Physics Subject Area Group

PART 1. The Academic's Evaluation of the Specific Competences

1. *General introduction*

To our knowledge this paper is the first attempt, aimed at identifying —at a EU level— the specific competences, which are appropriate for the physics degree courses in a two cycle scheme (Ba and Ma cycles in the current terminology of the Bologna Process). The present report deals with *competences* rather than with *skills*[1]. *Skill* is the ability to carry out a well-defined task. *Competence* is a broader concept, at a higher level than skill: it is the ability to do a wider task, where knowledge is needed (e.g. research competence, ability of fully organising a meeting,…). In this context we remark that the *Problem Solving* skill, even though it is listed by the questionnaires for the Tuning consultations among the generic skills, it is for Physics a very important and *specific* competence. *Problem solving* is here intrinsically linked to the ability of *making reference to the fundamentals* of the physics experiments and theories and to the ability of *using mathematics in a way related to the real world*.

The questionnaire listing the possible specific competences was initially prepared by a restricted group of contact persons in the Tuning

[1] Do notice, however, that in the actual questionnaire form, which was used in the present consultation, the distinction among the two words was not perceived clearly and therefore they are often equivalent. The involved concepts have been clarified later in the Tuning Glossary (see the *Closing Conference Brochure*).

Physics Network. They relied on some mission statements at institutional level (available through previous work made within EUPEN[2] network), on sets of educational aims/objectives as stated in some member states (either by law or by regulating agencies) and —finally— on their own experience. The competence list was finalised at the EUPEN Steering Committee held in Namur (January 2002) and then sent out by the Tuning general co-ordinators, according to a procedure, which was common to all the seven Tuning subjects. As a whole we got 121 returns from 13 institutions out of 14; the number of returns per institutions ranged from a minimum of 2 to a maximum of 20. We remind here that the Tuning Physics Group/Network consisted of representatives from 14 universities in 13 countries, all of them committed not only in course-work teaching and in learning by students, but also in physics research and in research training of young scientists, as truly qualifying aspects of their own mission.

The results for the specific competences in Physics —as evaluated by the Physics Academics, on a scale from 1 to 4— are shown in Table 1. Looking at Table 1, we see —first of all— that the «rating value» for the importance of a given 2nd cycle competence is always higher than the value for the same competence in the 1st cycle, the average difference (or «gap») among the two sets of values being 0.712 (see also Table 4 below). This gap reveals that the Academics perceive clearly the difference between the two cycles; its sign (i.e. a positive gap) might generally indicate that the 2nd cycle is supposed to enhance what already achieved, maybe only partially, in the 1st cycle. In short, the development of competences is a cumulative process. See also below.

A second remark concerns the variation range of the rating values over the competences. The variation ranges are 1.46 and 1.25, in the 1st and 2nd cycle respectively; they are definitely larger than the observed standard deviations. Having divided the variation range into three intervals of equal length (0.49 and 0.42 respectively), it is then meaningful to group the values into three categories (*high*, *intermediate*, *low* importance) depending on whether the actual value falls within the upper, middle or lower interval of the variation range.

[2] EUPEN (EUropean Physics Education Network) is a Socrates Thematic Network and can rightly be considered as the *mother* of the present Tuning Network.

Table 1

TUNING consultation among Academics: Averages, Standard deviations and number of returns for the specific competences

Question No.	Short name for the competence[3]	1st cycle			2nd cycle		
		averages	stdev	no. returns	averages	stdev	no. returns
1	Interdisciplinary Ability	2.121	0.724	116	2.872	0.826	117
2	Basic & Applied Research	2.793	0.729	116	3.595	0.589	116
3	Specific Comm. Skill	2.430	0.775	116	3.414	0.633	117
4	Applied Jobs	1.974	0.789	116	2.923	0.756	117
5	General Jobs	1.930	0.758	116	2.932	0.763	117
6	Modelling	2.696	0.840	116	3.667	0.525	117
7	Human/Professional Skill	2.580	0.834	118	3.219	0.701	118
8	Learning ability	2.748	0.836	118	3.670	0.525	118
9	Problem solving	3.391	0.658	118	3.724	0.521	118
10	Modelling & Prob. Solv.	2.957	0.785	118	3.786	0.412	118
11	Prob. Solv. & Comp. Skills	2.931	0.719	118	3.496	0.582	118
12	Literature search	2.767	0.715	118	3.675	0.554	118
13	Ethical awareness	2.534	0.899	118	3.060	0.813	118
14	Managing skills	2.200	0.775	118	3.376	0.691	118
15	Teaching	2.316	1.025	118	2.534	0.818	118
16	Updating skills	2.226	0.806	118	3.188	0.681	118
17	Deep knowledge	3.061	0.820	118	3.585	0.604	118
18	Frontier research	2.250	0.801	118	3.542	0.622	118
19	Theoretical understanding	3.226	0.663	118	3.653	0.529	118
20	Absolute standards	2.560	0.805	118	2.991	0.760	118
21	Physics culture	2.810	0.745	118	3.195	0.670	118
22	Experimental skill	2.966	0.779	118	3.466	0.580	118
23	Foreign Languages	2.474	0.839	118	3.102	0.831	118
24	Mathematical skills	3.207	0.640	118	3.576	0.513	118
	Average values	**2.631**	**0.782**	**117.5**	**3.343**	**0.646**	**117.7**

[3] The full definitions are given in Annex I.

The rating values can be ordered in three different ways:

1. Sorted by importance in the 1st cycle (see Table 2 below), thus revealing which competence is thought to be more important for the 1st cycle.
2. Sorted by importance in the 2nd cycle (see Table 3 below), thus revealing which competence is thought to be more important for the 2nd cycle.
3. Sorted by (descending) gap between the importance for the 2nd cycle and the one for the 1st cycle (see Table 4 below). Those competences, which show the largest positive gap, characterise the 2nd cycle with respect to the 1st one, while the possible existence of a negative gap would characterise a competence, which is dominant and specific for the 1st cycle.

A further overall characterisation of the 1st versus the 2nd cycle stems from plotting the average importance of a given competence in the 2nd cycle versus its importance in the 1st cycle. This is shown in Fig. 1 below and commented therein.

2. *Important competences in the first and second cycle*

In Table 2 and 3 we show the 24 competences identified for our consultation, in decreasing order of (average) importance for the 1st and the 2nd cycle respectively.

From Table 2, it is seen that «only» 7 competences lie in the interval of *high* importance for the 1st cycle. It is interesting to compare this ordering with the similar one, as obtained by looking at the 2nd cycle (Table 3). In the case of the 2nd cycle (Table 3), there are as many as 13 competences of *high* importance. They are a bit more than one half of the whole set of competences.

Deepening the comparison between 1st and 2nd cycle, we see that —out of the 13 «best» competences for the 2nd cycle, all of them of high importance— 11 competences fall within the 13 best ones for the 1st cycle. The excluded ones are «Frontier research» (rated 19th in the 1st cycle) and «Specific Comm. Skills» (rated 17th); the substituting entries are «Physics culture» (rated 8th) and «Human/Professional Skills» (rated 13th). *As a first general conclusion the best skills are similar in both cycles and the small differences are quite understandable on general grounds.*

Table 2

Competences ordered by importance in the first cycle.
(The upper section scores *high,* the intermediate section scores *intermediate,* and the lower section scores *low importance*)

Sorted by 1st cycle (coloured by importance)				
	Question	1st cycle	2nd cycle	GAP
Problem solving	09	3.391	3.724	0.333
Theoretical understanding	19	3.226	3.653	0.426
Mathematical skills	24	3.207	3.576	0.363
Deep knowledge	17	3.061	3.585	0.524
Experimental skill	22	2.966	3.466	0.501
Modelling & Prob. Solv.	10	2.957	3.786	0.829
Prob. Solv. (comp.)	11	2.931	3.496	0.565
Physics culture	21	2.810	3.195	0.385
Basic & Applied Research	02	2.793	3.595	0.802
Literature search	12	2.767	3.675	0.908
Learning ability	08	2.748	3.670	0.922
Modelling	06	2.696	3.667	0.971
Human/Professional Skill	07	2.580	3.219	0.639
Absolute standards	20	2.560	2.991	0.431
Ethical awareness	13	2.534	3.060	0.525
Foreign Languages	23	2.474	3.102	0.628
Specific Comm. Skill	03	2.430	3.141	0.984
Teaching	15	2.316	2.534	0.219
Frontier research	18	2.250	3.542	1.292
Updating skills	16	2.226	3.188	0.962
Managing skills	14	2.200	3.376	1.176
Interdisciplinary Ability	01	2.121	2.872	0.751
Applied Jobs	04	1.974	2.923	0.949
General Jobs	05	1.930	2.932	1.001
Averages		**2.631**	**3.343**	**0.712**

Table 3

Competences ordered by importance in the second cycle.
(See the explanation for the sections in Table 2)

Sorted by 1st cycle (coloured by importance)				
	Question	1st cycle	2nd cycle	GAP
Modelling & Prob. Solv.	10	2.957	3.786	0.829
Problem solving	09	3.391	3.724	0.333
Literature search	12	2.767	3.675	0.908
Learning ability	08	2.748	3.670	0.922
Modelling	06	2.696	3.667	0.971
Theoretical understanding	19	3.226	3.653	0.426
Basic & Applied Research	02	2.793	3.595	0.802
Deep knowledge	17	3.061	3.585	0.524
Mathematical skills	24	3.207	3.576	0.363
Frontier research	18	2.250	3.542	1.292
Prob. Solv. (comp.)	11	2.931	3.496	0.565
Experimental skill	22	2.966	3.466	0.501
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Foreign Languages	23	2.474	3.102	0.628
Ethical awareness	13	2.534	3.060	0.525
Absolute standards	20	2.560	2.991	0.431
General Jobs	05	1.930	2.932	1.001
Applied Jobs	04	1.974	2.923	0.949
Interdisciplinary Ability	01	2.121	2.872	0.751
Teaching	15	2.316	2.534	0.219
Averages		**2.631**	**3.343**	**0.712**

However, and this is meaningful, most of the 7 best competences of the 1st cycle (i.e. except two[4] of them, i.e. «Problem Solving» and «Modelling and Problem Solving») fall beyond the 8th position in the 2nd cycle ordering. In other words the skills which are most important in the first degree (except a couple of them) become somewhat less important at the 2nd cycle level. *In terms of competence development, the second cycle is then qualitatively new with respect to the 1st cycle.*

More in detail, we can certainly state that «Problem Solving» and «Modelling and Problem Solving» constitute together the *backbone* or the *signature* of the competences, to be developed by the two Physics degrees. However, in the 2nd cycle, just following «Problem Solving» (rated 1st) and «Modelling and Problem Solving» (2nd), we find —in order of decreasing importance— three entries, which are rated rather below in the 1st cycle. They are «Literature search skills» (ranked 3rd, as opposed to 10th in the 1st cycle); «Learning to learn ability» (4th against 11th); «Modelling»(5th against 12th). Moreover these latter abilities exhibit some of the largest gaps between the rating values in the two cycles, this very fact confirming their qualitative / constitutional importance in the 2nd cycle. In this respect, on the other side, it is worth noticing that the «Experimental skill» which is ranked only 12th in the second cycle, it is ranked high (5th position) in the first cycle (!).

