particular choice?*

The book that is currently in use in the book by Griffiths [1]. This book was selected in a small study group with the teacher of *Quantum Physics 2* and members of the Curriculum Committee for restructuring the bachelor. It is well known that no book on quantum physics is perfect, but this book has –with respect to a wide range of alternatives– the right volume, level and depth, and is well suited for having *Quantum Physics 1* and *2* in sequence, while *Quantum Physics 1* is then already covering the full range of topics that should be addressed during a physics bachelor.

Where the book is incomplete, I provide extra handouts that I in part wrote myself (a chapter on identical particles, see Appendix 15).

- *How do you activate and stimulate your students?*

Peer Instruction during the lectures. Providing a very clear and challenging set of problems for homework and the tutorials. Make it very clear to the students what the expected activities are (at home and during the lectures/tutorials) for a particular week. Provoke and pay a lot of attention to student questions. Give interesting and modern examples of research and applications during the lectures. Explain the students for all parts of the course why they need to know about it.

2.1.5 Supporting the learning process of students
(here for information for the teacher, in 2.3.5 it comes back for information to students)

- *How do you support the learning process of the students?*

This seems well covered in 2.1.4.

- *How do you motivate the students*

See the last point of 2.1.4.

- *How do you attune with the starting level of the students?*

Look up the contents of preceding courses. Ask the students. Carry out conceptual questions during a lecture where the students are provoked to confirm their starting level.

- *Which activities do you organize to help the students learn the content of the course?*

This seems well covered in 2.1.4.

- *How do you measure the progress of the students and how do you give them feedback about their progress?*

See section 2.1.7.

2.1.6 Use of Nestor, other course web pages and other ICT

- *Give a description of the way you use Nestor and other ICT.*

ALL materials, contents, information about organization, and communication about the course goes via the course website (Appendix 04a). A rare e-mail to draw attention to changes goes out via the Progress system. My philosophy (and simply because of practical advantages) is that it is good to have the course website as public as possible (hence it is in the form of the public website, http://www.quantumdevices.nl/teaching). Only a few items for which I like to have restricted access (solutions to the weekly problem sets, and some selected pages from commercial books) are made available via Nestor instead.

The course website and some of the actual lectures show links to related (popular) publications about research and selected *YouTube* movies.

I (often, but not always) use an electronic system for collecting the answers of Peer Instruction (with computer storage of results, see Appendix 14, slide 8). This has the advantage that it gives direct insight in answering statistics. You can share these with the students during the lecture, and you can look them up again after the course.

- *Indicate the goals and objectives of the way you use Nestor and other ICT.*

Make a situation where it is very clear to the students what they should do and what they should use. Facilitate to the students that they always have access to anything they need.
Create statistics/indicators for the progress of students with their learning.

- *How do you use Nestor to support your educational activities?*

See above.

- *How innovative is the way you use Nestor or ICT in this course?*

Concerning the website: I think it is an example of a well-organized and well-functioning use of a course website, but that it does no go beyond anything that I would call innovative.

The use of Peer Instruction with E-clickers is in principle well-established (a commercial product). However, for Physics in Groningen it is new, and using it for quantum physics is quite new, also in the international scene.

2.1.7 Assessment

- *How do you check whether or not you achieved the teaching goals? Not just the final exam but also during lecture or tutorial.*

Mid-term and final exam
The full statistics of the student performance for each sub-question is available, see also section 2.3.5 and Appendix 10b.

Lectures
Peer-instruction with E-clickers gives direct insight and statistics on the performance of students when introducing a new topic in the course (see Appendix 14, slide 8), via questions that can only be answered by conceptual reasoning (see Appendix 14, slide 10).

Simply by asking questions, and starting discussions with the fully group of students, and truly wait till answers come forward. Students rapidly get used to the format where it is normal to have group discussions during a hearing lecture.

Tutorials
During the tutorials, the teaching assistants make a few rounds where they pass all students for monitoring their progress and level of performance (the working method is specified in Appendix 03). After the tutorials of each week there is a meeting with all teaching assistants where we evaluate the student performance on working out the problem set.

- *Describe the different types of assessment you use and indicate why you think they give a valid representation of the learning results of the students.*

See above. For these methods, a strong point is that they include the performance of all students (but for lectures and tutorials only for those students who show up). Given the direct overlap between these activities and the intended learning outcomes, they form a valid representation for the full group.

