THE IMPLEMENTATION OF BOLOGNA PROCESS INTO PHYSICS IN EUROPE: THE LEVEL MASTER.

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Abstract

The Bologna Process has transformed the face of European higher education. Many of the original objectives have made a lot of progress. Other aspects need further development throughout all fields of study. This study was carried out in 2009/10 in the framework of a project coordinated by European Physical Society, in which the corresponding author was member of the group. Survey was carried in 129 universities in 24 bologna signatory countries. The basic characteristics of programs can be described along three features: (a) the majority (77 %) is research-oriented; (b) 56 % are offering a standard Physics curriculum and 22% are either specialized or interdisciplinary (c) 97% of programs are consecutive programs. The majority of Master level programs in Physics have duration of two years. The use of ECTS is widely established. The most elusive concept is that of modularization. Considerable differences can be found among countries and programs. Master programs in Physics mostly combined with other natural sciences (64%), followed by engineering (55 %), and medical sciences (24 %). Typically student performance is assessed after each module (91 %). The most dominant criterion for access into Master programs in Physics is the grade point average from the Bachelor degree. Some degree of harmonization was found at the macro level (two-cycle structure, ECTS) but a high amount of heterogeneity at the institutional and the program level.

Keywords: Bologna Process, study programs, Master level, quality management, standardization..

1. Introduction

1.1 Description of the Project

In 2007 the European Physical Society received funding from the European Commission to carry out a study of the implementation of the two-cycle (Bachelor/ Master) study and degree structure into Physics programs in European Universities. It was envisaged to cooperate with the National Physical Societies of at least 15 European countries to collect relevant Physics curricula for in-depth analysis. Representatives of the European Physical Society acted as members of the steering group of the project as a whole. In this study the results of the second phase of the study are presented concentrating on Master level Physics programs. The aims of the project can be summarized as follows:

-Provide an overview of the state of implementation of Master structures in Physics programs in Europe; -Analyze possible regional differences in the structures; -Determine to what extent

common standards and appropriate examinations have been introduced; -Provide information about the extent of modularization that can be found in the new structures; -Assess whether professional qualifications can be obtained within the framework of Master programs in Physics; and -Determine whether Master programs offer a higher degree of specialization and, thus, diversity; Analyze interfaces and transitions, i.e. the transition from Bachelor Physics programs into Master Physics programs and the transition either into the labor market or into a doctoral qualification phase. Overall, the study aims to provide a profile of the implementation of the Master structure in European Physics programs and arrive at conclusions pertaining to the following issues:

- Assessment whether major goals of the Bologna Process have been addressed.
- Yielding the basis for advice to students interested in changing university or spending some time of study abroad.

The sample size involved in the study was approximately 60 percent of all universities offering Physics programs in the large countries and as close as possible to 100 percent of all universities offering Physics programs in the small countries.

An online questionnaire was designed covering altogether nine areas: personal details of the respondent (status and function), institutional details (type, size), implementation of the two-cycle structure, implementation of complementary measures, characteristics and structure of the curriculum, forms of student assessment and examinations, mechanisms of quality assurance, employability and acquisition of transferable skills, number of international students, completion rates and transition into a doctoral qualification phase or into the labor market.

1.2 The Bologna Process: Structures and Elements of the New Study Programs

The overall goal of the Bologna Declaration and the resulting reform process (for short: Bologna Process), namely to create a European Higher Education Area (EHEA) by the year 2010 has been described as a "target on the move" **[1]**. And indeed, with every ministerial meeting after the one in Bologna in 1999 when the original Declaration was signed by 26 European countries, goals were added to the agenda and targets refined increasingly moving from a mostly structural level to also include content related goals**. [2, 3, 4]**

By now, the Bologna Process is regarded as the biggest and most far reaching reform of curricula and study structures since possibly the period after World War II. In addition to ever more countries joining the reform, stakeholder inclusion was extended as well. Starting as an intergovernmental initiative of ministers responsible for education, deliberations, follow-up and stocktaking now include the European Commission, the European University Association (EUA), the European Student Union (ESU), and a number of other actors. Despite the growing complexity of the reform agenda, there are a few core issues which can be said to have constituted the main targets for 2010:

