I. INTRODUCTION
In the present paper we try to give a consistent framework to the findings of the homework, which was carried out by the contact person at each Tuning institution in November 2003 (Athens homework). Their work aimed at identifying concrete ways through which the Tuning Physics-related competences (see ref. [1], [2]) could be developed in the students, who are attending a Physics degree-course at their institutions. The actual homework consisted in answering 5 questions for each competence [3].

On the other hand, the Physics SAG can also rely on some previous work in the field made by the EUPEN Socrates TNP, coordinated by the University of Gent under the supervision of Prof Hendrik Ferdinande (see ref [4]). Indeed already in 1997-98 the need for a characterisation of the teaching/learning styles in the different European educational systems was clearly perceived by EUPEN. A questionnaire was prepared with 21 (groups of) questions, most of them being either multiple choice questions or very simple questions. The questionnaire was sent to the key contact persons in 19 institutions of the EUPEN network, each one representing a country. The questionnaire included questions, which related to two broad classes of variables:

A – the "organisational variables":
1. procedure for entrance to the university, 2. teaching cycles, 3. institutional co-ordination of the curriculum, 4. possible ongoing reforms in the study organisation, 5. the control on the students' progress in their studies, 6. selectivity of the degree course; 7. the student assessment of the teaching offer.

B – the "teaching style variables":
- "formative" versus "factual" type of teaching;
- ways of giving lectures;
- physics laboratory hours,
- the contact of students with research environment;
- ways through which problem-solving abilities are taught;
- "academic" versus "open-to-civil-society" type of teaching;
- the nature and the organisation of the examinations;
- the awareness of the institution about training the students in communication skills.

A complete report can be found in the already quoted reference [4]. We report here only some of the findings, those thought to be more relevant to our attempt of giving a coherent framework to the Athens homework. Keep in mind that already at the time of the EUPEN consultation the legal framework was undergoing changes in many countries.

II. TYPES OF COURSES, METHODS AND TECHNIQUES OF INSTRUCTION AND LEARNING, WAYS OF ASSESSMENT

II.1 – Some general background facts from the EUPEN consultation

1) broadly speaking, in a scatter plot of "hours devoted to basic (mathematics and physics) teaching" versus "hours devoted to practical (i.e. class-work plus laboratory hours) teaching", two groups of institutions may be identified, a first group...
characterised by less practical education, with an average home work (i.e. private study hours) equal to 1.8 hours per contact hour, and a second one characterised by more practical education with a home work (i.e. private study hours) equal to 1.2 hours per contact hour. This sounds very reasonable, since hours spent in the lab usually imply less homework than other types of contact hours. Moreover, broadly speaking, the plot shows that the institutions with less basic education most probably offer a more factual type of teaching.

2) the plot of the "percentage of laboratory hours out of the total contact hours" in each institution versus the similar "percentage of the class-work hours" shows that they are inversely proportional, according to a gross but very clear relationship. There are extreme cases where either the lab work dominates (e.g. GB where in hours the lab work amounts to as much as 5 times the class-work; IE, 2.4 times; NL and RO, 2.0 times) or the class-work dominates (DK and FI, lab work is only 0.20 times the class-work; SK, 0.33 times; FR, 0.4 times; CZ, IT, SE, 0.5 times). Notice that sometimes much more class-work than what declared in the contact hours is done either through tutorials (see the case of GB) or in the home work.

II.2 – The organisational variables

Looking at the 19 answers, the general impression is that each institution has developed its own route to physics education, by grading in many ways the use of the different organisational and educational tools. So it seems difficult to catalogue the different approaches into a limited number of "models" (as it was hoped for). Take as an example the issue of co-ordination in contents of the different course units in the degree-course: only four institutions (CZ, ES, FR, IT) state that their curriculum contents are co-ordinated at a national level. In all other cases a local "co-ordination" occurs. Of course, a "local" autonomy in decision-making yields a much greater richness of behaviours. The co-ordinated contents could however be as low as 20-30% of the total (ES, PT and NO). Another important aspect concerns the so-called patterns of control of the student’s progress of studies. Three main patterns may be identified, as shown in Table 1: the key factors here are whether the student has freedom in choosing the exam date (and the examination session2) and whether the institution or the student’s will controls the progress in the study. Obviously correlated effects are the average overrun and the percentage of admission at entry (100% means no admission selection), the first year completion rate, the final completion rate. These latter three numbers together characterise the selectivity of the degree-course.

Table 1. – Patterns of control on progress in the studies and some related indicators

<table>
<thead>
<tr>
<th>PATTERN LABEL</th>
<th>FREE CHOICE OF EXAM DATE</th>
<th>CONTROLLING AGENT</th>
<th>OVER RUN</th>
<th>SELECTIVITY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>PERCENTAGE%</td>
<td>ADMISSION%</td>
</tr>
<tr>
<td>A</td>
<td>Yes</td>
<td>Will of student</td>
<td>1.392</td>
<td>92.7</td>
</tr>
<tr>
<td>B</td>
<td>No</td>
<td>Institution</td>
<td>1.072</td>
<td>53.3</td>
</tr>
<tr>
<td>C</td>
<td>Yes</td>
<td>Institution</td>
<td>1.089</td>
<td>82.0</td>
</tr>
</tbody>
</table>

The institutions of pattern A show an overrun around 40%, a high admission rate (often the admission is free), a rather strong course selectivity. Patterns B and C show low overrun (less than 10%) and, as an average, lower course selectivity. Notice that the standard deviation for the average values of the overrun is 0.26, 0.06 and 0.05 in the group A, B and C respectively. In each group of institutions there are noticeable exceptions, which characterise by themselves new interesting behaviours. In group A, the FI and PT institutions, which carefully select their 1st year students, show a very high completion rate; the reverse is true in group B and C where a free admission correlates with a [very] low completion rate and as a consequence selective institutions correlate with a very high one. As a conclusion the control pattern affects the overrun, while the completion rate seems heavily connected with the entry selection.

Another organisational variable was related to the student assessment of teaching. Only 6 out of 19 answering institutions did not practice a systematic evaluation. Among the other 13 institutions, some were more active in pursuing an adaptive structural response. In particular BE-Gent and FR could apply as many as five corrective actions (i.e. aiming at a modification

---

1 a difference of private study hours equal to 0.6 multiplied by the average number of contact hours (2390 hrs along four legal years of study) implies 1434 hrs of additional homework

2 In some countries the students are not obliged to take the examination right at the end of the course unit, but they may postpone it.
Another strong pattern of behaviour, which foresaw four possible actions (no action to change the pass rate), was the one adopted by DK, GB, NL and in a softer way by SK. In only two cases (AT, FI) actions towards the teacher cannot be taken, while in other two cases (DE, NO) only actions towards the teacher may be taken.

II.3 – The qualitative variables

The EUPEN questionnaire was sent out in the pre-Tuning age. For this very reason its findings must be taken only as a characterisation of the "humus", i.e. the breeding ground, where the Tuning process can nowadays display its reflection potential and its development action.

