Chemistry Subject Area Group: *The Chemistry «Eurobachelor»*

As a result of the Bologna Declaration, there are moves under way in a number of countries to revise their chemistry degree structures. These were previously either of the two-cycle or three-cycle type, and there are moves towards a general three-cycle structure (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 post-Bologna process is indeed gathering momentum much more rapidly than many would have expected, and it now appears likely that the number of countries which will introduce a Bologna first cycle degree as defined by the Helsinki conference in February 2001 will be considerably greater than initially seemed likely. It thus seems timely to propose a model for such a degree in chemistry.

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 more common than the 240 credit degree, so that we have chosen to base our model on 180 ECTS credits.

The common denominator in chemistry does seem to be the BSc degree as cycle one, with a three-year duration or, in some countries, up to four years. Thus is it logical to start by trying to define a 180 credit European BSc in Chemistry. 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 define (e.g. the Bachelor Thesis may well carry more credits).

In the context of lifelong learning, a first cycle degree could 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. Alternatively, it could be seen as an exit qualification for a student deemed not capable of completing the second cycle. The first of these viewpoints is the one taken in this paper. If a structure is made on the basis of the second viewpoint, then there will be difficulties when the student later wishes to use the exit qualification for the purposes of entry to a second cycle programme. It seems fundamental to the concept of lifelong learning that the difference between an exit qualification and an entry qualification must disappear.

We have attempted to divorce our thinking as far as possible from present national models, as these are either non-existent or diverge considerably. Although the UK and Ireland have well-established bachelor degrees, we have not incorporated the concepts of honours or pass degrees in our 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 degree 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 agreements.
- The chemistry Eurobachelor should, provided that his performance has been of the required standard, be able to continue his tertiary education either at his degree-awarding institution, at another equivalent institution in his 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 spell in industry.
- This 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 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 preeminent importance that institutions offering Eurobachelor degrees aim for high standards, so as to give their students good chances in the national or international job market and a good starting point to transfer to other academic programmes should they wish to do so.

ECTS and Student Workload

A European average for the total student workload per year is close to 1500 hours. This corresponds to an average number of teaching weeks of around 25. Simple mathematics thus gives a theoretical workload of 60 hours per week if the student only works during this period. Thus it is important to have guidelines on student workload distribution. These should include definition of pre-examination study periods and examination periods separate from the teaching period.

The ECTS value of 60 credits per year corresponds to an average of 25 hours of student work for 1 credit, i.e. on average 1 credit for 1 contact hour per week. It must be taken into account that the total workload involved in a 1-hour lecture is different than that involved in 1 hour of practical work. Factors thus have to be introduced which should in the course of time become uniform within the area of chemistry.

Outcomes

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:

(1) 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.
(2) 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

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

—Major aspects of chemical terminology, nomenclature, conventions and units.
—The major types of chemical reaction and the main characteristics associated with them.
—The principles and procedures used in chemical analysis and the characterisation of chemical compounds.
—The characteristics of the different states of matter and the theories used to describe them.
—The principles of quantum mechanics and their application to the description of the structure and properties of atoms and molecules.
—The principles of thermodynamics and their applications to chemistry.
—The kinetics of chemical change, including catalysis; the mechanistic interpretation of chemical reactions.
—The principal techniques of structural investigations, including spectroscopy.
—The characteristic properties of elements and their compounds, including group relationships and trends within the Periodic Table.
—The properties of aliphatic, aromatic, heterocyclic and organo-metallic compounds.
—The nature and behaviour of functional groups in organic molecules.

—The structural features of chemical elements and their compounds, including stereochemistry.
—Major synthetic pathways in organic chemistry, involving functional group interconversions and carbon-carbon and carbon-heteroatom bond formation.
—The relation between bulk properties and the properties of individual atoms and molecules, including macromolecules.
—The chemistry of biological molecules and processes.

Outcomes: Abilities and Skills

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

These 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. Transferable skills 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 skills that students are expected to have developed by the end of their Eurobachelor degree 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 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 infomed audience.
   —Computational and data-processing skills, relating to chemical information and data.

b. Chemistry-related practical skills

- —Skills in the safe handling of chemical materials, taking into account their physical and chemical properties, including any specific hazards associated with their use.
- —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.
- —Skills in the monitoring, by observation and measurement, of chemical properties, events or changes, and the systematic and reliable recording and documentation thereof.
- —Ability to interpret data derived from laboratory observations and measurements in terms of their significance and relate them to appropriate theory.
- —Ability to conduct risk assessments concerning the use of chemical substances and laboratory procedures.

c. «Transferable» or «soft» skills

- —Communication skills, covering both written and oral communication, in at least two of the official European languages.
- —Problem-solving skills, relating to qualitative and quantitative information.
- —Numeracy and calculation skills, including such aspects as error analysis, order-of-magnitude estimations, and correct use of units.
- —Information-retrieval skills, in relation to primary and secondary information sources, including information retrieval through online computer searches.
- —Information-technology skills such as word-processing and spreadsheet use, data-logging and storage,
- —Internet communication, etc.
- —Interpersonal skills, relating to the ability to interact with other people and to engage in team-working.
- —Study skills needed for continuing professional development.

