Study

Deutsche Physikalische Gesellschaft DPG

Theses for a Modern Teacher's Education in Physics

A study by the Deutsche Physikalische Gesellschaft e. V.
(German Physical Society)

March 2006
(Translation October 2010)

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Summary

The Need for a Fundamental Reform in Teacher Training in Physics

A substantial understanding of science and technology across the widest possible spectrum of society constitutes a resource whose value should not be underestimated in the competition of nations for cultural and economic success. This applies, in particular, to physics with its fundamental character as the "mother" of all sciences in terms of the supplied results and also with regard to its mindsets.

An education in science, and particularly physics, more often than not shapes young people their whole lifetime. It plays a major role in determining their basic knowledge that will accompany them through life and whether they will be motivated to continue learning or even pursue a science or technology degree.

The current education structure apparently fails to fulfil the necessary requirements. Germany is turning a blind eye to the decline in the scientific and technological standards of its population. The number of people trained in science and technology in the German population is far too low. Furthermore, over the last decade, the number of students pursuing degrees in "hard subjects" such as mathematics, physics, chemistry, electrical engineering and mechanical engineering has continually declined year for year (Fig. 1, Annex 1). This has lead to a drastic decrease of young talent in those branches of industry that are based on science and technology.

Among school children physics is considered to be one of the least popular subjects. Frequently, those who start school with a natural interest in nature and technology tend to become discouraged or even disinclined to the subject upon finishing their school education. The Deutsche Physikalische Gesellschaft (German Physical Society, DPG) has taken a self-critical look at this situation. As a prerequisite for fundamental change, DPG identifies a need to reform the university education of future physics teachers, and acknowledges its own share of responsibility in this context.

Up to now, prospective physics teachers have attended the same courses as students aiming for a physics-related career in research, industry or business. However, this procedure, resulting partly from a scarcity of resources, is detrimental to the quality of teacher training. In particular, modern and motivating physics courses in schools demand certain skills and know-how from the teachers, which differ significantly from those of modern professional physicists and therefore cannot be acquired along that very same path.

In recent decades, the ever growing volume of insights and findings in modern physics together with the simultaneous subject branching out into many specialised sub-areas had the consequences that "classical" physics courses, which

aim primarily at professional physicists, increasingly prevent the student teachers from gaining a holistic overview of the subject which is so crucial for their future work in schools. There is also an increasing awareness that together with their expertise in the subject of physics itself, student teachers also need to acquire sufficiently profound didactic and educational methods and skills.

Given the predetermined overall duration of study, the time available for specific physics courses practically rules out the same education for teachers and researchers over a whole degree programme. This already applies to the classical teacher's education courses leading to the state examination qualifications. However, these fundamental difficulties become particularly apparent in the stipulation of the corresponding course contingents in the context of introducing Bachelor and Master degree courses throughout Europe. The time available for physics, as a subject in the teacher's education course, has now been reduced to approximately a third of that scheduled for professional physicists' (Figs. 2 and 3 in Annex 1). It is therefore scarcely possible that such courses be taught together.

The DPG recommends:

1. In future, teacher training courses in physics should be organised as degree subjects *sui generis* (in their own right), orientated towards the high demands of modern, up to date teaching standards in school. The aim should be to provide student teachers with the best possible training in view of and in responsibility to the children and young people later entrusted to them.

2. In the context of a modern university degree, close cooperation between physics professors dedicated to physics research and professors responsible for teaching physics didactics and education should encourage their own understanding and position as student teachers, which is not based on a comparison with the professional physicists involved in research, but is orientated instead to the specific competences and teaching skills that are so important for our society.

3. The physics departments and faculties should develop an appropriate programme of advanced courses so that teachers can keep in touch with on-going scientific progress.

Preface

Science and technology are gaining increasing significance in the global competition among nations. People are increasingly expected to be so well educated that they are able to take proactively and innovatively part in scientific and technological development and, on that basis, being economically successful. They are also expected to develop appropriate powers of judgement concerning the fundamental principles and also the effects of technical products. This applies in particular to physics, being considered as the mother of all sciences due to its fundamental character not only in terms of the results and insight it provides but also with regard to its mindsets.

A modern industrial country must therefore aspire, on the one hand, to safeguarding a generally high standard of knowledge pertaining to physics and other sciences in the population at large in order to take up a leading role in the competing technology-related areas of economy. On the other hand, modern society needs cogitative and politically mature citizens with sound powers of judgement based on their education. In order to achieve all this, schools are of pivotal importance here.

In its efforts to create a European higher education domain, the so-called Bologna Process has prompted German universities to introduce new courses including those for teacher‘s education. Several federal states have established a two-step structure of their courses of study with Bachelor and Master degrees. Other federal states want to retain the previous teacher training system based on the state examination qualification. The differences between the states have become so pronounced that the compatibility of teacher training throughout Germany is at stake. In fact, the curricula drawn up as guidelines by the federal state ministries differ to such an extent that the exchange of students on a national scale is hardly possible anymore. This counteracts the original intention of greater comparability of courses at German and European universities. As a result and already

foreseeable, there will be a reduced mobility among teachers even within Germany because the different teacher training concepts tie them to a certain federal state.

