Reference Points for the Design and Delivery of Degree Programmes in Chemistry

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Tuning Educational Structures in Europe

The name *Tuning* was chosen for the project to reflect the idea that universities do not look for uniformity in their degree programmes or any sort of unified, prescriptive or definitive European curricula but simply for points of reference, convergence and common understanding. The protection of the rich diversity of European education has been paramount in the Tuning Project from the very start and the project in no way seeks to restrict the independence of academic and subject specialists, or undermine local and national academic authority.

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Table of Contents

1. Introduction

Tuning Educational Structures in Europe is a university driven project which aims to offer a universal approach to implement the **Bologna Process** at the level of higher education institutions and subject areas. The Tuning approach consists of a methodology to (re-) design, develop, implement and evaluate study programmes for each of the Bologna cycles.

Furthermore, Tuning serves as a platform for developing reference points at subject area level. These are relevant for making programmes of studies comparable, compatible and transparent. Reference points are expressed in terms of learning outcomes and competences. Learning outcomes are statements of what a learner is expected to know, understand and be able to demonstrate after completion of a learning experience According to Tuning, learning outcomes are expressed in terms of the *level of competence* to be obtained by the learner. Competences represent a dynamic combination of cognitive and meta-cognitive skills, knowledge and understanding, interpersonal, intellectual and practical skills, and ethical values. Fostering these competences is the object of all educational programmes. Competences are developed in all course units and assessed at different stages of a programme. Some competences are subject-area related (specific to a field of study), others are generic (common to any degree course). It is normally the case that competence development proceeds in an integrated and cyclical manner throughout a programme. To make levels of learning comparable the subject area groups/Thematic Networks have developed cycle (level) descriptors which are also expressed in terms of competences.

According to Tuning, the introduction of a three cycle system implies a change from a staff centred approach to a student oriented approach. It is the student that has to be prepared as well as possible for his or her future role in society. Therefore, Tuning has organized a Europe-wide consultation process including employers, graduates and academic staff / faculty to identify the most important competences that should be formed or developed in a degree programme. The outcome of this consultation process is reflected in the set of reference points —generic and subject specific competences— identified by each subject area.

Besides addressing the implementation of a three cycle system, Tuning has given attention to the Europe-wide use of the student workload based European Credit Transfer and Accumulation System (ECTS). According to Tuning ECTS is not only a system for facilitating the mobility of students across Europe through credit accumulation and transfer; ECTS can also facilitate programme design and development, particularly with respect to coordinating and rationalising the demands made on students by concurrent course units. In other words, ECTS permits us to plan how best to use students' time to achieve the aims of the educational process, rather than considering teachers' time as a constraint and students' time as basically limitless. According to the Tuning approach credits can only be awarded when the learning outcomes have been met.

The use of the learning outcomes and competences approach might also imply changes regarding the teaching, learning and assessment methods which are used in a programme. Tuning has identified approaches and best practices to form specific generic and subject specific competences.

Finally, Tuning has drawn attention to the role of quality in the process of (re-)designing, developing and implementing study programmes. It has developed an approach for quality enhancement which involves all elements of the learning chain. It has also developed a number of tools and has identified examples of good practice which can help institutions to boost the quality of their study programmes.

Launched in 2000 and strongly supported, financially and morally, by the European Commission, the Tuning Project now includes the vast majority of the Bologna signatory countries.

The work of Tuning is fully recognized by all the countries and major players involved in the Bologna Process. At the Berlin Bologna follow-up conference which took place in September 2003, degree programmes were identified as having a central role in the process. The conceptual framework on which the Berlin Communiqué is based is completely coherent with the Tuning approach. This is made evident by the language used, where the Ministers indicate that degrees should be described in terms of workload, level, learning outcomes, competences and profile.

As a sequel to the Berlin conference, the Bologna follow-up group has taken the initiative of developing an overarching *Framework for Qualifications of the European Higher Education Area* (EQF for HE) which, in concept and language, is in full agreement with the Tuning approach. This framework has been adopted at the Bergen Bologna follow-up conference of May 2005. The EQF for Higher Education has made use of the outcomes both of the Joint Quality Initiative (JQI) and of Tuning. The JQI, an informal group of higher education experts, produced a set of criteria to distinguish between the different cycles in a broad and general manner. These criteria are commonly known as the «*Dublin descriptors*». From the beginning, the JQI and the Tuning Project have been considered complementary. The JQI focuses on the comparability of cycles in general terms, whereas Tuning seeks to describe cycle degree programmes at the level of subject areas. An important aim of all three initiatives (EQF, JQI and Tuning) is to make European higher education more transparent. In this respect, the EQF is a major step forward because it gives guidance for the construction of national qualification frameworks based on learning outcomes and competences as well as on credits. We may also observe that there is a parallel between the EQF and Tuning with regard to the importance of initiating and maintaining a dialogue between higher education and society and the value of consultation — in the case of the EQF with respect to higher education in general; in that of Tuning with respect to degree profiles.

In the summer of 2006 the European Commission launched a European Qualification Framework for Life Long Learning. Its objective is to encompass all types of learning in one overall framework. Although the concepts on which the EQF for Higher Education and the EQF for LLL are based differ, both are fully coherent with the Tuning approach. Like the other two, the LLL variant is based on the development of level of competences. From the Tuning perspective both initiatives have their value and their roles to play in the further development of a consistent European Education Area.

This brochure reflects the outcomes of the work done by the Subject Area Group (SAG) Chemistry so far. The documents included show in synthesis the consensus reached by the subject area group after intense and lively discussions.

The Tuning Management Committee

2. Introduction to the Chemistry Brochure

ECTN and Tuning

ECTN (www.ectn.net) has participated in the Tuning project ever since its beginning, first as a Synergy Group and then from Phase II as a full member. All the original group members had previously been active within ECTN. Because of the work already done in various ECTN working groups, the foundations for Tuning activities were in many cases already present and could be built on very rapidly. This may explain why the chemistry group was able to make more progress than other groups.

ECTN is an ERASMUS Thematic Network devoted to enhancing transnational perspectives in all aspects of the chemical sciences within Europe (and beyond). The Network itself has its roots in the process of convergence and the growth of interaction between educational systems in Europe which began in the 1980s. Many of the founder members started their collaboration in 1988-89 as the Chemistry subject area group of the ECTS pilot project (which developed the framework for international student mobility, creating the basis for the present European Credit Accumulation and Transfer System). Subsequently, as new opportunities for collaboration emerged thanks to the Socrates-Erasmus programme, the group was able to expand both its membership and its activities. When it became possible to include central and east European countries in the partnership, understanding took another leap forward. ECTN now numbers around 150 higher education institutions and 11 national Chemical Societies, and it is very closely linked with EuCheMS, the European Association for Chemical and Molecular Sciences, which embraces about 50 chemical societies across Europe.

The objective of the Network is to use the remarkable opportunities presented by the creation of the European Union, its expansion and consolidation, to create comparable standards across European degrees and graduates, to increase mobility, and to promote the European dimension of chemistry education.

The ECTN Association

At a certain stage it became evident that the European Commission was in favour of Thematic networks developing parallel structures in the form of Associations, which are legal entities. ECTN grasped this nettle very early on, and after a very considerable period of discussion and legal negotiation the new Association was incorporated as a non-profit AISBL (Association internationale sans but lucratif).

ECTN members were invited to join the Association and pay a small yearly fee for the privilege, and the Association now has around 100 members. It has since been invited to become a member of AllChemE, the Alliance for Chemistry in Europe.

Chemistry is commonly regarded as a basic or pure science subject. However, chemistry also has a plethora of important applications in various industries and in environmental matters. It is one of the few subjects that has its own major industry – «The Chemical Industry». Multinational chemical and pharmaceutical manufacturing companies play a major role in the economy of many European countries. Graduate chemists are also found in many other industrial sectors including food, cosmetics, detergents, plastics, textiles, ceramics, computer hardware and environmental monitoring.

Accordingly, it is very important that graduate chemists have a good broad-based educational training in the subject and that the important subject specific competences are acquired and nurtured. Additionally a number of general competences, for example communication and teamwork, are very important as chemists often work in an interdisciplinary environment.

Chemistry is the first subject group in the Tuning Programme to develop two accredited European templates, the Chemistry Eurobachelor®, for first cycle degree programmes and Euromaster for the second cycle. Both incorporates the competence based approach of the European Tuning Programme. The aim of the Eurolabels is to harmonise the outcomes of chemistry degree programmes in the EU, while still providing great flexibility in order to take into account important national traditions and specialisations in certain areas of this broad subject.

Eurobachelor® and Euromaster

The process of establishing common reference points for chemistry programmes across Europe led rapidly to the development of the Eurobachelor® (trademark held by the ECTN Association) framework for first cycle degree programmes in the chemical sciences.

The idea was then born of using this framework to do exactly what the Bologna Process requires, namely the creation of transparent and compatible degree programmes across Europe. As a result, the Association submitted a proposal to the EU Commission for a pilot project (under Socrates) to set up and award a Eurobachelor Quality Label.

The proposal was approved, and between September 2004 and June 2006 no less than 30 degree programmes from 21 institutions in 11 countries were investigated, using standard accreditation procedures, and awarded the Label. The first was the University of Helsinki, and close behind was the University of Bologna, very appropriate in the context of the Bologna Process. In fact Bologna now has Labels for a total of 5 different programmes!

Sustainability of the Label is now assured, as ECTNA is cooperating with four other bodies (the German accreditation agency ASIIN, the Royal Society of Chemistry (UK), the Società Chimica Italiana and the Polish Accreditation Council UKA) which will administer the Label on behalf of ECTNA.

The Eurobachelor® paper, as revised at the end of the pilot project, is the first of the three key documents printed in this brochure (Section 8).

During the development of the Eurobachelor®, ECTN discussed whether to try to work in an analogous manner for the second cycle. Initial feelings that this might not be feasible were soon replaced by optimism, and so a Euromaster paper was written. The EU Commission approved a proposal for a second pilot project to devise and award the corresponding Quality Label for the second cycle, and this project has now (April 2008) just finished. It was also a great success: 20 applications for 40 stand-alone master programmes were received from institutions in 11 countries, as well as 3 applications from large international consortia running joint programmes.

Our partners are also able to award this second Eurolabel.

The Euromaster paper, which forms the basis for the Label, forms Section 9 of this brochure.

The Third Cycle

Following the decision of the ministers in Bergen in 2003 to add a third cycle, the doctorate, Tuning added this cycle to its agenda. ECTN, which had in the past run a project on a European PhD (unfortunately well ahead of its time), made a clear decision NOT to go for a EuroPhD Label, but to try to influence the third cycle using Tuning as its vehicle. It was helped in this by the results of a third cycle workshop held during the first-ever Bologna Seminar devoted to a single discipline, «Chemistry Studies in the European Higher Education Area», held in Dresden (Germany) in June 2004 with around 200 participants.

The conclusions of this workshop, and subsequent discussions by the Tuning group and by the ECTN working group on the 3rd cycle, led to the recommendations which form section 10 of this brochure.

Both Tuning and ECTN are «work in progress»; both are in their fourth phase. The fourth phase of ECTN has as its theme «Chemistry in the European Higher Education Area». Thus the synergy between the networks can continue, and we hope that this brochure will prove interesting and useful.

3. List of Chemistry Subject Area Group (SAG) Members

The working group is co-ordinated by Terence Mitchell, who takes responsibility for putting this brochure together; it is presently made up as follows:

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4. Introduction to the Chemistry Area

Chemistry is one of the basic scientific disciplines, along with physics and biology. It is thus a subject which is understood in the same way in all European countries, and indeed throughout the world. Until recently there would have been general agreement as to the way that chemical education at universities should be organised. Physics and mathematics are subjects which the chemist needs to study in the first year of chemistry education, since some aspects of these form a vital basis for understanding chemistry. Normally physics and mathematics departments provide the necessary teaching, but it is sometimes found advantageous that chemists themselves teach these two subjects to the necessary level.

The relationship between chemistry and biology is more complex. Biology has traditionally been to a large extent a science of description and classification, but modern biology has moved away from this picture, and indeed biology education at universities is developing in many important directions.

A chemist will often say that «modern biology is chemistry» because so much of modern biology is studied and described at the molecular level. Thus the biologist needs to know much more chemistry than before, and from the point of view of the chemist he or she needs to know much more about biology.

This has been reflected in the growth of biochemistry programmes, which seek to link chemistry and biology. However, biochemistry is not treated in the same way across Europe: it may or may not be integrated with chemistry as far as departmental structures are concerned. Thus there are no uniform platforms for discussion between chemists and biochemists in European universities.