The ranking shown by Table 2 and 3 above deserves a seeming surprise, when we look at the competences, which are related to the access to the job market. In particular both «General Jobs» (a short name for the high level positions, in which a physicist may profitably perform, see Annex I) and «Applied Jobs» (a short name for lower level positions, e.g. accessible after a first cycle degree) are ranked very low in both Tables. On the other hand, the differences between 2nd and 1st cycle values —i.e. the gap, see Table 4 below— are quite high. The *common* low ranking may be related to the fact that our Academics do not much care about the job market, since they are persuaded that the competences, for which a physicist is appreciated and is competitive in the job market, lie elsewhere (e.g. in the mental flexibility achieved by studying university physics). In other words a specific preparation, especially related to the job market, is not needed[5]. This possible

[4] Actually we might add a third competence, i.e. «Theoretical understanding», which is ranked second in the 1st cycle and becomes sixth in the 2nd cycle.

[5] Remind here that several times in the past we heard statements from industry people, praising the flexibility and the methodological abilities of Physics graduates, even if they lacked in specific vocational preparation.

attitude is confirmed by the results of the Tuning Consultation among graduates, which show that the «Employment Potential» of the Physics graduates is at present the highest among the graduates of the seven. Tuning Subjects. Moreover, the quite *high* gap, from the 1st cycle value to the 2nd cycle one (see Table 4), may indicate that our Academics feel that the preparation for the job market is really fruitful only once the 2nd cycle degree has been completed. In this very context, a further surprise comes from the very low ranking, with the lowest difference in the gap, of the ability connected to the «access to teaching» positions in the secondary school. As a (marginal) paradox, this competence is more important in the 1st cycle (rated 18th) than in the 2nd one (24th). The very low ranking of the «Teaching ability» shows that its development is not perceived among the tasks of the two cycles, either because the graduates need to take a further preparation period or because those, who wish to teach, need a different curriculum from the start[6].

Finally the very low ranking of the «Interdisciplinary ability», in both cycles (gap is 0.751), is rather puzzling. In our opinion this is a further confirmation of the fact that the Physics Academics feel that the present Physics didactic offer is well organised in itself and that there is no need or room for further and/or explicit cross-fertilisation during the two cycles. Indeed much of the research carried out by those, who teach, has good links with other subjects. Moreover the physics curricula develop specific competences, which may be used profitably in other fields later on. In other words, the interdisciplinary attitude is naturally embedded in the curriculum and shows up when a graduate starts working. As a confirmation to this interpretation, it can be reminded here that the somewhat related *generic* skills «Ability to work in an interdisciplinary team» and «Teamwork» are both characterised as having *High importance and Low achievement* in the consultations carried out by Tuning among the Physics graduates and the concerned employers[7].

[6] According to some preliminary brainstorming in the Tuning Physics Network, countries where a further period of study and/or preparation is needed are AT, BE (both BE-FR and BE-FL), ES, GB, GR, IT, NL (old organisation), …; in DK the university degree is enough in order to start teaching, but in the first working years an active in-job training is required (complemented by a reduced amount of teaching). In countries like DE, NL (new organisation), PT, SE and BE-FL (gradual implementation, following NL), a different curriculum since the beginning is needed. A model, according to which the option is made «half-way» in the university curriculum, is adopted in FI and in FR (where further study after the degree is needed).

[7] See page 31-33 blue in Document 4 of Tuning, where the heading for this kind of skills *High importance and Low achievement* is «CONCENTRATE EFFORTS», i.e. an interesting recommendation (!).

Moreover the same consultation (graduates' returns only) shows that the Physics graduates exhibit a percentage of people working in a position *related* to the degree lower than the average of the seven Tuning subjects; correspondingly the Physics graduates exhibit a percentage of people working in a position *not related* to the degree higher than the average; this percentages are again consistent with a «*de facto*» interdisciplinary mentality[8]. Of course the above position of the Physics Academics may have risks in itself, mainly because of the fact that Physics may be sometimes perceived by the students, who are going to enter the university, as closed in itself, thus limiting the number of fresh students in the subject.

3. *The gap in the competence values*

The gap or difference between the rating values in the two cycles of a given competence is always positive, i.e. on an absolute scale the competences of the 1st cycle are always evaluated as less important. As already noticed, this fact witnesses that the Physics academics perceive the competence development as a cumulative process. The gap amount can then be taken as a rough measure of the development, which may be further achieved in the 2nd cycle (for a given competence). The Table 4 shows the competences, as ordered by descending gap, again subdivided into three groups (high, intermediate, low gap). The variation range of the gap is 1.073, i.e. a meaningful one.

[8] Such a trend in the percentages is only found in History (quite pronounced) and perhaps in Geology.

Table 4

Competences ordered by «gap».
*See the explanation for the sections in Table 2)

Sorted by 1st cycle (coloured by importance)				
	Question	**1st cycle**	**2nd cycle**	**GAP**
Frontier research	18	2.250	3.542	1.292
Managing skills	14	2.200	3.376	1.176
General Jobs	05	1.930	2.932	1.001
Specific Comm. Skill	03	2.430	3.141	0.984
Modelling	06	2.696	3.667	0.971
Updating skills	16	2.226	3.188	0.962
Applied Jobs	04	1.974	2.923	0.949
Learning ability	08	2.748	3.670	0.922
Literature search	12	2.767	3.675	0.908
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Basic & Applied Research	02	2.793	3.595	0.802
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Human/Professional Skill	07	2.580	3.219	0.639
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Ethical awareness	13	2.534	3.060	0.525
Deep knowledge	17	3.061	3.585	0.524
Experimental skill	22	2.966	3.466	0.501
Absolute standards	20	2.560	2.991	0.431
Theoretical understanding	19	3.226	3.653	0.426
Physics culture	21	2.810	3.195	0.385
Mathematical skills	24	3.207	3.576	0.363
Problem solving	09	3.391	3.724	0.333
Teaching	15	2.316	2.534	0.219
Averages		**2.631**	**3.343**	**0.712**

According to a simple approach, the 7 competences, whose gap is the highest, should be those, which characterise the second cycle with respect to the first one. As already noticed above, however, most of them (e.g. «General jobs» and «Applied jobs») do not score «high importance». Among the ones with a high gap, only «Modelling» is evaluated as having high importance for the 2nd cycle (ranked 5th in Table 3). Notice however that «Literature search skills» (ranked 3rd) and «Learning to learn ability» (4th) score a gap quite close to «high». Then these latter three competences, together with the «signature» competences, i.e. «Problem Solving» and «Modelling and Problem Solving» (see above), may be taken as the genuine academic characterisation of the 2nd cycle degree. All the other competences, which enjoy high gap, are ranked at a lower position in Table 3. As an example, consider the two competences with highest gap: «Frontier research» is only 10th in that ranking, «Managing skills» is 14th. Moreover «Specific Comm. Skills» and «Updating skills» are ranked 13th and 17th respectively. Notice that these latter four competences have a very low importance in the 1st cycle. They occupy the 19th, 21st, 17th and 20th place respectively. This is the reason why we can say that they are the peculiar competences of the 2nd cycle (see also the comments to the upper left quadrant in Fig.1 below).

As a final and somewhat complementary remark, it easy to see (Table 2) that —in the case of the 1st cycle— the high importance correlates with the low gaps and the low importance correlates with high gaps. This is a further confirmation about the coherence of our data, showing that the development of the competences, which are important in for the 1st cycle, has achieved a satisfactory level already in the 1st cycle. Analogue correlation does not show up in the 2nd cycle It can only be stated that most of the high importance competences exhibit an intermediate gap.

