ENGINEERING EDUCATION IN THIS NEW MODEL OF EUROPEAN DEVELOPMENT

Chairperson: Liam Hodnett, Cork Institute of Technology
Contributor: Sebastião Feyo de Azevedo, University of Porto and Engineers Portugal

Biographical Note

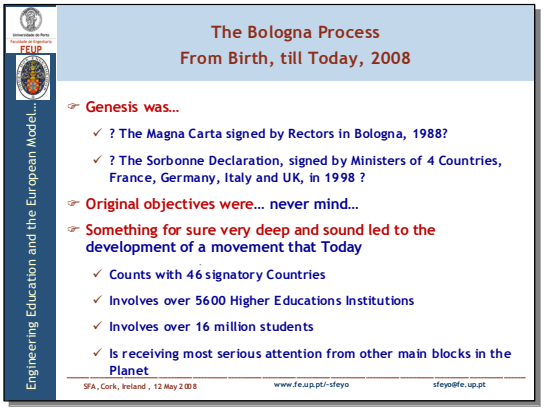
Sebastião Feyo de Azevedo was born in Porto, Portugal, in 1951. He holds a PhD in Chemical Engineering from the University of Wales (Swansea, UK, 1982) and the Habilitation Degree in Chemical Engineering, from the University of Porto (1996). He has been Professor of Chemical Engineering at the Department of Chemical Engineering, Faculty of Engineering, University of Porto (FEUP) since 1998 and currently his research is associated with LEPAE – Laboratory for Process, Environmental and Energy Engineering, a research unit of the same school. His main areas of interest are: process systems engineering; instrumentation and control; higher education – Bologna Process; and chemical engineering education. His current main functions are: Head of Department, Chemical Engineering, FEUP; National Vice-President of Ordem dos Engenheiros – Engineers Portugal; Portuguese Delegate to the BFUG-Bologna Follow-Up Group, by appointment of the Minister of Science, Technology and Higher Education; Chairman of the Working Party on Education – European Federation of Chemical Engineering; Representative of Engineers Portugal in ENAEE-European Network for Accreditation of Engineering Education. He is a Fellow of Ordem dos Engenheiros (Engineers Portugal), a member of the Portuguese Academy of Engineering, a founder member of the Portuguese Association for Automatic Control (APCA) and a member of several other Associations.

For detailed information, please see www.fe.up.pt/~sfeyo.

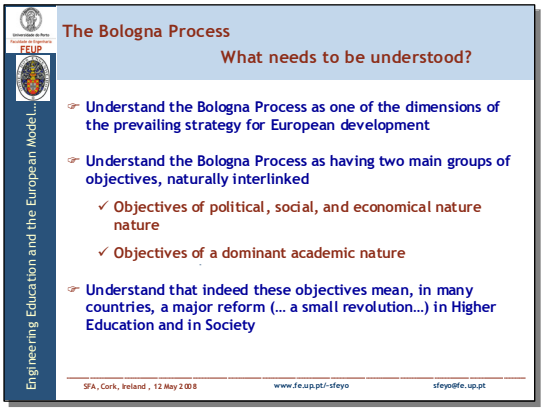
I am not sure if you Irish are aware of how much you are seen from the outside world of Ireland as an example in several ways. As we say in Portugal, *'the Irish miracle in terms of the economy'* and I keep saying that perhaps the reason behind this miracle is that you are extremely advanced in education and you are indeed in the driver's seat – you are not being transported in this Bologna Process. You are in the front of the process, you are living it, you are giving the example, and you have the National Qualifications Framework. You have, and I know well the example of Engineers Ireland, an accreditation system, and a very interesting and robust system on accreditation. Maybe that is the reason why eventually you achieved the economic miracle?

What I am going to do today is to go through a number of issues. I am very keen on the Bologna Process. A number of years ago I wrote my first paper about the Bologna Process – it was something like *Notes on the Bologna Process – an unmissable occasion for reform of the Portuguese system*. There are a number of reasons why I think that about the Bologna Process. I want to start by saying a few things about the Bologna Process within the European context and what I see as the historical significance of the Process. I like history! I will talk on what I see, historically, as the current European strategy for development, and later I will go through a number of issues which have to do with academic structures, and the Directive for Recognition of Professional Qualifications, which is a major document. I will then discuss qualification frameworks, quality assurance and a few ideas about paradigm

shifts in engineering education. I am not sure if I have the time to do all that but we shall see as we go along. Of course, I hope maybe one day to be giving lectures about all these topics!



It does not matter much when it started, whether it was with the Sorbonne Declaration (I do not think it was) or, as I think it was, with the rectors of European institutions many years before. In fact it was in Bologna when they signed the Magna Carta of universities that all this started. It must be something very deep and very sound to produce a movement that today can count 46 countries involving more than 5,000 higher education institutions and more than 16 million students. It cannot be just a political arrangement. It is something much wider and much stronger.



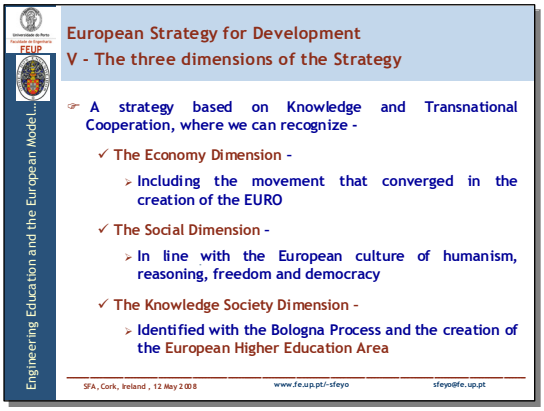
I believe we have to understand three things about the Bologna Process. We have to understand first of all, that it is simply one of the dimensions of the prevailing strategy for European development, albeit a very important one. Secondly we have to be able to see two main types of objectives. We have this list of ten action lines in Bologna – the ECTS, the quality assurance, etc. However, essentially we have two main types of objectives. One is of the more political, social and economic nature, and the other set of objectives, which are of a more dominant academic nature. Finally we have to understand that these objectives, in many of the 46 countries which are signatories to the agreement, are leading to a major reform, not only in higher education, but also in society.