2.1.8 Planning of the course

- *How the course is planned, what is the timetable for lectures tutorials, labs etc...*

See 2.1.4. For the actual roster of 2014-2015 see Appendix 06.

- *Explain the limiting conditions in planning the course (e.g. number of assistants, number of lectures etc.).*

See 2.1.4.

2.1.9 References

- *If you checked literature or looked at other courses while designing the course, please give the references here.*

For detailed references see the section References on the last page.

I frequently look at the course web sites of quantum physics course of other universities in the Netherlands, Europe, the USA, and other countries with top level programmes.

In 2009, we studied with a small group of colleagues (teacher *Quantum Physics 2*, members of the Core Curriculum committee for re-structuring of the Physics bachelor) the available text books, and what text books were commonly used by other (top) universities in the Netherlands, the USA, Germany and Switzerland.

For studying Peer Instruction, I used the references [5,6,7] (see last page of this document).

2.2 Teaching and supervising students (competence 2)

2.2.1 Description of an educational activity

- *Describe an educational activity during the course in which you play a central role, lecture presentation, instruction.*

I will use two examples from teaching the lectures in the course *Quantum Physics 1*, and two examples from the tutorials for this course:

1) **Example on activating students, and lecturing outside the book in adjustment to student needs:** This is about the lecturing and the slides (see Appendix 07a) used when the students run early in the 2nd week of the course into the fact that the formalism of quantum mechanics uses operators. I added these slides and questions to the students since the students have a lot of trouble grasping what these operators are, and why we need them. All textbooks I know simply skip the coaching of the step that the student needs to take at this point (they just postulate it). So, I try to turn this around, and try to give the students the confidence that they would readily invent operators themselves if they would be forced to think about it for a minute. The starting point is that they just got used to the idea that in quantum physics the particle's position or momentum do not need to have one value (a number), but that they can have many values at the same time. Instead of showing the slides (which I have so they can look it up on the web later), I initiate it on the backboard, and tell the students to work it out on a piece of paper in 30 seconds. Next, to compare and discuss it with their neighbor, and then I ask for results from the group, discuss the results, and work toward the outcome as on the slides.

2) **Peer instruction example:** This is an example of a Peer Instruction question that I run in the lecture where the course first makes the transition from one-dimensional to three-dimensional descriptions (the question itself is done on the black board, but made available in Appendix 07b). I explain that this immediately gives angular momentum (which they know from classical mechanics, we check this together). I ask the students to think about the questions whether the set of eigenvalues of a quantum operator for angular momentum has a discrete or continuous character, and what the reason is that underlies the correct answer. As for all peer-instruction questions, I first ask them to answer in silence within 30 sec, then to compare and discuss the answer with their neighbor for ~2 min (and practice shows only ~25% of the students answered correctly), and then to answer again (now more than ~50% give the correct answer). Since the migration to the correct answer is low for Peer Instruction, I usually still have a discussion to explain why *D* is here the best answer, and to draw an analogy with what they already knew (discrete states of a particle in the one-dimensional box). The result should be that the students remember very well that angular momentum always has a discrete set of eigenvalues, and that this is in fact quite logical. Appendix 14 slides 8 and 10 further illustrate how this is implemented.

3) **Problem set example - Clarifying representations:** This is an example of a question from the problem set of week 3. At this moment in the course the students are learning about the formalism of different representations of quantum states (x- and p-representation, and Dirac notation) and the Fourier transform relation between x- and p-representation. This is important, but the students find it difficult and confusing. At the same time, the (problems in the) book is (are) not very systematic in confronting the students with the meaning, usefulness and importance of it. I therefore made a question myself that does exactly this. It is presented in Appendix 08a (question and answer). In particular, the introduction to this question contains the sentence "*This problem (about a particle in a box) is meant to clarify how the same state of quantum system can be*

<u>*represented*</u> *in many different ways*".
I designed that the students work on this problem in the following way. They come to the tutorial, while they already studied the book and had some simple problems from the book as homework. At the tutorial, they get the problem set for that week as a handout. In week 3 this includes the question that I address here, see Appendix 08a (the full problem sets of all weeks, and example of model answers are presented in Appendices 08c, 08d). This problem as in Appendix 08a is too hard for most students to work out without opportunities for help. This help is available during the tutorial from peers and the teacher (who is providing such help according to our way of running the tutorials, which means students try to solve problems and do self-study >90% of the time, while they can interact with peers, see Appendix 03). At the end of the tutorial, model answers are provided. Students who miss the tutorial have access to all the material via the website of the course.