4. *Conclusions*

In Fig.1 we summarise the ratings of the competences, related to both degrees, in a single scatter plot. In the plot the dashed lines show the average values in each cycle and divide the plot itself into 4 quadrants[9]. The *upper right* quadrant contains all the competences, which score a rating higher than average in both cycles. This group of 11 «basic» competences may be taken as characterising in a general way

[9] A somewhat similar approach was used by the Business Tuning Network.

both physics degrees. It is a kind of *extended signature* of the subject. The distribution of the competence points in the quadrant, when «read» from left to right, gives the *flavour* of the 1st cycle, which is different from the *flavour* of the 2nd cycle, to be «read» from top to bottom. This is consistent with the description of §2 above. Do notice here that the spread in the rating values of the 1st cycle is twice as large as the spread of the 2nd cycle, a sign that the rating of the basic competences is much more homogeneous in the 2nd cycle than in the 1st one. Moreover, when moving from left to right (1st cycle flavour), it can be easily checked that the gap of the involved competence increases[10], varying from 0.33 for «Problem Solving» (an absolute minimum) to 0.97 for «Modelling». This very fact possibly shows an increasing potential for further development of the competences, when going from right to left. We emphasise again that the «queen» competence for both the 1st and 2nd cycle Physics degrees is «Problem Solving Skills», a short title for «*ability to evaluate clearly the orders of magnitude, to develop a clear perception and insight of situations which are physically different, but which show analogies and therefore allow the use of known solutions in new problems*». This is a qualitatively new specific skill, to be contrasted with the generic skill «Problem Solving», as presented in the Tuning Consultations among graduates and among employers. In these latter consultations the generic «Problem Solving» occupies respectively the 3rd and the 4th position, in the weighted ranking made over all Subjects. In the case of the Physics subgroup it occupies the 2nd position in both cases (graduates and employers). According to the present consultation the competence «Problem Solving Skills» together with the competence «Modelling and Problem Solving» constitutes the backbone of both Physics degrees. Do notice, in this context, that «Problem Solving Skills» exhibits the second lowest gap (see Table 4), i.e. it is a rather well developed competence already in the 1st cycle. Do notice —as a further sign of coherence in the present data— that the 2nd cycle *average* ratings for the competences, which crow this very quadrant, exhibit the lowest *standard deviations*.

[10] The *iso-gap* lines have slope equal to one, the gap increasing with their distance from the line passing trough the origin (*zero-gap* line).

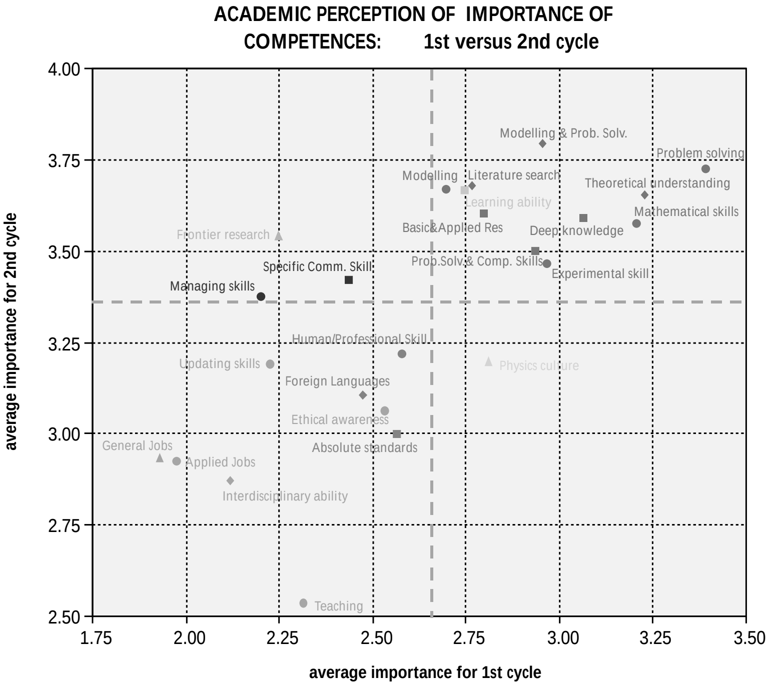

Fig.1

1st versus 2nd cycle competences.
The dashed lines show the average values in each cycle

The *lower right quadrant* indicates a «peculiar» priority of the 1st cycle, i.e. the development of a «general culture in physics». This indication is quite understandable in itself, since the graduate might then directly go to the job market, without further contacts with the university.

On the other end the *upper left quadrant* indicates «peculiar» priorities of the 2nd cycle. Such a peculiarity is reinforced by the high gap, which is exhibited by the involved competences (see Table 4) and which shows that the development of these competences is mainly a task for the second cycle.

Finally the *lower left quadrant* hosts those 9 competences, which are rated below the average in both cycles, thus enjoying a low priority in the Academics perception. They seem to be «minor» or «complementary» competences, rather than «basic» ones. In section

2 puzzling aspects, related to some of these competences, were discussed at length.

As a first conclusion, therefore, t he two degrees can be characterised in terms of competences in a rather detailed manner . The results presented here afford a preliminary classification of useful competences, according to their importance, as perceived by the Academics. Broadly speaking we can identify *basic*, *peculiar to 1st cycle*, *peculiar to 2nd cycle*, *minor* competences. The basic competences are ranked differently in the 1st and 2nd cycle, thus yielding the *competence «flavour»* of each of the two cycles. The distance from the zero-gap line of the competence points in the scatter plot gives information about the different importance that the given competence has in the two cycles. We may boldly say that it gives information about the competence potential for the competence itself to be further developed, when passing from the 1st to the 2nd cycle. Here an open problem is whether it is appropriate —and in case how it is possible— to establish a degree (a level) at which a given competence should be developed at the end of the 1st cycle and at the end of the 2nd cycle. Of course the immediately related problem is how to measure such a degree of development on an objective basis; this is further discussed below.

A second general and important concluding remark is that the answering Academics perceive the degree as essentially academic in nature, well-organised as it is and self-contained, without any urgent need for explicit links either with other subjects (for the sake of an *explicit* inter-disciplinar y approach) or with the job market (favouring e.g. a more *vocationally oriented* didactic offer). The real preparation for the job market and the competitiveness of the Physics graduates lies rather in the specific competences, ranked as having «high» (2nd cycle) or «high» and «upper intermediate» (1st cycle) importance. Their development grants by itself great mental flexibility in the graduate population. Moreover our Academics feel that the preparation for the job market is really fruitful only once the 2nd cycle degree has been completed. The arguments given in section 2 are quite sounded in this respect.

The final remark here concerns the future perspectives, which stem from this work. A first general problem to be faced concerns the ways through which the development of the specific competences can be monitored and even measured. Apart from many traditional assessment approaches based on a set of exams to be passed by the student, a preliminary suggestion —raised within the Physics Tuning Network— indicates the «comprehensive examination» as the right *more specific* tool. This latter is already extensively practised in Germany and in the United Kingdom. According to these experiences, the process itself of preparing the students for the comprehensive examination —a process which links *insight* and *knowledge*, in order to think the solution of the given comprehensive problem in an original way and not to reproduce standard solutions— may quite help the students to develop their competences. In more general terms, however, we still need to find *common* ways able to assess the process of competence development.

A second interesting perspective regards the definition of *content-related* specific competences, in order to provide a further characterisation of the *subject-related* competences, as discussed in the present paper. As possible examples of the *content-related* competences, for the sake of clarity, we list here (in the case of Physics):

After going through the degree course, the graduate should:

- —*be able to use perturbation theory to solve problems in atomic physics*
- —*be able to approach the calculation of thermo-dynamical/statistical properties of simple or even more complex systems*
- —*be able to carry out both simple and complex measurements, correctly evaluating the involved errors.*
- —*…*

In other words, so far, in this paper, we identified level descriptors for the Physics subject in a general manner. The further possible step may then be identifying coherent sets of content-related competences. These latter content-related level descriptors might be useful in order to establish and further monitor the degree/level, at which the broader specific competences are developed, either within a course unit of the degree course (as required by the Diploma Supplement approach) or more generally within the degree course itself (as possibly required by the implementation of the European Higher Education Area).

PART 2. Operational Definitions of the Core Contents

A. *The «Essential Elements» of a degree course*

In each country and/or university the structure of a degree course may be characterised by some specific *components,* which we name «essential components or elements» of that given degree course. These components are often compulsory elements too. As possible examples we quote here the core content (a very special essential element, see possible definitions below), the final year thesis work, the comprehensive exam(s), etc. The core content focuses on the «minimal» contents, which identify any degree course. The other essential elements —rather— are structural constraints, which may be satisfied by a variety of contents. Their occurrence in the curriculum and their *actual* content depends on a large extent on the institution/country and —quite often— on the student's choice.

Many possible essential elements are listed below. They are somewhat independent from each other and their proper and coherent mix yields the course curriculum. They are:

- —Core content[11] ;
- —Choice(s) from list(s), i.e. course units, which can be chosen by the student from one or more predefined list(s);
- —Free not-structured choice *or* Completely free choice, i.e. course units, which are totally left to the free choice of the student;
- —Final project/thesis work;
- —Other essential elements [comprehensive exam(s); intermediate project work; compulsory seminar, *stage* or placement;…].

Sometimes the local teaching authority «strongly recommends» to attend units, which are not compulsory. This is a kind of «*soft* » compulsory element.

The Physics Tuning Network made a «*Consultation about core contents and other essential elements*», which yielded some tables, where examples are given about how all these elements can be put together. These tables are shown in the Annex I. The Physics Tuning partners were asked for detailed information about the course units/activities in their institution, trying to identify what is compulsory, i.e. both in terms of contents and of the other elements. From the consultation, it appears that some of the essential elements are present in almost all the institutions of the Physics Tuning Network. These may be named *common essential elements.* The *core content* is by definition an essential (and compulsory!) element everywhere. Another quite usual compulsory essential element is the *final year project*. A thorough discussion of the results and features, which can be extracted from the just quoted tables is given below.

[11] See possible definitions below. We here make the choice of not using the terminology «core units» which may be ambiguous for several reasons (the same title often corresponds to different contents and/or level; the unit may have a different length in terms of credits depending on the institution, etc.).

B. *Definition of «Core Content»*

Definitions may be given with reference to three different contexts:

a) With reference to a degree course offered by a particular **university**: we define (core course units or) core content the set of course units/activities whose content is not left to the choice of the student but is compulsory and fixed by the academic authorities.

b) With reference to all the degree courses in the same subject offered by the universities of a given **country**, two different definitions may be given:

   b.1) *minimal core content*, defined as the set of the course units/activities which are fixed by law or other national requirements, in order for a university to be allowed to award that given degree title/qualification[12];

   b.2) *common core content*: the set of the course units/activities whose content is common to all the degree courses, conferring the same title in the country. This set may be larger than the one, as defined at (b.1) just above, and it requires a study/survey in order to be identified. It has to do with the *whole* didactic offer of the degree course rather than with the *compulsory* part of its offer.

c) With reference to all the degree courses of a given **ensemble of countries** (e.g. EU, the European countries, etc)*: common core content*: the set of the course units/activities whose content is common to all the degree courses, conferring the same or similar title and/or similar learning outcomes. Again this set requires a study/survey in order to be identified. Notice that in this case no supra-national requirements[13] are usually active. Indeed, do remind the EU Treaties, which explicitly state that no homogenising action can be carried out by the Union authorities in this field (as a consequence of the subsidiarity principle).