There are reasons for this. If we follow history and developments in the world and in Europe, it is very simple to see that firstly the progress is in science and technology, particularly in communications. The human being has a short memory. Not so long ago we had nothing like the internet. Then, secondly, in health and life sciences, which has led to the situation in western society at least, that life expectancy has increased and this brings a lot of problems such as social security sustainability, etc. For sure you will have to work for many more years, and that is where lifelong learning is obviously an issue. Then we have all these political changes that

took place in Europe, as you are all aware, which are symbolised by the fall of the Berlin wall in 1989. And of course, we are living in a very demanding society – a free, democratic and demanding society. We have an expectation of education for all, and we have quality requirements – we live in a comfort society nowadays, and this has requirements which we have to face and which brings consequences.

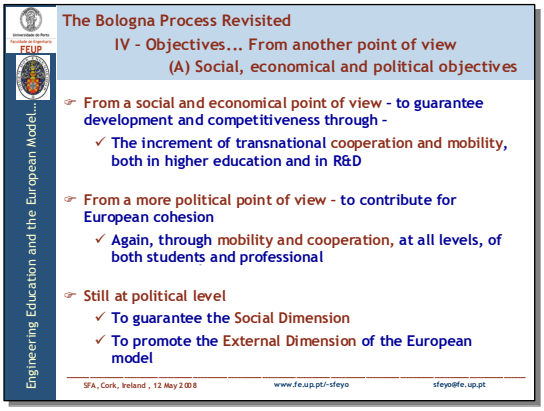
Because of all that, today, whether we like it or not, we live in an open market economy society. We live in an era of globalisation. Computers and communications have made really dramatic changes in concepts of time and space. There is a sharp increase in standards and competition. It is not only in our house, in our street, in our country, in Europe, it is worldwide. This means two important things we should not forget. There are significant changes in the concept of individual career management. The concepts that graduate students of today have are nothing to do with the concepts I had when I was, say, 29. And of course, the job markets and opportunities are also wider now.

This I believe has led, at the political level, to the European Council of Heads of State in 2000, where for the first time the Europeans placed themselves in a competitive position relative to the other power blocs on the planet. Somehow the Portuguese managed this trick – so both these Declarations were made in Lisbon and Lisbon is mentioned twice in this regard.

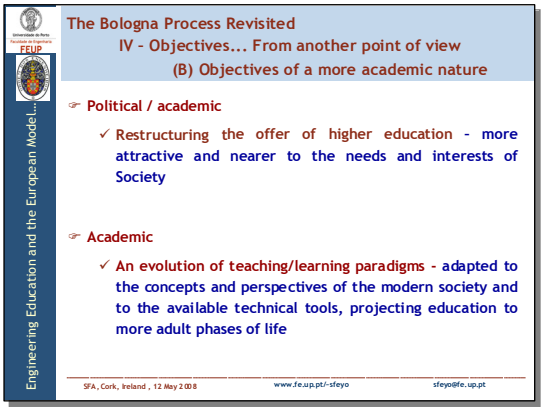


There are three dimensions to the strategy. One is the economy dimension that led to the euro – and the second is the social dimension. I always stress that despite the wars in the Balkans, despite all the difficulties, Europe is still an example of humanism, reason, freedom and democracy, and we still care a lot for that. The third is of course the knowledge dimension which is much wider than the European Union but it is clearly led by the European Union. We want to build an area of knowledge where education and research are placed together and where lifelong learning plays a measurable part.

Now from this point of view I see two major types of objective. These I call social, economical and political objectives, where the key words are cooperation and mobility, for guaranteeing development and competitiveness. From a political point of view it is a question of contributing to European cohesion and there are a number of issues concerning internal social dimensions and the ability to compete, to have a global dimension and to attract people into Europe.



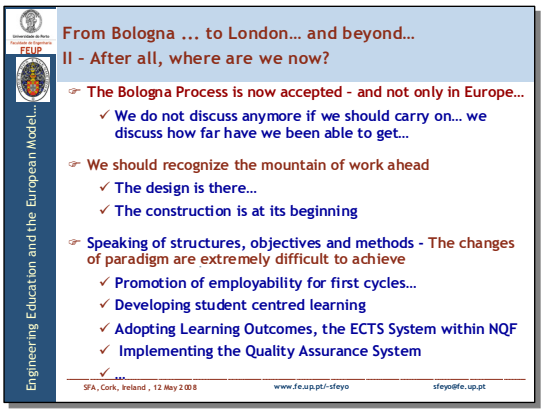
From a more academic point of view there are two main issues. First of all there is our obligation – the politicians, the government and we that work in the places where some decisions are taken – to put forward to young people a new offer of education that better serves their needs and the needs of society as a whole. Secondly, we must go for the difficult bit – that's an evolution on the teaching and learning paradigm – to adapt to the concepts and perspectives of modern societies and adapt of course to the techniques, to the tools that are available today and that were not before. That is why I say the Magna Carta, signed in 1988 by the rectors, was already pointing to the future direction.



What has happened after all these years and after the London communiqué in 2007? Let us start by looking at mobility. I am not saying it was a flop, but it was well behind what was expected in terms of mobility of students, but also in terms of mobility of staff and researchers, particularly that of staff. Staff mobility is almost zero for a number of reasons – among them because the social systems in Europe are not harmonised, so people cannot go away easily.

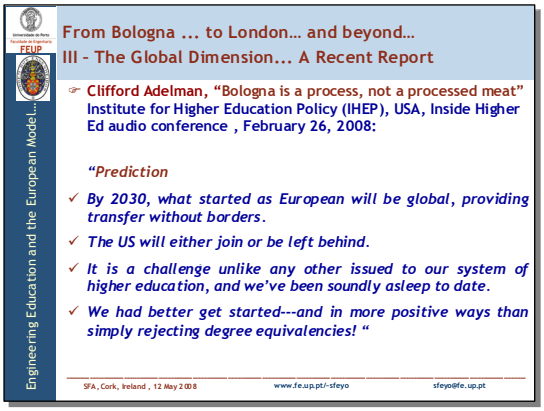
You have all these issues surrounding the Bologna Process: the degree system, teaching and learning, quality assurance, qualifications framework, recognition of degrees and lifelong learning. This is the core of the Process. And then you have the social dimension: the question of the employability of first cycle graduates and, as I mentioned previously, the global dimension. This was all at the centre of attention for ministers in 2007 and this is all embedded in the programme for 2007-2009 that we are running now.