A first qualitative characterisation of the teaching approach stemmed from the question "formative versus factual" degree course, i.e. "Would you characterise the degree course at your university as formative (i.e. based on ideas, methods, understanding) or rather as factual (i.e. based on factual knowledge of scientific information)?". The answers clearly contain individual perceptions. However they show a clear bias towards "formative", which is seemingly perceived as better than "factual". In any case 7 to 8 institutions (AT, CZ, FR, NO, PT, SE, SK and at a lower extent RO) "feel" that their course is well balanced between the two extreme characterisations. The latter are only chosen by IT ("very formative") and by FI ("very factual"). Perhaps in the "Tuning language" this question would become "Is the degree course at your university reflecting a competence based approach or rather does it privilege contents and facts?"

Another question tried to characterise the ways of lecturing, i.e. whether the lectures are offering a detailed and thorough mathematical treatment or rather are based on survey, understanding by examples and simplified models. In the answers, which had to state the percentages of the two "lecturing ways", both in the first two years and in the later years of the degree course, we find three main patterns. In a first pattern (11 institutions) the analytical detailed approach shows high percentages in both periods. According to a second pattern (2 institutions) the synthetic approach (second way of lecturing) shows high percentages in the first two years, while in the second period the two ways of lecturing are equally present (on a 50-50 basis). Moreover, as a general remark, it can be said that in the third and later years there is a trend towards a better balance between the two ways. Do notice that the pattern, which is actually adopted at an institution, possibly affects the type of academic work done by its students, during their private study time (see below). Even though the results described in the present paragraph refer to a pre-Bologna period, nevertheless they witness clear-cut educational traditions.

Another qualitative variable concerns the laboratory classes. Here again we find three main behaviours: the passive approach (10 institutions, for which the lab work is mainly based on cookbook recipes and/or detailed instructions); the most creative approach (2 institutions, for which the lab work is mainly based on general questions to be researched and/or project questions formulated and/or other; the moderately creative approach (6 institutions). As a general remark to these varied approaches, we may state that the passive approach is by far the most usual one. Innovation towards a more creative student commitment is certainly taking place, but since innovation is a voluntary, bottom-up phenomenon its occurrence shows no correlation with other behaviours.

Another important qualitative aspect relates to the student's contact with the research environment. Here the percentages of the different types of contact yield only an indication of the relative. The main contact occurs through the final thesis work, the corresponding percentage of relative importance, averaged over the 19 institutions, being 47.6%; the thesis work may last as much as 12 months (FTE). Other types of contact occur via the practical physics laboratory (14.8% average relative importance, very important in SE, 60%, and CZ, 40%); project works (19.7% as an average, very important - around 40% - in PT, FR, NO and AT); updated information during lectures (13.2 as an average, important in GB, 50%, and, to a lower extent, 25%, in BE-Gent and PT).

A group of questions concerned "problem solving". The percentages of problem-solving classes, which are run either with a "passive" listening by the student or rather with an "active" involvement of the same student came out almost equal (49.5% against 50.5%), when averaged over the 19 answers. These numbers do not have a statistical meaning, since they are the fruit of contents, of pass rate, of level of presentation or aiming at a training of the teacher or even at the removal of the teacher).
of a very simple consultation, but may indicate trends. Indeed, here again it can be noticed that the institutions split up into three main groups: a first one where the active teaching shows percentages as high as 75% or more (7 institutions: AT, BE-Mons, CZ, DK, GB, LV, NO); a second one where the passive teaching is largely dominant (7 institutions: BE-Gent, ES, FR, FI, HR, IT, NL); a third one where the two approaches are balanced (5 institutions, i.e. DE, PT, RO, SE, SK).

Within this context a specific question tried to understand whether the students of a particular institution are more prepared to "quick" problem solving, rather than to "in-depth" problem solving. In 8 institutions the students become "quick-in-solving", in 11 they need an "in-depth" insight. No apparent correlation exists between these abilities and the amount of guided coursework. The only correlation which we were able to find is that "quick" solving correlates with a number of practical physics contact hours which is well above (by 28.5%) the average value.

Only two institutions (GB and AT) declare the occurrence of integrated problem solving classes, i.e. classes where the students are taught to solve a problem, which tries to be realistic and, at the same time, aims at integrating different parts/areas of physics (comprehensive exam preparation). The GB experience consists in preparing the students through tutorials, where the feedback from the tutor is essential; tutorials are "open-book", but not the examinations. Usually a student takes two exams of this kind, in the 3rd year. The main point here is to teach the students how to select important from unimportant aspects. Quite a high percentage (18%) of the final degree mark is determined by this skill. The AT experience on the other hand consists in an intensive training (one week duration, in the final year) in order to let the students acquire this very ability. No examination of this kind has in general to be taken.

The answers to question whether the teaching approach is "academic" or "open to civil society" showed that our physics community is still rather academically orientated, which is probably correct for a traditional research subject as physics is. Moreover, the 8 institutions which stated that they have a balanced approach, show a number of hours devoted to general education (in physics and mathematics) lower than the average and a number of lab hours above average.

A group of questions referred to examinations. Remember that it was earlier asked whether the exam date was fixed by the institution, as a single deadline, or was a free choice. Here the aim was rather to investigate the quality of the exams. A first question aimed at identifying the most common examination types; four possible answers were proposed [1, multiple choice questions; 2, discussion of general concepts; 3, thorough and analytical treatment of the subject; 4, problem solving] plus an open answer, namely 5, other types of examinations. The average of the answers showed that the most used types were 4, problem solving, used in the 43.9% of the cases (at the average institution) and 3, thorough treatment, 34.4% of the cases. The open answer revealed as well the existence of "take home" exams (DK) and of Physics Lab problem solving (SE). Looking at each institution, we find a single pure behaviour (100% of problem solving in FR) and some strongly polarised behaviours: DE, with 80% of "general concepts discussion"; AT, BE-Mons, IT, LV, with 70% or more of "thorough treatment"; FI, NO, SE, with 75% or more of "problem solving" [notice that this latter behaviour coincides with a possible geographical characterisation, namely the Scandinavian model]. Exams with "multiple choice questions" occur as an appreciable percentage, 35% or more, only in CZ and SK (again a geographical signature?). Systems which adopt a differentiated approach are DK, ES, RO with four types of examinations, and BE-Gent, GB, HR, NL, SK with a balanced use of three types of examinations.

A second question tried to assess the percentage of oral and written examinations: here again the average values, 35 and 65% respectively, hide very different behaviours. Seven institutions (ES, FI, GB, NL, NO, PT, SE) show a percentage of written examinations equal to 90% or more. Two institutions only (DE and LV) show a pure behaviour, i.e. 100% oral examinations; two others (BE-Mons and IT) show 67% or more oral examinations. A fifty-fifty approach occurs at CZ, DK, HR, SK.

A clear correlation exists between the way in which examinations are taken (written or oral) and the type of examinations (as described right above). This is illustrated in Table 2: exams mostly consist of problem solving, in those institutions where written assessment is used; on the contrary they consist of a thorough and detailed treatment of the subject, when an oral approach is preferred. In the latter cases, we have testimony that it may take as much as one third of the student homework to memorise formulas, mathematical steps etc., once the concepts have been understood by the student.