Moreover, very often, the units/activities are not only characterised by the type of contents but also by a corresponding number of credits. The above definitions can then be phrased in terms of credits too. In this

[12] The partners of the Tuning Physics Network were asked in this connection: ***QUESTION 1 is this actually the case in your country*?** ☐ **YES** ☐ **NO.** Their answers are reported in Table 1

[13] Of either legal or other nature.

connection, the Socrates Thematic Network EUPEN, which is the *mother* of the present Tuning Physics Network, has provided an interesting and rich report about the «*common core content*»[14] of several European degree courses in Physics. The report is presented in the context of the present work in Annex II. This latter report is based on the data collected through the EUPEN 2001 Questionnaire (in that part, which was sent out on behalf of the EUPEN Working Group 2). The collected data involved as many as 65 European Institutions (including associated countries). The main result of the analysis given therein is that the identification of the *common* core contents seems certainly possible in the physics 1st cycle[15], but it becomes rather questionable at the 2nd cycle level. In fact, the total number of «common *core credits*» is 125 credits in the first cycle and 51 credits in the second cycle, i.e. respectively 65 % and (only) 35 % of the total average length in credits. New light is shed on this result by the discussion below, where the difference between the *common offer* versus the *common compulsory content* is further discussed.

C. *The structure and the description of the Core Content*

The core content itself may be required to satisfy some structural constraints. Possible examples are:

1. The existence of structural constraints, fixed by law or other national requirements, on the amount of credits relating to a particular type of units (e.g. basic mathematics, classical physics, modern physics, related subjects, etc.) which must be offered within the degree course. These constraints may be:

   a) Country specific[16];
   b) Institution specific[17].

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[14] Here and in the following, the word «common» means that as many as 69% of the institutions in the involved sample offer those contents.

[15] In the EUPEN consultation the wording «*1st cycle*» or «*2nd cycle*» corresponds to the *Ba* and *Ma levels* of the current Tuning terminology. For the sake of simplicity, in Annex II the data referring to the «*5 years integrated master degree courses*» (about 15% of those EUPEN returns) are included in the 2nd cycle data.

[16] The partners of the Tuning Physics Network were asked in this connection: ***QUESTION 2 Is this actually the case in your country*?** ☐ **YES** ☐ **NO.** Their answers are reported in Table 1.

[17] The partners of the Tuning Physics Network were asked in this connection: ***QUESTION 3 Is this actually the case in your institution*?** ☐ **YES** ☐ **NO.** Their answers are reported in Table 1.

2. The order in which units/activities must be taken by the student. Often a given unit needs as a pre-requisite the contents offered in a previous unit[18].

A Summary Table of the different situations/regulations, which exist in the institutions of the Physics Tuning Network —as yielded by the answer of the partners to the four questions 1 2, 3 and 4, see footnotes above— is shown in Table 1 below. In the Table the institutions are ordered according to the number of stated «YES», i.e. from a more regulated to a less regulated core content *structure*.

Table 1

Summary Table about local and national requirements related to the core content

Question	Content	Hannover	Paris VI	Granada	Göteborg University	Patras	Trieste	I.C. London	TU Wien	Aveiro	Kobenhavn	Helsinki	Nijmegen	Dublin CU	Gent
1	minimal core content fixed by law and/or national requirements	Y	Y	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N
2	national constraints of the amount of credits of a given kind/type	Y	Y	Y	Y	N	N	N	N	Y	N	N	N	N	N
3	local (i.e. institution) constraints of the amount of credits of a given kind/type	Y	Y	Y	N	Y	Y	N	N	Y	Y	Y	Y	N	N
4	the order in which (some) exams are taken is regulated	Y	Y	N	Y	Y	Y	Y	Y	N	Y	Y	N	Y	Y

[18] The partners of the Tuning Physics Network were asked in this connection: ***QUESTION 4 Is this actually the case in your institution*?** ☐ **YES** ☐ **NO**. Their answers are reported in Table 1.

Of course the core content can be further detailed, by giving for a given university the set of units, which actually constitute the core content. For each of the units belonging to this set, the actual content, the number of credits, the level of teaching/learning must be specified. The level may be specified in terms —for instance— of a *reference textbooks* or of a predefined and agreed «broad» *descriptive list*, under which the units may be grouped, or even by describing each unit in terms of its own specific contents and of the foreseen learning outcomes[19]. Another quick possibility is to attach to the unit a conventional label, which specifies the level (e.g., B for Basic; A for Advanced; S for Specialised;…). However, past attempts in this latter direction never attained easy reproducibility and/or effective extension to a wider set of institutions (see, for instance, the early Information Packages of the ECTS Pilot Project). In the present work we rely on a «rather detailed» *descriptive list* (comprehensive of 27 items, see §E below).

D. *Other Problems in defining a Core Content in Physics*

1. Two main approaches exist, when designing a Physics curriculum:
   - The initial years of the curriculum are common to the subjects of physics, mathematics, chemistry, (geology?, biology?…) and the students makes the choice of the subject only later (at the third year, e.g., see below the case of Copenhagen).
   - The *whole* degree course has «physics» as the key word
2. Our network has difficulty in defining a single core curriculum since our institutions offer degrees in physics, engineering physics, applied physics, theoretical physics, etc. Nevertheless experience shows (see for instance the EUPEN report of Annex II; see also below) that meaningful results can be obtained even with this apparently not homogeneous sample of institutions.

E. *The experience of the Tuning Physics Network*

The Tuning Physics Network produced an analytical characterisation of the core contents and the other essential elements offered in each institution, on the basis of a rather detailed *descriptive list* of entries

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[19] This *unit by unit* characterisation is adopted in the Diploma Supplement approach.

(see the column CORE CONTENT CHARACTERISATION in Table 2). Such a list (or grid) is made of two sub-lists, a first one of —so to speak— «broad» core contents and a second one of (other) essential elements, which were identified during the Tuning meetings. Each institution of the Tuning Network was asked to allocate to each entry in the list the appropriate number of ECTS credits; these latter ones then characterise the degree course of that institution.

We got returns from 15 institutions. At least two common discussions in the Network and several further checks from the contact persons confirmed the return from each institution. The returns were grouped, according to the pattern of the present organisation of studies in the institution. We ended up with two groups of institutions, i.e.:

A. Institutions with a «Bachelors - Masters (BaMa)» organisation of studies (which mostly adopt the «3+2» scheme). The institutions are Kobenhavn, Granada, Nijmegen, Paris VI, Trieste, Dublin City University and Patras (which adopts the «4+2» scheme).
B. Institutions, which offer an Integrated Masters level degree course. The institutions are: Gent, Göteborg, Chalmers University of Technology, Helsinki (Physics), Imperial College London, Aveiro, Hannover, Technical University Wien.

The corresponding detailed data are given in the Annex I. Some general remarks follow here below.

Table 2

Correspondence between the entries for the present core content characterisation (middle column), the EUPEN 2001 consultation grouping (left) and the new grouping «Tuning 2002» (right)

Core Content characterisation and two possible groupings		
EUPEN GROUPING GRID ITEMS in EUPEN QUESTIONNAIRE 2001	CORE CONTENT CHARACTERISATION	TUNING GROUPING 2002
BASIC UNITS	basic mathematics	Mathematics and Related Subjects
BASIC UNITS	mathematical methods for Physics	Mathematics and Related Subjects
RELATED 1	computing	Mathematics and Related Subjects
RELATED 2	numerical analysis	Mathematics and Related Subjects
GENERAL PHYSICS (characterising I)	introduction to physics	BASIC PHYSICS
GENERAL PHYSICS (characterising I)	classical physics (incl. demonstrations)	BASIC PHYSICS
MODERN PHYSICS (characterising II)	quantum physics (incl. demonstrations)	BASIC PHYSICS
LAB UNITS	laboratory	BASIC PHYSICS
MODERN PHYSICS (characterising II)	analytical mechanics	Theoretical Physics
MODERN PHYSICS (characterising II)	classical electromagnetism, relativity, etc	Theoretical Physics
MODERN PHYSICS (characterising II)	quantum mechanics / theory	Theoretical Physics
MODERN PHYSICS (characterising II)	statistical physics	Theoretical Physics
MODERN PHYSICS (characterising II)	modern physics (atomic, nuclear and subnuclear, solid state, astrophysics)	SPECIALISED CORE
MODERN PHYSICS (characterising II)	Comprehensive Physics	SPECIALISED CORE
MODERN PHYSICS (characterising II)	chemistry	Applied Physics and Related Subjects
RELATED 2	electronics&related	Applied Physics and Related Subjects
RELATED 2	choice(s) from list(s)	Applied Physics and Related Subjects
MINOR & OPTIONAL	physics project(s)	OTHER ESSENTIAL ELEMENTS
LAB UNITS	physics project(s)	OTHER ESSENTIAL ELEMENTS
LAB UNITS	advanced lab	OTHER ESSENTIAL ELEMENTS
FINAL YEAR PROJECT	final year project	OTHER ESSENTIAL ELEMENTS
MINOR & OPTIONAL	seminar	OTHER ESSENTIAL ELEMENTS
RELATED 2	other (technical drawing, autom. control)	Nonstandard Subjects
VOCATIONAL	vocational	Nonstandard Subjects
SKILLS	skills	Nonstandard Subjects
VOCATIONAL	placement	Nonstandard Subjects
COMPLETELY FREE	completely free choice	completely free choice

We adopted the choice of defining the length of a degree in terms of the credits' total and not in terms of the duration in years. In this context and for the sake of transparency, it must be noticed that, among the degrees, whose length is 240 credits, the Dublin CU degree is a Ba degree, in the current European terminology. On the contrary, the London IC degree (a so-called integrated Masters level course, MSci) as well as the Gent, Göteborg University and Helsinki degrees, all are Ma degrees; their length is equal to 240 credits. The case of Kobenhavn (BaMa, 300 credits) is a peculiar one, since during the first cycle the students usually study two subjects in parallel. Several combinations are possible concerning the main subjects (e.g. physics, mathematics, chemistry, etc.). Indeed, it is possible to study three subjects during the first year, then two subjects out of the three must be chosen for the next two years. In the second cycle only one subject is studied, being chosen out of the two subjects most studied during the first cycle.

