CONSEQUENCES OF THE BOLOGNA PROCESS FOR PHYSICS STUDIES

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1 INTRODUCTION AND OUTLINE

In this paper I shall first briefly review the main aims and features of the Bologna process. Then I shall discuss the experiences thus far in the field of physics, using results obtained in the STEPS project by EUPEN [1] as well as my own experiences. Next I shall address developments in the area of accreditation and the formulation of European standards (benchmarks). Finally, I shall discuss the ways in which the Bologna structure was or will be implemented in physics teacher training programmes.

2 AIMS AND PRINCIPAL FEATURES OF THE BOLOGNA PROCESS

The principal aim of the Bologna Process is to form a European Higher Education Area (EHEA), and so to increase the mobility of students and graduates. This is done by adopting a common structure of degree programmes, to make them comparable within the EHEA. It should be stressed that the aim is comparability and equivalence, not uniformity: the rich cultural variety in Europe should be maintained.

The structure decided upon consists of three cycles: the first cycle, lasting three to four years and leading to a bachelor degree, should provide qualifications relevant to the labour market and enable the graduates either to enter that labour market or to continue with a master programme, at their own university or elsewhere in the EHEA. Master programmes last for one or two years; they extend the knowledge and skills obtained in the first cycle (in depth as well as in scope) and qualify for more demanding types of employment, especially in research, as well as for doctoral studies. The third cycle, in physics typically a doctoral programme, usually requires five years of previous studies (bachelor plus master); its recommended duration is three years.

There are a number of additional features in the Bologna Process as well. An important one is the universal use of ECTS, the European Credit Transfer System, as well as the ECTS comparative grading system. A second common feature should be a modular structure of the curricula, which is also meant to facilitate students´ spending one or two semesters abroad in the course of their studies. A more recent addition is the development of comparable systems of quality assurance.

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3 EXPERIENCES WITH THE BOLOGNA PROCESS IN PHYSICS

The conversion to the Bologna Process has proceeded at different rates in the various participating countries. In several countries (e.g., Denmark, Poland, Italy, the Netherlands) the process has essentially been completed (though not for some of the additional features, such as the comparative grading system), and in most other countries the conversion has started; it is scheduled to be completed by 2010, at least for students then entering university. Most universities have opted for a three year bachelor followed by a two year master, mainly to have enough room in the master programme for an extended final thesis that involves genuine original research.

In most countries where there is no tradition of three year programmes, the labour market for bachelors in physics is not yet well developed, and most bachelor graduates continue with a master programme when they have the opportunity to do so. There appears to be a small but significant increase, however, in the number of students changing universities in the course of their studies; changes of university also occurred in the old integrated master programmes, but the new structure makes it easier and confronts all graduates with a clear point of decision. Also, several universities make a special effort to attract students at the master stage, especially from abroad.

Most curricula are still designed to yield the familiar qualifications of the integrated master courses at the end of the second cycle, but there is an increasing number of specialized or interdisciplinary master programmes; examples are biophysics, computational science, materials science and nanoscience and -technology. One also finds master programmes designed specifically for a particular area of employment (these are sometimes called professional master degrees, but this term is also used to designate programmes designed for candidates who already have experience on the labour market after a first academic degree, such as MBA programmes). Most examples are in the broad area of medical physics (including optics and acoustics for medical applications, especially in Central and Eastern Europe), but there are also a few examples of masters in the field of mathematics and science education, science journalism, and programmes combining science and business qualifications. There are also a small but increasing number of bachelor programmes that are broader than the traditional specialized physics ones, either combining various sciences or natural and social sciences.

The Bologna structure was designed to shape the academic landscape as a whole, not to meet the needs of specific fields of study. For some fields, such as medicine, the structure is not a natural one. One might argue that for physics, considered as an isolated subject, it may not be optimal either, but it appears to be one physics faculties can live with quite well. There are even some “accidental” benefits. First, it provided the necessity for a critical examination of the existing programmes, which in some cases was long overdue. More importantly, the necessity to provide for a bachelor thesis at the end of the third year naturally introduces project-type elements (as a preparation for the thesis) and contact with research much earlier in the programme. Such elements are much appreciated by most students and can strongly increase their motivation. In earlier international and international evaluations (see, e.g., [2]) it was noticed that in many physics programmes there was a clear decrease in motivation in the second and especially the third year, after the novelty of new subjects and new experiences had worn off and before the close contact with research in the master thesis and the specialized courses preparing for it. The overhaul required by the Bologna architecture provides an incentive to move away from the overdose of mainly reproductive learning, undesirable anyhow, and thus help combat these "third year blues". Such changes might have occurred in any case, but the Bologna restructuring was a welcome catalyst.