Adoption of a system essentially based on two main cycles, undergraduate and graduate; **[5]** -Establishment of a system of credits to promote student mobility; **[5] -**Promotion of mobility of students, teachers, researchers and administrative staff; **[5]-**Promotion of European cooperation in quality assurance to develop comparable criteria and methodologies; **[3, 5] -**Promotion of the necessary European dimensions in higher; **[5] -**To promote the attractiveness of the European Higher Education Area to students from Europe and other parts of the world; **[6] -**Establishment of a link between the Bologna reforms and the Lisbon Strategy to create a European Research Area; **[3] -**Adoption of an overall framework for qualifications comprising three cycles. **[7]**

There are a few subject specific analyses available as a recently published study on the choice of study options after the Bologna reforms in Political Sciences in Germany and Switzerland **[8]** and a larger study commissioned by the European Commission in order to gain insight into curriculum reform development in five study areas: medicine, law, engineering, teacher training and history in 32 European countries **[9]** Concerning Physics, we find the results of the Tuning Project **[10]** for Physics providing a template for how it should be done.
This study is a first attempt of a comprehensive and comparative analysis of Master Physics education at universities in 26 Bologna signatory countries: Albania, Austria, Belarus, Belgium, Croatia, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Lithuania, Macedonia, Netherlands, Poland, Portugal, Slovenia, Slovakia, Spain, Sweden, Switzerland, Ukraine, UK.

1.3 Sample Size, Responses, Specificities of the Curriculum Analysis

There are altogether 935 universities in the 26 countries involved in the study of which 362 (39 %) offer Physics programs. Total number of Master Programs was 371. The high number of Master level Physics programs can be explained by the fact that each specialization constitutes a separate program of study. Furthermore, it is widely known that the number of Master level programs in many European countries and in many subjects is higher than the number of Bachelor level programs. Altogether 90 percent are universities and 10 percent are technical universities. More than half of the respondents are working in universities with a relatively broad spectrum of subjects (Natural Sciences: 98 %, Engineering: 62%, Humanities: 70%, Social Sciences: 71%, Law: 61%, Medicine: 55 %).

2. The Bologna Process and Physics Programs

A notoriously difficult issue for the analysis of curricula was that we had to make a distinction between Physics programs and Physics curricula. The result is a considerable heterogeneity. Concerning the character of the Physics programs we find that approximately 12 percent are called “integrated” Master programs In the UK, Finland, Poland and Sweden integrated Master programs are consecutive programs culminating in a Master Physics degree designated as MPhys (Master in Physics) or MSci (Master in Science). The typical duration is four to five years. Figure 1 shows a threefold classification of Physics Master Program which can be found most commonly across Europe.
The first classification is the distinction between research-oriented and professionally-oriented programs. More than three quarters (77 %) of the programs included in the survey are of the former type and 23 percent are of the latter type. Professionally-oriented Master programs in Physics are found at both universities and technical universities and typically are combined with engineering or entrepreneurship, economics, or business administration. Thus they have a more applied character. In the UK, the research- and professionally-oriented programs can not be separated accurately. In France, 25 percent of the Physics Master programs are

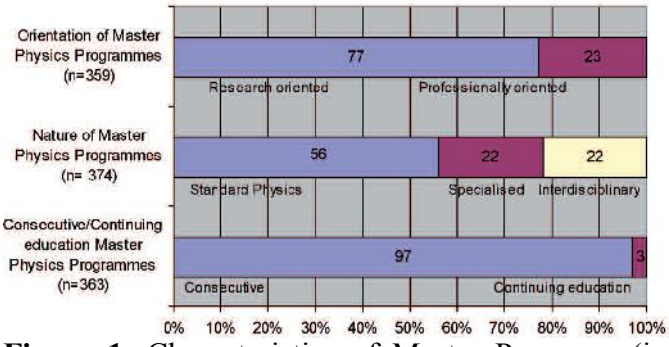

Figure 1: Characteristics of Master Programs (in percent) Threefold classification of Physics Master Program which can be found most commonly across Europe

both research- and professionally-oriented. The difference between the two types is only the training part: training in labs (for research-oriented programs) and in companies (for professionally-oriented programs). In the future this distinction is expected to be given up**.[11]**
The second classification distinguishes between standard, specialized, and interdisciplinary Physics programs. While the majority of programs in the survey have a profile of being 'straight' or 'pure' Physics (56 %), there is also a considerably proportion of specialized and interdisciplinary programs (22 % each). The final classification is distinguishing between consecutive Master programs (i.e. into which Bachelor graduates can enter directly after completion of the first cycle) and continuing education provisions at the Master level in Physics geared towards professional development, sometimes offered in part-time study mode or in form of evening and weekend classes. Special continuing education offers at the Master level in Physics comprise only a very small proportion (3 %) in our sample.