Perhaps as a result of this, there is an emerging trend for chemistry departments to offer new degree courses referred to as «chemical biology». These build on a considerable chemical basis, but include various elements of biology. However, even where such courses do not exist it is becoming apparent that every chemist needs to have competences in biology, and to deal with this an additional sub-discipline is being defined. The traditional basic sub-disciplines of chemistry are organic, inorganic and physical chemistry (analytical chemistry is considered by many as a separate sub-discipline, but there is no consensus: teaching of analytical chemistry is often subsumed under inorganic chemistry). The new sub-discipline is referred to as «biological chemistry», and the chemistry group in Tuning considers that teaching in this area is vital for a modern chemistry first cycle degree course, as competences in this area are an absolute must for the chemistry graduate of today.

5. Summary of Outcomes

5.1. Degree profiles and Occupations

Typical degrees offered in the subject area

— First cycle BSc in Chemistry (see Eurobachelor for planned structures: www.eurobachelor.eu). In most countries these are generally 180-credit degrees, but 210 credit or 240 credit degrees can also be found.

— Second cycle MSc in Chemistry (Masters degrees may be purely by research or, more typically, by a mixture of course work and a substantial thesis component). Typically such degrees will carry 120 ECTS credits.

— Third cycle PhD in Chemistry (Doctorate by research, usually requiring examination and defence of a substantial and original piece of research described in a comprehensive thesis, and taking on average 3 to 4 years). Chemistry doctoral qualifications are very rarely described in terms of ECTS credits, though the coursework involved in structured degree programmes may be awarded credit.

Typical occupations of the graduates in the subject area (map of professions)

— First cycle: apart from the UK and Ireland, no valid information on first cycle graduate employment is available, because there are still very few graduates holding such degrees.

— Second cycle: here there is not even information from the UK and Ireland, as Master programmes there exist almost only as professional (generally one-year Masters) run for people working, for example, in chemical/pharmaceutical/life science areas.

— Third cycle: here a majority will probably be employed in chemical/pharmaceutical/life science companies. Various other types of non-chemical employment are however known, particularly in those countries which do not have a manufacturing base in these areas.

5.2. Learning outcomes & competences - the «Budapest» level cycle descriptors

The «Dublin descriptors» which form the basis of the Qualifications Framework for the European Higher Education Area were adapted in April 2005 during the opening meeting of Tuning Phase 3 so that they can be applied directly to chemistry degrees. The result is the «Budapest chemistry descriptors», which are given below for all three cycles.

First cycle degrees in chemistry[1] are awarded to students who have shown themselves by appropriate assessment to:

- have a good grounding in the core areas of chemistry: inorganic, organic, physical, biological and analytical chemistry; and in addition the necessary background in mathematics and physics;
- have basic knowledge in several other more specialised areas of chemistry[2]
- have built up practical skills in chemistry during laboratory courses, at least in inorganic, organic and physical chemistry, in which they have worked individually or in groups as appropriate to the area;
- have developed generic skills in the context of chemistry which are applicable in many other contexts;
- have attained a standard of knowledge and competence which will give them access to second cycle course units or degree programmes.

Such graduates will:

- have the ability to gather and interpret relevant scientific data and make judgements that include reflection on relevant scientific and ethical issues;
- have the ability to communicate information, ideas, problems and solutions to informed audiences;

1 A Eurobachelor qualification.

2 Such as computational chemistry, materials chemistry, macromolecular chemistry, radiochemistry.

— have competences to fit them for entry-level graduate employment in the general workplace, including the chemical industry;

— have developed those learning skills that are necessary for them to undertake further study with a sufficient degree of autonomy.

Second cycle degrees in chemistry are awarded to students who have shown themselves by appropriate assessment to:

— have knowledge and understanding that is founded upon and extends that of the Bachelor's level in chemistry, and that provides a basis for originality in developing and applying ideas within a research context;

— have competences to fit them for employment as professional chemists in chemical and related industries;

— have attained a standard of knowledge and competence which will give them access to third cycle course units or degree programmes.

Such graduates will:

— have the ability to apply their knowledge and understanding, and problem solving abilities, in new or unfamiliar environments within broader (or multidisciplinary) contexts related to chemical sciences;

— have the ability to integrate knowledge and handle complexity, and formulate judgements with incomplete or limited information, but that include reflecting on ethical responsibilities linked to the application of their knowledge and judgements;

— have the ability to communicate their conclusions, and the knowledge and rationale underpinning these, to specialist and non-specialist audiences clearly and unambiguously;

— have developed those learning skills that will allow them to continue to study in a manner that may be largely self-directed or autonomous, and take responsibility for their own professional development.

Third cycle (doctoral) degrees in chemistry are awarded to students who:

— have demonstrated a systematic understanding of an aspect of the science of chemistry and mastery of those skills and methods of research associated with the topic of this research;

— have demonstrated the ability to conceive, design, implement and develop a substantial process of research in chemical sciences with rigour and integrity;

— have made a contribution through original research that extends the frontier of knowledge in chemical science by developing a substantial body of work, some of which merits national or international refereed publication;

— have competences which fit them for employment as professional chemists in senior positions in chemical and related industries, in public service, or for a progression to a career in academic research.

Such graduates:

— are capable of critical analysis, evaluation and synthesis of new and complex ideas;

— can communicate with their peers, the larger scholarly community and with society in general about their areas of expertise;

— can be expected to be able to promote, within both academic and professional contexts, scientific and technological advancement in a knowledge based society.

— are able to develop and apply methodology to the solution of novel problems, defining a strategy and an action plan to solve that problem.

5.3. Generic Competences

The chemistry subject area group has devised the Eurobachelor framework for a first cycle degree; the framework forms section 8 of this brochure. This framework refers directly to the Tuning list of generic competences and defines subject-based competences.

The generic competences to be developed during the first cycle (not in order of importance) are:

— capacity for applying knowledge in practice

— planning and time management

— oral and written communication in the native language

— knowledge of a second major European language

— capacity for analysis and synthesis (in a general, not a chemical sense)

— capacity to learn

— information management skills (ability to retrieve and analyse information from different sources)

— capacity to adapt to new situations

— problem-solving

— decision-making

— teamwork

— ability to work autonomously

— ethical commitment

5.4. Subject-specific Competences

In our discussion of subject-specific competences, which in the Eurobachelor framework we refer to as abilities and skills, we identified the following as relevant to the first cycle:

1. Chemistry-related cognitive abilities and skills

— Ability to demonstrate knowledge and understanding of essential facts, concepts, principles and theories relating to the subject areas identified above.

— Ability to apply such knowledge and understanding to the solution of qualitative and quantitative problems of a familiar nature.

— Skills in the evaluation, interpretation and synthesis of chemical information and data.

— Ability to recognise and implement good measurement science and practice.

— Skills in presenting scientific material and arguments in writing and orally, to an informed audience.

— Computational and data-processing skills, relating to chemical information and data.

2. Chemistry-related practical skills

1.1. Skills in the safe handling of chemical materials, taking into account their physical and chemical properties, including any specific hazards associated with their use.

1.2. Skills required for the conduct of standard laboratory procedures involved and use of instrumentation in synthetic and analytical work, in relation to both organic and inorganic systems.

1.3. Skills in the monitoring, by observation and measurement, of chemical properties, events or changes, and the systematic and reliable recording and documentation thereof.

1.4. Ability to interpret data derived from laboratory observations and measurements in terms of their significance and relate them to appropriate theory.

Naturally these will be developed further as necessary by students who continue to second and/or third cycle.

6. Teaching, Learning and Assessment

6.1. Methods and techniques of instruction and learning, taking into account the differences in cultures both in institutions and countries

In chemistry the differences in culture between countries and between institutions are not that great. Thus methods and techniques for instruction and learning will not differ in principle but more in the extent to which they are used. As has been detailed above, practical courses play a very important role in the education of a chemist. At the same time, these are the most expensive aspect of the training, as they require large amounts of laboratory space, very close supervision, expensive apparatus and chemicals etc. This, together with the fact that in some countries the student intake is very high, means that it is not always possible to provide the student with as much practical training as is really required during the first cycle. The deficits can be made up in the second and third cycles, of course, but here the student numbers are smaller.

6.2. Competence development

There is much discussion as to whether it is possible to separate generic and subject-specific competences. In some subject areas there are proposals to allocate a certain proportion of credits to courses on generic skills given by persons outside the subject area. It is our opinion that in chemistry courses this is not necessary and may even be counter-productive. These two types of competence are often inseparable, as will be shown below.

Our work on generic competences has shown clearly that the competences referred to above can be and indeed are developed within the normal teaching process (although teachers and students alike have in the past not given though to this). The one key competence where work needs to be done in some departments is teamwork, something which has not been emphasised in course design in the past. The other key competences are developed during normal teaching and thus cannot and should not be divorced from subject area teaching.

In some countries the subject of employability is discussed at some length, since the expression «relevance to the labour market» in the Bologna declaration has been misunderstood in translation. We, as chemists, often have the idea that a first cycle graduate in chemistry will not be employable in chemical industry, for example, simply because traditionally there were no bachelors on the market in our particular countries.

It is slowly becoming clear that this situation will change, as industry will certainly modify its attitude when universities offer the «product» bachelor and explain its profile with the help of the Diploma Supplement.

How counter-productive an employability discussion can be in our subject becomes clearer when we consider, say, a history graduate. History graduates are certainly employable, but not in a history industry! They are employable because of the generic skills which they have developed, and in some cases they will be employed in «history-related» positions.

The same is true of the chemistry graduate, as a look at the situation in the UK and Ireland will show. Here the chemistry graduate who takes up a job after graduating with a first degree (and this is the majority) may go into a «chemistry-related» job, but in many cases will not.

Europe needs first cycle degree graduates with a knowledge of chemistry, whatever these graduates do after leaving university!

6.3. Implementation of subject-specific competences: Three Examples

Three aspects of implementation will be covered, i.e. teaching, learning and assessment. In order to gather material on which to base some useful conclusions, a series of questions was posed to members of the chemistry group. Three of these will be considered here:

How do you help students to achieve this competence in your *teaching methods?*

What *learning activities* do your students engage with in order to develop this competence?

How do you *assess* whether, or to what degree, they have achieved this competence?

Ten subject-based competences were selected and members of the group were asked to answer these questions for the competences which were assigned to them. The selected competences had already been assigned by the group as being particularly relevant to the first cycle and thus could be considered as genuine «key competences» in the education of a chemist. Three examples are presented here. In each case corresponding generic competences are given.

1. **Ability to demonstrate knowledge and understanding of essential facts, concepts, principles and theories (Country: France, Grande École).** ***Corresponding generic skills: capacity for applying knowledge in practice, oral and written communication in the native language, capacity for analysis and synthesis, information management skills, capacity to adapt to new situations, problem-solving, ability to work autonomously.***

How do you help students to achieve this competence in your teaching methods?

Lectures, problem classes, practical classes, and an undergraduate research project. The knowledge and understanding is communicated by means of written answers to questions (problem classes or examinations) or by an oral presentation of the project work, or presentation of answers to problems in front of the tutorial group.

What learning activities do your students engage with in order to develop this competence?

Lectures, problem classes, practical classes, industrial placements and a research project.

How do you assess whether, or to what degree, they have achieved this competence?

By means of written (and sometimes oral) examinations, continuous assessment of practical work and problem classes. Assessment of the research project includes an oral presentation in which communication skills are assessed as well as scientific understanding.

All assessed work is returned to the student. They are given marks for each examination/assessment, and they are given their class ranking at the end of each semester. Students with difficulties are interviewed by the person responsible for the appropriate year of study, and, if necessary, by the head of studies.

There is a meeting each semester attended by all teachers and by elected representatives of the class. At this meeting, the performance of all students who have not achieved the standard required is discussed so that the reasons for non-achievement can be determined, and communicated to the student if necessary.

2. **Ability to recognise and analyse novel problems and plan strategies for their solution (Norway).** ***Corresponding generic competences: capacity for applying knowledge in practice, written communication in the native language, capacity for analysis and synthesis, information management skills, problem-solving, decision-making, ability to work autonomously.***

How do you help students to achieve this competence in your teaching methods?

Students are supervised throughout all laboratory exercises, and skills in observation trained by question and answers sessions, tutorials etc. The significance of the results obtained forms a part of all laboratory reports as does relation to the appropriate theory.

What learning activities do your students engage with in order to develop this competence?

Laboratory work and writing of laboratory reports is the most important method of achieving these skills.

How do you assess whether, or to what degree, they have achieved this competence?