---

4 The actual question was: Problem solving abilities are often considered as a strong asset of physics graduates. Problem solving may be understood as "quick" problem solving (using simplifications, models, giving a solution in a couple of hours or less) or rather as "in-depth" problem solving (after a complete understanding of the subject, within some days). Which type of problem solving qualities do you think are the strongest point of the graduates in the physics degree course at your university? [ ] "quick" problem solving [ ] "in-depth" problem solving
Table 2 – Types of examination vs. oral/written

<table>
<thead>
<tr>
<th>GROUP OF INSTITUTIONS</th>
<th>TYPE OF EXAMINATION (as % over the total)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Multiple choice</td>
</tr>
<tr>
<td>Balanced oral / written (CZ, DK, HR, SK)</td>
<td>18.8</td>
</tr>
<tr>
<td>Mainly oral exam        (BE-Mons, DE, IT, LV)</td>
<td>0.0</td>
</tr>
<tr>
<td>Mainly written exam     (ES, FI, FR, NL, NO, PT, SE)</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>5.8</td>
</tr>
</tbody>
</table>

Here again a comparison with the type of “private” academic work done by the students during the exam preparation weeks is enlightening! Indeed, qualitative characterisations of the teaching offer – such as types of examination or ways of lecturing (see above) – have a remarkable consequence on the learning style of the students. This very aspect was investigated through an adequate and simple EUPEN questionnaire (1998, see again ref. [4]). The students were asked for stating how the hours, which they spent in a week on private study, broke down into the following types of academic work:

(i) Preparing reports on laboratory work
(ii) Working on problem sheets or assignments
(iii) Studying lecture notes
(iv) Studying text books or other course books
(v) Background reading and essay writing
(vi) Learning a foreign language
(vii) Course related computing

The results showed that the students of those institutions, where the ways of lecturing quite privilege detailed and thorough mathematical treatment (first pattern, e.g. in AT, IT) and where the exam is mostly based on a thorough and detailed treatment of the subject (being an oral examination), spent most of their private study time on Studying lecture notes and Studying text books or other course books. On the contrary, in those institutions where the way of lecturing is based on “survey, example understanding, models” (second pattern, e.g. in GB) and where the exam is mostly based on general concepts and written problem solving, the students distributed their private study time more or less evenly through the seven types of academic work listed above.

II.4 – A preliminary conclusion

As a conclusion, the answers to the EUPEN early questionnaire are quite informative about a large range of existing behaviours: some of these behaviours have a striking impact on the student practices in the private study part of their career.

A similar richness of teaching /learning styles emerges also from the Athens homework, which – however – is not conceived as a comparative exercise. In Section III we try an homogeneous description of 15 Tuning Physics-related competences (see ref. [1]). The general idea is to assemble a kind of inspiring handbook on specific competences, to be used as common reference points in curricular planning or revising by the Tuning community and possibly by a wider European audience.

III - THE TUNING SUBJECT RELATED COMPETENCES

During Tuning I the Physics SAG identified a set of subject specific competences for both the first and second cycle. The short names for the most preferred ones in each cycle (out of a total of 24 identified as possible competences) are shown in Table 3, according to their ranking decreasing order, as decided by the Physics academics consultation (see ref. [1], pages 171-185). The full definitions of these competences (ibidem, page 294 -297) are repeated below for the sake of clarity. Eleven...
competences are common to both Bologna cycles; another one – Physics culture – is most important in the first cycle only; three others – Frontier research, Specific Communication Skills and Managing skills – are quite relevant in the second cycle only. As a whole we deal here with 15 specific competences. Because of the organisational details of the Athens homework, 7 out of these 15 competences were reviewed with reference to the first cycle and the remaining 8 ones with reference to the second cycle. The details are given below.

Table 3 – The most preferred Tuning subject related competences (short names), as ranked by the Tuning I consultation among academics

<table>
<thead>
<tr>
<th>Ranking order</th>
<th>First cycle</th>
<th>Second cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Problem solving</td>
<td>Modeling &amp; Prob. Solving</td>
</tr>
<tr>
<td>2</td>
<td>Theoretical understanding</td>
<td>Problem solving</td>
</tr>
<tr>
<td>3</td>
<td>Mathematical skills</td>
<td>Literature search</td>
</tr>
<tr>
<td>4</td>
<td>Deep knowledge</td>
<td>Learning ability</td>
</tr>
<tr>
<td>5</td>
<td>Experimental skill</td>
<td>Modeling</td>
</tr>
<tr>
<td>6</td>
<td>Modeling &amp; Prob. Solving</td>
<td>Theoretical understanding</td>
</tr>
<tr>
<td>7</td>
<td>Prob. Solving &amp; Comp. Skills</td>
<td>Basic &amp; Applied Research</td>
</tr>
<tr>
<td>8</td>
<td>Physics culture</td>
<td>Deep knowledge</td>
</tr>
<tr>
<td>9</td>
<td>Basic &amp; Applied Research</td>
<td>Mathematical skills</td>
</tr>
<tr>
<td>10</td>
<td>Literature search</td>
<td>Frontier research</td>
</tr>
<tr>
<td>11</td>
<td>Learning ability</td>
<td>Prob. Solving &amp; Comp. Skills</td>
</tr>
<tr>
<td>12</td>
<td>Modeling</td>
<td>Experimental skill</td>
</tr>
<tr>
<td>13</td>
<td>Experimental skill</td>
<td>Managing skills</td>
</tr>
</tbody>
</table>

In Table 4 for each competence above we show the educational activities appropriate to its development, by ticking with the figure “1” the box at the crossing of the corresponding column and row, on the basis of the answers to the 5 questions (mostly Question 2) of the Athens homework\(^1\). The table can be examined with reference both to rows (i.e. 27 different educational activities as emerging from the quoted Athens homework\(^2\)) and to columns (i.e. “out” 15 subject related competences). The last row, on the other hand, shows how many out of the identified educational activities contribute to the development of a given specific competence. It is then clear, from the point of view of educational activities, that some of them – e.g. lectures (active) problem solving classes, lab and practical classes, project work (including master thesis) – are holistic, in the sense that they develop many subject specific competences at a time. Other activities are more adapt to develop a single or a limited number of specific competences (e.g. lectures with demonstrations, scientific writing class, numerical calculation & computing class, individual activity in a class, etc.). On the other hand, from the perspective of competences, there is a group of competences, whose development occurs transversally to all or almost all existing educational activities, while a second group includes competences, which are developed mainly through a restricted set of well defined activities. Competences like Problem solving, Mathematical skills, Modelling and problem solving, Physics culture, Modelling clearly belong to the first group (transversal specific competences). Competences like Frontier research, Experimental skills (\(^3\)) and Managing skills are definitely in the second group. These latter competences, depending on the greater or lesser attention paid to them and/or on the performance achieved in them by the students, may differentiate the graduates’ final preparation and expectations (e.g. graduates who feel like becoming a researcher, an experimental physicist, a manager physicist, etc). This latter remark recalls an important aspect, which was somewhat obscured in the Athens homework, i.e. the existence of competences, which are more directly linked to the contents/specialisations offered within the degree-course. While at the first cycle level most institutions offer a generalist approach to physics contents (i.e. the graduate has to achieve a general background preparation, only in the second group usually many different content options are offered, yielding a final graduate who then has a specialisation competence’ either in nuclear physics or in condensed matter physics or in biophysics or in astro-physics and/or astronomy, etc., only seldom achieving a really generalist preparation.