3. Results of the Curriculum Analysis and the Survey

3.1 Duration of Master Programs in Physics

The majority of Master level programs in Physics have duration of two years in continental Europe and in the Nordic countries. In the UK/IE 54 percent of the program have a duration of one or two years (1 year: 47 %; 2 years: 7 %) and 46 percent a duration of four to five years.

3.2 Use of Credit Points, Workload, Modularization

The use of ECTS is now widely established. Typically for the second cycle Master Programs 120 ECTS credit points are required which is equivalent to duration of two years. UK/Ireland, Lithuania and Belarus are exceptions. In the UK the UK CATS (credit accumulation and transfer system) is more common, where one academic year of full-time studies is equivalent to 120 CATS. In Lithuania one academic year of full-time studies corresponds to 40 national credit points. In Belarus no credit system has been introduced yet.
In the majority of programs (92 %) credit points are calculated on the basis of contact hours plus independent study, but in some institutions (the Czech Republic, Poland and Switzerland) credit points are calculated on the basis of contact hours exclusively. In 69 percent of universities in their Master Physics programs 25 to 30 hours are required to earn one credit point. Exceptions are universities in UK and Ireland which use different credit systems: 67 percent stated that in their Master Physics programs 10 hours are required to earn one UK CATS credit point. Another 20 percent stated a workload of 15 to 20 hours and 13 percent a workload of 25 to 30 hours
Modularization is another one of the Bologna reform concepts which is rather elusive. In about two thirds of all Physics departments or faculties included in our survey (67 %) of all programs are modularized, in four percent some programs are modularized and in 29 percent programs are not modularized. This, however, is not uniform within countries. Only two countries (Belarus and Slovenia) answered that none of their programs are modularized, while five countries stated that all of their programs are modularized (Denmark, Germany, Macedonia, Netherlands and Ukraine). In the other countries some programs are modularized and others are not.
The tricky question here is what time unit constitutes a module. The majority stated that a module typically consists of different teaching formats (lectures, exercises, seminars etc.) and is completed by an examination or another form of assessment. While the assessment normally refers to the whole module we also found exceptional cases in which every course within a given

module is assessed independently or in which there is a midterm and a final examination pertaining to the module. The following classification provides an overview:

- In many of the countries included in the study modules tend to be rather small (between 1 and 6 ECTS). Bigger modules are used in relationship to practical phases (e.g. in Italy nine credit points for training, in France 12 credit points for training).
- In some countries (e.g. Austria, Netherlands, Belgium and Switzerland) classes or courses have been put together into larger study blocks. These study blocks are sometimes called modules or even a whole specialization, like "Medical Physics". This differs from the German and UK understanding of modules which are composed of two or more courses (lectures, seminars, etc.) or classes which are linked through content.

3.3 Specialization and Interdisciplinary

More than half (56 %) of the Master Physics programs have been characterized as standard Physics Programs. 22 % were characterized as specialized programs and 22 % as interdisciplinary programs (Engineering Physics included here) (see Figure 1 above). The interdisciplinary programs can, however, be combined with a variety of other subjects. Physics can be combined first and foremost with other natural sciences (64 %), followed by engineering sciences (55 %), medical sciences (24 %), but also with economics (12 %), social sciences (7 %), and humanities (2%). 19 % of the respondents stated that their Physics program can be combined with yet another area of study.

With regard to second cycle programs we were able to identify five main models of specialization:

- Master Physics programs with one or more specializations which are added to a general Physics part or are offered parallel to it;
- Master Physics programs with a variety of independent specialization curricula from the beginning;
- Specializations are independent programs with their own degrees and titles. e.g. Astrophysics program, Geophysics program, Meteorology, Climate Physics etc. (Germany, Slovakia).
- Master Physics programs are differentiated into research-oriented programs, interdisciplinary programs, and teacher training programs. Examples can be found in Belgium, the Netherlands, and the UK.
- France as a special case: separate curricula for the first and the second year of Master-level studies. If specializations are offered in the second year the program has four curricula, one for the joint first year and three for the specializations [11].