Student laboratory performance is assessed on a continuous basis by staff present in the laboratory, and laboratory reports carefully checked. Examinations in connection to laboratory courses are also of some importance

3. Planning, design and execution of practical investigations (Spain). *Corresponding generic skills: capacity for applying knowledge in practice, planning and time management, oral and written communication in the native language, capacity for analysis and synthesis, information management skills, capacity to adapt to new situations, decision-making, ability to work autonomously, ethical commitment.*

How do you help students to achieve this competence in your teaching methods?

Through exercises and practical examples: setting the scene, clarifying issues, and helping students to recognise and become familiar with the scheme for developing a correct strategy.

Homework tasks with selected topics which teams of students could make exercise.

Discuss their work in class in order to optimise their results.

What learning activities do your students engage with in order to develop this competence?

Attend seminars and tutorials. Participate in discussions after different working groups presentations analysing procedures.

How do you assess whether, or to what degree, they have achieved this competence?

Following up on their homework during tutorials.

7. Designing New Degree Programmes

Tuning has identified a series of steps in designing new degree programmes:

1. Definition of academic and professional profiles: translation into learning outcomes and generic and subject specific competences
2. Translation into curricula
3. Translation into modules and approaches towards teaching, learning and assessment
4. Programme quality assurance: built in monitoring, evaluation and updating procedures

As far as chemistry is concerned, these cannot be applied in the same manner to first, second and third cycle programmes. The following discussion will be structured according to points 1 to 4 and not according to cycles, however.

7.1. Definition of academic and professional profiles: translation into learning outcomes and generic and subject specific competences

First cycle

Academic and applied chemistry first cycle programmes are available in Europe. Applied chemistry-related degrees are more likely to be in chemical engineering. More 180-credit programmes are available, though there appears to be a trend towards 240 as one moves East in Europe.

The question of defining a difference in profile between 180- and 240-credit programmes does not appear to have been addressed so far. There are merely political, not subject-based, reasons for going in one direction or the other.

Second cycle

In chemistry it appears at present that «academic» Masters will become the norm in post-Bologna Europe. The 2004 Dresden Bologna Seminar made the following recommendations:

— 120 ECTS credits should be the reference point for Master programmes.

— The Master thesis should carry at least 30 ECTS credits and the research work should be organized over a defined period of time in order not to hamper student mobility.

— At the second-cycle stage institutions will in future have to compete on both a national and international basis for the best students. Thus they will need to design attractive study programmes which reflect their individual structures.

— The definition of a «Euromaster profile» analogous to the Eurobachelor will not be possible, because of the greater degree of specialisation of the former. However, the joint degree framework envisaged by the ERASMUS MUNDUS programme can act as a model for the development of genuinely «European» qualifications in chemistry.

— Access criteria for second-cycle programmes must be flexible and carefully-devised in order to make the programmes attractive. The right of access envisaged by the Lisbon Recognition Convention must be respected. No quota systems should be imposed, as these affect the rights of the individual as well as of the institution.

— Flexibility based on the bachelor diploma supplement should be introduced to handle specific situations (change of orientation, non-European students, excellent students)

— High-quality students must be afforded the possibility of transferring to a doctoral programme without formal completion of the Master degree, as stated in the recommendations of the Helsinki «Bologna series» Master conference.

— It is broadly accepted that a second cycle qualification will take a total of around five years of study to obtain, although the precise duration will depend on the learning outcomes to be achieved. Where the study pattern is, for example, 4+1 as opposed to 3+2 years, admission to a one-year second cycle course could at present involve a requirement for extra study or experience from a 3-year first cycle graduate, e.g. industrial experience.

— Master courses should be taught in English on request wherever possible.

The UK has second-cycle one-year Masters which can be referred to as more «professional» in nature, but there does not yet seem to be a tendency in continental Europe to go down that road. Instead, it appears likely that master programmes will carry 90-120 credits according to the Helsinki recommendations. The question of organising the transition of suitably qualified candidates from master to PhD programmes without formal award of a master qualification is still under discussion on a national basis, but mechanisms will become established in the next few years.

Third cycle

In chemistry, the third cycle has a purely academic profile. Traditionally, it consisted only of research (generally basic but also applied) supervised by a single academic supervisor and leading after an undefined period to the award of a PhD (or corresponding national qualification) on the basis of the thesis submitted and an examination carried out according to national or local regulations.

However, the picture across Europe is presently not uniform. More and more there is movement away from the «research only» PhD to structured PhD programmes, and quality enhancement will have as its major task the development of such programmes and their adaptation to the changing needs of our science.

The recommendations of the Dresden Bologna Seminar (2004) for the third cycle were as follows:

— Structured degree programmes which include coursework (in the widest sense of the term) should become a common feature of European PhD studies; however, research must still be the major element of such programmes. Part-time PhD studies should remain possible in institutions where it has been a normal feature.

— The average European PhD should spend 3 to 4 years on his or her studies. The research element of the PhD study programme should not be awarded ECTS credits.

— ECTS credits should be used to quantify the coursework component. These credits can however be ungraded, as the correct use of the (relative) ECTS grading scale will not be possible. A wide range of ECTS credits (anywhere between 20 and 60) can be envisaged. Use of the national grading scale is of course possible.

— Apart from research and coursework, further important elements of the PhD programme are teaching (as teaching assistants) and the training of key generic skills, such as those listed in the Appendix of the Chemistry Eurobachelor document.

— Institutions should issue transcripts containing information on all the coursework carried out, and on work done as a teaching assistant. Such transcripts will probably not use the standard European Diploma Supplement format.

— Institutions are encouraged to develop «Graduate School» structures at departmental, interdepartmental or regional level in order to increase their national and international visibility, to increase their research potential and to foster cooperation both between staff and between students.

— National structures for setting up research networks should be extended in order to internationalise such networks. PhD students should spend part of their research time at other institutions, preferably in foreign countries.

7.2. Translation into curricula

First cycle

The design of curricula is the province of the academic staff. It is important to try not to restrict their freedom unnecessarily, while at the same time defining standards.

The chemistry Eurobachelor®, (Section 8), does not attempt to define curricula in any detail. It suggests the following features:

a) a «core» of at least 90 credits of compulsory modules/courses, taken from the following areas:

- organic chemistry
- inorganic chemistry
- physical chemistry
- analytical chemistry
- biological chemistry
- physics
- mathematics

b) semi-optional courses covering at least three further sub-disciplines (at least 5 credits each)

c) optional courses

d) a Bachelor thesis with 15 credits.

Within these limits the institution is free to structure its degree.

Second cycle

The major element of Master programmes will be the research component, which will carry between 30 and 60 ECTS credits.

There will be a certain compulsory element in Master programmes, but these will generally be very flexible as there will be a connection between coursework and the direction of the research area chosen. The Master programme in chemistry will not be simply a continuation of the Bachelor programme.

The Euromaster framework for second cycle degrees forms Section 9 of this brochure.

Third cycle

There will be no defined curricula. Instead, the ideal situation is that each PhD student is counselled on the courses he/she should take as part of the defined amount of coursework. Our recommendations on the third cycle are included in this brochure as Section 10.

7.3. Translation into modules and approaches towards teaching, learning and assessment

First cycle

The translation into modules is left entirely to the department or faculty concerned. However, as far as teaching, learning and assessment is concerned, the Eurobachelor framework does make some important statements. Masters degrees may be purely by research or, more typically, by a mixture of course work and a substantial thesis component, usually involving one of the sub-disciplines listed above. A significant number of such courses have strong connection with industry.

Second cycle

The same applies as for the first cycle, as there is no fundamental change on going from one to the other. Naturally the competences will change. Details can be found in the Euromaster paper.

Third cycle

The important aspect here is assessment. Two points are involved, both of which are concerned with the thesis. Firstly, the reviewing and (if required) grading of the thesis needs to be put on an open footing, with the involvement of external examiners. Secondly the extremely disparate procedures for the final examinations of PhD students need to undergo a certain amount of harmonisation.

7.4. Programme quality assurance: built in monitoring, evaluation and updating procedures

In this respect, chemistry is no different from any other subject. Quality assurance is dealt with by accreditation and other QA bodies, which are now expected to work according to the European Standards and Guidelines issued by ENQA. QA bodies will soon be able to apply for membership of the European Quality Assurance Register.

Both the Eurobachelor and the Euromaster papers naturally discuss elements of quality.

8. The Chemistry «Eurobachelor®»

Preamble

As a result of the Bologna Process, there are moves under way throughout Europe to revise chemistry degree structures. As decided at the Berlin conference in September 2003, a three-cycle structure is to be implemented («BSc/MSc/PhD»). However, there is no general agreement on introducing the «3-5-8» model which has sometimes been misunderstood as the Bologna «recommendation». The Bologna process is gathering momentum very rapidly, and a Bologna first cycle degree as defined by the Helsinki conference in February 2001 will soon be the norm throughout the Bologna area, which now encompasses 45 countries (and stretches «from Cork to Vladivostok and from Crete to the North Cape»).

Although the Helsinki consensus was that a «bachelor-type» degree should correspond to 180-240 ECTS credits (3-4 years), there are indications that the 180 credit degree will become much more common than the 240 credit degree, so that the Eurobachelor model is based on 180 ECTS credits.

Those institutions which decide on 210 or 240 credits will obviously exceed the Eurobachelor criteria as defined here, but will hopefully use the Eurobachelor framework and define the remaining 30 or 60 credits according to principles which they will lay down (e.g. the Bachelor Thesis may well carry more credits or there may be an extended institution-supervised industrial placement).

In the context of lifelong learning, a first cycle degree can be seen as a landmark of progress in learning, achieved by a student who intends to proceed to a second cycle programme, either immediately or after a short break.

The primary aim of the Eurobachelor qualification is to provide a first cycle degree which will be recognised by other European institutions as being of a standard which will provide automatic right of access (though not right of admission, which is the prerogative of the receiving institution) to chemistry Master programmes.

The goals of a first cycle study programme can be described by the Budapest Descriptors developed by the Chemistry Subject Area Group working in the project «Tuning Educational Structures in Europe». They are as follows:

First cycle degrees in chemistry[1] are awarded to students who have shown themselves by appropriate assessment to:

— have a good grounding in the core areas of chemistry: inorganic, organic, physical, biological and analytical chemistry; and in addition the necessary background in mathematics and physics;

— have basic knowledge in several other more specialised areas of chemistry[2]

— have built up practical skills in chemistry during laboratory courses, at least in inorganic, organic and physical chemistry, in which they have worked individually or in groups as appropriate to the area;

— have developed generic skills in the context of chemistry which are applicable in many other contexts;

— have attained a standard of knowledge and competence which will give them access to second cycle course units or degree programmes.

Such graduates will:

— have the ability to gather and interpret relevant scientific data and make judgements that include reflection on relevant scientific and ethical issues;

— have the ability to communicate information, ideas, problems and solutions to informed audiences;

— have competences which fit them for entry-level graduate employment in the general workplace, including the chemical industry;

— have developed those learning skills that are necessary for them to undertake further study with a sufficient degree of autonomy.

1. A Eurobachelor qualification

2. Such as computational chemistry, materials chemistry, macromolecular chemistry, radiochemistry.

Although the UK and Ireland have well-established bachelor degrees, the concepts of honours or pass degrees are not incorporated in the Eurobachelor model for the BSc in chemistry, as these are not well understood in continental Europe and probably also not easily transferable.

Before presenting the model in detail, it seems advisable to list the options which should be available to any young chemist who obtains a Eurobachelor qualification in chemistry. As stated in the Bologna declaration, this qualification should be relevant to the European labour market, the emphasis lying here on the word «European». Thus it is necessary that the degree become an accepted qualification in all countries which are signatories to the Bologna/Prague/Berlin/Bergen/London agreements.

The chemistry Eurobachelor should, provided that his/her performance has been of the required standard, be able to continue his/her tertiary education either at his/her degree-awarding institution, at another equivalent institution in his/her home country, or at an equivalent institution in another European country. (At a later stage one can hope that world-wide acceptance of the Eurobachelor qualification will come into being). This continuation may either be immediate or, depending on the career planning of the individual, may take place after an intermediate period, for example in industry.

The continuation will often take the form of a course leading to an MSc degree, either in chemistry or in related fields. However, European institutions should pay regard to possibilities for providing «high flyers» with a direct or (perhaps more often) indirect transition to a PhD course, if this is permitted by national rules.

It must be made clear at the outset that each institution providing Eurobachelor-type degree programmes in chemistry is completely free to decide on the content, nature and organisation of its courses or modules. Chemistry degree programmes offered by individual institutions will thus logically have their own particular characteristics. The depth in which individual aspects are treated will vary with the nature of specific chemistry programmes.

It is of pre-eminent importance that institutions offering Eurobachelor qualifications aim for high standards, so as to give their students good chances in the national or international job market as well as a good starting point to transfer to other academic programmes should they wish to do so.