4) <u>**Problem set example - Application of quantum physics:**</u> This is a second example of a question from a problem set for a tutorial (week 6). It is used in the course as for the case (3) above here. This example is included to highlight that these questions can be used for making links to applications of quantum physics (here NMR and the MRI machine in the hospital). In addition, this question (and the question of case (3)) highlight that many of the intended learning outcomes are directly trained with these problems: the type of questioning varies from exact calculation of quantities, estimating quantities, writing short conceptual essays, and evaluating answers.

- *Explain which parts of the course are relevant in this activity. Indicate the teaching goals and objectives for his activity.*

This is included in the above.

- *Describe the instructor's activity and student's activity. Give arguments why these activities will help achieve the teaching goals…*

This is included in the above. In general, it is about getting students active (see below).

- *To what extent are these activities interactive, i.e. activate the students*

This is described in the above.

- *Explain how you check whether you achieved your teaching goals.*

In the first case (1), I check whether a reasonable number of students wrote down something sensible, and whether their discussions are on-topic (by walking around).
In the Peer Instruction case (2), you immediately see the statistics of the results (Appendix 14 slides 8 and 10), and part of the students tend to protest and ask for further discussion (which makes clear their brains are activated and on the right track). For case (3) and (4), the teachers of the problem sessions directly monitor the progress of each student.

2.2.2 Feedback and reflection on the educational activity

- *Analyze the activity of 2.2.1*

For the cases (1) and (2), what works well is that the students are active (in comparison with a traditional lecture) rather than passive. See further above and below here. For the cases (3) and (4), the performance on the mid-term and final exam shows that the students get trained in solving questions at this level. Students give as feedback in the evaluations that they like that all the material (including model answers) is made available.

- *Indicate what went well, and what could have gone better.*

For case (1), what goes well is that it is an open question where students become active. As compared to the time before I was using this part, I get less questions that basically say: "I find operators confusing and do not understand why they are used or needed". What can go better here is confirming that the goal is achieved.

For case (2) what goes well is that there is very vivid discussion in the group on the question. What can go better is to re-design the question in such a way that the migration to the correct answer after the interactions between peers more in the range 25% migrating to 90%. In that case, I need to spend less plenary time on the follow-up discussion and get better confirmation of the desired effect.

For case (3) and (4): see above on what works well. What can go better: with the team of teachers (using the teaching experience and student feedback) we still find each year points where the problem set can be improved in terms of removing confusion, having text put the students on track with self-study, or having a text and sub-question that cause that all students get the insight we aim for.

- *If possible get peer feedback on the activity.*

For a lecture in 2009-2010 where I used Peer Instruction I got video feedback and peer feedback from Enno van der Laan. The most remarkable outcome was that he observed that using Peer Instruction also enhances the amount of questions that are asked during a lecture, and that this was appreciated by the students (as checked via a question to the group of students). I have used this since then to provoke questions and follow-up discussion.

For the lectures, I frequently get peer feedback from a teacher of the tutorials who sits in on the lectures.

- *Explain what you think about the feedback.*

I think that for this example the feedback was valid and useful. More in general, feedback is good, as it sharpens my observations and reflections on what works well in a lecture, and what does not.

2.2.3 Using interactive learning activities

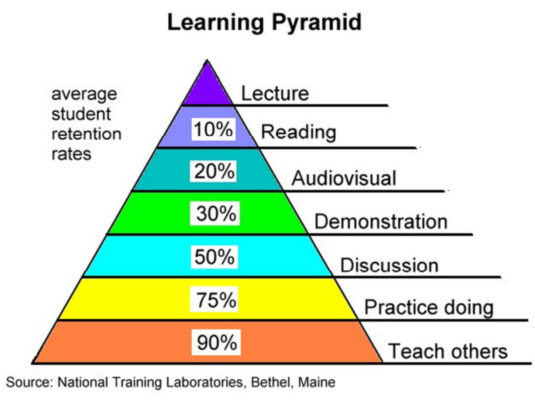
- *Indicate how you have designed a seminar/ tutorial / lab.*

See above in 2.2.1.