What is the situation today? The situation is simply this, I am positive that the Process is now accepted. We do not discuss any more whether it should be or should not be carried out. We discuss how it is and how it is going. That is an important change of attitude and we recognise that this is really only the beginning. To quote Sir Winston Churchill, the words may not be exactly these: *"this is not the end, not even the beginning of the end. It is, at most, the end of the beginning"*, and in fact the design is there, the construction is at its beginning.



There are things which are difficult to achieve. The promotion of employability for first cycles. It is a big discussion and I will come to that later. Student-centred learning is very difficult to speak about and very difficult to do. Adopting learning outcomes, the ECTS systems within the national qualifications frameworks, and the quality assurance system – these are not so difficult from my point of view. What is difficult is the development of student-centred learning and the issue of employability for first cycle graduates. Adopting learning outcomes and implementing quality assurance systems are difficult but are on the second level from my point of view.

But let me tell you this: I just came across a month ago, a very interesting report from a high-ranked official from the Institution for Higher Education Policy in the USA. He was giving a talk analysing the Bologna Process, and among the many things he said, if I understood him correctly, was: *"By 2030* (and this was a justification for his conclusions), *what started as European Union will be global and it will be without borders, and then the US will either join or be left behind. It is a challenge like any other issue to our system of higher education, and we have been soundly asleep to date and we had better get started!"*



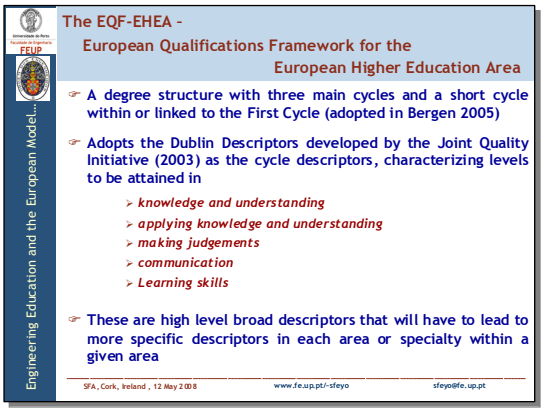
So I believe the Bologna Process is now impacting elsewhere. In Australia it is receiving a lot of attention. In the States, they are thinking very seriously about this, so it is not the situation that we have a system that is not recognised elsewhere – no, in contrast, elsewhere they are thinking that they should maybe adapt. It takes time of course.

The name of the game for me is in these four words: mobility, cooperation, trust and accreditation. Mobility and cooperation are fundamental for European cohesion and transnational cooperation. That requires trust. For that we need quality assurance. That is a kind of a syllogism. Of course, all this is achieved through comparable qualification frameworks, and through recognised quality assurance procedures.

Let me come now to the question of the academic degree structures and the Directive for the Recognition of Professional Qualifications. There are three major documents on this issue. Two of them are similar, competitive documents, i.e. the *Qualification Framework for the European Higher Education Area*, adopted in Bergen within the Bologna Process, and the *European Union European Qualifications Framework for Lifelong Learning (EQF-LLL)*.

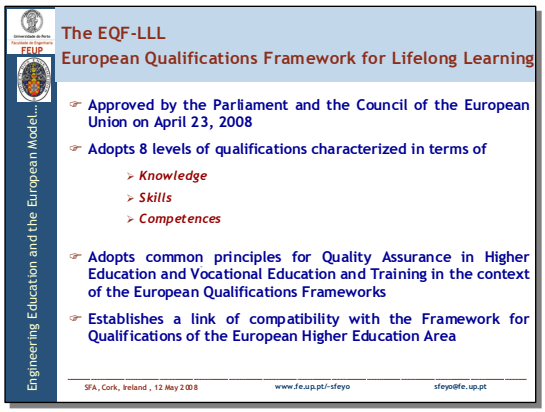
The first document is only concerned with higher education and it states that there should be three main cycles with a short cycle that should be within or linked to the first cycle. The second is a whole set of standards or levels that go from primary to secondary type education and then to the higher education level. There is a lack of comfort on this issue of two frameworks, but there is a compatibility. I have been studying them and I think it is not too difficult to see the compatibility between what each document proposes and what has been adopted.

The other document that is important is this Directive for Recognition which was approved in September 2005, and should have been adopted into national laws in all Member States within two years. In a few countries such as Portugal it is not yet adopted officially although it is already described in legal terms.

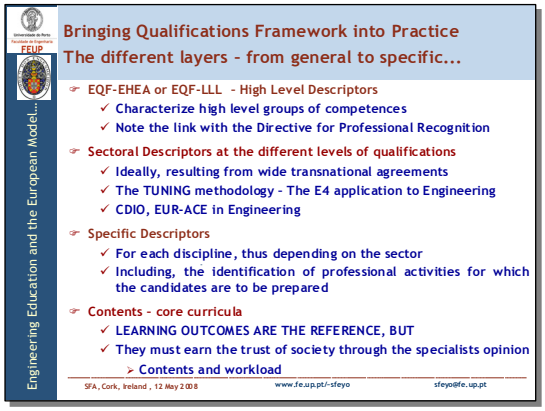


The *European Qualifications Framework for the European Higher Education Area* adopts these three main cycles, where they are described through classes of descriptors: knowledge and understanding, applying knowledge, making judgements, communication and learning skills.

Then you have this other competitive framework, EQF-LLL, where really there are now eight levels of qualification which are characterised in terms of three main descriptors: knowledge, skills and competences. Perhaps they got that idea from Ireland? It adopts common principles for quality assurance in higher education and vocational training in this European qualification work. It establishes a link for compatibility within the framework of the Bologna Process.



What is relevant here? For me a major issue is the qualifications framework. This is the top layer of four layers. At the second and third levels, we have the sectoral descriptors. It is very much encouraged by the European Union that European countries try to go transversal and try to describe some common criteria for each sector. That is where EUR-ACE was born. This is the concept behind EUR-ACE: to put people from different countries together and to bring criteria in a certain area, in this case engineering, together. Engineers Ireland was there and played a major role, and the Portuguese Ordem dos Engenheiros – Engineers Portugal we call ourselves now – was also there. And then there is another layer. Within each sector you may have certain domains – you have chemical engineering, civil engineering and mechanical engineering, which have some individual specificities. So we need to fine tune the descriptors to adapt the list of domains.