Apart from the distinction between research-oriented (77 % of the programs) and professionally-oriented programs (23 % of programs) another form of specialization is the distinction between consecutive programs (being studied immediately after the Bachelor degree) and continuing education programs (being studied after some time of professional experience outside the university). The vast majority of the programs included in our survey (97 %) have been characterized as consecutive programs and only three percent as continuing education programs (see Figure 1 above).

3.4 Mobility and Internationalization

In the Tuning Project 2007 the importance of mobility is highlighted as follows: *"An important aspect of the Physics community is its international character, in both research and education,*

which suggests the need for Physics students to be mobile during their learning path, almost compulsory in the final cycle. Attending examinations, carrying out placements, enjoying research activity during project work or while preparing a Master thesis or doctoral dissertation, all these activities at a host university add true value to the achievement of the physicist's competencies and skills" **[10].**

Concerning mobility and internationalization of Master programs in Physics was looked at four dimensions: first, the proportion of double and joint degree programs which typically have an integrated period of study abroad; second, the international composition of the student body; third, mobility of own students; and fourth, teaching in a foreign language.

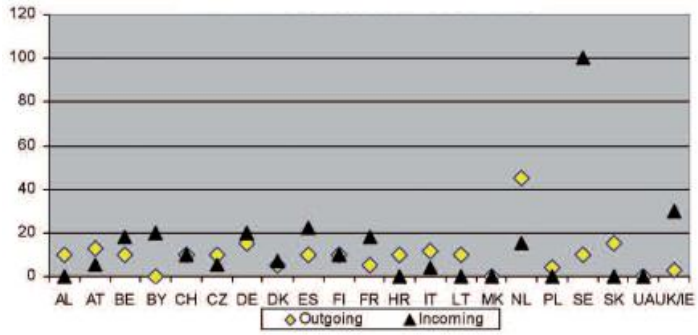

Figure 2: Incoming and Outgoing Students

Eight percent stated that there is a double-degree program offered in Physics and three percent stated that there is a joint-degree program, 14 percent stated that study abroad was part of the curriculum of some programs, and eight percent said that study abroad was part of all Physics curricula at the Master level, altogether is a total of 33 percent of respondents who stated that mobility is a required part of the curriculum.

Countries in which all respondents (100 %) stated that study abroad was not part of the curriculum are: Albania, Austria, Belarus, Croatia, Finland, Hungary, Macedonia, Poland, Slovenia, Switzerland, and Ukraine. High levels of responses that study abroad was part of all Physics Master curricula came from the Netherlands (50 %), from Belgium, Denmark, France, Lithuania, and Sweden (33 % each). Concerning the international composition of the student body in second-cycle Master Physics programs high proportions of international students were: in Spain (22%), in Germany (20 %), in Sweden (100 %), and in the UK and Ireland (30 %) (Figure 2). So the Master programs were opened to international students to get them started. High percentages of mobile students from the own institution for second-cycle Master programs can be found in Germany, the Slovakia and the Netherlands (see Figure 2). We were also interested in the typical time windows for mobility, i.e. in what phase of their studies do students normally go abroad. Then 57 percent of the respondents stated that mobility is envisaged in the first year of the Master program and 34 percent said that it was envisaged for the second year. Still, 37 percent stated that the time window for mobility was between the Bachelor and the Master phase of studies

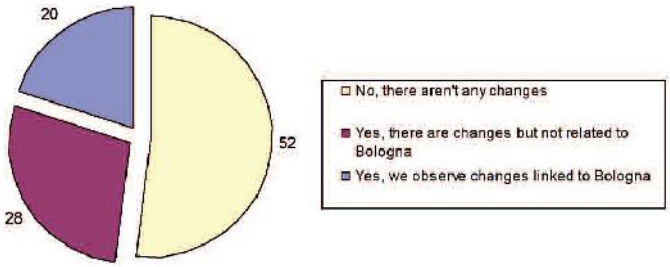

Figure 3: Changes in Student Mobility (percent by university)