The characterisation of the curricula through a list of specific core contents and a list of (other) essential elements was aimed at identifying the actual core content. Nevertheless it must be realised that, even in this framework, some uncertainty still remains in the identification. Take, as an example, the entries «Specialised Core Physics» and «Applied Physics»: both of them are very broadly defined subjects and —therefore— their contents can vary from institution to institution, thus smearing out the concept of Physics Core Content or, in other words, providing uncertainty in the definition of the core content.

Moreover it may happen that the *essential element* entry «Choice(s) from list(s)» refers to a predefined list, which is very focused as far as the content of the units listed therein is concerned. This again smears out the definition of core content, since in such a case all the units (to be chosen) may fall under a single specific *core content* entry.

In this same context care must be taken in order not to draw hasty conclusions from inspecting the returns from the Partners. It must be clearly born in mind that the offer of teaching/learning units is a much wider concept than the core content. What is core content in one institution, in another institution it may hide itself under another essential element [e.g. «Choice(s) from list(s)»], thus implying that this very content is not compulsory for all students. In particular it cannot at all be concluded that some core content entries, which are not mentioned in a given return, are not offered in the corresponding institution. In other words, we emphasise again that there is a clear conceptual distinction between what is common in the offer and what is common in the core content.

Some further clarifying remarks are:

- —The row named «Skills» appears as a rather empty one in the returns. As a matter of fact only some institutions offer course units fully devoted to the development of general skills. In most of our institutions the skill training is provided (or integrated) in other parts of the curriculum. It can be generally and safely stated that skills are developed in many more units than those explicitly mentioned by the returns.
- —In some institutions the practical physics (i.e. laboratory) activity is integrated in other course units;
- —The «Advanced Lab», classified among the *essential elements*, is not teacher-oriented, rather it is research oriented and it is meant to be creative and to develop a competence rather than mere skills.
- —The essential element «Completely free choice» is a kind of buffer element, whose use is quite widespread. Indeed, it allows an easy check of the total length of the curriculum in terms of ECTS credits.

For each institution we then sum the credits, which correspond either to the core contents or to the *other* essential elements. While the variation among the institutions witnesses the richness of different methodological approaches, we think that the average values of these quantities for the two above groups of institutions are meaningful. They are shown in Table 3 below. Do notice that we give three sets of values for the Group of institutions listed at point A above (i.e. values for the Ba cycle, for the Ma cycle, for the whole BaMa sequence).

Table 3

Average values (and dispersions) of the credit distribution over core contents and essential elements for different groups of the partner institutions of the Tuning Network

	Bachelors (1st cycle)		Masters (2nd cycle)		BaMa		Integrated Ma	
	av	stdev	av	stdev	av	stdev	av	stdev
Total core contents	152.4	30.1	41.4	17.2	190.8	44.4	160.2	29.7
Total *other* essential elements	48.2	22.9	79.6	17.9	124.2	35.2	106.4	26.9
Total length (in credits)	200.6	27.5	121.0	2.4	315.0	23.2	266.6	29.4
Total core content *over* length	**0.759**	**0.117**	**0.343**	**0.145**	**0.610**	**0.127**	**0.601**	**0.087**

As to the «BaMa» institutions, it is worth noticing that the ratio «core content to total» becomes lower when going from the 1st cycle to the sum of the 1st and 2nd cycle. This is clearly due to the fact that in the 2nd cycle the amount of compulsory (core) contents is much lower than in the 1st cycle. On the other hand, it is reassuring to notice that the above ratio is quite similar (~60 %) for the BaMa and for the Integrated Ma organisation of studies.

As a further check of our results, we grouped the entries of the two sub-lists into the items of the more general classification scheme or grid used in the EUPEN consultation 2001. There is some freedom in carrying out the grouping operation[20], but this latter —once completed— allows a comparison between the data collected in the Tuning Network and in EUPEN. This is shown in the following Figure 1, where for both sets of data we plot the *common* credits, as distributed over the items of the EUPEN grid.

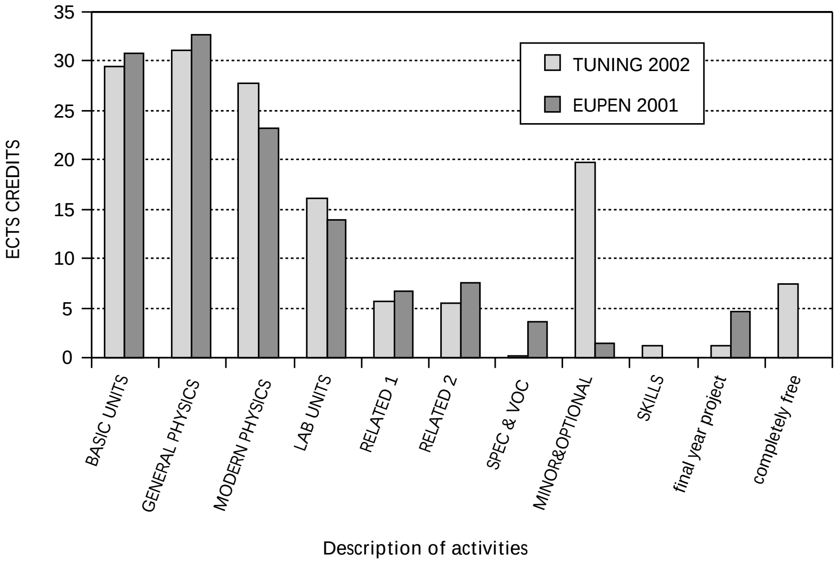

Fig. 1

Common credit distribution in Physics
1st cycle, according to 2 different consultations
(TUNING 2002 = 145.2 credits; EUPEN 2001 = 124.7 credits)

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[20] See for instance Table 2 above.

The main point here is that the *common*[21] «core» content, as obtained from the Tuning data, is definitely similar —both in distribution over the items and in percentage over the total length— to the one found in the EUPEN 2001 consultation. The percentage over the average «1st cycle (i.e. Ba) length» is 72.4 %, to be compared with the EUPEN value of 65 %. The higher value is somewhat accidental, being due to the large standard deviation[22] in the EUPEN returns concerning the item «minor&optional», which quite reduced the *common* part of the same item in the grid.

F. *Suggestion for a new grouping of the entries of the Tuning Consultation*

The entries of the Tuning *descriptive list* can also be grouped into the items of a more general classification scheme, different from the one used by the EUPEN 2001 consultation. This *new* scheme (also shown in Table 2, right hand side) is the fruit of the discussions held in the Tuning network. It may become useful for a better understanding of the distinct core contents and in any case for further reference.

This *Tuning Grouping* consists of 8 items against the 27 entries of the detailed descriptive list (see Table 2). By using the data returned by each institution, the credit distribution over the items of the *new* Tuning grouping may be easily calculated.

In the following Figures 2 and 3 we show the distributions over these items for the same groups of institutions as in Table 3. The Figure 2 compares the *average* credit distribution for the 1st and 2nd cycle of the institutions of group A. It confirms again the view, according to which the Ma cycle does not allow a meaningful definition of the core contents. Most of its credits (57 %) are devoted to «other essential elements». Of course, «basic Physics» plays a major role in the first cycle (33.5 %), but it is almost vanishing in the second cycle. If we look at the common (i.e. common to 69 % of the sample) credit distribution of the first cycle, the corresponding sum of credits is 72.6 % of the average total length, but if we exclude the items «other essential elements» and «completely free choice» this percentage reduces down to 57.4 %. This latter number is the one comparable to the percentages quoted when commenting Fig.1.

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[21] I.e. common to the 69% of the sample in each grid item.

[22] Due to a quite unusual organisation of contents in a responding institution.