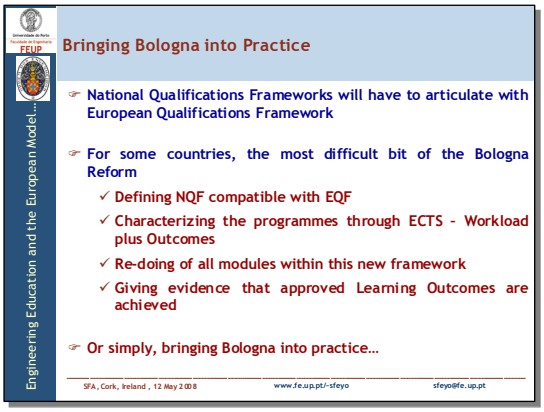


But that is not enough. It is very nice to speak about learning outcomes. It is very nice to speak about these types of products. But at the end of the day, you must give credibility to these sentences by also putting some context on it. It is not just to shift and change – we have had to do this before in universities. We did not speak out much. We thought, if we teach this subject they will be able to do that. Now it is the other way around. We think about what graduates have to be able to do in the end, but we cannot leave it like that. We need to go to the contents of the curriculum and we need to have some core contents to give credibility to it. This is my fourth layer.

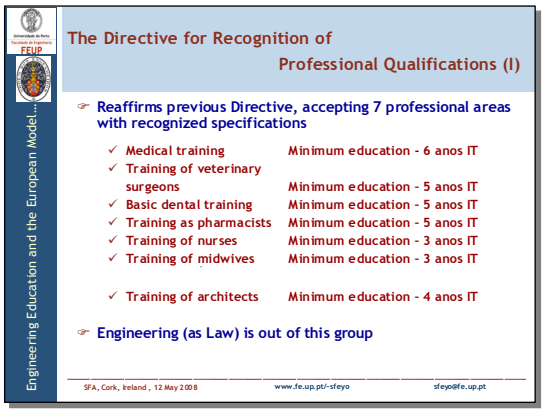
I work on the working party of education at the European Federation of Chemical Engineering. Brian Glennon from the University of Dublin is there with us, and we have approved, after many days of discussion, what we call core recommendations for minimum curricula. Let me give you an example. Of the 180 ECTS for the first cycle, we suggest about 110-120 – we leave a lot of room for further things. As our colleague Martin Pitt, from Sheffield University, with his British humour, said in more or less these words: "*Oh, it is very nice that they know all these kinds of skills. But it would not be bad if they could know something about chemical engineering, you know! It would be useful...*".

So really we need to say: OK, you want to tell me that this guy {graduate}, after this degree, is able to design a bioreactor or fermenter. That is very nice. Then I, as a professor, ask: how many ECTS do you have for this subject? He answers: I have only three ECTS. The professor says: then I do not think you are able to do that. Because I have experience and I think there is a minimum of curriculum, and of content that should be linked to the curriculum.

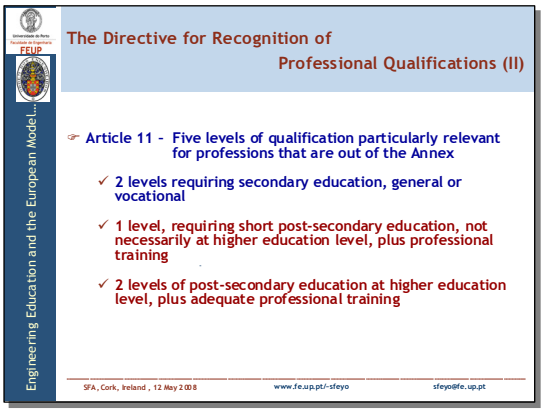
Thus to bring Bologna into practice to a large extent is to have a sound qualifications framework, to redesign all modules within the new framework and to give evidence that the approved learning outcomes are achieved – not decrees about structure and other related issues. That is not the key issue.



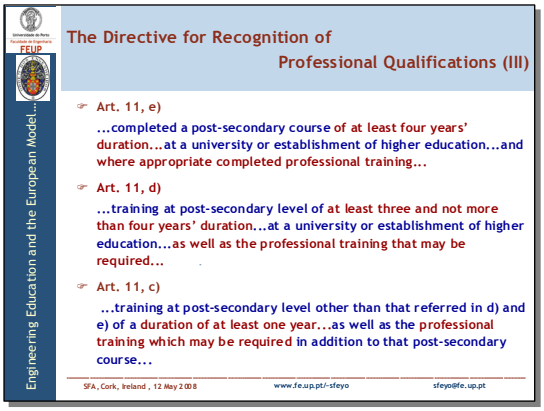
Let me tell you about the Directive for the Recognition of Professional Qualifications. There was a big discussion in Europe back in 2003 about this. Some people wanted to enforce that there would be only one form of qualification in engineering and others were arguing there were at least two main levels of qualifications for tasks in engineering, and that it would not be acceptable to have what they called a common qualification for all tasks. As a matter of fact the European Parliament considered there was not a uniform block or set of studies for engineering. Engineering, by law, is not of the group of annexed disciplines, which in fact are only related to the health area and architecture.



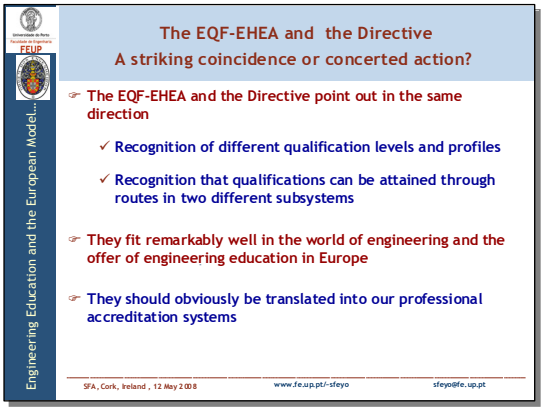
For these cases, which are not mentioned in the special annexes, there is the all-important Article 11 which approves five levels of qualification for this profession. Let me just go for these three levels where you may see, at the top you have post-secondary education of at least four years.