Employability

According to the Bologna declaration «The degree awarded after the first cycle shall also be relevant to the European labour market as an appropriate level of qualification». This statement has led to discussion in many countries regarding employability of first cycle degree holders, particularly in those countries which have previously been used to long five-year first degrees.

Although subject knowledge is one criterion for employability, other competences and skills gained during the degree course are vital outcomes of an academic training for general employability. These can be divided into generic and subject-related competences and skills, and what follows refers to both chemistry-related outcomes and generic competences.

Outcomes: General

In 2000, the United Kingdom Quality Assurance Agency (QAA) has published useful «benchmarks» which provided a starting point for our discussions. It was not the intention of the QAA to «define a chemistry degree» but to provide a set of factors which should be considered by institutions when setting up degree programmes. Similarly, the outcomes listed below are intended to be indicative, rather than a prescription to be adopted word-by-word across all chemistry degree programmes. In modifying the QAA benchmarks, two aspects were particularly considered:

The benchmarks were written for a British BSc Honours degree, identified by QAA as a first cycle degree and yet leading directly to enrolment on a doctoral programme. The Eurobachelor is intended only to prepare for entry to the second cycle, and some benchmarks have been deleted because they were considered more appropriate to the second cycle.

The benchmarks are intended to support education and employability, and it is recognised that many chemistry graduates obtain employment outside the discipline. The Tuning Project survey of employers and graduates in employment (2001) shows the importance of those outcomes which look beyond knowledge and recall of chemistry. Some additions have been made in the light of the results of this survey.

Outcomes: Subject Knowledge[3]

It is suggested that all programmes ensure that students become conversant with the following main aspects of chemistry:

a) Major aspects of chemical terminology, nomenclature, conventions and units

b) The major types of chemical reaction and the main characteristics associated with them

c) The principles and procedures used in chemical analysis and the characterisation of chemical compounds

d) The principal techniques of structural investigations, including spectroscopy

e) The characteristics of the different states of matter and the theories used to describe them.

f) The principles of quantum mechanics and their application to the description of the structure and properties of atoms and molecules

g) The principles of thermodynamics and their applications to chemistry

h) The kinetics of chemical change, including catalysis; the mechanistic interpretation of chemical reactions

i) The characteristic properties of elements and their compounds, including group relationships and trends within the Periodic Table

j) The structural features of chemical elements and their compounds, including stereochemistry

k) The properties of aliphatic, aromatic, heterocyclic and organometallic compounds

l) The nature and behaviour of functional groups in organic molecules

m) Major synthetic pathways in organic chemistry, involving functional group interconversions and carbon-carbon and carbon-heteroatom bond formation

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3. This section is derived from the chemistry subject benchmark published by the UK Quality Assurance body QAA.

n) The relation between bulk properties and the properties of individual atoms and molecules, including macromolecules (both natural and man-made), polymers and other related materials

o) The structure and reactivity of important classes of biomolecules and the chemistry of important biological processes.

Outcomes: Abilities and Skills[3]

At Eurobachelor level, students are expected to develop a wide range of different abilities, skills and competences.

These may be divided into three broad categories:

1. Chemistry-related cognitive abilities and competences, i.e. abilities and competences relating to intellectual tasks, including problem solving;
2. Chemistry-related practical skills, e.g. skills relating to the conduct of laboratory work;
3. Generic competences that may be developed in the context of chemistry and are of a general nature and applicable in many other contexts.

The main abilities and competences that students are expected to have developed by the end of their Eurobachelor programme in chemistry, are as follows.

1. Chemistry-related cognitive abilities and competences

1.1. Ability to demonstrate knowledge and understanding of essential facts, concepts, principles and theories relating to the subject areas identified above.

1.2. Ability to apply such knowledge and understanding to the solution of qualitative and quantitative problems of a familiar nature.

1.3. Competences in the evaluation, interpretation and synthesis of chemical information and data.

1.4. Ability to recognise and implement good measurement science and practice.

1.5. Competences in presenting scientific material and arguments in writing and orally, to an informed audience.

1.6. Computational and data-processing skills, relating to chemical information and data.

2. Chemistry-related practical skills

2.1. Skills in the safe handling of chemical materials, taking into account their physical and chemical properties, including any specific hazards associated with their use.

2.2. Skills required for the conduct of standard laboratory procedures involved and use of instrumentation in synthetic and analytical work, in relation to both organic and inorganic systems.

2.3. Skills in the monitoring, by observation and measurement, of chemical properties, events or changes, and the systematic and reliable recording and documentation thereof.

2.4. Ability to interpret data derived from laboratory observations and measurements in terms of their significance and relate them to appropriate theory.

2.5. Ability to conduct risk assessments concerning the use of chemical substances and laboratory procedures.

3. Generic competences

3.1. The capacity to apply knowledge in practice, in particular problem-solving competences, relating to both qualitative and quantitative information.

3.2. Numeracy and calculation skills, including such aspects as error analysis, order-of-magnitude estimations, and correct use of units.

3.3. Information-management competences, in relation to primary and secondary information sources, including information retrieval through on-line computer searches

3.4. Ability to analyse material and synthesise concepts.

3.5. The capacity to adapt to new situations and to make decisions.

3.6. Information-technology skills such as word-processing and spreadsheet use, data-logging and storage, subject-related use of the Internet.

3.7. Skills in planning and time management.

3.8. Interpersonal skills, relating to the ability to interact with other people and to engage in team-working.

3.9. Communication competences, covering both written and oral communication, in one of the major European languages (English, German, Italian, French, Spanish) as well as in the language in which the degree course is taught.

3.10. Study competences needed for continuing professional development. These will include in particular the ability to work autonomously.

3.11. Ethical commitment

Content

It is highly recommended that the Eurobachelor course material should be presented in a modular form, whereby modules should correspond to at least 5 credits. The use of double or perhaps triple modules can certainly be envisaged, *a Bachelor Thesis or equivalent requiring 15 credits*. Thus a degree course should not contain more than 34 modules, but may well contain less. It must be remembered that 34 modules require more than 10 examinations per year.

Apart from the Bachelor Thesis[4], which will be the last module in the course to be completed, it appears logical to define modules as being compulsory, semi-optional (where a student is required to select one or more modules from a limited range), and elective (where the student may choose one or more modules from a normally much wider range).

While institutions should be encouraged to break down the traditional barriers between the chemical sub-disciplines, it is realised that this proc-

4. An individual research or industrial project, the results of which will be presented in the form of a written report. This report may be subject to examination and will in any case be graded. Projects leading to the Bachelor Thesis could well involve teamwork, as this is an important aspect of employability which is often neglected in traditional chemistry degree courses.

ess will not always be rapid. Thus the traditional classification is retained in what follows.

Compulsory chemistry modules will deal with the main sub-disciplines:

— Analytical chemistry
— Inorganic chemistry
— Organic chemistry
— Physical chemistry
— Biological chemistry.

Depending on the staff structure of the department, semi-optional modules will deal with sub-disciplines such as:

— Computational chemistry
— Chemical technology
— Macromolecular chemistry
— Biochemistry

Non-chemical modules will deal with mathematics, physics and biology. It can be expected that there will be compulsory mathematics and physics modules.

Practical courses may be organised as separate modules or as integrated modules. Both alternatives have advantages and disadvantages: if they are organised as separate modules, the practical content of the degree course will be more transparent. Integrated modules offer better possibilities for synchronising theory and practice.

Modules corresponding to a total of at least 150 credits (including the Bachelor Thesis) should deal with chemistry, physics, biology or mathematics.

Students should be informed in advance of the expected learning outcomes for each module.

Distribution of credits

Each individual institution will of course make its own decision as to the distribution of credits between compulsory, semi-optional and elective modules. It will however be necessary to define a «core» in the form of a *recommended minimum* number of credits for the main sub-disciplines, mathematics and physics. This «core» should neither be too large nor too small, and a volume of 50% of the total number of credits, i.e. 90 out of 180, seems a good compromise in view of the different philosophies present in Europe.

These 90 credits will cover the following areas:

— Analytical chemistry
— Inorganic chemistry
— Organic chemistry
— Physical chemistry
— Biological chemistry
— Physics
— Mathematics

In other words, the 90 credits form the «core» of the degree course. It must be noted that this is a minimum, which will often be exceeded, particularly in degree courses with 210 or 240 ECTS credits.

As far as semi-optional modules in chemistry are concerned, it is recommended that the student should study *at least three* additional chemistry-related sub-disciplines, depending on the structure of the department: examples are biology, theoretical/computational chemistry, chemical technology, macromolecular chemistry. *Each of these should correspond to at least 5 credits*.

Additional semi-optional and elective modules will certainly be favoured in many institutions: these can be chemistry modules, but may also be taken from any other subjects defined by the appropriate Regulations.

Language modules (stand-alone or integrated) will often be semi-optional, as the Eurobachelor should be proficient in a second major European language (these being English, German, Italian, French and Spanish) as well as the language of his/her home country.

In summary, for the 180 credits available, ≥90 credits are allocated to the core, ≥15 credits to the bachelor thesis,≥ 15 credits to the semi-optional modules. The remaining credits (30 of which may come from modules not dealing with chemistry, mathematics, physics or biology) are freely allocable.

The Bachelor Thesis[4]

The academic goal of the Bachelor degree in the chemical sciences is to give graduates an initial research experience. The intention is the graduate will successfully complete an individual research project. This is important not only for those going on to do higher degrees, but also for those leaving the system with a first degree, for whom it is vital that they have personal first-hand experience of what research is about.

An industrial placement may be considered a valid alternative to a Bachelor Thesis; such placements should be organised in such a way that their outcomes are clearly documented and that they can be given credits.

Thus the Bachelor Thesis should normally carry at least 15 credits.

The Thesis will be written in the language prescribed by the institution and defended according to the rules of the institution. It should be remembered that Thesis presentation can be used as a tool for improving presentation skills, also in a foreign language.

The supervision (and assessment) of the Bachelor thesis must be transparent.

Compensation/Condonement

The Chemistry Eurobachelor does not recommend compensation (in which failed modules/course units are considered to be «passed» because of an overall grade average.

Recognition of Credits Gained Abroad

The Eurobachelor is concerned with mobility and recognition. Thus Eurobachelor institutions must guarantee automatic recognition of credits gained at other institutions if they have been obtained according to the terms of a learning agreement. The institution must comply with the standard ECTS procedures:

— Learning agreements must be concluded with students going abroad before their departure and corrected if necessary during the stay at the host institution

— Because the learning agreement is a contract, it must be signed by someone in the Eurobachelor institution who is responsible for recognition as well as by the student and by a responsible representative of the host institution

— Credits gained which are listed in the learning agreement must be recognised automatically and should be referred to or listed in the Diploma Supplement issued to the graduate. Alternatively, the Transcript of Records issued by the host institution can be appended to the Diploma Supplement.

— Grade transfer, if it occurs, must be carried out on the basis of ECTS rankings. If the foreign host institution does not use ECTS rankings, a procedure for grade transfer must be used which does not result in «downgrading» of the grades awarded by the host institution.

Mobility can also involve students seeking to enter programmes from elsewhere without a learning agreement; in such cases institutions will make judgements on an individual basis.

ECTS and Student Workload

A European average for the total (expected) student workload per year is close to 1500 hours; this figure refers to full-time students in a standard academic programme. The average number of teaching weeks is around 25. Simple mathematics thus gives a theoretical workload of around 60 hours per week if the student only works during this period; such a high workload is obviously out of the question! However, generally European institutions seem to expect their students to do degree-relevant work during 36-40 weeks per year.

Thus it is important to have clear guidelines on student workload distribution. These should always include definition of pre-examination study periods and examination periods separate from the teaching period, as these periods form an integral part of the total workload.

When defining workload for the different teaching/learning elements of a chemistry degree course it must be taken into account that, for example, the total workload connected with a 1-hour lecture is different than that corresponding to 1 hour of practical work. Factors thus have to be introduced when workload is being estimated.

Initial institutional estimates of workload for the average student will of course not necessarily be correct; thus there must be a clear mechanism for continuous student feedback on actual workload and the use of this feedback to correct the structure of programmes where necessary.

Modules and Mobility

Mobility must be an important feature of Eurobachelor qualifications. It will obviously be made easier if subject areas can agree on module sizes, at least within the core of compulsory modules.