The Deutsche Physikalische Gesellschaft views this development with great concern. While in the past, a sometimes highly controversial diversity of opinions regarding teacher training concepts and regulations constituted a difficult hindrance for setting up modern, up-to-date physics courses at universities, there are now fears that the thicket of controversy and state regulations may squander the chance offered by the Bologna Process to obtain new seminal degree courses.

The Deutsche Physikalische Gesellschaft has therefore drawn up this document with the intention of pursuing a path different from the one most frequently used.

The initial step consists of fundamental deliberations on school teaching, starting from the premise that physics teaching has the task to pick up and develop the children's undoubted interest and potential. The aim of this holistic view is to achieve the greatest possible motivation for physics as an educational asset among as many school children as possible, regardless of what kind of jobs they want to take up in their later lives. At the same time, it is about supporting those school children showing talent and inclination for the sciences and even encouraging them to take up corresponding degree courses.

When organizing the study courses for future physics teachers who are expected to later implement this kind of school teaching methods, the Deutsche Physikalische Gesellschaft works on the basis of two points:

Firstly, the task performed by teachers is of great significance for society. This must be brought to the general awareness of society as a whole, and to every single member of the universities where student teachers are trained. At the moment, the social prestige of teachers is blatantly disproportionate to their tasks in culture and economy.

Secondly, young student teachers must be given the best possible training and ideal tools to accomplish their task. Experience shows that the teacher training modules frequently performed as no more than "add-ons" to a physics degree course (Diploma or Bachelor/Master degree in physics) fail to live up to these demands. Consequently, teacher training in physics must consist of a degree that is geared in the best possible way to the corresponding requirements – a course of studies *sui generis*, consisting of improved dedicated physics modules as well as physics-related teacher training.

This study aims to offer stimulus and assistance in setting up competitive, up-to-date degree courses. The DPG would like to recommend a uniform national concept, at least for physics, to those responsible for planning activities in the departments, faculties, university management boards and corresponding authorities in order to make teacher training qualifications comparable throughout the country. In addition, it wants to convince the physics faculty that teacher training is one of their most important tasks, and that different, modern and innovative ways of communicating and teaching physics for teacher students have to be developed.

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1. Background to the presented theses

German universities are rightly proud of the quality of their physics teaching; after all, physicists who have studied and been trained at German universities are internationally appreciated as the next generation of highly qualified specialists for research, industry and business. For decades, it seemed only appropriate for student teachers of physics to be offered the same training as for professional physicists, both attending the same lectures and courses at the corresponding universities – only much less for the student teachers.

However, the corresponding expectations regarding the professional quality of teacher training in physics proved to be partly exaggerated and partly inappropriate with regard to the different aims of the training required. Teaching activities in schools demand a broad approach to the subject. Unfortunately, the time available in a teacher's education for specific physics modules is more and more insufficient in order to give the students an adequate overview of all those aspects of modern physics that should be part of their qualified school lessons.

The professional requirements for physicists working in research and industry demand a thorough, systematic approach to the subject and the specialisation in selected areas, which is inevitably at the expense of a broad overview. Yet, the corresponding amount of time available to future professional physicists in hours per week per semester, or ECTS credit points (CP), is about three times as much than for the physics modules of student teachers of physics[1].

When it comes to teacher training, future physics teachers must be prepared to teach and encourage average talented and motivated children as well as scientifically highly gifted children. Thus, degree courses for teachers and for professional physicists cannot be compared for several reasons. Teachers should develop their own self-image different to the one of professional physicists. Their social acceptance and professional satisfaction have other roots. One of the important basic principles to achieve these is the close linking and interaction of specialist physics and physics-related didactics[2] in the teacher training courses.

Various studies such as TIMSS, PISA etc. have implicitly revealed the flaws of the previous approach. The implementation of the Bologna Process and the accompanying regulations imposed by the Standing Conference of the Ministers of Education and Cultural Affairs (KMK) and the state ministries with a greater focus on education and didactics place even greater pressure on the time available for specific physics modules.

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[1] ECTS stands for European Credit Transfer and Accumulation System. This was developed by the Commission of the European Union to provide a uniform procedure for reliable academic acknowledgement of course achievements obtained abroad. It provides a method of measuring and comparing course achievements so that they can be transferred from one institution to another.

[2] The meaning of the German term "Didaktik" should not be associated with the Anglo-Saxon meaning of "didactical". Whereas the latter primarily denotes issues of educational technology, Didaktik stands for a multi-faceted view of planning and performing instruction that is based on the German conception of "Bildung".

Having evaluated the experience gained with previous teacher training courses for physics, the Deutsche Physikalische Gesellschaft therefore suggests a longer-term concept for a teacher training *sui generis*, as laid out in the following theses.

2. Six theses on student training courses for physics teachers

Thesis 1: Teacher‘s education in the physics departments today are oriented primarily to the highly fragmented approach to partial areas of physics. However, student teachers should learn to approach physics with a stronger connection to their future task, namely to teach physics to young school children in overall concepts and against the background of their general pre-knowledge shaped by television, children’s experience of nature and the environment, computer games etc.