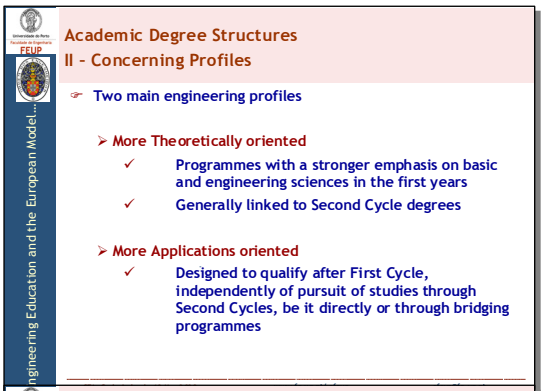
Then you have education which should be between three and not more than four years. Eventually at the bottom of these three you have the training at post-secondary level. Why do I put this one last? Because the way they wrote it, they called it training other than that referred to in d). A duration of at least one year of professional training is required.



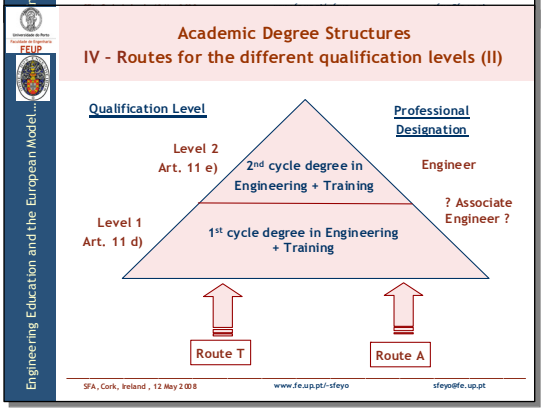
Let me indicate a striking coincidence that both the Qualifications Framework and the Directive point in the same direction. They say the top level before PhD is at least four years. The second level corresponds to three to four years, and the third corresponds to short post-secondary vocational courses.



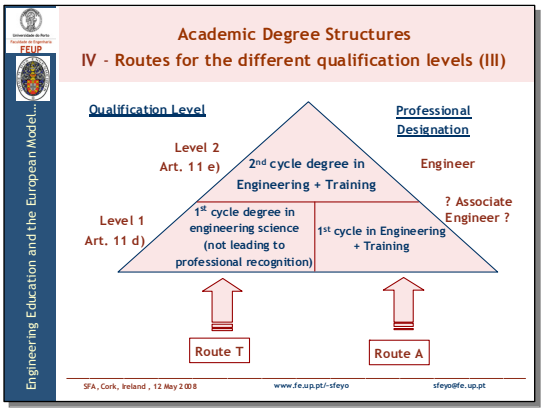
After all this discussion, what we ended up with is essentially two types of engineering profiles – what we called more theoretically oriented, or more applications oriented courses. And of course this could be given in a scheme such as this, you have a route for the more theoretically applied degrees, and a route for the more applications-oriented.



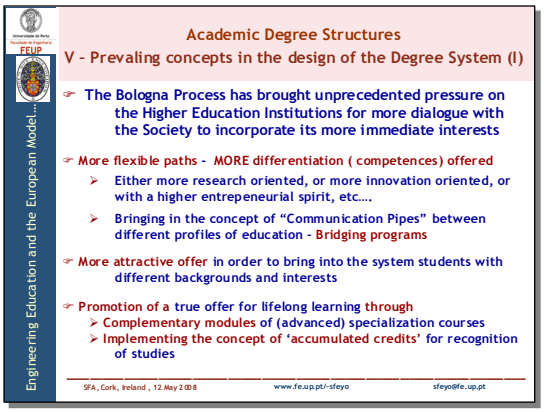
Now you have two routes. Either you do it in two parts, or as many people in Europe have commented, and after all as many universities already do it, via the applications route. Or there is a theoretical route where the first degree may not lead to professional recognition. This is what is generally known, I think, with some slight changes from country to country, as the integrated Master's programmes.



This reminds me of an analogy. In 2004 I was in Athens, Greece, before the Olympics, and a colleague was commenting on this discussion between architects and engineers. Calatrava developed a design for the Olympic Stadium and the structural engineers apparently said no, we cannot build it, we are not able to do that. After a lot of discussion they eventually agreed on some changes and things were done. And I believe there is an analogy between the architects, who are the politicians, and the engineers, who are the academics, in the Bologna process. The architects said: this is the scheme, a first cycle with full employability and the second cycle and so on. And the engineers said, "*No look, it is not possible to do it in all situations. In some situations yes, in other situations it is by no means possible; it is not good; it is not appropriate; it is not efficient*". In fact what is happening now in engineering in Europe is that there are a set of schools, a set of programmes that are sticking to having some integrated Master's, and I believe they have a case. I could give you several examples in Denmark, in Germany, in the UK, in Sweden and in a number of other countries.



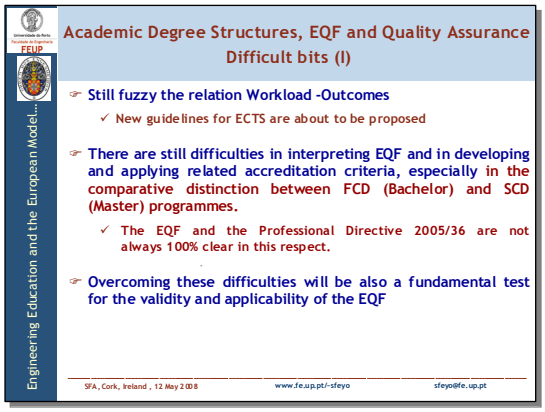
What are the prevailing concepts? I believe this is really the name of the game. Communications by bridging programmes to bring different profiles of education together. With today's concepts in society I believe that is the way it has to be. That is the way to bring students into the system with different backgrounds and with different interests. The other issue is the one already mentioned, the question of lifelong learning through complementary modules and the concept of accumulative credits, which is a major issue.



