A developmental research on introducing the quantum mechanics formalism at university level
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Chapter 11

Challenges for Higher Education

In the previous chapter we have drawn conclusions concerning the teaching of quantum mechanics and quantum chemistry. We also reflected on the research methodology that was followed. In this chapter we discuss the challenges in higher education and the role (physics) education research can play in facing these challenges.

We may discern two, very general challenges in higher education: 1) how to improve the efficiency of education, and 2) how to increase the quality of education. With efficiency we here mean the fraction of students that pass a course in one go and proceed to a next level. These are two competing, as well as interdependent challenges. Competing, because the efficiency of education may for instance be improved by lowering standards, and thus the quality of education. The challenges are interdependent, because improving the quality of teaching is very likely to also improve the efficiency. The first challenge is also a question of how financial and human resources can be effectively employed. If, in the economical sense, teaching is efficient, more resources can be spent on the quality of teaching. Physics Education Research (PER) has been concerned with both challenges. For example, PER has shown us that what is taught is not necessarily learned (McDermott, 1991). In various areas it has contributed to the understanding and quality of physics education (McDermott & Redish, 1999).

A question related to the above-mentioned two challenges is how PER can contribute to the improvement of physics education. We note here that this is not an easy question, as the word improve depends on what we find important (i.e. what goals we set) and if and how we can measure this. For instance, we might feel our education is improved if students are better able to memorize as many facts as possible. If instead we find understanding of abstract concepts more important, our teaching would be very different. The question if and how educational changes are an improvement is also a measurement problem.
related to the research methodology (Redish & Wittmann, 2005). Based on this research, we may identify three related areas in which, or through which, higher education can be improved: the development of courses and curricula, the quality of examinations, and the education of the lecturer/teacher. For each of these areas we give our experiences at our department, the Faculty of Science, and next discuss possibilities for improvements based on these experiences as well as on research literature.

Development of courses and curricula The most important motive for the development of courses and curricula should be an effort to improve education and teaching. The education research community has gathered much expertise in developing education and educational materials. This developmental process has certainly played a major role in this research. We have concluded in the previous chapter that this is a delicate process. For one thing, it requires faculty who are familiar with this developmental process. Furthermore, experienced educational researchers are also important. Developmental research is a suitable approach. Currently no such approach is followed in our department. Regularly, bachelor curriculum committees are formed consisting of physics faculty that assess the order and topics of the courses. However, the curriculum, nor the courses themselves are “developed” in the sense that this is not done in a developmental manner. In the case of courses, common practice is that once in four, or five years a new lecturer takes over and adopts part of the course setup of his predecessor. There is no real design process where choices are explicated, or problems to be solved are defined. There is also much difference between lecturers. Some enthusiastic lecturers put a lot of effort in their courses, but there is not much incentive, nor reward for such initiatives.

Any developmental process requires a clear problem description and a way to measure improvement. Currently, there are two main instruments to monitor the quality of teaching: student surveys and exam results. As we will argue below, exam results are not a reliable measure for the quality of teaching. Student surveys can reveal strengths and weaknesses of a course, but there is a risk to only rely on them for the monitoring of the quality of teaching. For example, it cannot be expected of students, who are in the middle of their study, to assess whether what is taught is relevant and whether it prepares them sufficiently for courses that are yet to come. Furthermore, it is our experience that students sometimes prefer the easy route: a teacher who explains exactly what to do, without letting them struggle too much, is positively evaluated. It may be questioned though, what students learn from such an approach. Also, experience shows that it is difficult to motivate students to give detailed feedback on the educational process. It also does not give us a detailed description if and why a change in the curriculum works.

There are PER groups at other universities that have incorporated the developmental research approach in improving the quality of teaching. They have been described in Chapter University of Washington (McDermott & Shaf-
Quality of examinations  In general, exams play the most important role in determining the extent to which a student meets a course’s objectives. This certainly holds for our science department, where most exams are designed by the lecturer, with input from the teachers of the problem solving sessions. There does not seem to be any input from lecturers outside the course. Nor are there any guidelines or criteria for the exams. In short: the exam is completely the responsibility of the lecturer. However, this research has shown that students may pass the exam with good grades, but still show limited understanding of basic concepts (Chapter 8). Others have come to this same conclusion (Hestenes, Wells, & Swackhamer, 1992; Mazur, 1997). Students are able to successfully perform on exams, but appear to have limited conceptual understanding of the course content. This is not satisfying at all.