\(^1\) A few boxes are ticked with the figure “\(\ast\)” (i.e. in italics), indicating a filling of the box on the basis of the author’s experience only.

\(^2\) Do notice that the listed activities are 27 indeed, but that one of them, i.e. (passive) problem solving classes, is not quoted in the Athens homework. This is good for Tuning! Nevertheless it is included here, since the previous EUPEN consultation (see Section II above and ref. [4]) found that it exists and that it is more or less used, probably depending on the teacher’s habits and local traditions.

\(^3\) Having this type of competences in mind, it might be appropriate to identify three main sets of competences: generic, subject related competences (the ones identified by the Tuning subject areas), specialisation or content related competences.
Table 4 – Main educational activities for Physics students versus subject specific competences

<table>
<thead>
<tr>
<th>EDUCATIONAL ACTIVITIES</th>
<th>SUBJECT RELATED COMPETENCES</th>
<th>first cycle</th>
<th>second cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Problem solving</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Theoretical understanding</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Prob. Solv. &amp; Comp. Skills</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Experiments skills</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Deep knowledge</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Physical culture (*)</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Modelling &amp; Prob. solv.</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Modelling (*)</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Literature search</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Learning ability</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Basic &amp; Applied Research</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Specific Comm. Skills</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Project research</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Research laboratory work</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Managing skills</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>TOTAL NUMBER OF ACTIVITIES</td>
<td>14</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>PER COMPETENCE</td>
<td>65</td>
<td>5</td>
</tr>
</tbody>
</table>

From the table it is also clear, and this is often stressed in the answers contained in the Athens homework, that the development of specific competences is a complex cumulative process, which lasts for the whole degree course (and even beyond in real life). Such a development is very similar in its nature and dynamics to the development of generic skills.

In the following we report for each of the above 15 competences:
The short name, with a number indicating the ranking by the academics, see Table3,
The Tuning definition,
Interesting aspects concerning the teaching strategies, the students’ engagement and the assessment procedures, as
extracted from the Athens homework [3]. As far as possible sentences taken from the homework exercises are quoted
in arial italics characters.

III.1 – PHYSICS SUBJECT RELATED COMPETENCES – FIRST CYCLE

Problem solving skills [1]

Definition: Be able to evaluate clearly the orders of magnitude, to develop a clear perception and insight of
situations which are physically different, but which show analogies; hence allow the use of known solutions in new
problems (problem solving skills).

The text below includes also remarks, which are relevant, but which were expressed in the homework relating to a different
competence.

One respondent notices that many students at first level think that problem solving is the same as exercise solving and do not
understand those teachers, who insist in giving them assignments, that need mastering more complex reasoning or cross-disciplinary
knowledge. Students in the last stage of the degree-course do not show this kind of problem.

In order to develop this competence an obvious pre-requisite seems to be theoretical and practical knowledge, gained in
specific course units.

A case of good practice for competence development comes from GB:

“This competence is mainly developed through assigning the students many examples of problems to solve. Some of these are assigned as
‘homework’ but others are set in real time mainly in tutorials. The cooperative development of solutions in tutorials is the most important
method. This involves a great deal of to-and-fro, trial and error etc. rather than following standard techniques. There are also special problem
solving classes which involve students attempting problems themselves but with immediate help on hand from academic staff and PhD
students. Special tutorials are arranged in the 3rd or 4th years for realistic problem solving (comprehensive problems)”.

Another example comes from DE:

The exercise class sessions are organised as follows:
- Problems to be solved on the spot. During a course unit problems are usually given with a gradual increase in difficulty, in the perspective
  of increasing independence of the student, i.e. thorough cooking recipes get gradually replaced by fewer and fewer hints
- Home work problems to be discussed in the exercise class, after the homework is handed in and graded.

A third example comes from PT:
Active Learning: in all classes (theory, lab or problem solving)
• Several questions are posed to the theory class and a certain amount of time is allowed for discussion in the same class.
• Several question-problems are set to the class and assigned to groups of students. They should find an answer (either exact or
  approximate) in a certain amount of time. They are also requested to explain their reasoning to other students (Did they divide the problem
  in simpler problems? Did they use analogies with problems, for which they already knew the answer? why are they confident about their
  own answer?…)
• In the exercise class the students are requested to correct and comment other students ways of solving the exercises.
• In the lab classes students are frequently asked to solve experimentally or propose ways for solving other more complex problems that
  may be considered extensions of the material proposed in the class. (ex: after studying an LC circuit they are encouraged to solve the
  problem of coupled LC circuits and think about the problem of impedance adaptation in a transmission line).

The main assessment procedures of the present competence span the whole degree-course and involve: end of year
examination marks; performance in problem solving classes. marks for assessed problem sheets; project work assessment;
performance in tutorials (usually not formally assessed).

Theoretical understanding [2]

Definition: Have a good understanding of the most important physical theories, with insight into their logical and
mathematical structure, their experimental support and the physical phenomena that can be described with them
(theoretical understanding of physical phenomena).
According to a first respondent “for first cycle physics students this competence can only be acquired in a gradual way. Since they lack normally a profound mathematical knowledge at the start, the general physics courses can only be more descriptive in approach. When more mathematics is known, the intermediate and advanced undergraduate course units can present the logical structure of the discipline. Hereby the cognitive objective understanding or comprehension means the ability to identify; illustrate; represent; formulate; explain; contrast more and more the wide range of physical phenomena”. In this case one competence needs for its own development the development of another competence (i.e. Mathematical skills, see below). The lectures are of course the central elements in order to achieve this competence. The respondent emphasizes the corresponding need of an harmonious curricular planning: “In order to develop this competence particular attention should have been given to the physics course design. Indeed the student starts with a restricted knowledge of mathematics and is offered in the first bachelor year a more descriptive way of the physical phenomena. Because the student acquires in parallel a more elaborate mathematical knowledge, in the final bachelor he can be exposed to physics course units with a much deeper insight into the mathematical and theoretical structure of the discipline. Hence here we see how important it is that the different course units are particularly matched in this sense so that the degree of this ability can expand with the student progressing in the course”.

“A second respondent” – within the description of a different competence – gives his own strategy in order to help students to overcome difficulties in understanding and in using the understanding: (i) the recognition of the students starting level; (ii) a teaching progression appropriate to the potential of the students and related to the expected learning outcomes; (iii) the implementation of question sessions, in order to help students to formulate their own difficulties (which is the first step in order to overcome them); (iv) requiring self-study; (v) encouraging students in case of frustration.

The assessment is of a traditional type in this case too. The first respondent acutely notices that “of course the student can still know if (s)he did achieve this competence in a sufficient way by listening carefully to the feedback (s)he receives from all the educational actors in the study programme. Normally they will tell the student that (s)he is lacking this competence, whenever the student progress in the course is unbalanced in favour of her/his pure empirical or experimental interest in physics. Nevertheless this competence could be felt as a sort of hidden variable, since its development should be built in a well-structured physics degree course”.