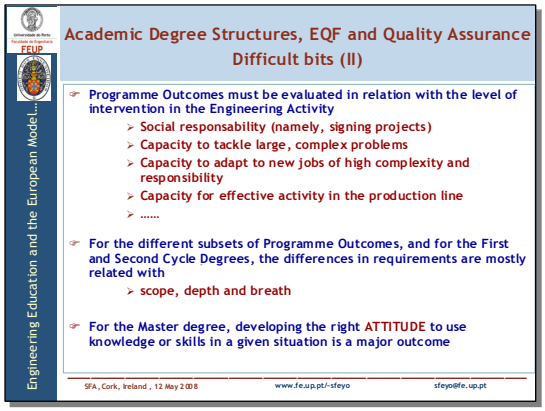
Let me just give you this example of how in general things could go. You have two lines of the more theoretically oriented degrees and the more applications oriented. But then of course you should always have provision for the possibility that, if someone says no, I am not going to carry on and I wish to do some professional work, the facility should be provided to allow him to have some orientation in that direction, including mainly the design and practical work, and to be able to be accredited.

Then, if someone with this more vocational degree wishes to carry on, and go for a Master's, this should be possible through some bridging programme, whatever it is. From my point of view this is something I believe is a general, useful scheme, for today's interests in society, and that could meet all needs: the focus of the universities, what employers want, and what politicians like to have in their own scheme.

But there are a number of difficulties. Chiefly there is the distinction between what we call first level and second level or first cycle and second cycle qualifications. We have to agree that things are not 100% clear in this respect and that is why there are so many discussions on this issue and I believe that overcoming these difficulties will be a way to check the validity and applicability of the qualifications for everyone.

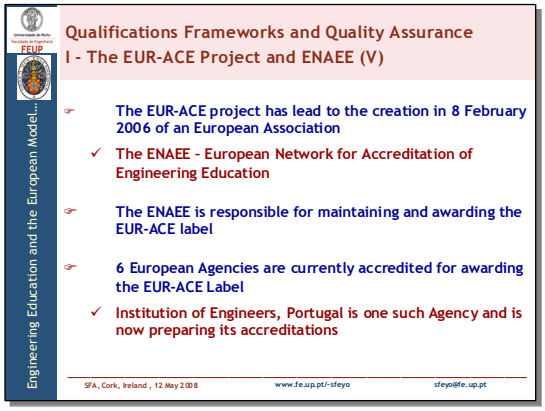


The other thing is what should we have as the difference between the first and second cycles? To a large extent that has much to do with the competences in terms of social responsibility, of tackling large complex problems, of being able to adapt to new jobs, of being able to do effective activity in the production line. That is more a question of scope, depth and breadth, or as our colleagues from the Netherlands have very nicely put it in their book about qualification frameworks, about the requirement for the Master's degree in developing the right attitude. I would say whatever it means, and we know what it means, and maybe we do not define it, it is to be able to use knowledge and skills in a given situation.



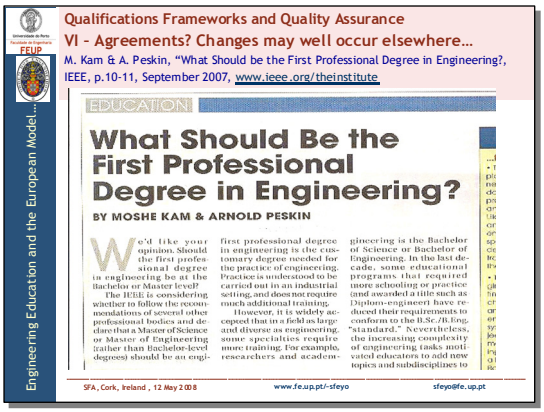
A few words about qualification frameworks. I will be short on this topic. I spoke to you about the EUR-ACE project. I believe it is a very useful project - I am involved so I am a suspect - but I do believe it's a very useful example of European cooperation. You can find out about the project on the website, www.ordemengenheiros.pt. It is a system which has been developed by fourteen European institutions, among them Engineers Portugal and Engineers Ireland, and it has benefited from the experiences in different countries and it has put together criteria for first and second cycles in six main areas. I will tell you, because we have done this exercise, it is completely compatible with the European Qualifications Framework. If you put the two together and if you make a matrix, it is very easy to see that the type of criteria we adopt really fits very well with the criteria which are set out in the EQF.

In 2006 EUR-ACE led to the creation of a kind of an agency or register (previous to the European register, but with several similarities...) ENAEE, (the European Network for the Accreditation of Engineering) which is responsible for awarding the EUR-ACE label. At the moment there are six agencies that are pre-accredited for awarding the EUR-ACE label.



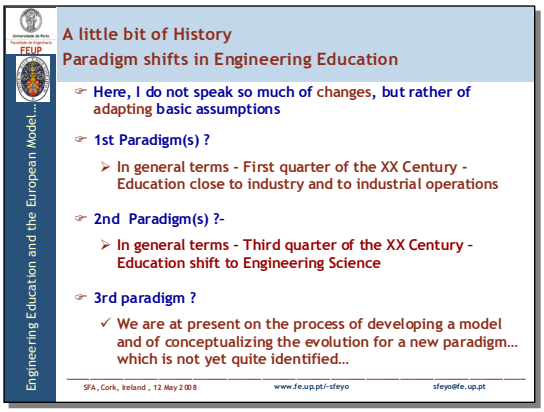
Engineering Portugal is one of them, another one is Engineers Ireland, but we have to prove this year that we are fit for the job in order to be given the accreditation for the next five years. We have to be re-accredited.

One interesting issue which I am not going to take long to discuss, but just to mention, is the question of comparing this type of accreditation awards with some other agreements, mainly the Washington Accord and the Sydney Accord, etc.



I have to say that there are some fundamental differences in the concepts, because in the spirit of EQF the Bachelor's does not give full recognition of engineers, whereas in the Washington Accord it does. There will be issues concerning recognition which have to be overcome, I think, although I am not sure at the moment how far the conversations which I know are happening have progressed. But let me just give you this example. Again it is not a one-way problem. It is a two-way problem. Because somewhere in the States, a number of people start by saying: '*oh what should be the first professional degree in engineering?*'. I want you to see this paper which can be accessed from www.ieee.org/theinstitute . These two people, Kam and Peskin, say "we can read in the United States, that the National Academy of Engineering, and the American Society of Civil Engineers, have advocated that Master of Science be declared the first professional degree in engineering".