Mobility will only be possible in the second and third years, but will be restricted unnecessarily if institutions define a high proportion of course modules as being «non-transferable», i.e. they must be taken at the home institution. *Thus wherever possible only first-year modules should be treated as «non-transferable».*

Modules or course units should be fully described according to the ECTS «Key Features». Thus the following information is necessary for each course unit:

- Course title
- Course code
- Type of course
- Level of course
- Year of study
- Semester/trimester
- Number of credits allocated (workload based)
- Name of lecturer
- Objective of the course (expected learning outcomes and competences to be acquired)
- Prerequisites
- Course contents
- Recommended reading
- Teaching methods
- Assessment methods
- Language of instruction

Methods of Teaching and Learning

Chemistry is an «unusual» subject in that the student not only has to learn, comprehend and apply factual material but also spends a large proportion of his/her studies on practical courses with «hands-on» experiments, i.e. there are important elements of «handicraft» involved.

Practical courses must continue to play an important role in university chemical education in spite of financial constraints imposed by the situation of individual institutions.

Lectures should be supported by multimedia teaching techniques wherever possible and also by problem-solving classes. These offer an ideal platform for teaching in smaller groups, and institutions are advised to consider the introduction of tutorial systems.

Learning

We can help the student to learn and develop his/her capacity for learning by providing him or her with a constant flow of small learning tasks, for example in the form of regular problem-solving classes where it is necessary to give in answers by datelines clearly defined in advance.

It is obviously vital to have regular contacts between the teachers involved in the modules being taught to a class in any one semester to avoid overloading the student.

Assessment procedures and performance criteria

a) Coursework

The assessment of student performance will be based on a combination of the following:

— Written examinations
— Oral examinations
— Laboratory reports
— Problem-solving exercises
— Oral presentations

Additional factors which may be taken into account when assessing student performance may be derived from:

— Literature surveys and evaluations
— Collaborative work
— Preparation and displays of posters reporting thesis or other work.

b) The Thesis

To ensure comparability of standards throughout institutions operating the programme, a significant part of the assessment should be «competence based». Different levels of performance clearly need to be defined, and this can be facilitated through a series of statements which describe student skills, attitude and behaviour during the Bachelor Thesis. Attainment levels achieved by particular students can then be judged and compared. For example, keys to a successful Bachelor Thesis are the intellectual and scientific input of the student, the comprehension of the project, organisation and planning besides a well-written report.

The following two statements might encapsulate the range of abilities expected of students under the heading of *Intellectual and scientific input*: «The student demonstrated an enquiring mind and an ability to innovate by controlling the direction of the project» an «The student provided a technical rather than an intellectual contribution to the project». Such statements can be equated to a mark or grading. Use of such grading tools allows us to move beyond the sometimes subjective assessment of a written document which only reports on the outcome and background to a project. Used in conjunction with a report, student log book, oral presentation and poster, such a range of assessments can provide a very accurate picture of student ability.

Since Eurobachelor programmes are credit-based, assessment should be carried out with examinations at the end of each term or semester. It should be noted that the use of ECTS does not automatically preclude the use of «comprehensive examinations» at the end of the degree course; if these are used they must however also be included in the credit distribution process *and carry appropriate credits!*

Written examinations will probably predominate over oral examinations, for objectivity reasons; these also allow a «second opinion» in the case of disagreement between examiner and student.

Examinations should not be overlong; 2-3 hour examinations will probably be the norm.

Examination questions should be problem-based as far as possible; though essay-type questions may be appropriate in some cases, questions involving the reproduction of material learned more or less by heart should be avoided as far as possible.

Questions should be designed to cover the following aspects:

— The knowledge base
— Conceptual understanding
— Problem-solving ability
— Experimental and related skills
— Transferable skills

The student should be provided with feedback wherever possible in the form of «model answers».

Grading

The ECTS ranking system will obviously form an integral part of Eurobachelor assessment. While the national grading systems will no doubt initially be used alongside ECTS «grades», which are by definition based on ranking rather than «absolute» assessment criteria, it seems necessary to aim for the establishment of a recognised pan-European ranking system.

The Diploma Supplement

All chemistry Eurobachelors should be provided with a Diploma Supplement (as described under http://europa.eu.int/comm/education/policies/rec_qual/recognition/diploma_en.html) in English and if required in the language of the degree-awarding institution.

Quality Assurance

The chemistry Eurobachelor designation will be a quality label and must wherever possible involve national chemical societies and their pan-European counterpart (the European Association for Chemical and Molecular Sciences (EuCheMS)) as well as wider European chemistry organisations such as CEFIC and AllChemE. It will thus involve the formation of one of the first trans-national European quality assurance networks in the emerging European Higher Education Area.

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Adopted as the basis for award of the Chemistry Eurobachelor Label by the Assembly of the European Chemistry Thematic Network Association in Toulouse (April 2004).

Recommended by the Bologna seminar «Chemistry Studies in the European Higher Education Area», Dresden, June 2004.

Revised at the end of the Eurobachelor pilot project, June 2006.

9. The Chemistry «Euromaster»

The Aims of the Euromaster

The primary aims of the Euromaster qualification are to provide a second cycle degree of the highest standard which will be:

— recognised by other European institutions as being of a standard which will provide automatic right of access (though not right of admission, which is the prerogative of the receiving institution) to chemistry doctoral programmes.

— recognised by employers as being of a standard which fit the graduates for employment as professional chemists in chemical and related industries or in public service

— recognised by the European Chemist Registration Board of EuCheMS as meeting the educational standard necessary to allow the graduates to obtain the status of European Chemist.

It must be made clear at the outset that each institution providing Master-type degree programmes in chemistry is completely free to decide on the content, nature and organisation of its courses or modules. These degree programmes must relate to the European Qualifications Framework for the European Higher Education Area (EHEA) and to the corresponding National Qualifications Framework.

Chemistry degree programmes offered by individual institutions will thus logically have their own particular characteristics. The extent to which individual aspects are treated will vary with the nature of specific programmes.

Outcomes: The Descriptor

The goals of a second cycle study programme can be described by the «Budapest» Descriptors developed in May 2005 by the Chemistry Subject Area Group working in the project «Tuning Educational Structures in Europe». They are as follows:

Second cycle degrees in chemistry are awarded to students who have shown themselves by appropriate assessment to:

— have knowledge and understanding that is founded upon and extends that of the Bachelor's level in chemistry, and that provides a basis for originality in developing and applying ideas within a research context;

— have competences which fit them for employment as professional chemists in chemical and related industries or in public service;

— have attained a standard of knowledge and competence which will give them access to third cycle course units or degree programmes.

Such graduates will:

— have the ability to apply their knowledge and understanding, and problem solving abilities, in new or unfamiliar environments within broader (or multidisciplinary) contexts related to chemical sciences;

— have the ability to integrate knowledge and handle complexity, and formulate judgements with incomplete or limited information, but that include reflecting on ethical responsibilities linked to the application of their knowledge and judgements;

— have the ability to communicate their conclusions, and the knowledge and rationale underpinning these, to specialist and non-specialist audiences clearly and unambiguously;

— have developed those learning skills that will allow them to continue to study in a manner that may be largely self-directed or autonomous, and to take responsibility for their own professional development.

Transition to the Third Cycle

The chemistry Euromaster should, provided that his/her performance has been of the required standard, be able to continue his/her tertiary education either at his/her degree-awarding institution, at another equivalent institution in his/her home country, or at an equivalent institution in another European country. (At a later stage one can hope that world-wide acceptance of the Euromaster qualification will come into being).

This continuation will take the form of a course leading to a doctoral degree, either in chemistry or in related fields. Any master programme must end with a Thesis, as this will generally be considered to be the necessary prerequisite for access to the Bologna third cycle.

It is of pre-eminent importance that institutions offering Euromaster qualifications aim for high standards, so as to give their students good chances in the national or international job market as well as a good starting point to transfer to doctoral programmes should they wish to do so.

Master Programmes in the Context of Bologna

As a result of the Bologna Declaration, there are moves under way throughout Europe to revise chemistry degree structures. As decided at the Berlin conference in September 2003, a three-cycle structure is to be implemented («BSc/MSc/PhD»). However, there is no general agreement on introducing the «3-5-8» model which has sometimes been misunderstood as the Bologna «recommendation».

The Helsinki Master Conference of March 2003 provided the following recommendation: Master study programmes should involve 90-120 credits, at least 60 of which must be *at Master level*. This recommendation was used in defining the Second Cycle in the Qualifications Framework for the EHEA. Master programmes with a research orientation form a link between the EHEA and the European Research Area.

In this European Qualifications Framework, the length of the Bachelor degree is defined as 180 to 240 credits.

Thus any national requirement that a combination of Bachelor and Master must be necessarily equivalent to 300 credits is contrary to the provisions of the European Qualifications Framework, which foresees a «corridor» of 270 (180 + 90) to a maximum of 360 (240 + 120) credits for a combination of Bachelor and Master. Mobile students must not be penalised by not allowing a Bachelor graduate with a 180-credit degree to take a 90-credit Master.

Euromaster programmes will normally require 90-120 ECTS credits

Countries which have traditionally had «long» degrees qualifying for admission to PhD training will generally consider the Master programmes which they introduce to be similar in aim to the higher semesters in their earlier long degrees, but must of course not simply split long programmes into two (unequal) parts, which they then label Bachelor and Master.

Judging the Quality of Euromaster Programmes: «Fitness for Purpose»

Since it is neither necessary nor advisable to set up stringent parameters for a Master programme in chemistry, the question immediately arises as to how a programme can be judged when a «Euromaster Label» is under consideration.

The above «Budapest Descriptor» gives a global description of the aims of such a programme, and institutions are advised on the basis of this descriptor to start planning their programme by drafting a statement which defines the aims and the profile of the programme. Such a statement, which will probably run to between one and two pages of A4 text when a 12-point typeface is used, will describe the elements of the programme with reference to the above descriptor. It will describe the skills and competences which the graduate will have amassed at the end of the programme.

This statement defines the purpose of the programme, and the accreditation process will then be designed to find out whether the programme as set out in detail in the application is fit for the purpose for which it is designed.

The points which follow should be mentioned as appropriate in the statement of aims and profile, and will be the subject of questions in the Guidelines for Applicants.

Access and Entry

According to the conclusions of the Helsinki conference on Master degrees: *«All bachelor degrees should open access to master studies and all master degrees should give access to doctoral studies».* Access is also considered in detail in the Lisbon recognition convention, which has so far been ratified by 40 countries and international institutions.

The prerequisite for entry will be **either** a qualification of Eurobachelor standard **or** a first cycle degree in one of the disciplines defined by the institution for that particular programme.

Transnational mobility at the Bachelor/Master interface will often involve setting up admissions procedures at a level *previously unknown* in many European countries. While European students will be aided by their possession of the Diploma Supplement, the detailed information which the latter contains may often not be available for students from countries outside the EHEA.

If Europe wishes to *compete* with countries such as the USA for the best graduate students, it must offer structures and possibilities as least as good as those present in such countries. Many regret that in the USA a Master in chemistry will very often in fact be a «failed PhD», and they plan to develop high quality programmes leading to Masters who are *not* failed PhD's.

The Number of Credits

As stated above, Master study programmes should involve 90-120 ECTS credits, at least 60 of which must be *at Master level*. A normal academic year corresponds to 60 ECTS credits, a European average workload of 1500 hours and an average of 40 weeks per year during which the student will be studying.

Why the emphasis on «at Master level»? Because of the expected flexibility of Master programmes, it may for example be possible in a particular institution for a Physics Bachelor to enrol as a Chemistry Master. In such a case, the Master candidate may well have to make up work (*at Bachelor level*) in order to be able to reach the defined learning outcomes.

Depending on the structure of the individual programme and the number of credits involved, these may be EXTRA credits or may be included in the 90 or 120 which the complete programme carries.

Such «bridging» modules or course units must be given credit and mentioned in the Diploma Supplement.

The Master Thesis

The academic goal of the Master degree in the chemical sciences is to give graduates a research experience much broader and deeper than that involved in the limited Bachelor Thesis. The intention is the graduate will successfully complete a research project, the outcome of which is of a quality that is potentially publishable.

Thus the Master Thesis should normally carry at least 30 credits.

The Thesis will be written in the language prescribed by the institution and defended according to the rules of the institution. It should be remembered that Thesis presentation can be used as a tool for improving presentation skills, also in a foreign language.

The supervision (and assessment) of the Master thesis must be transparent.

Teaching Staff

The thesis supervisors referred to above bear a heavy responsibility in the Master programmes, as indeed do all members of staff involved at teaching at this level. Institutions applying for a Euromaster Label will be asked to provide brief details of the members of the teaching staff involved in the degree programme and of their recent publication records and other scholarly activity.

This information is necessary in order to judge the background of the programme. Naturally no outside interference in the teaching staff policy of the institution is intended.