There are also some dangers and points that need special attention. There is the temptation to cram all subjects treated in a longer curriculum into the shorter time now available (roughly one less year of course work, with extra time to be made for the bachelor thesis and other project work, as discussed above). This leads to overloaded curricula, impossible for all but the brightest students to complete in time. The remedy is "the courage to be incomplete", i.e., to focus more on skills than on content, treating some fields (such as electromagnetism) in depth, while treating some other subjects (such as hydrodynamics) that use similar methods, in much less detail. One of the skills that then need special attention is the capability to master unfamiliar or only sketchily treated subjects from the literature and other sources. Again, such a preparation for life long learning might have been advisable even independent of the Bologna restructuring.

A second problem concerns the possibility for students to spend some time abroad. Unless special precautions are exercised, the more tightly structured programme and the reduced time horizon makes it less easy to spend a semester or a year at a foreign university. The modularisation of the curricula, often advertised as a solution for this problem, does not really help much: each university designs the modules in its own way, and only in exceptional cases can modules absolves at one university be used *in toto* at another one. Two types of solution have been tried in this connection. The first one is for two or more universities to coordinate their curricula in such a way, that students can spend one or more semesters at a partner university without loss of time. This solution has a serious drawback, however: it means that rather large groups of students go from one university to the same partner university, so one of the main advantages of student exchange, learning to cope in an initially unfamiliar environment, gets largely lost.

A better solution, tried, e.g., at some Dutch universities, is to reserve one semester, usually the fifth one in a bachelor programme, for electives. These can be either from a minor subject, as in the major-minor scheme discussed above, or specialised physics courses, or a combination of both. Such a semester is of course almost predestined for spending abroad. The disadvantage is that spending a full year abroad still will still be difficult. However, master programmes may be designed to have a natural "mobility window" as well, usually in the third semester, mainly used for electives and preparation for the master thesis. Such a semester can again be usefully spent abroad, especially if there are research contacts with the host university that enable the student to do part of the preparation for the thesis work, and ideally part of the thesis research itself, at the host university. Again, more “international” theses would be a welcome development, even apart from the Bologna restructuring.

In spite of these opportunities, chances are that the Bologna process will lead, at least initially, to a decrease in international mobility, within the individual programmes, if not between them. The ultimate solution must be a more generous policy of recognizing work done abroad, involving a shift from contents to skills and from identity to equivalence of courses absolved. As departments get used to receiving master students who have a bachelor from another university, they might regard the possibility that their own students do not all have identical knowledge and skills with more equanimity. Of course, assuring that such a more liberal policy does not lead to a lowering of standards requires a lot of attention and additional effort on the part of the functionaries or committees charged with recognition procedures, but at least in subjects such as physics, with only a moderate number of students, this should be feasible.

The possibilities opened by the Bologna architecture might even be put to good use to increase the number of students studying physics or programmes with physics as a main constituent. Whereas the number of students overall has increased enormously over the last thirty years, the number of physics students has at best stayed constant in most countries. The new structure might provide an incentive to introduce new, shorter programmes that might attract students who are not attracted by the more traditional programmes. There are some initiatives along those lines, especially by the Institute of Physics in the UK, but as yet not much experience.

4 ACCREDITATION AND BENCHMARKING

A common formal structure will not in itself be sufficient to reach the stated goal of increased mobility. Employers or universities offering master or Ph. D. programmes will need some assurance about the quality and the content of the programmes as well. To address this issue, a European system of quality assurance, with accreditation as its main feature, is being developed. In the course of an accreditation, a programme is examined by a specialized agency; the procedure usually involves a visit by a panel of experts, consisting of colleagues from other institutions, and usually representatives of potential employers and students as well. Issues examined are the stated aims of the programme, to be expressed as learning outcomes, e.g., in terms of the TUNING proposals [3] and the Dublin descriptors for academic studies [4], the coherence of the programme and its relation to the stated aims, the resources, in particular size and qualifications of the academic staff, the student support and guidance system, the internal quality assurance system (evaluation of courses by students, feedback from alumni and employers) and the documentation of the programme. Other topics often considered are the educational concept, the examination system and the attention paid to "generic" skills, such as oral and written presentation skills, the ability to work in teams and against deadlines and project management capabilities. In principle, the accreditation process results in a yes-or-no-decision only, but visiting committees often formulate recommendations for further improvements of the programmes as well.

Accreditation is usually not concerned with the specific content of a programme; this is intentional, since it is not considered desirable to impede the development of novel types of programmes, as long as they attain accepted academic standards. Employers and universities chosen for further studies, however, may want information about the nature of the knowledge and skills applicants possess. For this purpose, various professional societies developed so called benchmarks that "regular" studies in their fields should reach. On a national level, such benchmarks were formulated under the auspices of the Institute of Physics in the UK. The chemistry thematic network developed a label "Eurobachelor" in chemistry [5]. This label, a registered trademark to which the network owns the rights, is granted in the course of an accreditation process with international participation. Participating universities agree to admit graduates carrying the label to their master programmes on the same conditions as their own graduates. The universities are not obliged to offer *only* programmes satisfying the conditions stated as requirements for the label; several of them offer other options to their students in addition. The network has meanwhile instituted a Euromaster as well and is working on a Eurodoctor.