- *Explain what the added value of this activity is.*

The added value of Peer Instruction is well described in the literature [5,6,7], see also Appendix 14 for a set of my own lecture slides from one of the workshops I gave to other teachers on using Peer Instruction.

For an alternative way of explaining the added value, one can use the Learning Pyramid of the National Training Laboratories, Bethel, Maine (see figure, source http://ohspd.blogspot.nl/2009/05/pd-for-tuesday-may-5-2009.html).



This presents the outcomes of research on the retention rate as a function of the type of study activity done by a student. For the possible activities during a lecture, peer instruction moves the lecture activity from the top (passive, traditional lecture) to the bottom (active), where in particular the fact that students teach each other moves the retention rate from the <10% zone to the 90% zone.

- *Explain how interaction with the students takes place during the activity.*

See 2.2.1

2.2.4 Supervising students (individually or in groups)

- *Describe the way you supervise an individual student or small groups.*

The situation is typically that the student(s) has(have) to perform a research task in the lab, or write a student report. We meet periodically (typically once per week) ono-on-one, up to 45 min. We discuss and explore together what the task actually is, and what a good approach is for actually working on it. This results in an agreement (work plan) on what the desired product/achievement is for the coming week. Progress in writing must be delivered before a next meeting such that I can read it first. In the next meeting, we check together whether the work plan has been achieved, evaluate the ups and downs, and adjust the plan or make plans for a next step. I then also give the student feedback on his/her functioning. During the week I will ask about progress and give some on-the-spot feedback when walking around during a lab tour. The progress of an individual student is linked to, and also reported in progress meetings with the full team, to ensure that the various activities can stimulate each other.

- *Indicate why you chose this type of supervision.*

It is flexible and well suited for providing feedback and education that is tailored to the individual needs of the student.

- *Describe the goals and objectives you want to achieve with bachelor, master and PhD students.*

I want that these students get trained and develop themselves in academic researchers. I want to achieve research goals that we can publish together with these students.

- *Describe the procedure and planning that is used.*

See also the first point of this section. Concerning the planning and goals of the full project: at the start we write down the intended end date, what we hope to achieve, and what type of written reports and oral presentations the student should give on the way and at the end. We build in some mid-term checks for monitoring progress, and for highlighting the possible need for adjusting the goals if what we try turns out to be impossible.

- *Indicate why you chose this type of supervision.*

It is a good way for training the student on performing well in the academic research environment, while the progress monitoring and the assessment of the performance level on the way is built-in in a systematic way.

2.3 Testing and assessment (competence 3)

Summative assessment

This section 2.3 is written for the course *Quantum Physics 1.*

For evaluating the final exams, I use three different finals exams (presented as Appendices 9, 10, 11), since I already worked on these during the UTQ/BKO course, or because they are suited for illustrating changes and developments that I have implemented after evaluations (also used for section 2.4).

2.3.1 Form of examination

- *Describe the final examination and other tests that are used to determine the final score of the students*

The final examination is implemented as one written exam of 3 hours with open questions. In addition, students have the option to participate in a mid-term exam (written exam, 1 hour, open questions), for which they can earn up to 1 bonus point for the final grade.
A written exam with open questions is the best option, since the group is too large for oral exams, while open questions are the best choice for getting good insight into the student's abilities with respect to the intended learning outcomes, and while having a direct link to the learning in the lectures and tutorials.

- *Explain how you can see whether you achieved your teaching goals.*

I design an exam for which the answering requires that a student has mastered all the learning outcomes (section 2.1.1, also worked out below here). The extent to which a particular student gives correct answers on these exam questions thus directly reflects whether the student meets the learning outcomes. The statistics of this give insight in whether the full student population of a year meets the learning outcomes, and directly reflect whether the teaching of the course is effective in guiding the students to the learning outcomes. The score of each student on each sub-questions is administrated in a big table (Excel sheet), such that I can directly review the performance of one particular student and that of the full student population (see Appendix 10b, averages on the bottom row).