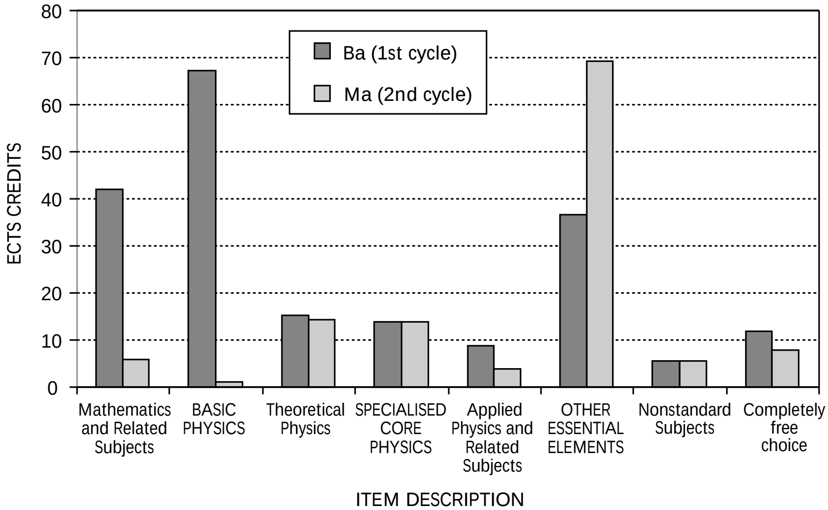

Fig. 2

Average Core Content characterisation
TUNING 2002 (Ba = 200.6 credits; Ma = 121.0 credits)

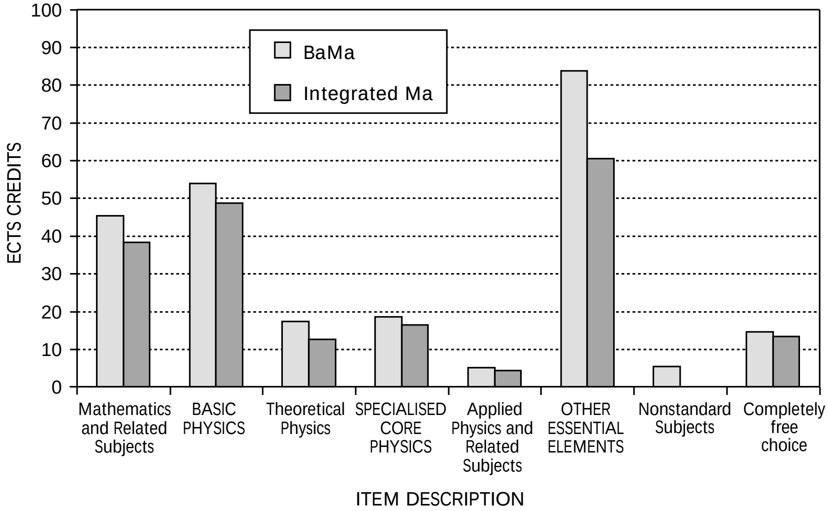

Fig. 3

Common Core Content characterisation
TUNING 2002 (BaMa = 291.8 credits; IntMa = 237.3 credits)

In Fig. 3 we present the *common* credit distribution for the «BaMa» institutions (Group A) and for the institutions offering a single integrated Masters level degree instead (Group B). The Figure confirms the rather close similarity of the two distributions, in very good agreement with the findings of Table 3 of the present paper. If the same two distributions, given here in terms of credits' *absolute* values, are translated into credits' percentage distributions, the variations among the items are small, except for the item «other essential elements», which is 3.6 % higher in the BaMa Institutions (its actual value is 28.7 %). The *common* core content (neither including «other essential elements» nor «completely free choice») is respectively 49.9 % and 50.7 % of the average total length.

G. *Summary and Conclusions*

In this paper, we present a careful discussion of the concept of *core content* of a degree course, providing some operational definitions. We distinguish between actual *core content* and other *essential elements,* i.e. structural elements, which act as constraints to the degree course organisation, but which may be satisfied by a variety of contents. When we refer to several institutions, in order to give a clear operational definition, the difference between the *common* didactic offer and the *common* compulsory part of the curriculum must be kept in mind. The word *common* here means those credits, which are allocated to a given item of a «grid» and which are common for each item to the 69 % of the sample of the consulted institutions.

On the basis of the returns from the partners of the Tuning network[23], we filled in a matrix of amounts of credits, whose columns represent the institutions and whose rows refer to distinct *core contents* and the other *essential elements*. The matrix tables can be seen in Annex I. From these data, grouping the entries in the rows according to two different schemes (EUPEN and Tuning approaches), we calculated the corresponding *common* credit distributions in Physics. The EUPEN approach is probably more appropriate when the characterisation of the *whole* didactic offer is aimed at. The Tuning approach puts the accent on the *compulsory* contents and aspects of the curriculum.

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[23] We remind here that the Tuning Physics Group/Network consisted of representatives from 14 universities in 13 countries, all of them committed not only in course-work teaching and in learning by students, but also in physics research and in research training of young scientists, as truly qualifying aspects of their own mission.

We discuss the features of these distributions, on the basis of the different organisation of studies, which occur in the partner institutions. The most important conclusions are:

1) In a BaMa organisation of studies, the concept of core content has a really fruitful meaning only in the first cycle. In this cycle, according to the estimates, the *common* core content may vary from ~70 % (EUPEN scheme, *didactic offer* oriented) to 57 % of the credits' total (Tuning scheme, oriented on the *compulsory contents*).
2) When comparing both cycles *together* of the BaMa organisation with the single cycle of the Integrated Masters level organisation, we find that the corresponding credit distributions are quite similar. The *common* core content (neither including «other essential elements» nor «completely free choice») is respectively 49.9 % and 50.7 %, in terms of credit percentage over the total.

As it is to be expected, the *common* core content, if quantified with respect to the total length, decreases when going from the first cycle to either the sum of the two cycles or to the integrated cycle. In this context, see also the numbers in Table 3, where *average* figures are reported.

Moreover a decrease in the *common* core content occurs when going from the EUPEN to the Tuning approach. This latter decrease reflects the fact that that the *common core content* may quite differ from the *minimal core content* (by about 15 % in our estimate for the first cycle). Indeed, the Tuning consultation —focusing the attention on *all* the compulsory «essential elements», among which the core content is *one*— definitely hides a part of what is common in the didactic offer, as already pointed out in Sections B and E above.

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Annexes

Annex I

—*First part*: institutions with a two cycle organisation of studies (bachelors and masters, BaMa).
—*Second part:* institutions with an integrated master level degree course.

Annex II. The *Common* Core Content in the EUPEN 2001 Consultation (a new analysis, with reference to the line 2 of Tuning).

ANNEX 1 (first part)
Institutions with a two cycle organisation of studies (Bachelors and Masters, BaMa)

CORE CONTENT CHARACTERISATION	FIRST CYCLE (BACHELORS)							FIRST and SECON CYCLE (BaMa)						
	Kobenhavn (**)	Granada	Nijmegen	Paris VI	Trieste (*)	Dublin City University	Patras	Kobenhavn (**)	Granada (**)	Nijmegen (exptl)	Paris VI	Trieste (theor)	Dublin City Un. (***)	Patras (Physics)
Basic mathematics	30		22,5	25	32	10	36	30		22,5	25	32		36
Mathematical methods for Physics		33	15	7,5	8	10			33	15	7,5	8		10
Computing	10		6	12,5	4	15	10	10		12	12,5	12		10
Numerical analysis		6		2					6	6	7			
Introduction to physics		12				10	17		12					17
Classical physics (incl. demonstrations)	15	42	33	53,5	38	25	19	15	42	33	53,5	38		19
Quantum physics (incl. demonstrations)		10,5	19,5	7,5	14	10			10,5	19,5	7,5	14		
Laboratory	0	24	24	26	22	25	24	0	24	30	26	22		24
Analytical mechanics			3				6		6	3				16
Classical electromagnetism, relativity, etc.	15		3	3,5			17	15	7,5	3	3,5	6		27
Quantum mechanics/theory	15						14	15	7,5		5	6		24
Statistical physics	5		6		7	5	7	5	7,5	6		7		17
Modern physics (atomic, nuclear and subnuclear, solid state, antrophysics)	10		11	3,5	12	37,5	22	10	15	26	33,5	34		22
Comprehensive Physics														
Applied physics														
Chemiatry				17	6		6				17	6		6
Electronics&related			3	5		17,5	6		12	3	15			6
Choice(s) from list(s)	50	37,5	6	3,5	16	45	56	80	87	33	38,5	40		96
Physics project(s)														
Advanced lab								5			20			
Final year project	10				6	25		65		60		46		30
Seminar														
Other (technical drawing, autom control)														
Vocational			12	5						12	5			
Skills			3	10	3	5		10		3	10	11		
Placement											15			
Completely free choice	20	15	22	13,5	12			40	30	28	13,5	18		
Total length (in credits)	**180**	**180**	**189**	**195**	**180**	**240**	**240**	**300**	**300**	**315**	**315**	**300**	**0**	**360**
	Kobenhavn	Granada	Nijmegen	Paris VI	Trieste	Dublin CU	Patras	Kobenhavn	Granada	Nijmegen	Paris VI	Trieste	Dublin CU	Patras

(*) Vocational credits are offered as a «choice from lists». (**) The 2nd cycle in Dublin is under development. (***) In addition to the lab units, some laboratory teaching is integrated in the other units.

ANNEX 1 (second part)
Institutions with an integrated master level degree course

CORE CONTENT CHARACTERISATION	Gent	Göteborg University	Chalmers University of Technology	Helsinki (Physics)	I.C. London	Aveiro (**)	Hannover	TU Wien
Basic mathematics	32		27			29,5	27	24
Mathematical methods for Physics	16	40,5	12	33	15		15	13,5
Computing	6		7,5			10		6,5
Numerical analysis	6	15	7,5			19,5		6
Introduction to physics			7,5	3		5,5		
Classical physics (incl. demonstrations)	18	37,5	43,5	30	25	35,5	13	25
Quantum physics (incl. demonstrations)	10	7,5	10,5		15	7	16	10
Laboratory	15	30	15	28,5	18,75	0	10	10
Analytical mechanics	11						5	9
Classical electromagnetism, relativity, etc.	11			9	11,25		5	11
Quantum mechanics/theory	7						20	18,5
Statistical physics	4	7,5	7,5		3	8	10	10
Modern physics (atomic, nuclear and subnuclear, solid state, astrophysics)	26	15	12	9	30	26	20	22
Comprehensive Physics					6			
Applied physics					15	14,5		7
Chemistry	6					11,5		6,5
Electronica & related			4,5	6	2	27,5		5
Choice(s) from list(s)	50		13,5	31,5	69	24	47	34
Physics project(s)					7,5			36
Advanced lab						18	20	
Final year project	22	30	30	30	22,5	36	60	30
Seminar							18	
Other (technical drawing, autom. control)			4,5			4,5		
Vocational						16		
Skills			2					
Placement								
Completely free choice		60	65,5	60		7	14	16
Total length (in credits)	240	243	270	240	240	300	300	300
	Gent	Göteborg	Chalmers UT	Helsinki Physics	I.C. London	Aveiro	Hannover	Wien TU

(**) In addition to the lab units, some laboratory teaching is integrated in the other units.