So it is not only individuals saying that by 2030 everything is going to be like in Europe; these people at professional level also claim they should think of raising the standards and putting the Master's as the standard for the profession.

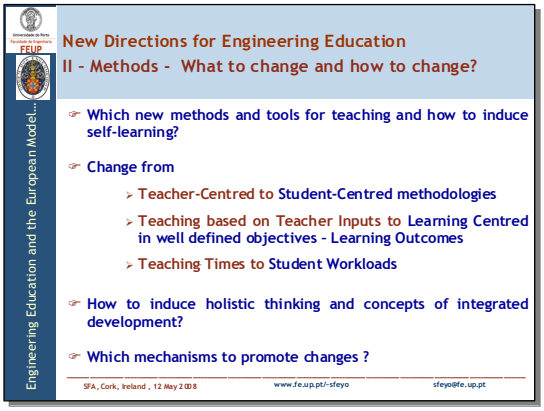


I want to give you some notes about paradigm shifts in engineering education. Well, it is not so much about changes happening now. It is about changes that occurred in the early second part of the twentieth century, the 1950s and 1960s. If we look at the history and something like what we call the first paradigm in engineering education could be recognised in the first quarter of the twentieth century. More than 100 years ago! It was close to industry and industrial operation.

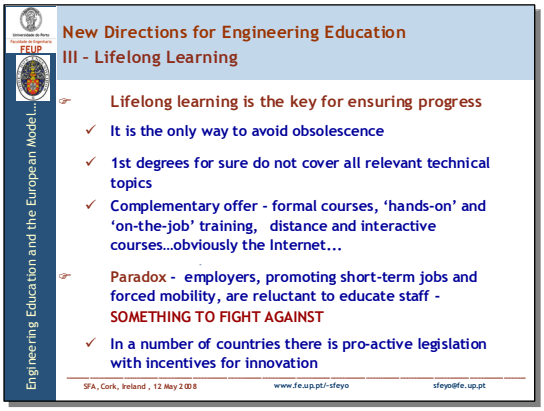
Then late in the 1950s and 1960s, there were a number of major developments that led to a shift to engineering science, specifically in chemical engineering with transport phenomena and those kinds of concepts.

Are we in the third paradigm? I do not think we are. We are developing an evolution, conceptualising an evolution for a new paradigm, but it is not yet quite identified. The

question is of course how we have to be directed to technical knowledge – remember this comment that it would be useful to know a bit of engineering as well? But it is true that now we are in a paradigm where we are asked to go back to more practical work, to go and make important some skills and competences which were not considered very relevant in university curricula not so long ago.



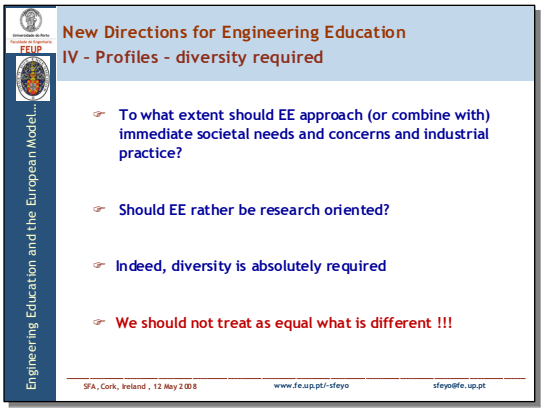
Professors should think of the tools they have available nowadays. They should think of the new way of being of a young person, and in the same way they were different from their parents, now the young people are different from what we are. With all these conditions, we should go and make things more responsive to the students, which is not an easy thing. In Portugal students are very conservative from that point of view. They do not like to hear that, but they are very conservative, because they are afraid of what they do not know. So we have to make changes in a number of the issues which I have listed.



From teacher-centred to student-centred methodologies, learning outcomes, and learning-centred questions, from teaching times to student workloads, all these are important. And so too, of course, is lifelong learning; I wish to speak about that, as a major issue. I want to highlight a problem which is a paradox from my point of view. It is very nice to give political speeches about lifelong learning but at the end of the day people work in private companies and they work from eight to eight, or from nine to ten in the evening, and employers are not very keen about promoting this kind of lifelong learning studies for their employees.

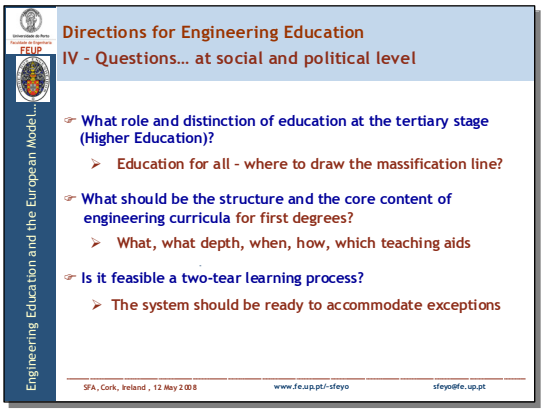
In a number of countries there are incentives for innovation and for bringing people back to learning, but it is a bit of a paradox and also a problem, because it is very nice to speak about this need, but when you come to give conditions for it, not everyone is in agreement.

Diversity is required. To what extent should engineering education mirror societal needs, or should it be research-oriented? Our solution is diversity. Something that is very important at the political level is the principle that we should not treat as equal what is different. So really the question is: should we establish two main profiles?

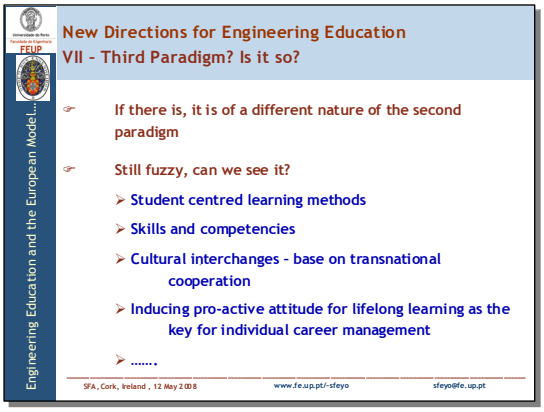


Society needs two types of competences and we must make a way to have them and not to have a uniform system of education.