Thesis 2: Children show their interests by observing, asking and understanding, in other words through analysis of phenomena. Their interest is generated on a holistic level according to the encountered phenomena and is then directed towards an increasingly profound explanation. Children learn physics through analysis and not along synthetic or subject-specific lines: detailed knowledge results from questions of interest, and not the other way round.

Thesis 3: Teachers will organise their lessons in school in the same way that they themselves experienced and learnt about physics in their university courses. Thus, in order to be able to teach school children adequately, their teacher training course has to focus on the experiences they gain through analytical learning. Their courses should allow them to experience what later-on will be their basis to design their own lessons on a level that is comprehensible, motivating and exciting for school children, particularly the younger year groups. Therefore, university lecturers and professors for physics must develop and offer such forms of teaching.

Thesis 4: Training courses for teachers in physics dispose of far less time for the actual physics modules than the courses for professional physicists. Looking at a three-year Bachelor degree (BA) with 180 credit points (CP) and a two-year Master’s degree (MA) with 120 credit points (CP) in the ECTS system, student teachers currently only have around 90 CP for the subject (physics) itself. In addition, there are courses for the didactic aspects of the subject, comprising with about 30 CP. Of the total number of 300 CP, only 120 CP are allocated to the subject of physics itself. In contrast to the pure physics degree course, teachers-to-be study two equally weighted subjects and not just physics as their major subject. For details, please refer to **Annex II: Facts and Figures**.

These are the general conditions for organising the priorities in the teacher training course regulations. In the interest of efficiency, the course regulations must be drawn up so as to make the best possible use of the short time available without the additional burden of inevitably having to adapt to the course regulations for pure physics when the courses are combined.

There are two reasons why there is only very limited time available for the actual physics course of student teachers. Firstly, two equally weighted subjects, both relevant for school teaching, have to be studied. The DPG considers this two-subject course as the right approach to teacher training. Secondly, a considerable share of the course timetable is compulsory for educational studies. In our opinion, this share is too big for the following reasons: i) it reduces the time needed to acquire a sufficient level of expertise in the individual subject, and ii) the subjects are better able to convey specific teaching skills through their own didactics. The DPG therefore recommends a reduction of the educational studies share of teacher's education. We believe that it would be the wrong approach to study a further science (education) if this was detrimental to acquiring the necessary expertise in the chosen subjects.

Thesis 5: The obvious consequence of these insights is to separate the more analytical teacher training courses – moving progressively from an overall view to a more detailed approach – from the more subject-specific teaching of the various branches of physics for the professional physicists. Teacher's education must become a course *sui generis* because of its entirely different objectives. It must not merely consist of an abbreviated, interrupted or diluted part of the courses for professional physicists, provided more or less casually, as has happened in the past. This fails to acknowledge the actual value of teacher training and also harms the self-esteem of the future physics teachers. On the contrary, this self-esteem must be enhanced and reinforced!

Teacher training must be put on more professional terms. The aim must be to obtain outstanding physicists and outstanding teachers. Treating teacher training as a course *sui generis* means that the objectives and tasks must be oriented to the future working lives of physics teachers in schools. Here the demands differ again, depending on the type of school the student teachers will be working at.

Thesis 6: Although teacher training should be seen as a course *sui generis*, the subject-specific aspects of the course must be provided by the professors of the universities' physics departments and in particular also by those actively researching. They are the guarantee for quality, state-of-the-art course content and on-going subject development. However, teacher training as a course *sui generis* for future physics teachers at various levels and types of schools also demands an intensive interaction of subject-specific and related didactic teaching. It must make use of the findings generated by teaching and learning research. The departments and faculties offering teacher training are responsible for both, i.e. also for a research-based teaching in the related didactics.

3. Consequences

A teacher training course referring specifically to the modern approach of teaching physics in schools has to provide the necessary leeway in terms of time and contents to fulfil these demands. This means that the physics specialists will have

to redesign the teaching methods and teaching contents (curricula) for teacher training along the lines of the stated basic theses. This is a task of the university lecturers and professors of physics who are lecturing the physics courses both for future professional physicists and future physics teachers.

The teacher training curriculum has to make a realistically limited and yet appropriate selection from the extraordinary multitude of results generated by classical and modern physics that can be taught within the set timeframe. The curriculum must be exemplary while still maintaining the focus on physics as a whole. It will differ considerably from the subject-specific curricula. The selection should not be based on the current research interests of the particular faculty but on physics as a whole, as a scientific discipline and as a culture of thought, recognition and curiosity. There will be several such curricula, depending on the selection made. However, despite their exemplary selection, universities should only offer those curricula that still teach physics as a whole.

The curriculum must not be geared exclusively (but of course also) to teaching the advanced level courses in upper secondary schools. Good physics teachers are needed in all types of schools and for all age groups. To a far greater extent than in the past, appropriate consideration has also to be given to the wonderful willingness to learn and special learning abilities shown particularly by young school children. Physics must appeal to all school children, not only to those intending to take a physics degree later, but especially also to future craftsmen, bank clerks, artists, doctors, business people and office workers etc. They will all be playing a responsible role in a world dominated by science and technology that they live and participate in. Moreover, they will decide on the extent to which physics is accepted, and the significance accorded to physics by society at large.