Without defining and motivating our examination standards and without consistency between course goals and exam questions, we cannot be certain of what we are testing. This has consequences for both the efficiency as well as the quality of education. First, because we do not know the quality of our exams, we cannot be certain that the right students pass or fail for the exam. In other words, students who do not understand the course content may pass the exam or, conversely, students who understand the course content may fail for the exam. We thus do not know whether our teaching is really efficient. Secondly, as already mentioned in the previous section, if we do not know what we are testing, then we are not able to measure the quality of our teaching. Furthermore, when students pass a course, but in fact lack essential knowledge, skills, and understanding, this will show itself in follow-up courses. An effect due to the importance of written exams in education, is for students to adopt strategies to pass exams efficiently. For instance by starting to study shortly before the exam, studying content by heart, memorizing rules, etc. If the exams are unable to distinguish between rotely and meaningfully learned content, these strategies will be successful. Students will pass on to a next level without properly understanding the content that is required to successfully take part in follow-up courses. Moreover, retention of rotely learned content is poor: students will probably not even be able to use the rotely learned content in follow-up courses.

There are thus enough reasons to improve the quality of examinations. The quality of testing is a topic well covered in various handbooks on educational research (Hopkins, 1998; Cohen, Manion, & Morrison, 2007). We give the following three recommendations to improve the quality of written exams:

1. Education of lecturers and teachers
Lecturers and teachers should and can be educated about the importance of the quality of exams. To improve the quality of their exams, lecturers could first adopt those techniques that have highest impact. (Also see below, under “Education of the lecturer/teacher”.)

2. Shared responsibility of examination

A small team specialized in testing might support lecturers and teachers in developing high quality exams. They also might give critical feedback to the lecturer on what is actually tested. Test reliability might be checked by default. Test validity is of course more difficult, as this requires enough understanding of the course given and the content of the course. To address this, exams might be exchanged between all lectures/teachers of, for instance, one study year.

3. Curriculum tests

It might be advisable to not only test within courses, but also at the end of the bachelor curriculum. This has the advantage that the test can be given independently from the bachelor courses. Furthermore, it gives an opportunity to test the coherency in students’ understanding. Such a test might even be developed together with other universities to compare the quality of education between different institutions.

The use of curriculum tests (the third recommendation) could also play a role in research on the conceptual development of students during their bachelor career, as was suggested in Chapter 10.

Education of the lecturer/teacher

As mentioned in Chapter 1, new lectures and teachers at the University of Amsterdam, as well as several other Dutch universities are trained as teachers. Each university has its own program in which new faculty members are trained. These programs are recognized among the Dutch universities. However, for existing lecturers and teachers there is not (yet) such a program. The two topics we discussed above (the development of courses and curriculum and the quality of examinations) are examples where existing lecturers and teachers may also benefit from a teacher training. But besides these topics, an “in-service” teacher training could more generally improve the teaching skills of existing lecturers and teachers. It could extend their “toolkit” of educational methods. A teacher training program that is potentially meaningful is one where lecturers and teachers are supported during their teaching activities, where they receive feedback on their teaching, and where they are given the opportunity to guide their own development as a teacher, according to their personal needs and interest.

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1. In Dutch this is called a “BasisKwalificatie Onderwijs”, or BKO, translated as “Learning & Teaching in Higher Education Certificate” (LTHEP: http://www.science.uva.nl/research/amstel/dws/lthe/).

2. As agreed by the members of the VSNU (the Association of Universities in the Netherlands).
We have discussed three areas in which higher education can be improved and have sketched how this might be done, in part by referring to examples at other universities. In all these areas it is important that both the educational community as well as the physics education research community are well integrated. Heron and Meltzer (2005) note:

\[\ldots\text{education research conducted by physicists in physics departments is more credible, more accessible, and, in general, more relevant to physics faculty than that conducted in colleges of education or departments of psychology (although the conclusions are typically consistent). Thus for PER to be influential, it is essential that its researchers maintain close ties with the traditional physics community. (p. 391)}\]

A close link between the physics community and the PER community is important for both. Physics education can benefit, as the research will be more relevant, and more applied. It also enables PER to conduct research in a meaningful (i.e. concrete) context, making contributions to education research potentially valuable and relevant to other physics departments. Thus, this symbiosis can be of benefit to both.

The question how the results of PER can be implemented is thereby largely answered: by having PER groups within the physics departments, ensuring close bonds between the physics community and the PER community. There is, however, also a threat in such a constellation, as signaled by Heron and Meltzer (2005):

\[\ldots\text{there is a tendency in some departments for PER faculty to be viewed as resource people whose major responsibility is to provide local support for instruction rather than to conduct scholarly research. The responsibilities of PER faculty should be consistent with those of the other faculty in their departments, and they should have the same opportunities for promotion and tenure as faculty in other areas of physics. These conditions are necessary for ensuring that the quality of PER is high and for ensuring that talented people continue to enter the field. (p. 392)}\]

Unfortunately, the Faculty of Science at the University of Amsterdam, faced with financial cuts, has recently decided to dismantle the science education institute AMSTEL. In this new situation it is difficult, if not impossible, to implement any of the recommendations made in this thesis.

References