- *Relate the exam to the goals and objectives to the course*

For both the final exam and the mid-term exam, the contents and topics of the questions cover a broad sample of the topics that the students must master during this course, which at least covers each main area of topics. In addition, the types of questions cover the full range of skills that are listed in the learning outcomes for this course, and the levels at which the student should be able to perform these skills (Bloom's taxonomy [9]). During the course, students are instructed and trained to solve problems in a systematic manner (see Appendix 05), including the evaluation of the answers they get (an electron mass of -28 kg [negative!] should switch on an alarm bell). The following appendices illustrate how I carried out analyses of final exams on these three aspects:

Analysis of levels in the cognitive domain	Appendix 9b
Analysis of skills	Appendix 11b, table 1
Analysis of topics / knowledge items	Appendix 11b, table 2

- *How do you design the summative assessment / examination?*
    - *Cooperation with other teachers/ teaching assistants*
    - *Peer feedback on the exam*

For designing an exam, I make 3 to 4 problems with various sub questions, and aim to cover all aspects with respect to knowledge, skills, and levels of cognitive actions. I often ask the teaching assistants to provide an idea and a first draft for an exam question.

For testing whether a final exam is suited, I do the following checks with my peers:

- I check myself whether the questions reasonably cover all learning outcomes.
- I check whether (most) sub-questions can be answered without the need to have the answer on an earlier sub-question.
- I make the exam myself, and write up model answers.
- I ask one of the teaching assistants to make the exam, with the request to check the work load (in hours) and whether questions are unambiguous.
- As a final check for errors/confusing points and a peer review on the overall level of the exam I ask the coordinator of the course *Quantum Physics 2* to approve the exam.

- *How are the students informed about the way they will be assessed?*

At the beginning of the course the students are informed about the way they will be assessed. This is described in OCASYS, and in more detail in the syllabus of the course. The students are informed that the (mid-term) exam questions are very similar to the problem sets that are given to the students each week during the course (which contains in fact several questions that have their origin in an exam). In addition, I give the students a set of exams of previous years as practice material.

2.3.2 Validity and reliability

- *Explain why the exam gives a valid and reliable idea of the achievements of the students*

Validity

The exam are valid because I design and check with the analyses as for the 3rd point of section 2.3.1 (checks for representativeness and relevance). Concerning criterion validity: the criteria for performing well and point scores per sub-questions are clear to the students, since the questions and model answers are very directly in line with the learning and exercise materials during the course.

Reliability

I consider my exams reliable, since I observe very strong correlations between the exam grades and the level that I find when doing qualitative inspections of the full body of exame answering by a student (see also 2.3.3 below here). In addition, I know many students in person from discussions and behavior in class, and the point score from the exam correlates well with the level they show in discussions and their attitude to actually work on the course (also when the exam is corrected by a teacher of the tutorials who does not personally know >75% of the students).

2.3.3 Scoring criteria and transparency

- *Explain how the exam is scored and how the final score is established*

Per sub-question a student gets a score on the usual scale 0 to 10. In comparison with the model answer (that is, the intended learning outcomes), I assess (or instruct my teaching assistants to do this) whether the level of answering is very poor (<4), insufficient (<6), just (6) or more than (7) sufficient, good (8), very good (9) or perfect / with other evidence of a (more than) brilliant level for this questions (10).

The final grade is then simply calculated as 1 + 9 x (sum of scored points / max. score).

After the grading I check for several exams with grades 3-4, or 5-6, grades 8-9 etc, whether the grades make sense. By assessing the work from the student based on an overall impression of what kind of level and skills they show, I check whether the actual grades correlate well with this impression. This is always the case.

In addition, I do an overall check for all cases with a grade in the range 5 to 6, with the approach to answer the question whether the student is ready to move on to follow-up courses, or whether the student is really better off when studying my course one more time. I then check whether this comes back correctly in the grading per sub-question, and whether the overall score correlates with my impression. There is almost never any fine adjustment of scores needed.

I list for each sub-questions on the sheet with exam questions what the weight is (number of points that can be scored). In addition, I mention how the exam grade is calculated. When communicating the final grade to the students, I also list for them how they scored on each sub-question (see Appendix 10b). How the exam grade is calculated is thus fully transparent for the students.

That this works well in practice is apparent from the fact that I almost never get students who like have a personal meeting for checking on how the exam was corrected and how they scored (for a group of about 100 students per year).