ANNEX II

The Common Core Content of 52 Physics Institutions

i.e. the «credit core contents» as yielded by the EUPEN[1] 2001 Consultation

1. *The «Common Core Content»*

While the Tuning Pilot Project was evolving, it became clearer and clearer that some of the results[2] shown at the EUPEN General Forum in Köln (September 2001) were quite meaningful with respect to the issues raised within the Tuning *Line 2 - Subject specific competences (Knowledge and Skills).* The approach illustrated here is based on induction, i.e. on concrete cases, and it is in a way complementary to the approach described by the Business Group (see Document 3 of Tuning, blue pages, *paper WP3.2.1 Business*).

We start from the following operational definition of the *core content*, among the several possible ones (as discussed in the main text[3]). When reference is made to the degree courses of a given subject in a given ensemble of countries (e.g. EU, the European countries, etc), it is appropriate to speak about the *common core content*, i.e. the set of the course units/activities which are common to all the degree courses having possibly the same or similar name and/or similar learning outcomes. Of course, in order to produce a quantitative (statistical) description, the course units/activities must be characterised by a number (the ECTS credits in our case) and by a label, which broadly identifies their content and possibly their level (in our case the we identified 11 such labels, as seen in the reference grid, Table I below).

The present results are based on the returns to that part of the EUPEN 2001 questionnaire, which asked for the distribution —over a pre-defined reference grid (see Table I)— of the credits allocated to the units/activities, which are offered in each answering institution in the first two cycles (the doctoral studies were never considered in this study). All the answering institutions adopted either ECTS credits (89 % of the EUPEN whole 2001 sample) or nationally defined credits, whose

[1] EUPEN, i.e. EUropean Physics Education Network, is a TNP funded under Socrates-Erasmus by the European Commission.

[2] See Ref. [1].

[3] See §C of the main text.

relationship with the ECTS credits was well understood/codified. Therefore in the following «credits» mean «ECTS credits».

2. *The general results of the EUPEN survey*

As many as 52 institutions filled in the «grid» for the course activities, 46 (72 % of the whole sample) for the 1st cycle and 43 (67 %) for the 2nd cycle[4]. From the returns, information can be extracted about the distribution of credits over 11 different «labels or typical items», under which the «course units» or —with a better and clearer wording— the «teaching/learning activities» may be grouped. The 11 typical items (activities) are chosen as follows: *basic*; *characterizing 1* (or general physics); *characterizing 2* (or modern physics); *lab*; *related 1* (or informatics); *related 2* (or chemistry, mathematics, etc.); *specialized & vocational*; *minor or optional*; *skills*; *thesis if declared*; *completely free choice*. The credit distributions are given in Fig 1 for both cycles. With respect to the 2nd cycle, the 1st cycle distribution strongly privileges *basic* and *characterizing 1*—as it is to be expected, of course— and, at a lower extent but somewhat unexpectedly, *related 1*, *related 2* and *skills*. The 2nd cycle distribution —on the other hand— clearly prefers *specialized & vocational* and *thesis work* (if declared). The l*ab* activities are slightly preferred in the 2nd cycle, but their relative weight is higher, considering the shorter «duration» of the second cycle[5].

[4] Those degree courses, which have a legal duration equal to 5 years, were counted as «2nd cycle» degrees; they are 9 in total, mostly from AT and DE.

[5] The overall duration in credits for the sample institutions is 191 credits for the 1st cycle and 146 credits for the 2nd cycle (see also Table II).

Table I

EUPEN WG2 Questionnaire - March 2001

REFERENCE GRID FOR THE COURSE UNITS			CREDITS		% of CONTACT HOURS	
MAIN TYPES OF UNITS	Code number for sub-type	Contents of sub-type	First cycle	Second cycle	First cycle	Second cycle
BASIC UNITS	I	MATHEMATICS				
UNITS CHARACTERISING THE PHYSICS DEGREE	II.1	GENERAL PHYSICS				
	II.2	MODERN PHYSICS (quantum physics, Theoretical Physics, Condensed matter, Nuclear and Sub-nuclear Physics, Astrophysics)				
LAB UNITS	III	LAB WORK				
CLOSELY RELATED And/or COMPLEMENTARY UNITS	IV.1	INFORMATION TECHNOLOGY				
	IV.2	Complementary courses (mathematics, chemistry,…)				
SPECIALISED, VOCATIONAL UNITS	V	Specialized and/or vocational physics (Geophysics, Health Physics,…)				
MINOR and OPTIONAL UNITS	VI	Minor and optional units				
SKILLS UNITS And/or ACTIVITIES	VII	Transversal skills (Pedagogy, foreign languages, Project management, Oral and written communication,…)				
		TOTAL				
DURATION OF THE CYCLE (in years)						

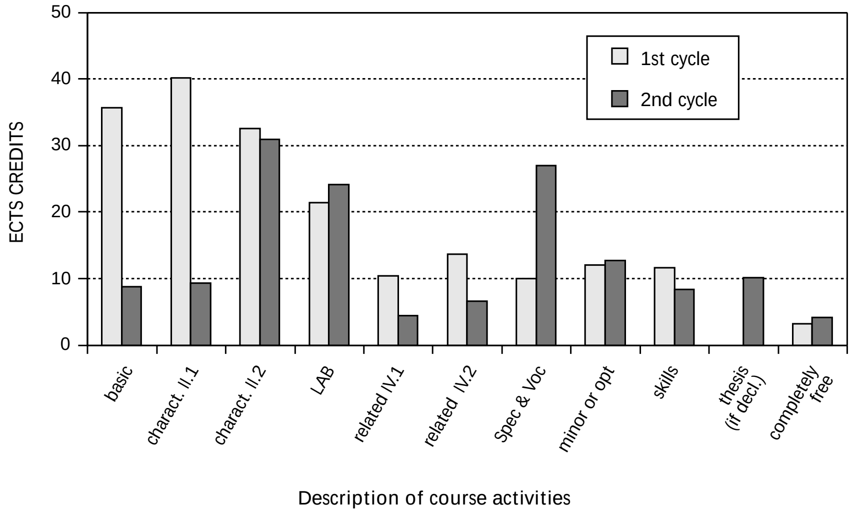

Fig. 1

Grid for Course Activities (all 52 returns)
1st and 2nd cycle Average Credits' Distribution

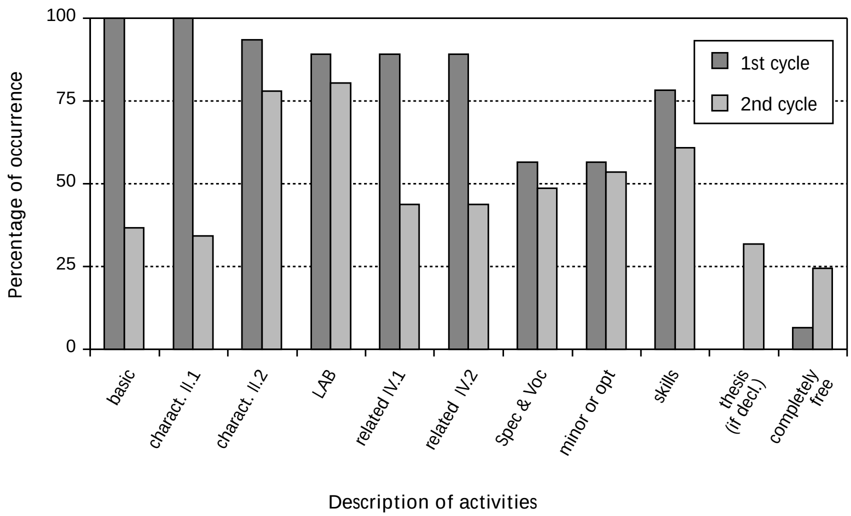

Fig. 2

Take-up Rate or Use of Different Course Units / Activities
in the Physics Curriculum (1st cycle vs 2nd cycle)

A first general remark concerns the structure of the two distributions of the credits over the typical items. While in the case of the first cycle, almost all institutions build their curricula relying on the whole set of the eleven types of teaching/learning activities, in the case of the 2nd cycle most of the institutions use only a limited amount of them. This is clearly seen from Fig. 2, where, for each activity item and for both cycles, we report the percentage of occurrence of each grid item in the curricular offer of the institutions. In the first cycle only 2.4 items per curriculum out of 11 are not used, while in the case of the 2nd cycle curricula the number of items per curriculum, which are «not used», raises to 6.5. In other words, the number of institutions that do not use the corresponding types of credits in their curricular offer is quite high. Indeed, if you do not consider the item «*completely free choice*» —a view, which may be appropriate in the 1st cycle—, we *even* conclude that 1.5 items per curriculum out of 11 are not used in the 1st cycle. Only the items «*specialized & vocational*» units and «*minor or optional*» units are used with some limitations. In the 2nd cycle, on the contrary, at least six items are used rather randomly when building the curricula; in other words, these very items are absent in more than 50 % of the institutions of the meaningful sample. As a conclusion, the curricula of the 2nd cycle may be formed by using (several) *different combinations* of «typical items». In this context, of course, the definition of the «typical items» plays a crucial role. For instance, broader definitions, which reduce their number, might favour a more homogeneous use of them across the institutions, i.e. more similar (patterns of) credit distribution. From Fig. 1 we nevertheless see that the items «*characterizing 2*» and «*specialized & vocational*» units play the most important role[6] in the distribution of the 2nd cycle credits. Since both these very items intrinsically allow a widely differentiated offer in terms of teaching contents, it is concluded that several *combinations* of *different* course activities are possible in general, when building a second cycle curriculum, even when the number of typical items is reduced. The present remarks are important when trying to define the core contents of a scientific subject area, physics in our case. The identification of the core contents seems certainly possible in the physics 1st cycle, but it becomes rather questionable at the 2nd cycle level (see also below for a more precise statement).