Recently, the European Physical Society, with the participation of eighteen national physical societies decided to have a study performed of the way in which the conversion to the Bologna architecture has been and is being carried out in physics. As a part of the project, various bachelor and master curricula will be analyzed, and it is expected that benchmarks for physics bachelor and master programmes will emerge from the study. It has not yet been decided, whether these benchmarks will also be used to establish a label analogous to the chemistry Eurobachelor.

5 TEACHER TRAINING PROGRAMMES

Even before the transition to the Bologna structure, teacher training programmes differed greatly between various countries, as shown, e.g., in an EPS study carried out by Michael Vollmer [6]; an update including the effects of the Bologna Process will appear in the coming year. Some more recent results were collected by Working Group 5 of the STEPS project and presented at the 2007 EUPEN General Forum [1]; here I restrict myself to a few general trends.

Usually for secondary school teachers a master degree is required; for teachers in the upper classes in schools qualifying for university studies it takes in general five years in total, for lower classes and/or other types of school four year programmes with a one year master occur as well.

In most countries a qualification in two subjects is required; this leads to additional complications in the transition to the Bologna structure. When qualification in just one subject is required, a natural solution is to require a three year bachelor degree in the subject area, in our case physics, to be followed by a master in which the emphasis is on general pedagogy and physics education, with some room for additional physics courses, in particular on subjects with special relevance to high school teaching. This has the advantage that with a bachelor degree graduates have options on the labour market outside of teaching as well. The disadvantage is that students primarily interested in a teaching career are not brought into contact with schools and the teaching practice. As a partial remedy, educational minors may be offered. Perhaps more importantly: the optimal preparation of a future teacher requires a different emphasis in the "pure" physics part of the curriculum as well. In at least some of the theoretical courses conceptual issues should be stressed more, and calculating abilities less, then in courses designed for future researchers or industrial physicists; in laboratory work, the design and presentation of demonstration experiments suitable for use in school should be part of the curriculum, preferably already early on in the programme [7].

The disadvantages of postponing education related subjects to the master stage are compounded when a qualification in two subjects is required. A bachelor programme consisting of the fundamentals of two subjects does not necessarily lead to a combination of skills that is well adapted to the labour market outside of teaching (with maybe some exceptions for "niche" fields such as adult education and science journalism) [8]. Therefore, an alternative model, in which already the bachelor programme is directed primarily at future teachers and contains both educational and pure science components, is being developed at some universities, notably in some German states, such as Rhineland-Palatinate (Rheinland-Pfalz). The disadvantage is that such a curriculum offers an even less attractive profile of qualifications for the labour market outside of teaching than a programme combining two "pure" science subjects, and thus in some ways violates the spirit of the Bologna architecture. The improved preparation for the chosen subject of most students may more than compensate for this somewhat theoretical drawback, however. Similar deviations from the pure Bologna philosophy will probably occur in other studies directed primarily at a specific type of employment, such as medicine, unless one wants to adopt the US model of medical education. If this model of teacher education is adopted, it becomes mandatory that students are confronted quite early with school practice to enable them to decide early on in their studies, whether or not they are suited for the profession; if not they cab change programmes without loosing too much time in a programme with limited prospects outside teaching.

6 CONCLUSION

Though the Bologna architecture may at first sight not seem a natural one for physics, it offers enough flexibility to design satisfactory curricula. The increased international mobility of students and graduates will be especially advantageous for physics, and the new structure offers a number of novel possibilities that can and should be exploited.

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REFERENCES

[1] For recent results see http://www.eupen.ugent.be , especially the reports on the EUPEN General For a 2006 and 2007. The results of the preceding EUPEN project are presented in the series “Inquiries into European Higher Education in Physics”, Vols. 1-6, 1997-2002, edited by H. Ferdinande et al., published by the EUPEN Consortium, p/a University of Gent.

[2] “Cross Border Quality Assessment in Physics, an Evaluation Report” 2001, edited by U. M. Titulaer, ZEvA Evaluation Agency, Hannover.

[3] http://www.tuning.unideusto.org/tuningeu/

[4] http://www.jointquality.nl/content/descriptors /CompletesetDublinDescriptors.doc

[5] http://www.cpe.fr/ectn-assoc/eurobachelor/

[6] M. Vollmer 2003, Eur. J. Phys. **24** 131-147. This study can also be reached via the website of the Physics Education Division of the European Physical Society, http://europhysnet.org:8080/div in the section documents/reports.

[7] See the report “Thesen für ein modernes Lehramtsstudium im Fach Physik” (in German) of the German Physical Society (DPG), available as a brochure and via the DPG website http://www.dpg-physik.de .

[8] This problem is especially pronounced in the natural sciences. In the humanities and social sciences, curricula combining two subjects that are not specifically addressed to future teachers were more common, and are familiar to potential employers.