- *How are the final scores and marking criteria communicated to the students?*

I announce the final scores of the students on the website of the course. In this document I also list for them how they scored on each sub-question (see Appendix 10b).

The model answers are given to the students, and for marking criteria it is evident for the students that their score on each sub-question directly reflects to what extent their answer is correct, suited and equivalent. The type and format of answering that is considered correct is also directly in line with the questions and model answers that are provided each week as problem set for the tutorial sessions.

2.3.4 Feedback to students about test results

- *How do you give feedback to the students about their exam results?*

Directly at the end of an exam I give the students copies of the model answers. When communicating the final grade to the students, I also list for them how they scored on each sub-question (see Appendix 10b).

A one-hour exam discussion (plenary session, open to the full group) after the final exam is a standard event in roster of the course, and students know they can always request an individual session for further feedback on their exam performance. Both of these options for feedback after the exam are almost not used at all.

Formative assessment

2.3.5 Giving feedback to the students about their learning progress

- *This was also discussed in part § 2.1.5. The emphasis there was on information for the teacher. Here the emphasis is on signaling the students about their learning curve. How do you show students through intermediary test and assignments what level they have achieved?*

<u>During lectures</u>
As mentioned before (and see example in 2.2.1), I use during the lectures Peer Instruction (often with E-clickers) for formative assessment. This provides direct feedback to the students on their level in conceptual reasoning with contents during the course.

<u>During tutorials</u>
The weekly problem set (Appendices 08a, 08b, 08c) with model answers (which are also provided to the students, examples are in Appendices 08a, 08b, 08d), and the option to get feedback on this during the tutorials provide a good means for the student to get feedback and self-evaluation on their level in problem solving. We also encourage interactions between students during the tutorials, and this also gives them insight in their relative performance level.

<u>Mid-term exam</u>
As mentioned before, the structure of the course has a mid-term exam. The outcome for the student provides feedback on their ability to pass the final exam, halfway into the course.

2.4 Evaluation (competence 4)

Also section 2.4 is written for the course *Quantum Physics 1*.

2.4.1 Analysis of test results

- *Describe how you analyzed the test results and used this analysis in the (re)design of the course.*

See also the statistics in the table presented in Appendix 10b, with at the bottom of the table the average score on each sub-question.

This was the first exam after the topic addition of angular momentum had been added to the course. The bad average score on question 2b (about the addition of angular momentum) shows that many of the students did not master this well enough. Notably, some other questions also have a bad average score. However, these are the last sub-questions (with small weight) in a range of questions, at the highest level, meant to make contrast between the grade 9 and 10. Question 2b, however, should have been a question at basic level (and also has a high weight), that most students should be able to answer.

<u>Action taken</u>: This exam problem was introduced in the homework set as a very suitable question for students to confront themselves with the task to master how addition of angular momentum is treated in quantum mechanics. In later years I observed indeed better exam scores on questions related to the addition of angular momentum.

2.4.2 Analysis of the course evaluation

- *Describe how you used the students evaluation of the course in the (re)design of your course.*

Appendix 12 gives the course evaluation outcomes for the year 2011-2012 (summary of main outcome and full statistics per question, this is the most recent evaluation I have available).

For this particular year, the indications for possible improvement concerned:

1) The course work load was considered “not good” in comparison with other courses (the students meant too high, this was more clear from extra remarks students could make on the evaluation sheet).

<u>Action taken</u>: In the extensive set of homework problems, we made a distinction between “must-do” problems, and problems that are useful if a student needs extra training on a topic.

2) The grading standard for the exam was unclear.

<u>Action taken</u>: From that moment on I indicated on the exam for each sub-question the number of points that could be earned with that sub-question (1a, 1b. etc.).

3) The evaluations also show that 38% of the students did not work on the course on a weekly basis all throughout the course. I think that this points to an open challenge that needs to be addressed, and where the overall student performance can increase.

<u>Improvement plan</u>: see 2.4.5.

2.4.3 Evaluation of the use of Peer Instruction

First it should be noted that the use of E-clickers showed that 100% (!) of the students present in the lectures always enthusiastically participated in the Peer Instruction (by clicking on answers, and by my observation also by participating in peer discussions).