Drawing up the curriculum must not be limited to just stating the conventional rough framework (mechanics, thermodynamics, electrodynamics etc.) It must be broken down into more detailed sections with the contents geared to physics as a whole while focussing on individual aspects, staying within the given time-limits. Thought must be given to realistic indications of the time needed to teach the individual sub-topics, thus avoiding any contents-related overload of the modules making up the course of studies. Added together, these individual time specifications must not seriously exceed the total (very short!) time allowed for the modules and the course as such. The professors will have to realize and fulfil the demands of this task to design the individual modules and the course as a whole.

Teachings in physics at university should be defined by comprehensive topics and less by systematic, highly specialized aspects. Examples for major topical areas could be

Floating – flowing – flying

Aggregate states – substances – atoms

Energy – heat – entropy

Electricity – machinery – electronics

Light – colours – laser beams

Communication – radio – television

Micro world – quantum physics – macromolecules

Gravitation – the cosmos – particles

Earth – weather – environment.

Examples of productive, appealing sub-topics include for example *Light*: spectacles, telescopes, microscopes, colours, lasers, interference, the rainbow; *Environment*: weather, air pressure, temperature, heat, pollutants, earthquakes, typhoons; *Technology*: power generation, machines, refrigerators, cars, GPS; *Communication*: waves, radio, television, mobile phones, CD, DVD; *Cosmos*: sundial, stars, double stars, star formation, galaxies, black holes, relativity theory, dark matter.

No matter which of these topics[3] is covered at the particular university, it must be imparted to the students on an appropriately demanding level. The need to limit the selection of topical groups must not be understood as an invitation to shallowness. It is the approach that needs to be changed, not the quality demands regarding the student teachers.

The students must be made aware of the characteristic strengths of physics. These include curiosity, observation and a systematic search for explanations; specific, experimental questions, neutral verification or falsification; the development of suitable terms; physics as a quantitative science (models of the world can be calculated); measuring, instruments; physics as a part of or the foundation for many other disciplines such as medicine, biology and chemistry. Insight and knowledge are part of the quality of life; physics in the form of personal education is more important than expert knowledge.

Therefore, the objectives, the physics canon and the way physics is taught must be exemplified on a professional level during teacher training. Many, possibly too many, details from the courses offered on sub-areas for professional physicists and researchers will unfortunately have to be omitted; of course it would be good to know about them, but not at the expense of a holistic approach to physics, and not through an unrealistic overload of the stipulated short course duration. On the other hand, student teachers will be taught a lot of things that the future professional physicists will not learn.

The high value of modern, contemporary physics teaching at school and the corresponding qualifications required of physics teachers must always be clear to the future professional physicists, the university professors and the student teachers. This is the only way for the teachers to acquire the sort of self-esteem that corresponds to the significance of their profession.

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3 In the Physik Journal 5(2), 2006, 7-8, astro-physicist Professor Harald Lesch, also known as a radio and TV journalist and awarded the DPG Medal of 2005 for scientific journalism, put it this way: „These beacons of questions must always remain clearly visible on the horizon without disappearing in the flood of assignments. Students are driven by … the fundamental questions: How was the universe created? What does matter consist of? What is time? … Making a round trip through the history of nature ("From the Big Bang to the human brain") could ensure that especially first-year physics students do not completely lose their motivation but remain focused on what made them want to study physics in the first place."

4. Implementation aspects

The following section comments on certain specific issues.

a. Mathematics education, subject combinations

An important question is what subjects should be combined with teacher‘s education in physics. Here the individual federal states are taking up very different stances. There is a general accordance that teacher‘s education in physics, particularly for teachers at grammar schools, ought to cover the following subjects: educational studies, two equally weighed science subjects and the corresponding didactics of these subjects. This is the structure that copes best with the future, professional challenges. This again shows clearly that teacher training is about preparing to teach physics in schools, not about obtaining a pure physics expertise. Therefore, the shares of subject modules in teacher‘s education do not equate with a specialist Bachelor or Master degree in the corresponding subject. In particular, the volume of the subject modules is necessarily smaller.

The DPG comments as follows on the issue of subject combinations and the significance of mathematics for physics:

If physics is chosen as one of the subjects for a teacher‘s education, the ideal combination would be mathematics as the second subject. This is because physics is not just an experimental science but also a quantitative, mathematised one. The laws of physics are formulated in mathematical terms, and mathematics is used to calculate the phenomena of physics and to make corresponding predictions.

The interrelation between physics and mathematics has repeatedly played a major role in the historical development of both sciences. Thus, physics irrefutably needs mathematical knowledge and skills. The Konferenz der Fachbereiche Physik[4] (The Standing Conference of Physics Departments) presumes that an equivalent of at least 20 CP is necessary to give physicists an appropriate grounding in mathematics. A limited, particularly physics-specific part is included in the physics modules. The rest can (and must) be acquired in the second subject, i.e. mathematics.

Combinations of physics with other subjects on a teacher training course inevitably results in an additional work load (overload) when it comes to acquiring the necessary mathematical abilities needed to cope with the physics course. During course counselling, students considering such a different subject combination should insistingly be advised about the resulting additional load they will encounter during their particular teacher training course.