Outcomes: Subject Knowledge

By its very nature, a Master programme will be much more flexible than a Bachelor programme. It is therefore neither necessary nor advisable to list areas of subject knowledge which the programme should cover. According to the needs of the institution, such programmes will be either broadly-based or specialised. Thus the second cycle graduate will often have an in depth knowledge of an area of specialism in chemical science.

Euromaster programmes will have NO defined «core» comparable to the «core» of 90 credits in the Eurobachelor framework.

Outcomes: Abilities and Skills

In addition to the aspects covered in the Descriptor, the following points should be taken into account.

At Euromaster level, students coming from a chemistry Eurobachelor background are expected to develop further the range of abilities and skills already gained in the Eurobachelor programme. If they come from a *different* undergraduate background, these abilities and skills may not always be present, but may need development during the Master phase.

The abilities and skills may be divided into three broad categories:

a. Chemistry-related cognitive abilities and skills, i.e. abilities and skills relating to intellectual tasks, including problem solving;

b. Chemistry-related practical skills, e.g. skills relating to the conduct of laboratory work;

c. Generic skills that may be developed in the context of chemistry and are of a general nature and applicable in many other contexts. The generic skills defined in the Eurobachelor document, which need to be developed further as appropriate during the Master phase, are listed in Appendix 1.

The main abilities and skills that students are expected to have by the end of their Euromaster programme in chemistry, are as follows.

a. Chemistry-related cognitive abilities and skills

Ability to demonstrate knowledge and understanding of essential facts, concepts, principles and theories relating to the subject areas studied during the Master programme.

Ability to apply such knowledge and understanding to the solution of qualitative and quantitative problems of an unfamiliar nature.

Ability to adopt and apply methodology to the solution of unfamiliar problems.

b. Chemistry-related practical skills

Skills required for the conduct of advanced laboratory procedures and use of instrumentation in synthetic and analytical work.

Ability to plan and carry out experiments independently and be self critical in the evaluation of experimental procedures and outcomes.

Ability to take responsibility for laboratory work.

Ability to use an understanding of the limits of accuracy of experimental data to inform the planning of future work.

c. Generic skills

Study skills needed for continuing professional development.

Ability to interact with scientists from other disciplines on inter or multidisciplinary problems.

Ability to assimilate, evaluate and present research results objectively

Curricular Structure

It is highly recommended that the Euromaster course material should be presented in a modular form, whereby modules should correspond to at least 5 credits. The use of double or perhaps triple modules can certainly be envisaged, the Master Thesis requiring at least 30 credits. Apart from the Master Thesis, it appears logical to define modules as being compulsory, semi-optional (where a student is required to select one or more modules from a limited range), and elective (where the student may choose one or more modules from a normally much wider range).

Students must be informed in advance of the expected learning outcomes for each module.

Each individual institution will of course make its own decision as to the distribution of credits between compulsory, semi-optional and elective modules.

Because Euromaster programmes will often allow the student a considerable amount of freedom of choice when selecting course units or modules, institutions should provide study advisers to give guidance on course unit/module selection.

Language

At Euromaster level, where the research component forms a main component of the programme, language proficiency *must* include *communication competences* in English, the *lingua franca* of scientific communication. Competences in reading and understanding English should be achieved automatically, since the vast majority of the chemical literature to be consulted is now written in this language.

ECTS and Student Workload

A European average for the total (expected) student workload per year is close to 1500 hours; this figure refers to full-time students in a standard academic programme. For most institutions, this is based on a working week of 40 hours. Thus it is important to have clear guidelines on student workload distribution. These should always include definition of pre-examination study periods and examination periods separate from the teaching period, as these periods form an integral part of the total workload.

When defining workload for the different teaching/learning elements of a chemistry degree course it must be taken into account that, for example, the total workload connected with a 1-hour lecture is different than that corresponding to 1 hour of practical work.

Initial institutional estimates of workload for the average student will of course not necessarily be correct; thus there must be a clear mechanism for continuous student feedback on actual workload and the use of this feedback to correct the structure of programmes where necessary.

Modules and Mobility

Mobility must be an important feature of Euromaster qualifications. It should be possible throughout the course, but particularly at the Thesis level, where use can be made of existing research cooperation with external partners.

Mobility will be restricted unnecessarily if institutions define a high proportion of course modules as being «non-transferable», i.e. they must be taken at the home institution.

Modules or course units should be fully described according to the ECTS «Key Features» (ec.europa.eu/education/programmes/ socrates/ects/index_en.html). Thus the following information is necessary for each course unit:

— Course title
— Course code
— Type of course
— Level of course
— Year of study
— Semester/trimester
— Number of credits allocated (workload based)
— Name of lecturer
— Objective of the course (expected learning outcomes and competences to be acquired)
— Prerequisites
— Course contents
— Recommended reading
— Teaching methods
— Assessment methods
— Language of instruction

Compensation/Condonement

The Chemistry Euromaster does not recommend compensation (in which failed modules/course units are considered to be «passed» because of an overall grade average).

Recognition of Credits Gained Abroad

The Euromaster is concerned with mobility and recognition. Thus Euromaster institutions must guarantee automatic recognition of credits gained at foreign host institutions if they have been obtained according to the terms of a learning agreement. The Euromaster institution must comply with the standard ECTS procedures:

— Learning agreements must be concluded with students going abroad before their departure and corrected if necessary during the stay at the host institution

— Because the learning agreement is a contract, it must be signed by someone in the Eurobachelor institution who is responsible for recognition as well as by the student and a responsible representative of the host institution

— Credits gained which are listed in the learning agreement must be recognised automatically and should be referred to or listed in the Diploma Supplement issued to the graduate. Alternatively, the Transcript of Records issued by the host institution can be appended to the Diploma Supplement.

— Grade transfer, if it occurs, must be carried out on the basis of ECTS rankings. If the foreign host institution does not use ECTS rankings, a procedure for grade transfer must be used which does not result in «downgrading» of the grades awarded by the host institution

Methods of Teaching and Learning

A wide variety of learning and teaching approaches is to be recommended. The element of research involved in a Euromaster course will, as stated above, be considerable.

Lectures should be supported by multimedia teaching techniques wherever possible and also by problem-solving classes. These offer an ideal platform for teaching in smaller groups, and institutions are advised to consider the introduction of tutor/mentor systems as a standard feature of Master programmes, where the student will need guidance on his or her study programme because of the initially unexpected degree of freedom in choosing modules/course units.

Assessment procedures and performance criteria

The assessment must be designed to cover the defined learning outcomes.

a) Coursework

The assessment of student performance must involve as many procedures as possible, such as:

— Written examinations
— Oral examinations
— Laboratory reports
— Problem-solving exercises
— Oral presentations
— Preparation and displays of posters reporting thesis or other work.

Since Euromaster programmes are credit-based, assessment should be carried out with examinations at the end of each term or semester. It should be noted that the use of ECTS does not automatically preclude the use of «comprehensive examinations» at the end of the degree course; if these are used they must however also be included in the credit distribution process and carry appropriate credits!

Examination questions should be problem-based as far as possible; though essay-type questions may be appropriate in some cases, questions involving the reproduction of material learned more or less by heart should be avoided as far as possible.

Members of the teaching staff should aim for a consistent and transparent policy on assessment.

b) The Thesis

To ensure comparability of standards throughout institutions operating the programme, a significant part of the assessment should be «competence based». Different levels of performance clearly need to be defined, and this can be facilitated through a series of statements which describe student skills, attitude and behaviour during the Master Thesis. Attainment levels achieved by particular students can then be judged and compared. For example, keys to a successful Master Thesis are the intellectual and scientific input of the student, the comprehension of the project, organisation and planning besides a well-written report.

The following two statements might encapsulate the range of abilities expected of students under the heading of *Intellectual and scientific input*: «The student demonstrated an enquiring mind and an ability to innovate by controlling the direction of the project» and «The student provided a technical rather than an intellectual contribution to the project». Such statements can be equated to a mark or grading. Use of such grading tools allows us to move beyond the sometimes subjective assessment of a written document which only reports on the outcome and background to a project. Used in conjunction with a report, student log book, oral presentation and poster, such a range of assessments can provide a very accurate picture of student ability.

Grading

While the national grading systems will be used initially, it seems necessary to aim for the establishment of a recognised pan-European grading system.

The Diploma Supplement

All chemistry Euromasters must be provided with a European Diploma Supplement (as described under http://europa.eu.int/comm/education/policies/rec_qual/recognition/diploma_en.html) in English and, if required, in the language of the degree-awarding institution.

Quality Assurance

The chemistry Euromaster designation will be a quality label and must involve national chemical societies and their pan-European counterpart (the European Association for Chemical and Molecular Sciences (EuCheMS)) as well as wider European chemistry organisations such as CEFIC and AllChemE. It will thus involve the formation of one of the first trans-national European quality assurance networks in the emerging European Higher Education Area.

Appendix I

Generic competences as defined in the Eurobachelor framework

— The capacity to apply knowledge in practice, in particular problem-solving competences, relating to both qualitative and quantitative information.

— Numeracy and calculation skills, including such aspects as error analysis, order-of-magnitude estimations, and correct use of units.

- Information-management competences, in relation to primary and secondary information sources, including information retrieval through on-line computer searches.
- Ability to analyse material and synthesise concepts.
- The capacity to adapt to new situations and to make decisions.
- Information-technology skills such as word-processing and spreadsheet use, data-logging and storage, subject-related use of the Internet.
- Skills in planning and time management.
- Interpersonal skills, relating to the ability to interact with other people and to engage in team-working.
- Communication competences, covering both written and oral communication, in one of the major European languages (English, German, Italian, French, Spanish) as well as in the language of the home country.
- Study competences needed for continuing professional development. These will include in particular the ability to work autonomously.
- Ethical commitment

Original discussion paper written by T. N. Mitchell (Dortmund, DE)

Modified by the augmented chemistry Tuning group, April 2006

Approved by the ECTNA General Assembly, Vienna, April 2006

10. Recommendations for the Third Cycle

Preamble

In June 2004 the first Bologna Seminar devoted to a single discipline was held in Dresden, Germany. The results of the seminar, «Chemistry Studies in the European Higher Education Area», formed the basis for the discussions of the Tuning SAG and of a working party of ECTN. The recommendations presented below are the result of a joint meeting of both groups held in Helsinki, Finland, in February 2006. The Helsinki discussion also took account of the statements on the third cycle in the Bergen Communiqué 2005:

> *«…doctoral level qualifications need to be fully aligned with the EHEA overarching framework for qualifications using the outcomes-based approach. The core component of doctoral training is the advancement of knowledge through original research. Considering the need for structured doctoral programmes and the need for transparent supervision and assessment, we note that the normal workload of the third cycle in most countries would correspond to 3-4 years full time. We urge universities to ensure that their doctoral programmes promote interdisciplinary training and the development of transferable skills, thus meeting the needs of the wider employment market. We need to achieve an overall increase in the numbers of doctoral candidates taking up research careers within the EHEA. We consider participants in third cycle programmes both as students and as early stage researchers. We charge the Bologna Follow-up Group with inviting the European University Association, together with other interested partners, to prepare a report under the responsibility of the Follow-up Group on the further development of the basic principles for doctoral programmes, to be presented to Ministers in 2007. Overregulation of doctoral programmes must be avoided.»*

Chemistry and the EHEA Overarching Framework

This framework was approved by the Ministers in Bergen. It is a simple framework with which national systems must be aligned. The main elements of the framework are Descriptors and ECTS credits.

The outcomes-based Descriptors used in the framework are the so-called «Dublin Descriptors», and the chemistry Tuning group has used the Dublin descriptors as a basis for formulating chemistry cycle descriptors. The result is the set of «Budapest Descriptors», and that for the third cycle follows:

Third cycle (doctoral) degrees in chemistry are awarded to students who:

— have demonstrated a systematic understanding of an aspect of the science of chemistry and mastery of those skills and methods of research associated with the topic of this research;

— have demonstrated the ability to conceive, design, implement and develop a substantial process of research in chemical sciences with rigour and integrity;

— have made a contribution through original research that extends the frontier of knowledge in chemical science by developing a substantial body of work, some of which merits international refereed publication;

— have competences which fit them for employment as professional chemists in research positions in chemical and related industries, in public service, or for a progression to a career in academic research.

Such graduates:

— are capable of critical analysis, evaluation and synthesis of new and complex ideas;

— can communicate with their peers, the larger scholarly community and with society in general about their areas of expertise;

— can be expected to be able to promote, within both academic and professional contexts, scientific and technological advancement in a knowledge based society.

Recommendations for Third Cycle Programmes in Chemistry

In the discussion which follows, the Dresden Recommendations will be used as a framework, since they have lost none of their relevance. Indeed in many aspects the Bergen recommendations appear to have been derived from those formulated in Dresden! The recommendations will be illustrated, where possible, by examples of good practice.