The “second respondent” points out that oral comprehensive exams are used to assess quite effectively the degree to which students have overcome difficulties in understanding and in using the understanding. Those exams are taken by the end of the 4th semester in the subjects experimental physics, theoretical physics, mathematics and in an elective subject (and in the final oral MSc exam in experimental physics, theoretical physics and in two elective subjects).

Mathematical skills [3]

Definition Understand and master the use of the most commonly used mathematical and numerical methods (problem solving skills and mathematical skills).

An individual strategy is described by one of the respondents: “In lectures I first introduce the concepts and then I illustrate them making reference to examples from case studies from physics. Using a structured mathematical or analytical approach to problem solving help the students to understand the importance of mathematics. In problem classes the teachers give to the students regular question sheets at least one week in advance. Students are asked to find the answers during the week either by themselves or using textbooks or may be working in groups. Many of them do the job and during the class’s one student at the time go to the blackboard to give his/her solution of the exercise and the others students make comments or criticize… answers during the week either by themselves or using textbooks or may be working in groups. Many of them do the job and during the class’s one student at the time go to the blackboard to give his/her solution of the exercise and the others students make comments or criticize…

As to the assessment, “solutions to exercises are handed in at the scheduled time (shown on each sheet) for marking. The assignments form an essential part of the learning process and are used to give a mark, which is part (~1/3) of the formal assessment. The final writing exam is used to assess the achievement of the competence (~2/3 of the total mark)”. An interesting form of assessment is in use at the other institution: “(i) the recognition of the students starting level; (ii) a teaching progression appropriate to the potential of the students and related to the expected learning outcomes; (iii) the implementation of question sessions, in order to help students to formulate their own difficulties (which is the first step in order to overcome them); (iv) requiring self-study; (v) encouraging students in case of frustration.

The other respondent gives an important tactical suggestion in order to improve the benefit of lectures: “Give out all lecture notes to students so that they participate in lectures and do not have half of their minds closed, while concentrating on writing.”

As to the assessment, “solutions to exercises are handed in at the scheduled time (shown on each sheet) for marking. The assignments form an essential part of the learning process and are used to give a mark, which is part (~1/3) of the formal assessment. The final writing exam is used to assess the achievement of the competence (~2/3 of the total mark)”.

An interesting form of assessment is in use at the other institution: “Each student will read and comment on another student’s work (self selected pairs). They hand in the critique and their response to this as part of their self-assessment of the unit outcomes”.

Deep knowledge [4]

Definition Have a deep knowledge of the foundations of modern physics, say quantum theory, etc. (deep general culture in physics)
Here again the individual approach of a respondent may be enlightening: “I help the students to achieve this competence by always giving them a very physical and broad (and even historical) introduction to the unsolved problems that gave origin to a new theory. In presenting the solution I then give different approaches like for example the operator and the path-integral approach. Furthermore I hint to less standard approaches and give them material and reading assignment if they want to study these topics further”. The other respondent proposal is – among other more traditional tools – “organizing discussion sessions in order to study or deepen some aspects of the physical theories, as explained during lectures”.

The assessment is quite traditional in this case (e.g. oral and/or written examination at the end of the unit or at the end of the whole degree-course).

Experimental skills [5]

Definition: Have become familiar with most important experimental methods; moreover be able to perform experiments independently, as well as to describe, analyse and critically evaluate experimental data (experimental and lab skills)

This competence is widely thought to be essential to any physics curriculum, even though at one Tuning institution is not considered to be a competence that should necessarily be acquired by all students. It is stated there that a number of jobs performed by physicists do not require such a competence (!).

In any case the two respondents state that a rather small number of credits is allocated at their institutions to the activities, which are appropriate for the development of this very competence [i.e. lectures embedding practical demonstrations, lab classes, project work at Ba level (and Ma thesis in the second cycle)]. These answers are to be contrasted with the Tuning I results (cfr ref [1], page 200-201), where the total amount devoted to lab classes in the institutions of the Physics SAG is between 10 and 30 ECTS credits (with a slightly higher average amount in the second cycle), while the credits devoted to the final project may be as many as 25 ECTS (in the first cycle, where however for several institutions is simply “zero!”) and as 65 ECTS in the second cycle or in the integrated master level degree courses. For a correct understanding of the role of lab classes in different educational traditions see also above, at § II.1.

The assessment of the achievement of this competence takes place through the students’ written reports and oral presentations.


Definition: Be able to perform calculations independently, even when a small PC or a large computer is needed; the graduate should be able to develop software programmes (problem solving skills and computer skills)

The development / achievement of this competence is closely related to the development of the competence Problem solving (see above), which is a kind of simultaneously required complementary competence. This latter is richly described above, also relying on some remarks given within the context of the present composite competence, which might more appropriately be renamed as “computer aided problem solving”.

The respondents highlight two different ways of perceiving this competence:

a) Using the computer in physics studies does not mean running an inherited code and getting output. It means doing physics with the help of computers. … Students do not usually employ existing software, but they have to develop their own.

b) The students are happy to learn one computing language (Fortran or C) and are very keen on using computer packages such as Mathematica and MatLab. The students also recognise a clear intention of most teachers in the department in developing this competence. They feel quite happy and confident at this level with their computer mastering. They seem a bit less confident about computer modeling.

At one respondent’s institution, in order to train in this competence, all lectures are supplemented by exercise classes. More precisely, “each of the four compulsory course units in theoretical physics, i.e., classical physics with mechanics, electrodynamics and relativity, quantum mechanics, statistical mechanics and advanced quantum mechanics with an introduction to quantum field theory, are supplemented by a computer project of ½ semester length”. Moreover, the research training during the final master thesis work, is usually also computer-based and therefore requires and trains computational skills in varying aspects depending on the research field, being it in theoretical, experimental or applied physics.
At another institution, computing and modelling skills are developed in specific computing classes (1st year) and then all across the curriculum. The used strategies are:

- In lab reports all data should be treated using the appropriate computer tools.
- Individual (or group) home assignments are given in many disciplines that require the use of computer tools or modelling.
- In some specific units in the degree-course computer modelling and programming is set as one of the main learning outcomes (mathematical methods for physics, elasticity and fluid physics, computational physics).

Also with regard to assessment the two respondents have complementary views:

a) The development of the present competence is continuously assessed by the performance of students in the exercise classes accompanying the lectures, by grading the home work problems and the reports about the used methodology and the results obtained in the computer projects and – finally – by monitoring the progress of students during their research training. The basis for problem solving and for the effective use of computer skills is the understanding of physics. Thus, the continuous assessment of the student ability of problem solving yields very clear and effective indicators also for the general progression in understanding physics.

b) Most teachers give a strong weight to this competence in their evaluation (especially in those units / disciplines where it is stated as one of the intended learning outcomes).

Physics culture

Definition

Have become familiar with areas of physics most important not only through their intrinsic significance, but because of their expected future relevance for physics and its applications; familiarity with approaches that span many areas in physics (general culture in physics).