The extra work load during the course appears to be less when combining

4 The Konferenz der Fachbereiche Physik is the body which represents the physics departments at German universities and is chaired by a Member of the Executive Board of the Deutsche Physikalische Gesellschaft.

physics with neighbouring science subjects. However, consideration should always be given to the fact that physics is an experimental subject and involves a great deal of lesson preparation for the teachers at school. If they teach two experimental subjects, this workload is compounded even further.

b. Implementing a teacher's education in physics *sui generis*

There is a great number of possibilities for the physics departments to implement a teacher's education *sui generis*. Converting the specialist subject course to a completely independent student teacher training concept might take place in various stages. The following section describes some suitable steps on this way. The physics departments are indicating a new approach to teacher training courses by implementing a substantial choice of such structuring elements already in the initial phases of the new concept.

Steps towards implementing a teacher training course in physics *sui generis* include:

- Separate tutorial groups for student teachers (while retaining joint basic course lectures). A specific concept will be developed for the contents, types of assignment and working methods of these tutorial groups. Essential aspects of the assignments will be geared to teacher training, taking into account the different school levels (from grammar school through to primary school).

- physics didactics courses accompanying experimental physics lectures. Referring to selected topics of experimental physics, the in-depth didactic courses deal with typical learning difficulties faced by school children (and students) together with possibilities for supporting the learning process when it comes to definitions and principles of physics.

- Separate theoretical physics lectures for student teachers ("Gymnasium"/Grammar School). Acquiring an understanding for the specific role played by theory in physics as a whole, with its range of working strategies and thought patterns; having a good command of selected concepts, methods and approaches (relevant to basic and advanced courses in physics at school).

- "Modern physics" courses for student teachers intending to teach at secondary schools of general and intermediate levels. Possible examples would include a "journey through the dimensions" from the microcosm to the macrocosm.

- Specific teacher training courses on comprehensive concepts and applications. This looks at clarifying the structural relationships on the level of physical concepts and methods inherent in many sub-areas and belonging to the theoretical structure of the subject (e.g. dimension analyses, the concept of fields, determining the structure of matter by scattering experiments etc.).

- Specific teacher training courses on how physics is used in technology and scientific research. Examples include information and communication

technology, medical technology, power engineering, the geo sciences as well as climate and weather.

- Specific *sui generis* teacher training courses on experimental physics as from the second year of the course, possibly integrated lectures and seminars with experimental and theoretical components. The central requirement here is for the approach to be based on topical areas, in contrast to the conventional approach based on the physical subject structure as normally found in pure physics courses.

c. Example curriculum

It may be useful to provide an example of how to draw up a curriculum that corresponds with the stated considerations on training teachers for physics. Various adjustments may of course be required in order to accommodate the necessary arrangements to those of the lecturers of other subjects (educational studies, mathematics…). These result e.g. from the guiding value of about 30 CP per semester for the corresponding workload. The subjects involved can account for a differing share of this amount, should the need arise, but must not exceed the number of CP stipulated for each semester in total. In addition, there will be various local regulations within the federal states that also have to be included. Accordingly, the following example (see Table 1) serves as a proposal to be handled with all the freedom of discretion the departments and faculties are entitled to, demonstrating at the same time that it can be done and also how this could be achieved. Thus, the example serves as verification as well.

d. Contents of a hands-on course

The courses in the 9th semester are jointly organised by the physics and didactics departments as hands-on and minds-on courses. Here small groups work with physical subject matters in the form of projects. The course could be called e.g. “Observing, understanding and explaining physical phenomena”. Suitable topics, again on an exemplary basis, could include:

- Tides: When does the tide come in, and how high will it be?
- GPS: Who is tracking us from above?
- Ultrasound: Can you see the heart beating?
- Flows: How is blood transported to the cells? Why do airplanes fly?
- Satellite dishes: How do television programmes get into our living rooms?
- Weather: Will there be snow at Christmas?
- Power stations: How does the electricity get into the sockets?

	Semester	Subject modules	SWS	CP	CP	Didactics modules	SWS
BA	1	Mechanics, Fluids, Thermodynamics	4 L + 3 T	15			
		Mathematics for Physics	2 L + 1 T				
BA	2	Electrodynamics, Optics, Astronomy	4 L + 3 T	15	3	Didactics of experimental physics	2
		Mathematics for Physics	1 L + 2 T				
BA	3	Basic lab course in experimental physics	4 LS	6	3	Didactics of experimental physics	2
					3	Fundamentals of physics didactics	2
BA	4	Quantum Physics	4 L + 2 T	9			
		Basic lab course in experimental physics	4 LS	6			
BA	5				6	Lab course: physics experiments for schools	4
BA	6	Theoretical Physics: Statistical Physics, Multi-Particle Quantum Mechanics	4 L + 2 T	9			
Bachelor of Education, total			40	60	15		10
MA	7	Solids, Atoms, Nuclei, Particles, Astrophysics, Relativity	4 L + 2 T	9	3	Advanced lab course for school experiments	2
MA	8				3	Physics didactics: theories and research, L and S	2
MA	9	Applied Physics, Cross-sectional Topics, Concepts	4 L	6	6	Applied Physics, Cross-sectional Topics, Concepts, 2 T and 2 S	4
					3	School practical studies	2
MA	10	Thesis	10 MA	15			
Master of Education, total			20	30	15		10
Bachelor and Master of Education, altogether:			60 SWS	90 + 30 =120 CP			20 SWS