In many continental European countries, however, the new study structures have been implemented with more rigidity in the content and the amount of course work. This has led to criticism that time windows for mobility were being reduced. Almost half of our respondents to

our survey (48 %) stated, that they observed changes in the mobility patterns at their institutions in recent years. Among these, only 20 percent stated that they see these changes linked to the Bologna Process though (see Figure 3). However compared to the traditional programs the majority of respondents stated that in their Master Physics programs incoming as well as outgoing mobility is higher compared to traditional programs (see Figure 3). The fourth dimension to cover various aspects of internationalization is teaching in a foreign language. 41 percent of the programs included in our survey offered teaching in a foreign language. But 100 percent of the respondents from the following countries stated that teaching is taking place in a foreign language Austria, Croatia, Denmark, Finland, the Netherlands, Slovakia, Slovenia, Sweden, and Switzerland. Altogether 50 percent of the respondents stated that they don't observe any changes regarding teaching in a foreign language, 32 percent said that teaching in a foreign language increased but was not related to the Bologna Process, and only 18 percent saw a link between an increase in teaching Physics in a foreign language and the Bologna Process. The majority of respondents stated that teaching is offered in English (71 %), followed by German (17 %), French (14 %), Spanish and Italian (7 % each).

3.5 Assessment, Examinations, and the Concept of Learning Outcomes

Assessment of student performance shows a wide variety of forms reaching from written tests (93 %) to oral examinations (79 %), project presentations (77 %), and homework papers (67 %). Less frequent but used as well are multiple choice questions (23 %), interview with the teacher (21 %), and other forms of assessment (14 %) (Table 1).

Table 1. Assessment types in percent of multiple replies

	%
Written tests	93
Multiple choice questions	23
Homework papers	67
Interview with teacher	21
Oral examination	79
Project presentation	77
Other forms of assessment	14

Typically student performance is assessed after each module or unit of teaching and learning (91 %). When asked if they asses subject knowledge only or also transferable skills, 44 percent of the respondents said that only subject knowledge is examined and 56 percent stated that subject knowledge as well as transferable skills are included in the assessment.

In the assessment almost 90 percent of respondents use absolute marking, i.e. the degree of fulfillment of established criteria, while relative marking (performance of a student in relation to the group of fellow students) is used by 11 percent of our respondents. Still, 20 percent just use pass or fail and 16 percent mark the individually acquired knowledge and competences during a module or class (Table 2).

Table 2. Types of marking in percent of multiple reply question

	%
Just pass/fail/passed with distinction or honours	20
Relative marking (performance of individual student in relation to group)	11
Absolute marking (degree of fulfilment of established criteria)	89
Individually acquired knowledge/competencies during a module/class	16
Other forms	3

75 percent of our respondents also stated that student performance during the program is included into the calculation of the final mark or the final classification for the degree. Only 25 percent of the respondents stated that this is not the case. Countries in which the latter frequently occurs are predominantly located in the central and eastern European region. This indicates that in these countries the examination system is still rather traditional, taking into account only the performance of the student during a final written or oral test.

As the final examination for the award of a Master degree in Physics still plays an important role in basically all countries, we asked what types of assessment are used in the process. About two thirds of the respondents stated that it is a thesis plus defense, however, a quarter each also included an oral examination and project presentations.

3.6 Employability, Key or Transferable Skills

The issue of employability and transmission of key skills is closely related with the demand to prepare more highly qualified students for nonacademic jobs. The Physics validation Panel mentions the fact that because of the high importance of mathematical and experimental skills, students in Physics develop generic competences *"which endow the graduates with a flexible mind, able to approach and model increasingly complex systems, even outside the realm of the physical world"* **[10, p. 21].**

Typically the generic or transferable skills which students of Physics acquire in their programs include problem solving, communication, presentation, creativity and originality.

The reply to the question of any cooperation with employers in the design and development of Master level curricula in Physics 46 percent of our respondents stated that cooperation with employers was sought for all the Physics program, 17 percent stated that this was the case for some of the curricula and 37 percent said that this was not the case. High proportions of respondents who stated that they did not cooperate with employers can be found in the Netherlands (100 %), Belgium (67 %), Hungary (60 %), Germany (57 %), and Sweden (50 %)

An interesting distinction turned up in this complex of questions, namely that between universities and technical universities. Indeed, 71 percent of the respondents from universities stated that the acquisition of transferable skills is part of their Master curriculum in Physics; eight percent stated that this was the case for some of the curricula and 22 percent said that transferable skills were not part of their curriculum. The figures for technical Universities show a different trend: i.e. 90 percent of the respondents from technical universities stated that transferable skills were part of their Physics curricula in all programs and only 10 percent stated that this was not the case.