The achievement of this competence is again a fruit of the whole degree-course. According to one of the respondents all teaching and learning of physics supports the development of a “physical world view”, which is the “culture” of physics. Some anecdotes of history of physics and its heroes increase the feeling of togetherness and may also belong to the “culture”. Some activities however are proposed as examples of specifically targeted good practice, e.g. attendance at general interest lectures & seminars; students preparing short oral presentations on topics such as Nobel Prize winners or current technologies; moreover, informal groups of students aimed at solving exercise problems may help in developing a common “culture”.

There is no separate assessment for this competence, but the students’ learning in this area will contribute to their overall performance in physics assessments. At one institution the attendance to talks is assessed and form a small part of the laboratory mark.

III.2 – PHYSICS SUBJECT RELATED COMPETENCES – SECOND CYCLE

Modelling & Prob. Solving

Definition

Be able to identify the essentials of a process / situation and to set up a working model of the same; the graduate should be able to perform the required approximations in order to reduce the problem at a manageable level; i.e. critical thinking to construct physical models (modelling skills and problem solving skills)

Here we have one respondent only (continental tradition, AT). In any case the remarks made here can be complemented by those given for Modelling (see below, this same paragraph III.2) and for Problem Solving (see above, § III.1). The present competence focuses on the ability of critically adopting workable approximations for the solution of a given problem. We might more appropriately rename it as “critical creative thinking”. Again we are facing a kind of composite competence, which clearly is developed throughout the curriculum.

Adding to this, the respondent envisages a couple of quite unforeseeable – at least at a first sight – teaching strategies for the development of this competence:

- a first strategy may be described as “promoting awareness of what is essential learning through general academic processes, which may help the so-called critical thinking”. The processes quoted by the respondent are: (i) alumni take over part of a course unit, in order to give to the attending students an impression (or better an updated perception) of what professional employment/life is; (ii) students spend some time (e.g. during vacation) to learn about professional employment possibilities. (iii) students study abroad.
- a second strategy has to do again with being realistic, but on the side of the student, who should become able to adapt her/his own curriculum to individual wishes and potentialities. Indeed during year 4 and 5 of the physics curriculum (second cycle) course units and modules are offered, which allow for advanced and independent educational paths. Students have the possibility to arrange an individual programme by choosing lectures from a predefined list.
In this general context there several educational activities, which develop the present competence: course-units, other lectures, seminars, laboratories, small group courses, poster presentations, discussions at oral presentations and discussions at conferences. Of course, a special attention should be paid to identifying examples of workable approximations, which are at the heart of this competence, and to becoming able to use them critically. The students should be able to compare the approximate solutions with existing reference solutions (e.g. exact and/or ab initio calculations or other more or less rigorous results) or even to produce new ones. This often implies that the students has to complete the offered educational activities with an effective use of the Department library and of the existing computer facilities, whenever this is appropriate and especially during project work and diploma thesis (when again the students perform independent advanced studies and may experience team-work).

The assessment of this competence, which is very transversal to all educational activities, is intrinsically embedded in the traditional procedures, as in use for each specified educational activity (see list above), and it includes a range of options from giving marks to individual/public feedback.

**Literature search [3]**

**Definition** Be able to search for and use physical and other technical literature, as well as any other sources of information relevant to research work and technical project development. Good knowledge of technical English is required (literature search and use skills)

Both our respondents point out that nowadays part of this competence consists in knowing how to use the web resources: e.g. the intelligent use of search engines, such as google, or the use of ‘Internet Physicist’, a very handy free online tutorial designed to improve literacy and IT skills: [http://www.vts.rdn.ac.uk](http://www.vts.rdn.ac.uk).

The two respondents describe two different strategies. A first respondent (continental tradition, in BE) enlightens the several ways through which this competence is developed in traditional educational activities:

- **Course-work and/or lab work:** during lectures and in lecture notes: teachers should make full reference as much as possible to literature (also about historical experiments and older knowledge) in order to create interest and stimulate students to search by all means for original articles, already from the start of the studies; in laboratory classes: teachers should not always cite the needed data but stimulate the students to search them from all kinds of resources; in homework tasks and problem sessions: again teachers should not provide all needed data and should let the students search in books and/or databases, whose reference is given or whose reference has to be searched for.
- **Project work:** Students are most directly confronted with literature searching, when they have to add a reference list in presenting their project work; in this case they first have to go into detailed literature in order to present later on their work in an effective, authoritative and condensed way.

The students are asked to develop this competence gradually. In the beginning of the degree-course they are stimulated to undertake the literature search themselves, but are not fully obliged; gradually in the lab sessions they receive more and more examples, up to the project work, where they cannot avoid it.

The assessment is here almost only directly possible at the lab session or at the project work stage. This means that the supervisor checks during the academic year and at the end of the thesis work, to what degree the competence is achieved. The students then know if they have achieved this competence by all usual means of a regular feedback system. More particularly, in the project work, the supervisor regularly oversees the progress in the project and – if needed – corrects the student for forgotten literature or stimulates the student in going to more details.

The second respondent (GB tradition) presents specifically targeted activities:

A seminar-based course, called 'Professional Skills for Physicists', is taken by all students in years 1 and 2. It includes exercises in finding sources and in summarizing information from them. This is supported by discussions with staff and with particular instruction in use of library and internet facilities. They also are required to give presentations in Year 1 on topics resulting from literature surveys. They also will do a project in Year 1, which will include a literature survey. The final research project, which starts in the 3rd year and lasts for one year will typically start with a guided literature search of a particular topic. The results of this must be reported by the student. Guidance on this is given in a special course called 'Research Interfaces'.

The students must fully engage in the above activities and present their results to the seminar leader, their tutor or their research supervisor. They are also required to prepare summaries of particular papers that they have identified and to give presentations on topics that they have researched in this way.

Performance in written summaries and oral presentations in Years 1 and 2 are assessed and given a mark. Competence in this area as part of both the 1st year project and the final research project is assessed as a specific part of the students' project assessment. The summaries of papers are marked too.
Of course, students who are not native English speakers need to be trained in the knowledge of (technical) English. A used strategy is addressing the students to evening classes or extra elective courses, where the necessary knowledge of standard and/or more scientific or technical English is offered.

**Learning ability [4]**

**Definition** Be able to enter new fields through independent study (*learning to learn ability*)

The great European tradition is here well described by a sentence, which appears on the stained-glass windows of the Cathedral of Chartres, France: “we sit on the shoulders of those giants who researched and learned before us and thus we are able to see farther”. In other words, starting from some background knowledge, one should be able to put new questions, to find answers, to re-organise her/his increased knowledge on the basis of the new findings.

Our two physics respondents are however much more pragmatic. A respondent states at first that – apart from learning the basic physics theories (with the relevant mathematics) – this competence is really the most important. Very pragmatically he further states that this competence is acquired “by learning” and he identifies the open space, where to develop and practice such an ability, in that part of the curriculum, which the students plan on their own, by choosing units from a list or in a completely free manner. Indeed at the respondent’s institution the compulsory units define only a small part of the programme (50 ECTS of physics units and 30 ECTS of mathematics units). The underlying philosophy is here that it does not matter so much what the students learn, but it matters that they learn (to learn).