CP = Credit Points SWS = hours per week per semester

Table 1. Example of a curriculum for a 10-semester teacher's education for a "Master of Education" degree. The federal states stipulate that there must be 120 CP for the physics component, about 90 CP for the subject and about 30 CP for physics didactics. Using conventional calculation methods, this results in approx. 60 hours per week per semester (SWS) plus 20 SWS for didactics. L: lectures, T: tutorials, LS: lab sessions and S: seminars.

e. Possibilities of gaining a doctorate after a teacher's education *sui generis*

Apart from teaching at schools, doctorates open the doors for student teachers to a range of occupational fields in industry and business, university research, administration and teacher's education. Therefore, graduates with particularly high levels of qualification should have the opportunity to obtain further qualifications in research. Graduates who have qualified with the first state examination for teaching physics or with a Master degree in physics that is equivalent to the state examination can earn a doctorate in physics or physics didactics if the corresponding specialist field is represented at the department in research and teaching. Post-graduate programmes and PhD studies stipulate, where appropriate, the corresponding criteria and course programmes that qualify candidates to gain a doctorate in physics or physics didactics.

f. Polyvalency of the BA degree courses

A BA degree is termed polyvalent if it is not geared to a specific profession but leaves the graduate with a wide choice of future jobs. The DPG approves the polyvalency of Bachelor degrees in the sense of acquiring a non-restrictive professional qualification (only) to the extent that this is not at the expense of the requirements in terms of appropriate physics course contents. The objectives regarding the future skills and competences pursued by teacher's education degree courses in physics and by pure physics degree courses differ far too much to be taught in a common course of studies. This does not contradict the possibility of occasionally using the same modules for parts of the two courses (basic modules), insofar as they are compatible with the characteristic demands of *both* of them.

This also does not contradict the possibility of changing courses. The student would have to catch up on the specific profession-related contents and aspects, as it would be necessary with any course change. The curriculum, however, must not be designed in an aimless, non-specific way for all students, only to enable a few of them a potential change of courses.

As has frequently happened in the past, for physics graduates (formerly graduates with a physics diploma, BA/MA graduates in future) and doctors of physics (after special studies) it should still be possible to become teachers after graduation. This option must be accompanied by supplementary teacher training to acquire the specific skills and knowledge, thus becoming a personal gain. However, this is not suitable as a general pattern for teacher training as it takes more time to obtain the necessary qualification.

At the moment the DPG does not see any need for a two-subject Bachelor degree course with physics as one of the two subjects in addition to the teacher's education course, which is why the planning activities should not be burdened with it.

g. Further training offers

Part of the reorganisation of teacher training must be to develop the student teachers' aptitudes for further training during later professional life (advanced training). It is a major task for every university to encourage their students' early embrace of the idea of life-long learning. Here the curriculum can be supplemented by advanced courses in physics and subject-related education/didactics like e.g. colloquia, programmes of scientific lectures, workshops and seminars, incorporating the specific profile of the subject at the respective university.

In particular, student teachers should be offered advanced training possibilities towards the end of their degree courses and during transition into their professional lives. Proven forms include seminars for young entrants and trainee teachers as well as attending congresses. Examples here include the national congresses of the DPG, MNU[5], GDCP[6], VDI[7] and the international congresses of the GIREP[8], ESERA[9] and other professional associations. Further possibilities are offered by the Science Centres, student laboratories, Saturday Morning Physics and other events offered by the universities and research institutions beyond university walls.

There is considerable potential for enhancing the advanced training of our teachers in the hitherto young idea of advanced training sabbaticals for a certain period of time during which they are exempt from teaching. The possibilities entailed here constitute a quantitative and qualitative leap in life-long learning, which is indispensable for teachers in modern knowledge societies. Up to now, some federal states have offered the possibility of taking (unpaid) leave as a first step in this direction.

h. Variety and comparability

The declared, major objective of the Bologna Process is to promote the free movement of students by making degree courses and qualifications comparable. The DPG is therefore concerned about the current trend emerging in German federal states to implement different new regulations which result in highly differing stu-

5 MNU = German Association to Promote Mathematics and Science Teaching

6 GDCP = Association for Chemistry and Physics Didactics

7 VDI = Association of German Engineers

8 GIREP = Groupe International de Recherche sur l'Enseignement de la Physique (International Research Group on Physics Teaching)

9 ESERA = European Science Education Research Association

dy guidelines, sometimes even among the individual universities of one and the same federal state. To safeguard that comparability and free movement are not lost completely, the departments and faculties must ensure that the ECTS credit point system is effectively implemented when drawing up their study and examination regulations.

Acquired credit points (CP) should be acknowledged in a student-friendly manner insofar as certain global criteria can be considered as fulfilled. This includes the compliance with the shares and weighting of the specialist subject and the related didactics or of the laboratory modules in relation to tutorials and lectures within reasonable tolerance levels to be granted. There is no reason why the actual contents of course modules should not differ, as is already the case in present curricula. This leaves room for free scope and diversity alongside global comparability and free movement – in the interests of the young students.