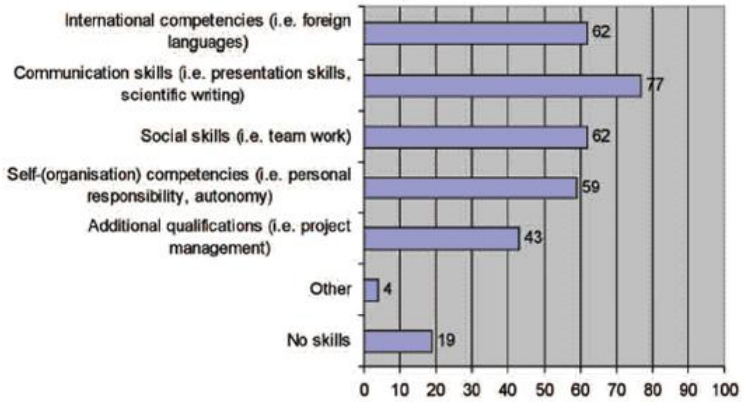

Figure 4. Preferences of transferable skills that were part of the Physics curriculum (multiple replies were possible)

Preferences of transferable skills that were part of the Physics curriculum are shown in Figure 4 The highest proportion being received for communication skills (77 %), followed by social skills (62 %) and international competences (62 %), self organization competences (59 %) and additional qualifications like project management (43 %) Mostly the acquisition of transferable skills is integrated into the Physics curricula (61 %) but some respondents also stated that there is a mixture of integration and provision in separate special courses (32 %).

While respondents from technical university mostly did not see any changes in the provision of transferable skills, those that did see them did not relate them to the Bologna Process. This is a

bit different for universities: 60 percent of the respondents saw a rise in the acquisition of transferable skills and 23 percent linked this to the Bologna Process.

3.7 Transitions

Master programs are framed by two transition phases. The first stage is the selection and admission onto the program, the second stage is the transition into the labor market or onto a doctoral program. This is essentially the continental European model. The students enter Masters Programs following completion of their Bachelor degrees and on completion; they either enter the job market or progress to doctoral studies. With regard to second-cycle programs, about two thirds of our respondents stated that there are special requirements for access, namely the grade point average from the Bachelor degree (63 %), an interview (34 %), a written test (6 %) and various other requirements (32 %)

Typically the curricula state for most of the Master Physics programs analyzed that they prepare for research careers as well as for professional careers in the non-academic labor markets.

Interestingly, when comparing transition rates of Master Graduates and of traditional graduates into the labor market, the figures are quite similar, while the comparison of transition rates of Master graduates and of traditional graduates into a doctoral program shows a more varied picture (see Figure 5). There were observed differences between 30 percent of Physics graduates (in Slovakia) and of almost 100 percent (in the Netherlands) going into the labor market

4. Conclusions: Physics Studies in Europe Today. The Master Level

With regard to the general picture of the implementation of Bologna Process into Physics studies in Europe at the Master level we can summarized our findings as follows.

1. There is some degree of harmonization at the macro level (two-cycle structure, ECTS) but a high amount of heterogeneity at the institutional and the program level.
2. The number of Master level programs has multiplied.
3. The majority of new second-cycle programs have duration of two years (after a three-year Bachelor program).
4. The use of ECTS is widely established. The calculation is frequently based on student workload
5. Modularization continues to be elusive concept despite of efforts to understand it..
6. We found a relatively high number of examples of integrated mobility (33 percent). Optional mobility is included in an even higher proportion of programs.
7. Assessment of student performance varies widely but performance of the student throughout the course of study is increasingly included in the final grade (75 %).
8. Transferable skills to prepare for entrance into the labor market have a high importance. Communication skills, international competencies, and social skills were given the highest importance.
9. Master level Physics programs prepare for both an academic or research career and a professional career in the non-academic labor market.

5. Acknowledgements

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