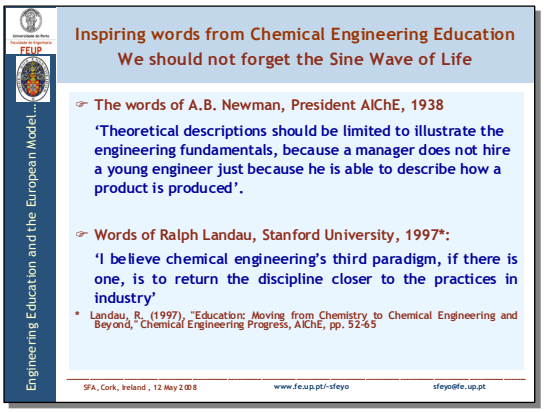
The other question to do with the Bologna Process is that, when we discuss education for all, where should we draw the line of massification? Surely it is not the second cycle? It is the first cycle or short courses in some countries. So that is another issue which has to be dealt with at the political level.



And then there are a number of other questions. Is there a third paradigm? Is it of a different nature to the second paradigm? I think it is still fuzzy. Is it more in attitudes and methods rather than in technical or scientific concepts?

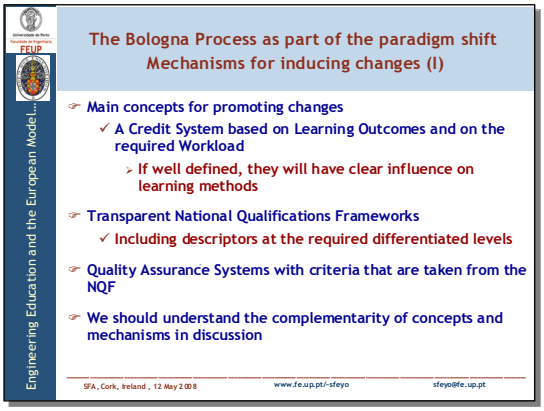


I like to recall, that I used to say that life is to a large extent a sine wave. I read some years ago the words of the former President of the American Institute of Chemical Engineering, A.B. Newman, back in 1938, where he said "*Theoretical descriptions should be limited to illustrating engineering fundamentals because a manager does not hire a young engineer just because he is able to describe how a product is produced.*"



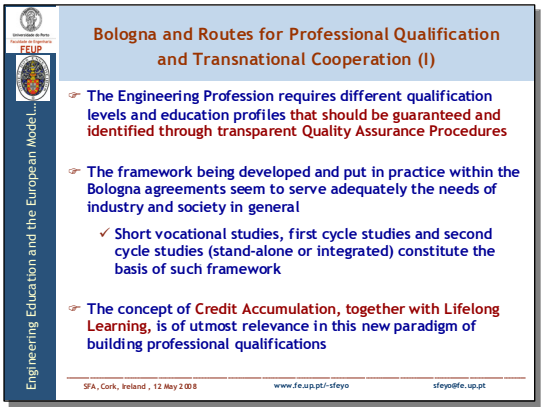
After this we had the engineering or chemical science period. Recently, a well-known man from Stanford University wrote a paper (in 1997) in which he said "*I believe chemical engineering's third paradigm, if there is one, is to return the discipline closer to the practices of industry*". So life is like that, it has a period, goes another way, comes back – it is like that politically and socially; it is a sine wave.

The Bologna Process has a number of mechanisms to promote changes within this paradigm shift, that are mainly to do with the qualifications framework and quality assurance. Several seminars have been held – one in Edinburgh in February 2008, one in Moscow in April 2008, one in Porto due in June 2008 – on these key issues of ECTS, learning outcomes and student workload, which are at the centre of the problems.



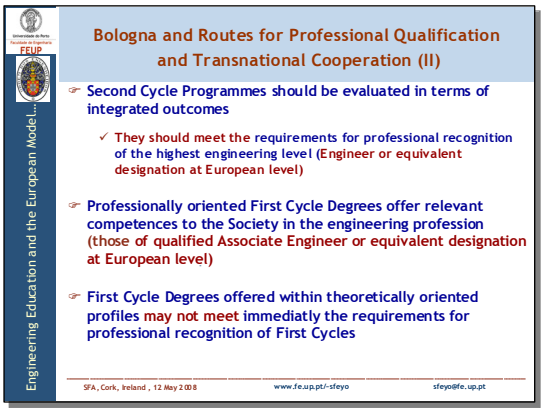
Some closing comments:

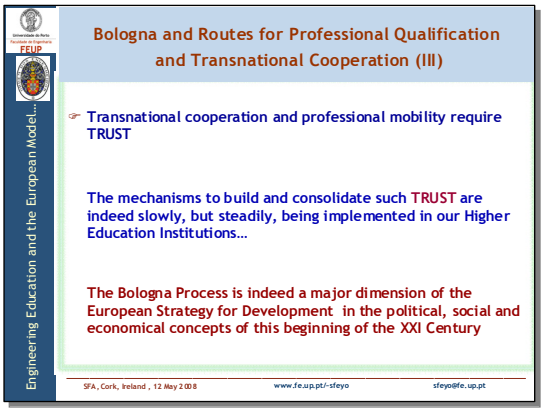
1. Let us focus on the engineering profession in that it requires different qualification levels and different education profiles, as discussed earlier, and they should be guaranteed and identified through transparent quality assurance procedures.



2. I believe the framework that is being developed and put into practice serves society well. Short vocational studies, first cycles and second cycles, stand-alone and integrated, are the key issues for the framework. Of course the concept of accumulation of credits is a major issue today as well as in a lifelong learning context.

3. The second cycle programmes should be evaluated in terms of integrated outcomes. They should meet the requirements for professional recognition at the highest engineering level. A professionally oriented first cycle often offers relevant competences to society for the engineering profession. They could be called – perhaps associated engineers – the name does not matter.



4. First cycle degrees offering theoretically-oriented profiles may not meet the requirements of the engineering profession.

To finish, the name of the game for me is the word trust. The mechanisms to build and consolidate such trust are slowly but really steadily being implemented in our higher education system. I have no doubt in saying I consider the Bologna Process a major dimension of this European strategy for development in the context we have now, at the beginning of the twenty-first century, at political, at social and at economic level.