Structured degree programmes which include coursework (in the widest sense of the term) should become a common feature of European PhD studies; however, research must still be the major element of such programmes. Part-time PhD studies should remain possible in institutions where it has been a normal feature.

Only structured programmes can be «tuned»! Thus any Tuning recommendations can only deal with ***programmes***: the traditional «master-apprentice» system of doctoral supervision is no longer appropriate at the beginning of the 21st century. Naturally no-one wishes to suggest that a PhD in chemical science should not be gained because of the research done; doctorates which ONLY involve coursework should never be introduced in chemistry!

However, coursework —and here the important point is the phrase «in the widest sense of the term»— does have a vital role to play. The danger inherent in the master-apprentice system is that the student spends several years concentrating on a very narrow piece of research and loses the skills gained during the first and second cycles.

We must not forget that the research element of the PhD will in the vast majority of cases be something unique in the career of the young person involved. He or she will almost certainly never again have the chance to work relatively undisturbed on a topic which is (hopefully) found to be fascinating. Later on in life various other elements will probably come to the fore:

— Work in an interdisciplinary team: thus it is vital that the PhD student continually looks outside the narrow area of the research project
— Problem-solving: one could perhaps say that the whole purpose of our scientific training is to make us capable of problem-solving on ever higher levels
— Communication and dialogue: communication and defence of one's own results and discussion of their relevance.

The «coursework» on offer should be oriented towards these goals and be output- rather than input-oriented.

Some examples of the elements which could well be involved are:

— Specialised lectures
— Research seminars (not only within the student's own research group)

— Lectures by visiting scientists
— Workshops
— Summer schools
— Formulation of research projects
— Posters, lectures

Coursework must not necessarily count towards the award of a PhD, although it is often assessed. Instead a credit score can be assigned to various items to gauge how much has been completed; successful collection of a prescribed number of credits may entitle students to submit their thesis for examination. Coursework can be used as source material for oral questioning.

The quantity of coursework (in ECTS credits) varies widely throughout Europe, the typical range being 15-30 credits. More coursework than this should not be needed.

Tuning recommends that not less than 15 and not more than 30 ECTS credits should be required as part of the requirements for a PhD.

Part-time students will often find it difficult to become involved in such activities; dependent on their background these may not be so necessary. Thus it seems logical not to forbid part-time PhDs in future, if these have in the past formed a normal part of the institution's structure.

The average European PhD should spend 3 to 4 years on his or her studies. The research element of the PhD study programme should not be awarded ECTS credits.

Students doing first and second cycle degree courses often work part-time and thus extend the time required to complete their courses. At the PhD level, however, it is vital that (apart from work done as a teaching assistant) the student should be able to work full-time on his or her studies (apart from the case just noted). Thus a period of three to four years of full-time study must suffice for a PhD.

There appears to be no advantage in quantifying a research-based third cycle degree course in terms of ECTS credits. Indeed, to award such credits to research work seems to be potentially very dangerous, now that ECTS credits are moving from being just a reflection of time spent on studying to being a measure of learning outcomes.

ECTS credits should be used to quantify the coursework component. These credits can however be ungraded, as the correct use of the (relative) ECTS grading (ranking) scale will not be possible. A wide range of ECTS credits (anywhere between 20 and 60) can be envisaged. Use of the national grading scale is of course possible.

The coursework component of the PhD is, as we have stated above, outcome-oriented, and thus can indeed by quantified in terms of ECTS credits. Since it will not be possible to use the ECTS relative ranking scale for such coursework, there seems to be no advantage in grading this coursework (although if required the national grading scale can be used).

Apart from research and coursework, further important elements of the PhD programme are teaching (as teaching assistants) and the training of key generic skills, such as those listed in the Chemistry Eurobachelor document.

The Eurobachelor document lists a number of key generic skills:

— The capacity to apply knowledge in practice, in particular problem-solving competences, relating to both qualitative and quantitative information.

— Numeracy and calculation skills, including such aspects as error analysis, order-of-magnitude estimations, and correct use of units.

— Information-management competences, in relation to primary and secondary information sources, including information retrieval through on-line computer searches

— Ability to analyse material and synthesise concepts.

— The capacity to adapt to new situations and to make decisions.

— Information-technology skills such as word-processing and spreadsheet use, data-logging and storage, subject-related use of the Internet.

— Skills in planning and time management.

— Interpersonal skills, relating to the ability to interact with other people and to engage in team-working.

— Communication competences, covering both written and oral communication, in one of the major European languages (English, German, Italian, French, Spanish) as well as in the language in which the degree course is taught.

— Study competences needed for continuing professional development. These will include in particular the ability to work autonomously.

— Ethical commitment

These skills are not to be forgotten at the end of the first cycle, but must be developed further during second and third cycle studies.

Work as teaching assistants, which is a normal feature of the time spent on PhD research throughout Europe (though the financial background varies enormously), has a very positive effect on the development of most students.

PhD programmes should be flexible enough to include a component of teaching in the accumulation of 'coursework' credits, but it should not be considered as a compulsory component. The usual form of teaching is in the teaching laboratories, but graduates are also used to give tutorials, look after problem classes, and to check student exercises.

A common situation is that students may supervise laboratories provided a member of staff is responsible and on call. This may not be either good practice or legal, and other countries demand the presence of a staff member in the laboratory along with the graduate. Thus in Italy, where there are three levels of staff, PhD students are at the lowest level, and lab supervision is done by the highest level of staff (Professors). In the UK, academic related staff (Laboratory Managers or Instructors) assist with laboratory supervision.

Most graduates are paid for some or all of their teaching, but rates vary.

Initially, this responsibility as a teaching assistant in a laboratory puts students in what can be a difficult situation, as they undergo a transformation from learner to teacher status.

Thus it is vital that there be an induction phase before work as teaching assistants starts.

Institutions should issue transcripts containing information on all the coursework carried out, and on work done as a teaching assistant. Such transcripts will probably not use the standard European Diploma Supplement format.

The European Diploma Supplement is perhaps not ideal for describing a PhD programme. The DS is composed of eight sections (information identifying the holder of the qualification, information identifying the qualification, information on the level of the qualification, information on the contents and results gained, information on the function of the qualification, additional information, certification of the Supplement, information on the national higher education system). The key component of the DS which makes it so valuable for the first and second cycles is section 4, information on the contents and results gained.

Such information will be much less detailed for a PhD programme, the main contents of which are a thesis containing the results of the research. Nevertheless, it is important that the graduate be supplied with a transcript detailing coursework, as well as details of the activities in teaching, if any.

The DS should be taken as a model and modified to fit the necessities of PhD programmes.

Institutions are encouraged to develop «Graduate School» structures at departmental, interdepartmental or regional level in order to increase their national and international visibility, to increase their research potential and to foster cooperation both between staff and between students.

The following passage is taken from the Bergen communiqué:

> *«We underline the importance of higher education in further enhancing research and the importance of research in underpinning higher education for the economic and cultural development of our societies and for social cohesion. We note that the efforts to introduce structural change and improve the quality of teaching should not detract from the effort to strengthen research and innovation. We therefore emphasise the importance of research and research training in maintaining and improving the quality of and enhancing the competitiveness and attractiveness of the EHEA. With a view to achieving better results we*

recognise the need to improve the synergy between the higher education sector and other research sectors throughout our respective countries and between the EHEA and the European Research Area.»

Thus the reference to increasing the national and international visibility of HE institutions was slightly ahead of its time. The traditional master-apprentice system of PhD training tends to keep students within the limits of the research group in which they are working, which can of course be very large, but also very small. The idea of «Graduate School» structures in which the individual student is integrated into a departmental, interdepartmental, regional or even international structure will be a great help in putting the research project into perspective as well as for offering possibilities for advancing generic skills.

National structures for setting up research networks should be extended in order to internationalise such networks. PhD students should spend part of their research time at other institutions, preferably in foreign countries.

The European Research Area is intended to internationalise research within Europe, and the European Research Council will hopefully stimulate the formation of international research networks, both within EU Framework Plans and without. As research is internationalised, so will the possibilities increase for PhD students to do some of their project work in another institution, and they will often benefit more if this institution is in another country. Individual institutions should do all they can to encourage suitable students to spend a period of time in another institution.

In appropriate circumstances, suitably qualified candidates (from foreign institutions) should be able to go directly to PhD studies without first completing a Master programme.

Here it is necessary to quote from the recommendations of the Helsinki seminar on Master programmes, which provided the ground rules for Master programmes in the EHEA.

«A transition from master level to doctoral studies without the formal award of a master's degree should be considered possible if the student demonstrates that he/she ha the necessary abilities».

The excellent student must be rewarded in the Bologna framework. He or she must be allowed to proceed faster than the majority. Why? These are young people who may well become the leaders, and/or the university professors, of tomorrow. They must be offered a «fast-track option».

Students from foreign institutions may well have qualifications different from both a European bachelor and a European master; their needs must be catered for.

The Dresden conference made it clear that institutional regulations should be written in such a way that this is indeed a real possibility.

This has not yet been done in all national systems, so that competition for the best among European institutions may lead to a «brain drain» within Europe rather than just across the Atlantic! But certainly US institutions are coming to terms with the European Bachelor, and will be pragmatic enough to take the best of these into their Graduate Schools, even if they do not have a Master's degree in their pocket.

Thus the phrase «from foreign institutions», which reflected the state of the discussion in Spring 2004, should now be removed, as our thinking has moved on. Thus the German Chemical Society (GDCh) and the Conference of Heads of Chemistry Departments (KFC) is preparing a document with recommendations on PhD programmes which deals in detail with the transition from Bachelor to PhD studies.

In PhD examinations, institutions should consider the widespread involvement of external examiners. Examinations should be open. There appears to be no advantage in grading the PhD.

There are many different ways in which PhD examinations are organised across Europe. One extreme is the UK/Ireland «viva», involving only the student and two examiners (neither of whom, however, is the PhD supervisor). The other extreme, of which there are several slightly different versions, is the completely open examination, with either a «jury» of professors (including external examiners) or participation by any professor in the department.

One general theme is that external examiners are present and actively involved in the examination process. «Incestual» systems in which the PhD supervisor dominates the examination proceedings are outdated.

Open examinations are in a majority in Europe, and should be made possible without the possibility of a veto by the candidate.

Grading is not a standard feature, but does occur in some systems. «Grade inflation» can however mean that the results are questionable: thus of the close to 1200 PhDs awarded in Germany in 2005, 70% were awarded the grade of «very good» and another 16% were considered to be «excellent». When one realises that this grade is to a very large extent determined by the PhD supervisor, and that at least 80% of those who take their first degree (Diplom) go on to do a PhD, it becomes clear that such grades really mean that the academics are grading themselves!

Recommendations arising from Post-Dresden Discussions

PhD Supervision

Few countries appear to have training for supervisors of PhD students, and this is something that is to be encouraged.

Too many regulations are to be avoided, as PhD students are adults, and should be responsible for their own development, but they must not be left to get on completely by themselves.

It is not justifiable to assume that because a person is a good researcher they will automatically be a good supervisor of research students (although in Germany a professor with Habilitation is assumed to have gained a licence to teach, and thus to supervise students, his capabilities in this second area are never tested). The academic community should seek to ensure that the students get the best possible guidance, or at least guarantee a minimum standard. Unfortunately institutions that have tried to impose regulations have been seen as interfering in academic freedom by some staff.

Examples of good practice:

Strathclyde (Glasgow, UK) has a one-day training session, and a handbook that sets out the responsibility of both student and supervisor. In Slovakia rules are set out for students in all Cycles, which are especially useful in the 3rd Cycle when many students are coming into a new environment from different institutions or countries. In the Netherlands, a

PhD student becomes an employee of the university, and signs a contract that also outlines the responsibility of the supervisor. In Finland it is proposed that only professors should supervise PhDs; while in Slovakia, younger researchers understudy a more experienced professor before taking on students of their own.

In several countries the supervisor is not the only person with responsibility for the PhD student. An advisor may also be appointed, not necessarily from the same subject area as the student, or even a small support group. This group may not even include the supervisor on the once a year occasion when the student reports to it and outlines plans for the coming year. In the Czech Republic, this group effectively supervises the quality of the supervisors. Having a formal connection between graduate students and other specialists from the department can be beneficial both to student and staff member, and the valuable stimulus of interdisciplinarity has been confirmed in Italy, even at the Master thesis level.

A common arrangement is that students submit interim reports (at least every six months is usual) to be evaluated by their supervisor (sometimes an external staff member), which may take the form of a presentation; but in Italy, the student may not have much contact with the supervisor because of the way that PhD students are selected and allocated to projects. In the Czech Republic, a brief report is presented by the supervisor to a committee that oversees all PhD projects in their area of expertise, and which may include staff from other institutions.