In the year 2009-2010 I also did my own evaluation of the use of Peer Instruction (simply by using the E-clickers for multiple-choice questions on how the students liked it in comparison to the part of my lectures that did not use peer instruction). About 40% see the use of Peer Instruction as an improvement. About 30% finds it equally good. About 30% prefers traditional lectures. From personal feedback and observations I also noted the following. If I would announce that a next lecture would contain Peer Instruction, a certain circle of students would tell each other and based on that decide to come to the lecture (these students were not always coming). The lectures had then indeed more students present. Also, from personal feedback I know that for some of the students who prefer the traditional lectures they may not have good insight in how they can learn efficiently. Instead, they are used to get to exam success in a certain way, by always coming to the lecture and taking notes. These students have a fixed, earnest work attitude, and they would rather not be disturbed in that mode.

2.4.4 Evaluation and check with the tools from the UTQ/BKO course

- *In addition to the above, good checks on the function of the course can be based on various performance matrices that I encountered in the UTQ/BKO course. This is worked out in this section.*

<u>Complete course</u>
An important example of a check is to analyze the course on the performance of instructional functions. This is presented in Appendix 13. The conclusion from checking this performance matrix is that it does not reveal any serious omissions in the structure and execution of the course.

<u>Examination</u>
Also based on these tools from the UTQ/BKO course, I have evaluated and in recent years changed the range of questions I ask on exams. I have implemented that the exam questions give a better representation of all the <u>*skills*</u> that are listed under the intended learning outcomes. In particular (see section 2.3), analysis of the exams showed that the exams mostly tested the skills calculating or estimating physical quantities, and much less the skill conceptual reasoning. In recent years the exams therefore include questions where the student are tested on this, with questions that ask an answer in the form of a short essay of specified length (see for example question 2b, and also question 1b and 1c of the exam in Appendix 11a). An analysis that checks whether all the skills and topics listed in section 2.1.1 are now covered in this exam is presented in Appendix 11b. The overview shows that this exam is covering all skills and topics in a balanced way.

2.4.5 Improvement plan

- *Describe the improvement plan you have for the course based on the two analyses.*

The improvement I want to make will be centered around the goal to have a higher percentage of the students work harder all throughout the lecture period of the course. The boundary condition I have for this is that I do not want a format where this creates additional correction work of student work for any of the teachers. The plan I have for this, is to use ideas from Eric Mazur and the book *Just-in-time teaching* by G. M. Novak et al. [10]. Here they propose a moment at the beginning of each class (lecture and tutorial), where the first few minutes are spent on participating in a question session that you can only do if you made your homework. If a student can participate this should be a rewarding learning/confirmation experience on itself (without getting a bonus point for it on the final grade or so). Student who come unprepared should get the signal from it that they are left out.

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[9] Lecture notes (lecture 1, 4) from the 2009-2010 BKO course FWN-University of Groningen. Adapted from http://www.valdosta.peachnet.edu/~whuitt/psy702/cogsys/bloom.html and Ref. [8].

[10] *Just-in-time teaching*, G. M. Novak *et al.*, (Prentice Hall, New Jersey, 1999).

Appendices

The appendices are provided via the following website (pdf or html links)
http://www.quantumdevices.nl/teaching/utq/

Overview:

Appendix 01	Self-assessment form UTQ
Appendix 02	Education CV Caspar van der Wal
Appendix 03	Instruction note to the teachers of the tutorials
Appendix 04	Clarifying course contents and organization to the students
Appendix 05	Handout for the students on a systematic approach to solving problems
Appendix 06	Actual roster of the course 2014-2015
Appendix 07	Examples of material used in lectures
Appendix 08	Examples and complete overview of the problem set for the course
Appendix 09	Example final exam (questions and model answers), 21 Jan. 2010
Appendix 10	Example final exam (questions and model answers), 3 Nov. 2011
Appendix 11	Example final exam (questions and model answers), 28 Nov. 2013
Appendix 12	Outcome FWN course evaluation for Quantum Physics 1, 2011-2012
Appendix 13	Analysis of the course on the performance of instructional functions
Appendix 14	Slides from workshop by Caspar van der Wal on Peer Instruction use for Quantum Physics teaching (ICAB 2013)
Appendix 15	Text book material written by Caspar van der Wal (on identical particles)