A second respondent, who did a small consultation among the students and the teachers at the home institution found that both groups “are unanimous in stating that the major strategy is to include in the teaching methods small individual and team project-works (either theoretical or experimental ones)”. Then the respondent describes a case of good practice: “since our degree-course is an applied one, most of the project works include an experiment: the students are asked to measure some quantity. Before doing the experiment itself, they have to plan it (experimentally and theoretically) and explain their choices (why are they using a given experimental method, which temperature intervals will they be covering, do they have everything in the lab or do they have to build some equipment or circuit in the workshop…). The students then go to the lab and measure whatever is necessary. Afterwards they need to learn some new physics in order to interpret the data. In the last two years some units give a weight as much as 50% and more to this type of work”.

**Modelling [5]**

**Definition** Be able to compare new experimental data with available models to check their validity and to suggest changes in order to improve the agreement of the models with the data (*modelling skills*);

Here again we have one respondent only (continental tradition, DE), who gives a nice explanation / extension of the definition: Modelling in the general sense follows from understanding and requires applying that understanding. Modelling is therefore developed in all learning activities of physics. Modelling in a narrow sense means finding a simplified mathematical description of a complex phenomenon. It is usually less than creating a proper theory. It often means also applying tools of theoretical physics to non-physics situations. Modelling is a phenomenological account of data in general, but it should also have some limited predictive power.

Then he goes on: there is no course unit named Modelling. Students learn the modelling description of nature throughout their whole degree-course. As a consequence the whole teaching offer becomes important: in lectures, exercise classes, in lab classes, in student seminars and during research training students learn about how theories were developed, how to select and then apply theoretical tools (including models) to a particular physical problem and how to model the building blocks of a theory, by adapting these latter to the experimental data description.

---

8 As a concrete example of project work (example given by a teacher): “The student is given a thin quantum layer of material and is asked to identify the substrate and layer material and to measure layer thickness and the strain in the layer by optical spectroscopy. To accomplish this the student has to use several experimental techniques and to study new quantum physics”.

9 The respondent quotes as possible examples: the “modelling” neglect of friction in the description of the free fall, the abundant use of the harmonic oscillator for phenomena in the neighbourhood of stable equilibria, the shell model average field for nucleons in nuclei, the modelling of two-nucleon and three-nucleon forces, and so on.
On the other hand students do not usually learn in compulsory or elective course units how to select and then to apply useful models taken from physics to non-physics phenomena
d. Students (usually or sometimes) learn about this latter modeling as an exotic application of physics, by attending seminars at the Department or elsewhere.

The respondent concludes that he assesses the students' progress in developing this competence on the basis of their: (i) growing ability in solving exercise problems, (ii) written reports for the lab experiments, (iii) talks in student seminars, (iv) success in the comprehensive oral exams, (v) progress in research projects / Master thesis. Most of these activities are of course given marks, which contribute to the student’s career.


**Definition**
Acquire an understanding of the nature of physics research, of the ways it is carried out, and of how physics research is applicable to many fields other than physics, e.g. engineering; ability to design experimental and/or theoretical procedures for: (i) solving current problems in academic or industrial research; (ii) improving the existing results (basic and applied research skills);

A respondent emphasises an aspect of this competence, which is neglected in the definition, i.e. being familiar with problem decomposition. Here it would be again appropriate to remind the sentence in the Chartes Cathedral (see above, Learning to learn competence)

The Master thesis is here recognised as the key strategy for the development / achievement of this competence, but research activities as a part of the lab class, working groups and projects are considered important as well. During the Master thesis the students are often working in a research group, thus taking part in “real” research. In any case the idea is to assign students a short research work that can be developed in a few months with the help of a tutor. As to short projects, they – although not really research projects – can also be assigned in advanced modules. These projects would require designing some experimental set-up or following some new theoretical procedure to solve a problem, i.e. they are projects which would require the development of something new from the point of view of the student, although it might not be really new for the Physics community.

The assessment of the Master thesis may become rather formal: the research procedures and the results of the master thesis should have to be written and presented in front of a committee of professors, that will be able to evaluate and discuss with the student her / his results. It will be also important to evaluate the capacity of the students to relate their work with other work and results, which are already available in the literature. On the other hand the results of the small projects within a module can be written in a short note and evaluated by the professor in charge of the module, taking into account the student performance in the whole project.

Frontier research [10]

**Definition**
Have a good knowledge of the state of the art in - at least - one of the presently active physics specialities (familiarity with frontier research)

A first respondent perceives the development of this competence as an exciting way of learning, working or discovering. … The students are often surprised by the discovery of the organisation, which is implied by research. He illustrates his experience as it follows: “in advanced lectures such as Lasers Physics or Diluted Matter, in addition to the basic knowledge of the specific discipline, I teach the students how to approach the actual research area. When possible I illustrate the studied concepts by means of a current research problem. In problem classes the exercises are derived as far as possible from current research subjects. Finally all our second cycle students have to spend at least few weeks in a research laboratory. It is mostly at that time that they are confronted with a particular research subject. … It is surprising to see how much time and interest the students can spend on a particular research subject if they are interested. They read books chapters, magazines, they search on the web more information, they spend nights on computers...and discuss with researchers.”

An interesting aspect is the assessment procedure of the advanced course unit: “the basic knowledge is mandatory and it is assessed by a written exam, which is usually divided into three intertwined parts. The first part checks the understanding of (at least) part of the content, the second one is intended to control the mastering of mathematical and/or numerical methods and the third part deals with a recent theoretical or experimental result, for which the student is asked to answer an open question.

10 e.g., applying the dynamics of a linear chain or hydrodynamics to traffic problems, chaos theory to the stock market, diffusion equations to the territorial spread of species in nature or to the spread of opinions in society to the spread of national euro coins in euro-area and so on.
The second respondent – on the other hand – identifies different strategies: attendance at invited research seminars (given by staff and visiting lecturers); attendance at national and international research conferences; asking the students to prepare posters and/or oral presentations on their research topics. These activities are usually not assessed.

**Specific Comm. Skills [13]**

**Definition** Be able to work in an interdisciplinary team; to present one's own research or literature search results to professional as well as to lay audiences (specific communication skills).

This definition is enriched by the students of a first respondent, who recommend – when communicating – to catch the listener’s attention, e.g. by telling something, which is really new, and to avoid aseptic and cold wording. According to both respondents communication includes also putting questions. Both respondents desperately try during their lectures to encourage questions and moreover, when a question is put, they often ask the students to re-phrase it in a better manner, thus testing their capacity to communicate.

A respondent quotes the following interesting example of good practice: “I often take the students with me when I visit the high school they come from, in a campaign to attract students to physics. I then ask my students to talk to those pupils and say what it is like studying physics at our university.”

A number of educational activities may contribute to develop the present competence. They are:
- For lower level students: minor projects like the preparation of a poster, to be presented at the end of a course-unit in a special session. Such a task should teach the students how to make a long story short.
- During problem sessions students may be encouraged (or forced) to present their solutions on blackboard.
- Participation in and giving a talk in a seminar series is a compulsory part of the curriculum at the respondent’s department.
- Preparation for and taking an oral examination (a respondent quotes as many as 27 oral examinations at his institution in the first three years).
- Oral presentation of extra topics, which the student may be reading for her/his thesis.