Content

It is highly recommended that the Eurobachelor degree 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 probably 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, which will be the last module in the course to be completed, it appears logical to define modules as being compulsory, semi-optional, and elective.

While institutions should be encouraged to break down the traditional barriers between the chemical sub-disciplines, we realise that this process will not always be rapid. Thus we retain the traditional classification in what follows.

- Compulsory chemistry modules will deal with:
  Analytical chemistry, inorganic chemistry, organic chemistry, physical chemistry, biological chemistry.
- Semi-optional modules will deal with:
  Computational chemistry, chemical technology, macromolecular chemistry.
- 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-compulsory 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 as well as for 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:

- General chemistry.
- Analytical chemistry.
- Inorganic chemistry.
- Organic chemistry.
- Physical chemistry.
- Physics.
- Mathematics.

In other words, the 90 credits form the «core» of the degree course.

If 15 credits are allocated to the Bachelor Thesis (compulsory), a total of 75 credits is left to the institution to allocate.

As far as semi-optional modules in chemistry are concerned, it is recommended that

- The student should study at least three of the following subjects, depending on the structure of the department: biology, 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. The course load should be organised in such a manner that the student distributes these models evenly across the 3 years.
- Language modules (stand-alone or integrated) will often be semi-optional, as the Eurobachelor should be proficient in a second European language as well as his mother tongue.

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 are freely allocable by the institution.

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 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 must also be an element of research involved in a Eurobachelor course; thus the Bachelor Thesis referred to above should be compulsory. 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.

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 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 necessary in this context to have regular contacts between the teachers involved in the modules being taught to one class in 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.

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 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.

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 regurgitation of material «digested» by rote learning should be avoided as far as possible.

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

Multiple choice questions should be used only when knowledge is tested using computer programmes.

Grading

The ECTS grading system will obviously form an integral part of the Eurobachelor assessment system. 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 European grading system. In order to stimulate discussion on how ECTS can be converted to the European norm, we make use of the grading definitions produced in the QAA chemistry benchmarking paper to illustrate how grades in the Eurobachelor degree should reflect performance in the discipline of chemistry.

Students graduating at bachelors level in chemistry are expected to demonstrate that they have acquired knowledge, abilities and skills as defined above. There will however be significant differences in their performance. The following criteria are suggested as indicators of different levels of attainment.

Attainment Level **a** (highest):

- —Knowledge base is extensive and extends well beyond the work covered in the programme. Conceptual understanding is outstanding.
- —Problems of a familiar and unfamiliar nature are solved with efficiency and accuracy; problem-solving procedures are adjusted to the nature of the problem.
- —Experimental skills are exemplary and show a thorough analysis and appraisal of experimental results, with appropriate suggestions for improvements.
- —Performance in transferable skills is generally very good.

Attainment Level **b**:

- —Knowledge base covers all essential aspects of subject matter dealt with in the programme and shows some evidence of enquiry beyond this. Conceptual understanding is good.
- —Problems of a familiar and unfamiliar nature are solved in a logical manner; solutions are generally correct or acceptable.
- —Experimental work is carried out in a reliable and efficient manner.
- —Performance in transferable skills is sound and shows no significant deficiencies.

Attainment Level **c:**

- —Knowledge base is sound, but is largely confined to the content of the programme. Level of conceptual understanding is generally sound.
- —Problem-solving ability is sound in relation to problems of a familiar type or those that can be tackled through the straight-forward application of standard procedures and/or algorithms.
- —Experimental work is generally satisfactory and reliable.
- —Performance in transferable skills is largely sound.

Attainment Level **d:**

- —Knowledge and understanding of the content covered in the course are basic.
- —Problems of a routine nature are generally adequately solved.
- —Standard laboratory experiments are usually carried out with reasonable success though significance and limitations of experimental data and/or observations may not be fully recognised.
- —Transferable skills are at a basic level.

Students who are awarded a Eurobachelor degree in Chemistry should be expected to demonstrate knowledge, abilities and skills corresponding on balance to at least attainment level **d**.

These levels have been given the letters **a** to **d** in order to avoid confusion with the ECTS grading system. It could be envisaged that in the course of time a convergence between these levels and ECTS grading in chemistry could take place, subject to international consensus.

The Diploma Supplement

All chemistry Eurobachelors should be provided with a Diploma Supplement in English and if required in the language of the degree-awarding institution.

Quality Assurance

The Prague agreement foresees that the European Network of Quality Associations (ENQA) will in future play an important role in establishing and maintaining European standards in university education. As far as the Eurobachelor in chemistry is concerned, it can also be foreseen that national chemical societies and their pan-European counterpart (the Federation of European Chemical Societies) as well as wider European chemistry organisations such as AllChemE will become involved in quality assurance procedures. It is important to put trans-national quality assurance procedures into place in order to achieve greater transparency.

Conclusion

There is obviously no reason for those countries or institutions which already offer Bologna-type first cycle degrees of a high standard to make any change to their degree structures, since these are sure to find ready recognition in the newly-emerging «Espace Europe» in higher education. The authors, and indeed the members of ECTN at its Plenary Meeting in Perugia in May 2002, however consider that the arguments set out here will stimulate productive discussion within the framework necessary to provide for young Europeans tertiary educational structures which have a genuine European rather than as heretofore a purely national background.

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