5. Conclusion

In the course of its work, the DPG expert group has frequently been asked whether its approach to appropriate teaching and a corresponding teacher training really stood a chance of being implemented in the real world of everyday university and institutional proceedings.

Our answer:

We believe that in the context of global competition, Germany simply cannot afford to offer its school children anything less than the best possible teaching in science subjects, in particular in physics. Competition can only be won with creativity. It is imperative to strengthen this creativity in science teaching. Deficits in competitive ability have economic consequences, as has become painfully apparent enough in recent years – and this is most likely only the beginning. In addition, the quality of the range of course offerings available will become an increasingly important factor in the competition between the universities over the next few years and will be a criterion for students when choosing their places of study.

Annex I: Statistics and diagrams

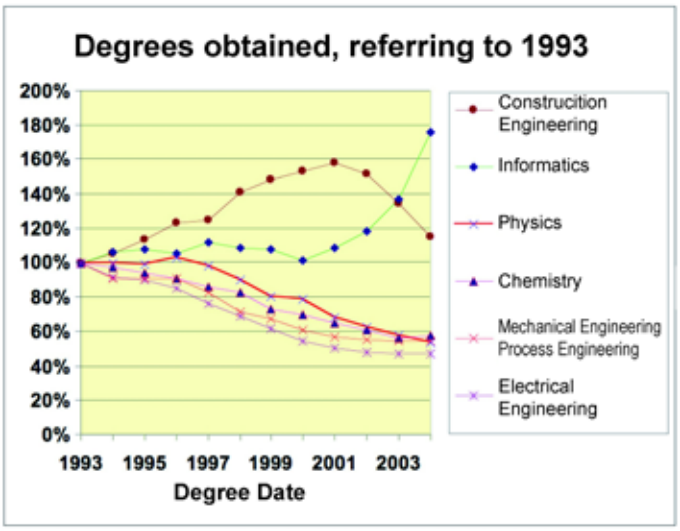

Fig. 1: The number of graduates in the "hard subjects" is declining steadily, the only exception so far being information sciences which is popular on account of the presumed better job chances (Source: Federal Statistical Office).

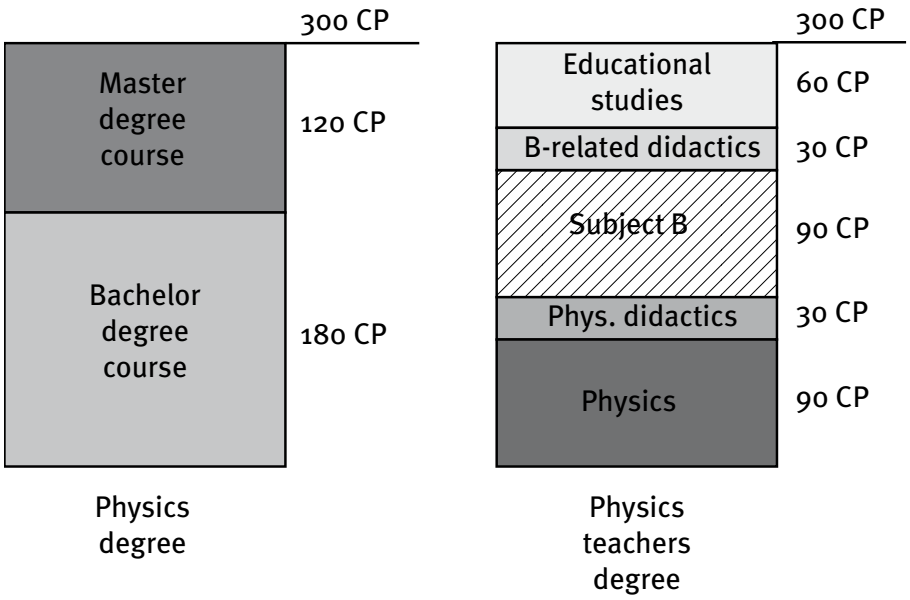

Fig. 2: Comparison of the 10-semester study course for a BA and MA degree in pure physics with the course for physics teacher training. The ratio of the study period scheduled for physics within the teacher training course compared to the one for a pure degree course amounts to 90 CP:300 CP resp. 120 C:300 CP. This means that physics as a subject accounts for only 30% resp. 40% of the total study period in the teacher's education. It should be noted that subsidiary subjects also supplement physics in the BA/MA degree course.