A second line of comments deals with the large range of variations in credit allocation encountered across the answering institutions. The average spread over all the items is 65 credits in the 1st cycle

[6] Together with «Lab activities».

and 42 credits in the 2nd cycle. The range of variation for all items is presented in Fig. 3. By a quick comparison with Fig. 1, we see that the actual variation is much larger than the average value of credits allocated to each item. This is a relevant fact by itself, even though a couple of exceedingly high variation can be explained in terms of «extreme» credit allocations by the institutions[7].

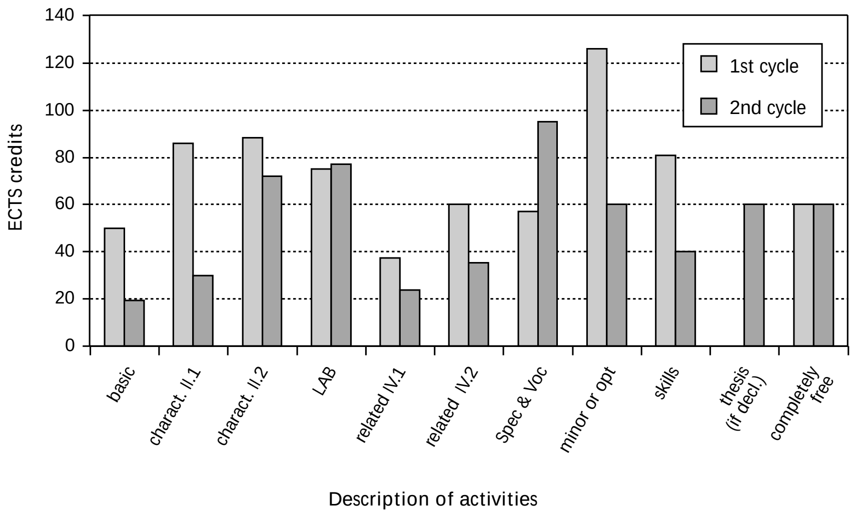

Fig. 3

The Variation of Credits over Activities (52 returns)

3. *The «core credit distribution» for Physics*

In the above general context, we can easily find the *common* core contents (see above) for each cycle, We assume that it is represented by that very credit distribution, which is common to 69 % of the sample institutions («*core credit distribution*» for short). Such distributions (1st and 2nd cycle) are shown in Fig. 4. The total number of «core credits» is 125 credits in the first cycle and 51 credits in the second cycle, i.e. respectively 65 % and 35 % of the total average length in credits of the

7 See ref. [1].

involved cycle. These latter numbers and the data of Fig. 4 quite confirm the general conclusion —already sketched above in §2— about the impossibility of identifying a core content in the 2nd cycle.

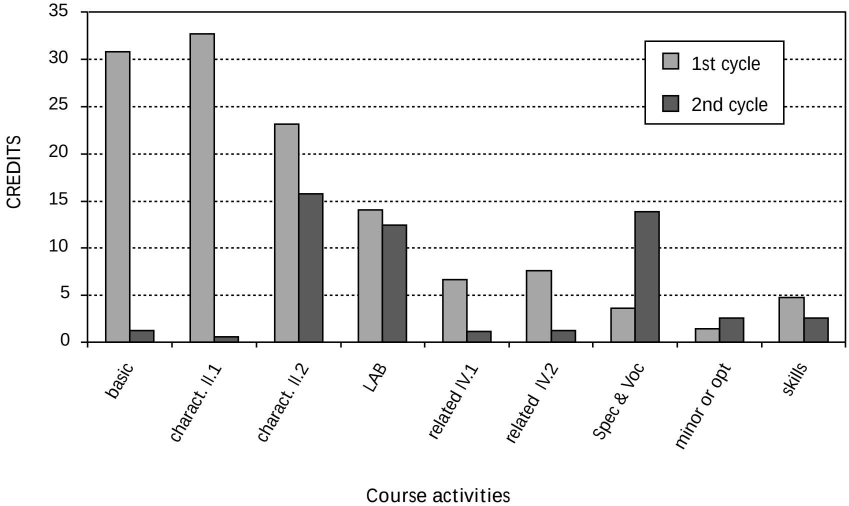

Fig. 4

Core Credit Distribution
i.e. Sahred by 69% of the sample
(1st cycle = 124.7 credits; 2nd cycle = 51 credits)

Three items only are common in this case, all of them being characterised by a wide choice of options. On the contrary, the common aspects in the 1st cycle are clearly identified and relevant with respect to the total[8].

A number of interesting comparisons can be made at this stage. For the sake of clarity, it must be reminded here that the institutions answering the EUPEN consultation can be classified according to the adopted *two-tier* pattern (in the wording of the Bologna Declaration[9]). We found the distribution given in Fig 5.

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[8] Some of the relevant totals are shown in Table II below.

[9] About the Bologna Process see —for instance— the very complete ESIB (European Student Information Board) web site http://www.esib.org/prague/

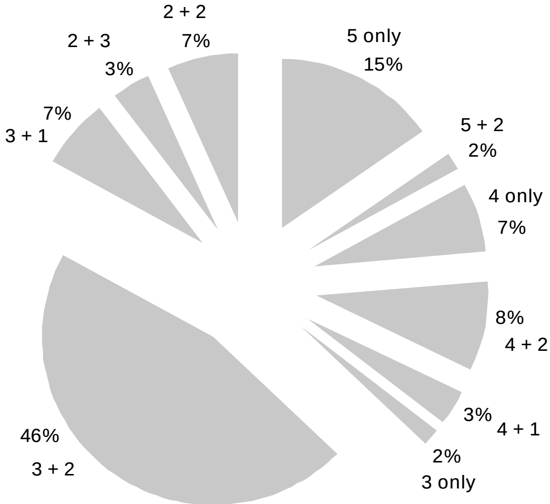

Fig. 5

Distribution of two-tier patterns
EUPEN 2001 questionnaire

The «5 only» group contains 3 Austrian and 4 German universities. The «4+X» group —where «X» stands for 0 or 1 or 2— includes institutions from 10 countries. The «3+2» group, which is the most numerous, totalling 46 % of the sample, includes 7 Italian, 6 Polish and 3 French institutions together with representatives from 9 other countries. The «3+1» group includes 3 Swedish institutions. On the basis of such a classification it is possible to correlate some of the quantities and distributions discussed here with the specific «*two-tier*» pattern.

From our data we can extract an interesting feature, concerning the range of variation per grid item of the allocated credits. If we look at systems, which are supposedly homogeneous, say the «3+2» institutions in IT or in PL; say the «5 only» institutions; etc. Indeed, in the case of the «3+2» institutions the average variation in the first cycle is much lower than the 62 credits pertaining to the whole sample (see above): it is 15 credits in IT and 16 in PL, the largest variation never exceeding 24 credits! In the «5 only» institutions the average variation is 47 credits, the largest variations being in the items *characterizing 2 (*92 credits*), specialized & vocational* (74)*, minor or optional* (78)*.*

In Fig. 6 we show the core credit distribution of the first cycle for the «3+2» group, for the whole sample and for the «4+X» group. Amazingly enough there are no great differences among the distributions, except for the fact that the «4+X» group, having an average 1st cycle total length which is longer in term of credits, can allocate more credits to the items «*characterizing 2*» and «*minor or optional*».

The totals referring to both the core and the average credits per grid item and the ratio among these two totals are more interesting. As shown in Table II, the «3+2» pattern exhibits a number of core credits which covers 75 % of the total, many more points than what shown in the other two lines for «all returns» and for the «4+X» group.

Table II

Total amount of core credits vs total average length in credits for the 1st cycle in different cycle organisations (EUPEN 2001 consultation, ref. [1])

two-tier pattern	core credits	total length average credits	core over total (%)
3 + 2	135.4	181.6	74.5
all 52 returns	124.7	190.9	65.3
4 + X	158.0	242.7	65.1

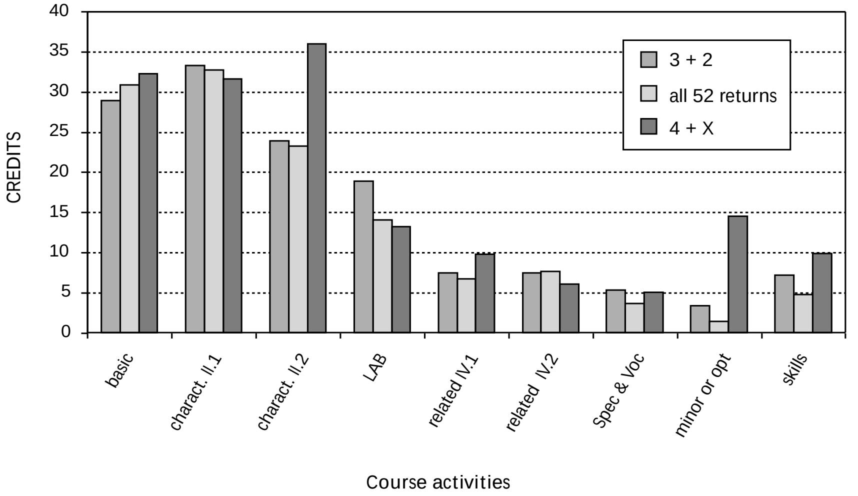

Fig. 6

Core Credit distribution on the 1st cycle in different cycle organizations

A final remark should be kept in mind when reporting the present results. The institutions of the EUPEN sample offer different types of Physics curricula, ranging from theoretical physics to applied physics and engineering physics. Nevertheless the definition of a *common core content* or —more precisely— of the *core credit distribution* can be easily and concretely applied and yields meaningful results.

Reference

[1] *Report of Working Group 2: First and Second Cycle in the Context of the Bologna Declaration* in «Inquiries into European Higher Education in Physics», Proceedings of the fifth EUPEN General Forum 2001, Koeln (DE), September 2001, edited by H. Ferdinande & E. Valcke, Volume 6, Universiteit Gent, Gent 2002.