A normal allocation of PhD students to a supervisor could be 4-6, but it depends on whether the research group also includes a number of post-doctorate workers. Interaction between graduates at various stages of their PhDs is also valuable, but rarely needs regulation; 'though in large research groups it is important for the supervisor to set up a 'chain of command.' Quite unlike Arts PhD students, group working, group meetings, group support and a group spirit are the day-by-day experiences of researchers in chemistry and other science disciplines. Indeed this enables a requirement for teamwork and integration to be included in the coursework credits of a chemistry PhD student.

With tough selection procedures and highly motivated students, drop-out is usually low in the 3rd Cycle, and rarely for scientific reasons; it most often occurs because of health, family or financial problems. More frequent is the situation where students fail to write up their theses after completing their research work because of the demands of taking up employment. In the UK, departments are penalised for any students that do not complete their PhDs; whereas in Slovakia, departments are rewarded for every PhD gained! In Poland students have to pay back their funding if they fail to gain their degree. In Finland an incomplete PhD can be written up for the lesser degree of Licentiate; and in the UK a distinctive Masters degree, MPhil, is awarded for theses that do not reach PhD standard.

In the infrequent situation of a dispute between student and supervisor there should be a mechanism in place to bring about rapid resolution.

Specifying a member of staff, at least as senior as the student's supervisor (senior professor, or Head of Department) as arbitrator is the usual approach. It must be someone who is prepared to listen to the student as well as to the staff member. Most disputes arise over misunderstandings and can readily be sorted out or endured. A change of supervisor should be allowable, but in practice this is rare, as it usually means a change of research topic part way through the programme.

Assessment of PhD Candidates

Within each country the assessment of PhDs seems to be fundamentally the same across Arts and Sciences, but national differences need to be addressed.

In some countries the preferred term is «defence» of a thesis rather than an examination. The supervisor is not usually involved in this final process, except as an observer; but in almost every country one or more external experts (sometimes from other countries, not just other universities) participate.

In most countries the principal (or only) criterion for awarding a PhD is the quality and quantity of the research and its accurate, effective presentation in the thesis. Students are expected to produce a reasonable quantity of high-grade research, understand what they have done, and appreciate the wider context into which it fits.

In the Netherlands the work is first approved by a committee, then 300-500 copies of the thesis are printed before holding an open defence; Finland is similar.

In Poland and Slovakia the thesis is available in the Library before the defence. Two referees (three in the Czech Republic) give written comments and decide whether the defence should be held. The questions asked from the floor and the student responses are all formally recorded. The candidate may also be examined beforehand on the area of the research, making assessment a three-stage process, as the work is proved to be acceptable successively to the supervisor (and department), experts in the field, and the chemistry community at large. As a result the assessment (and even the decision of the award) is often complete before the defence takes place (so this is largely a formality).

In the UK a single stage procedure follows an informal agreement between student and supervisor that the thesis is ready for submission. An examination focused on the research in the thesis is conducted by a member of the Department (the internal examiner) and an external examiner.

Institutions should formulate guidelines on how PhD assessment is carried out as part of their internal Quality Assurance mechanisms.

11. Report of the Chemistry Tuning Validation Panel

As a part of the Tuning Validation strategy, the material which forms this Chemistry Tuning Brochure was submitted to a panel of eight international experts at the end of February 2007, care of the Tuning General Co-ordinators, who asked the panel to review them. The panel and the Chemistry Tuning Area Group met in Brussels on March 23rd 2007, where a preliminary oral assessment report was presented to the Chemistry Group by the panel. The written report by the panel was received in April 2007 and is presented in its entirety below. Observations and suggestions made by the panel often need to be read in the context of the Eurobachelor *and* Euromaster *papers which form Sections 9 and10 of this brochure.*

We thank the panel for their valuable contribution to the exercise of Tuning Chemistry!

Members of the Validation Panel are very impressed with the valuable and very good work that the Chemistry Subject Area Group has accomplished as part of Tuning. This report is based on our deliberations over a single day. We appreciate that the SAG has spent far more time debating and producing the Chemistry SAG document and its associated Template; nevertheless we hope that our comments and suggestions will be useful to the Group as its members seek to refine and develop Eurobachelor and Euromaster labels and to consider further the third cycle doctoral qualification. We appreciate that some of the points made below are present already in the SAG document; where they are restated, it is to provide some context for our own discussions. From a reading of this report, it will be apparent that there was not universal agreement on the detail of all aspects but rather that there were some differences in emphases within the Panel. These differences are reflected in the text. However, there is a large degree of agreement among us. For the most part, the differences possibly reflect the Panel members' experiences of different national systems.

The report is structured around six topics which are themselves based on the seven questions that were posed to the Panel. The verbal report given to the Tuning Validation Conference is summarised and this present Report additionally contains a number of specific points made by individual (or groups of) Panel members.

11.1. Description of the Subject Area

The description of what is meant by the Chemistry subject area is probably, of necessity, rather general.

(i) However, what should be present in a first cycle course programme (Eurobachelor) is, in places, too specific. Some elements of prescription can be justified because of the European diversity but a proper balance must be found. Learning Outcomes are the priority.

(ii) Descriptions offered should attempt to anticipate developments; they should look forward rather than backwards. Tuning should dare to have a vision for the future. It could be said that much of the Tuning exercise is a description of the past!

(iii) A statement that 'it is sometimes found advantageous that chemists themselves teach Mathematics and Physics' is dangerous in that it may provoke needless controversy among disciplines.

11. 2. Degree Profiles and Occupations

Employability patterns differ from country to country and at each level.

(i) Tuning should keep and enhance this diversity rather than attempt to produce a standardised programme.

(ii) Universities should be encouraged strongly to be aware of the fate of their own students; employability, statistics and quality assessment are all connected. We recognise that in many national systems, information on employment gained, particularly after the first cycle, is very scanty. However, one Italian University, for example, collects employment data from its students after they graduate. It is found that over 80% of those with a Bachelor degree proceed to a Master degree. This means that a major objective of the first cycle is to prepare students for the second. This is the pattern also at present in many other national systems.

(iii) There are some hard questions that must be asked about a three year Bachelor degree. Is there a real job market? Are we «over-educating» students for more or less standard jobs that are unrelated to chemistry? If this is so, does it make 'economic' sense? Are we following the US model with a college-level education that is unrelated to the labour market?

(iv) It can be argued that if the holders of Bachelor degrees are to find employment as «qualified technicians» in the Chemistry field, there is a need for the first cycle programme to have significant practical teaching, see also # 3 (vi) below.

(v) Competences should be related to employability in its most general sense. Although there must be a clear progression, first → second → third cycle, it is important to keep in mind that the end of first cycle is a legitimate exit point. Thus a Bachelor degree must fulfil both the qualities required for consideration for entry to a Master programme and those sought by potential employers. This ideal may be a difficult balance to achieve.

(vi) Whatever the degree objectives are, it is most important to ensure that any «Euro label» is viewed as *added-value* by the national authorities in charge, particularly those responsible for accreditation of programmes.

11.3. Generic and Subject Specific Competences

We follow very much the view of the SAG that generic competences should be embedded in the subject teaching. For this reason, both types (if indeed they can be really separated) are dealt with together.

(i) However, we recognise that the balance between subject specific and generic competences will be different at first and second cycles. At the first cycle, generic competences should be at least as important as subject-specific, whereas at the second cycle subject-specific competences should be dominant.

(ii) References to the important «Problem-Solving» competence in the documents should be made more specific; at the Master level problem-solving will be tied closely to research, reflecting a situation where most Master graduates in Chemistry will be employed in Chemistry-related sectors.

(iii) Other generic competencies that are very relevant and that should emphasised further are project management, general business understanding and, possibly also, entrepreneurship. These, and the other generic competences, are not simply «add-ons» but need to be integrated into the context of the coursework.

(iv) It is necessary to review competences at regular intervals to maintain relevance. In the present documents there are references to software such as Word and Excel. Specifics like these should be avoided; otherwise the competences could date rapidly.

(v) The Panel discussed language and ethics-related competences in some detail. The (difficult) issues relating to language competences are recognised; students should be capable of communicating their chemistry to those with, possibly, different language backgrounds. Language competence should be located firmly within chemistry. Languages are therefore part of the chemistry teaching. This presupposes that students will be able to cope. Do the school systems within Europe provide the required background? There may be an implicit assumption that the necessary background is present but this may be unsafe in some cases. A second or third modern language should be encouraged but rather than concentrate unduly on «major European languages» competences should include important «world» languages; skills in the Chinese language would be an appropriate example.

Rather than focus on the teaching of Chemistry in the English language (for example the reference to «Master level teaching being in English whenever possible»), it would be more positive to «encourage the teaching of Chemistry in two or even three modern languages whenever possible».

(vi) Ethics-related competences should emphasise Chemistry-relevant matters such as safe laboratory working with a range of chemicals (universally recognised as important) and responsible management of waste. The latter is increasingly regarded as being a crucial part. Throughout all published documents, it would be useful to replace references to «safety» with «safety considerations in the handling of a range of chemicals and in waste management».

11.4. Length of Studies/Workload

The Panel had a spirited discussion regarding the primacy of Learning Outcomes as opposed to Knowledge-Driven Credits for the determination of Reference/Exit points and appropriate points for student mobility.

(i) It is recognised that ECTS is very useful, and probably required, in order to handle student mobility situations properly (the issues that surround Credit recognition and Credit accumulation for example). With this in mind, thought should be given to the issue, «How many ECTS credits are required for a student to gain a host University «diploma», which will reflect the student's achievement there?» Is it possible to generate a tariff, which will be widely accepted, as an arrangement to enhance mobility?

(ii) To parameterise a study programme in terms of Credits and to relate these to workload is, in principle, good. However, this approach requires a serious effort to be made to quantify the actual study time required for comprehension. In practice this concept seems to be easier for the teachers than it is for the students!

(iii) We note that Reference/End Points are expressed in terms of Outcomes in the Tuning Structures document but in the Chemistry SAG document, Credits are emphasised to a greater extent. Learning Outcomes are important but there must be sufficient flexibility in making judgements on how (and in what time scale) they are achieved.

(iv) It was agreed that the sections in the Chemistry document dealing with Learning Outcomes/Reference Points require re-examination in the light of the Validation exercise with the possibility of modifying and/or updating.

11.5. Teaching/Learning/Assessment

(i) All these activities are closely related and should be related in obvious ways to Learning Outcomes and Competences. It is particularly important that students can see the importance of Learning Outcomes and Competences reflected in their assessments. This is far more important than merely listing assessment methods that are regarded as being appropriate.

(ii) Since Chemistry is a practical subject, there must be great emphasis on laboratory-centred activities. The point that teachers and students together should be solving problems rather than students simply reaching a solution that is known already to the teacher should be emphasised.

11.6. Quality Enhancement

(i) Mechanisms to ensure quality should be output-based and not simply a box-ticking exercise.

(ii) Any measures that are put in place through Tuning should not interfere with nor be in opposition to, Institutional and/or National systems.

(iii) It is recommended strongly that the Chemistry SAG consults with QA experts (possibly *via* fixed-term group memberships of the SAG) to make specific proposals to «kick-start» QA applications to Chemistry. A set of criteria against which individual programme performance can be measured should be developed. These criteria should be supplemented with illustrations giving examples of how Quality Enhancement might be achieved in Chemistry programmes.

(iv) The Panel does not underestimate the difficulties of finding ways of involving students in the work of the Chemistry SAG, however, it believes that this is required to achieve continuing success.

(v) Co-supervision of Ph.D. programmes should be encouraged, as this can be viewed as a «fruit» of mobility (for students and staff). Many institutions try to promote such co-operations; they should be encouraged in this and co-operation should be facilitated, particularly in cases where national systems are reluctant to recognise or award «double-degrees».

(vi) If the Eurobachelor and Euromaster are to gain respect as cognate labels, which are relevant to the subject, see also #2 (vi) above, they must be recognised both as being related closely to well defined Learning Outcomes and Competences and be recognised as requiring sufficient conditions (stated criteria must have been fulfilled) for their award. This means that possibly not all of the existing systems will automatically qualify. The use of these labels should challenge existing systems with a clear vision.

(vii) Notwithstanding the last point, as yet unknown, positive developments are certain to occur in the future. There could be a risk that these might be hindered or hampered by too many «musts». Tuning of Chemistry should therefore lead to a process that is open-minded and that is not afraid of diversity.

This report was compiled by J.M. Winfield but it reflects the views of and inputs from all Chemistry Tuning Validation Panel Members.

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