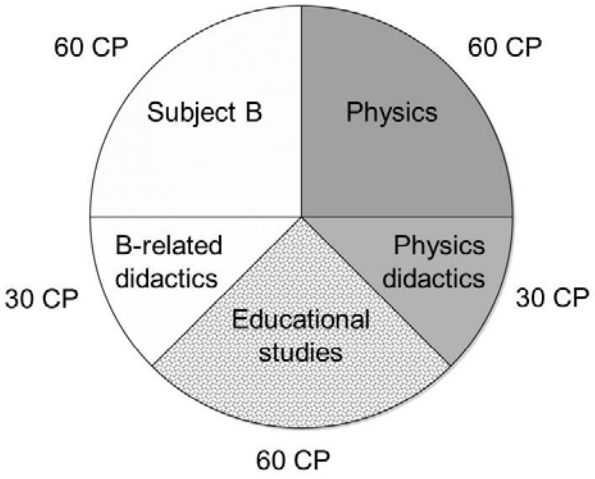

Fig. 3. Breakdown of an 8-semester teacher's education course with 240 CP in 60 + 30 for subject A and its related didactics, 60 + 30 for subject B and its related didactics and 60 for educational studies. The ratio of credit points for pure physics to the total number is 60 CP:240 CP or 25% resp. physics (pure physics plus physics-related didactics) to the total number is 90 CP:240 CP or 37.5 %.

Annex II: Facts and Figures

1. Federal State regulations

Not all states have reorganised their teacher's education into the Bachelor/Master model or are planning to do so. In most states, however, the corresponding conversion has already been completed or is in progress.

The guidelines issued by the state ministries differ considerably in their details, for example in terms of permitted subject combinations, polyvalency of the Bachelor study course, amount of school practice involved and the way two subjects are divided between the Bachelor and the Master degrees. A uniform requirement is that future teachers will have to study two subjects that they will teach in school. Moreover, all states (including those retaining the old course structures) have joined the European Credit Transfer and Accumulation System (ECTS), whereby the workload involved in a study course is measured in credit points (CP). Here, 3 CP correspond to approximately 2 hours per week per semester (SWS).

2. Calculated study time according to the ECTS system

The ECTS system is based on the following time targets: 8 hours study time per day, 5 days a week, and 45 weeks per year. This results in 1,800 hours of study p.a. or 900 hours per semester, including work done in and outside the university, including the lecture-free periods.

30 study hours are awarded one credit point (1 CP). It is thus possible to acquire 30 CP per semester on average.

Both a three-year Bachelor degree and a three-year teacher's education for primary school, secondary general school and intermediate secondary school teachers (as in the state of Hesse, for example) comprise 180 CP. A four-year teacher's education for grammar school teachers (Hesse) requires 240 CP.

Most federal states demand a three-year Bachelor and a two-year Master degree for grammar school teachers, i.e. students are expected to achieve an equivalent of in total 300 CP. Primary school, secondary general school and intermediate secondary school teachers only need to complete a one-year Master degree on top of the Bachelor degree with a total of merely 240 CP.

3. Division into specialist subject, didactics and educational studies

In all federal states, teacher's education consist of the following components: two subjects, the corresponding subject-related didactics and educational studies. Admittedly, there are considerable differences in their relative weighting and division between the Bachelor and Master study courses, emerging not only between the individual states but also from one university to the next within the federal states.

However, for a five-year teacher training course for grammar school tea-

chers, the bottom line for all is that of the 300 credit points the student teachers need to acquire, the two specialist subjects account for 120 each, and 60 CP for educational studies. The 120 CP for the specialist subjects are broken down into approx. 90 CP for the specialist subject itself and 30 CP for subject-related didactics.

In the four-year teacher training course for grammar school teachers (example: Hesse) with altogether 240 CP, the two specialist subjects account for 90 CP each (60 CP for the specialist subject itself and 30 CP for subject-related didactics) and 60 CP again for educational studies.

In the four-year teacher training course for primary school, secondary general school and intermediate secondary school teachers with 240 CP, educational studies are usually the major subject with approx. 90 CP, leaving 75 CP each for the two specialist subjects. This breaks down into 45 CP for the specialist subject itself and 30 CP for subject-related didactics. Again, the proportion of physics is a small one accounting for a mere 31 %. - In Hesse, the corresponding courses are scheduled for only three years with in total 180 CP only.

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Study

The Deutsche Physikalische Gesellschaft e.V. (DPG), which dates back to 1845, is the world's longest-existing physical society and the largest in existence today, with approximately 58,000 members. It serves as an open forum for physicists, and its status as a registered association forbids all commercial interests. The DPG draws its membership from all walks of life, including school students and teachers as well as university students, patent attorneys, industrial researchers, academic professors and Nobel laureates. Former presidents of the DPG include worldfamous scientists such as Max Planck and Albert Einstein.

The DPG organises seminars and workshops to promote the exchange of intellectual ideas among members of the scientific community, and awards internationally recognised prizes for outstanding achievements in physics such as the Max Planck Medal for theoretical physics. The DPG also plays an active role in the current political debate, according special priority to the topics of education, research, climate change and energy policy. It supports junior science fairs such as "Jugend forscht" and offers prizes to school-leavers who achieve the best results in their physics exams.

The DPG has offices in Bad Honnef in the Rhineland, where it also has its "physics centre", a conference centre for the DPG and meeting place for scientists from all over the world. Since being amalgamated with its former East-German counterpart in 1990, the DPG possesses a second forum in Berlin: the Magnus-Haus, which serves as a venue for regular scientific debates and public lectures.

The DPG brings physics to the public: The DPG is actively involved in the dialogue between science and the general public, through its popular-science publications and public events, working alongside other science organisations and in collaboration with the Federal Ministry of Education and Research. It is one of the deepest aspirations of the DPG to open up the world of physics to all who have a desire to know.

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