The Chemistry "Eurobachelor"

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Replaces all earlier versions.

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;

[1] A Eurobachelor qualification

- 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.

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 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.

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.

[2] Such as computational chemistry, materials chemistry, macromolecular chemistry, radiochemistry

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. 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

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 an English 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 recent Tuning Project survey of employers and graduates in employment 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.

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

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
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[1]

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 of the home country.
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 modules from a normally much wider range).
While institutions should be encouraged to break down the traditional barriers between the

[4] This can be defined as a research 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.

chemical sub-disciplines, it is realised that this process 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
- Biophysics.

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 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.

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.

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, and 60 credits (30 of which may come from modules not dealing with chemistry, mathematics, physics or biology) are freely allocable by the institution (or, where the institution offers individual programmes) by the student.

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.
There should also be an element of research involved in a Eurobachelor course; thus the Bachelor Thesis referred to above is a highly recommended feature of the Eurobachelor. It 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.
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. Teaching committees with student participation seem to be an obvious measure here.

Assessment procedures and performance criteria

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
- The Bachelor Thesis
- Industrial placement documentation.

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.

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!
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

Examination papers should be marked anonymously and the student should be provided with feedback wherever possible in the form of "model answers".

Grading

The ECTS grading 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 ranking rather than "absolute" grades, it seems necessary to aim for the establishment of a recognised pan-European grading 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.

Original discussion paper written by T. N. Mitchell (Dortmund, DE) and R. J. Whewell (Glasgow, UK)
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