Moreover at the department of one respondent’s a specific course unit in scientific writing was recently started. In any case both respondents agree that a great challenge and opportunity to develop this skill lies in the final thesis work (either at Ba or at Ma level), which usually implies a written report. The role of the teacher here is to point out to the student lapses of language and continuity, the possible lack of (clear) definitions and to suggest more adequate expressions for some concepts. At one respondent’s institution the final project implies also an oral presentation, half-an-hour long for the Ba thesis and one-hour-long for the master thesis.

As to assessment and feedback, the Master thesis is always given a mark, which includes as an important factor its readability/presentation. Similar assessment usually occurs for the Ba final project. The marks gained at the oral examinations include again a judgement about the present specific competence. As to the posters’ good practice, which we mentioned above, it was reported that the students are encouraged rather than criticised during the poster session, but the posters are graded too, on a mild scale, yielding additional credit points for the degree-course.

**Managing skills [14]**

**Definition** Be able to work with a high degree of autonomy, even accepting responsibilities in project planning and in the managing of structures (managing skills).

This competence is very precious in the post-graduate life either in the job market or even in future research careers. It is well known, as an example in this latter respect, that many large experiments need strong leadership, endowed with extended managing skills. Moreover it becomes increasingly important to know the essential administrative elements, in order to achieve an effective funding of many research programmes and to optimise the use of different sources.

Here we have one respondent only (from GR). According to this respondent, at the level of a second cycle student life, this competence preliminarily implies a well-structured organisation of the student’s own knowledge, starting from previous firm foundations. As a consequence an intelligent attendance to lectures is required, possibly free from constraints like “taking notes”, which hinder a full openness of the mind to understanding. Lectures notes prepared by the teacher or annotated bibliographies, prepared by a group of students may quite help. Intelligent attendance also means some follow-up activities, like reading of recommended texts or preparing for the next lecture through some discovery tasks 11.

11 e.g. thinking about and possibly solving a problem, assigned by the teacher and allowing to enter the contents/issues of the forthcoming lecture.
According to our respondent, this competence further means: (i) Ability to analyse both oral and written texts to identify both surface and underlying meanings; (ii) Ability to describe and follow a well defined procedure to achieve a goal; (iii) Ability to manage the bureaucratic formalities a programme needs; (iv) Ability to have discussions (contacts) with other researchers in order to establish collaborations. The students develop these abilities mainly undertaking little research projects. A case of good practice is described by the respondent in the following manner:

"teams of students search, via internet, other research teams which deal with similar projects, and from their publications and sites draw useful information concerning their work (methods, installation, staff, etc.). The students' team then has to:
- classify similarities and differences of its own project work with respect to the project of other research teams;
- classify similarities and differences in order of importance;
- make a list of lacking equipments;
- get in touch with companies and their product catalogues;
- estimate costs and – in case – search for alternative choices.
- make presentations of its work e.g. in posters;
- see and understand other students' similar work."

In this case the assessment occurs mainly through the unit feedback session, when students are asked to consider their own performance and contribution. In particular there is a question about what anyone personally considers as being the key step for the success of the whole process. The student feedback is summarised anonymously and then discussed as a whole group, so that issues about achievement can be discussed as well, including the annotated comments pointing out where the students could have gone further in developing knowledge and concepts.

III.3 – CONCLUSIONS

The 15 competences described above are the most important subject related competences to be developed in a Physics degree course according to the Tuning Physics community. Their descriptions mainly rely on the answers to the Athens homework. Taking into account the fact that each competence was described by at most two respondents, it may very well be that some important aspects have been lost in each single description. Nevertheless the author – within the heavy time constraints, which his other activities put on him – tried to integrate the descriptions, whenever he thought it appropriate, and tried to organise them in a unique coherent review. The main idea behind this Section III was to give an extended description of each competence, reviewing the corresponding answers to the five questions put by the Tuning General Co-ordinators and identifying as much as possible good ideas and the existing cases of good practice.

Each description gives in itself extended material for reflection. Sometimes, even recognising that only normal everyday-life behaviour occurs may be encouraging in itself. However precious (sometimes really original) ideas pop up here and there in the review. The cases of good practice seem limited in number, but it is difficult to identify them on the basis of common and shared criteria. Some descriptions among the ones given here, apparently without any innovative character, may nevertheless be considered as cases where things are really well done! Our hope is that these descriptions may raise awareness about the importance of subject related competences in curricular design and stimulate actions aimed at improving the way the several educational activities are offered to students and the transparency in assessment procedures. Our further hope is that each institution by comparing its teaching/learning approach with the average trends, which were described in Section II and with the many existing patterns of behaviour, may improve its general approach to teaching/learning, without losing the values of its traditional identity.

As to the assessment procedures, on the basis of the review in this Section III, it appears clearly that the achievement of most of the Tuning competences cannot be "measured" as such, but it contributes to the marks of the educational activity under assessment in a varying and usually complicated manner. An alternative tool consists in the feedback procedures, which are envisaged case by case, but which do not usually lead to true assessment.

A deeper analysis of the meaning of the 15 competences allowed revealing close links among some of them. For instance, this is the case of Problem Solving, Problem Solv & Comp. Skills, Modelling & Prob. Solving. In this very context a possible practical result of the above review might be renaming the short name of a couple of competences12. But this definitely needs agreement from the Tuning Physics community.

Finally it is appropriate to remind here that in my opinion the curricular planning requires to keep in mind a third type of competences, in addition to the generic ones and to the subject specific ones, which are the object of the present paper. These additional competences are more strictly related to contents (in a previous footnote we named them specialisation competences) and identify the content area, where a Physics graduate is competent. In other words, that graduate – beside being competent in Physics in a general way – is competent in nuclear physics or in condensed matter physics or in quantum optics, and so on. Sub-specialisation competences might also be easily identified.

Acknowledgements

I would like to thank warmly all the friends of the Tuning Physics SAG for their contribution to the Athens homework exercise, see ref [3]. A very special thank goes to Prof Hendrik Ferdinande, University of Gent, for his continuous and encouraging support.

References


[2] LF Donà dalle Rose, F Cornet, E Cunningham, MC do Carmo, M Ebel, H Ferdinande, H Geurts, E Gozzi, WG Jones, J Niskanen, G Nyman, JC Rivoal, P Sauer, S Steenstrup, EG Vitoratos: Physics Subject Area Group: Part 2. OPERATIONAL DEFINITIONS OF THE CORE CONTENTS, pagine 185 – 211 di “Tuning Educational Structures in Europe, Final Report, Pilot Project – Phase 1, carried out by over 100 Universities, coordinated by the University of Deusto (Spain) and the University of Groningen (The Netherlands) and supported by the European Commission”, eds Julia Gonzalez and Robert Wagenaar, University of Deusto and University of Groningen, 2003.

[3] The Athens homework material is available only in electronic files, care of the Tuning Managing Committee.