Queste engineering education “model” for Europe

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The overall context

The preparation of the European engineering work force is a major stake for the European Union

In a competitive world mainly driven by technological breakthroughs, engineers have a key role to preserve the competitiveness of our economies

Basic function of engineering is to establish a bridge between science, technology and expectations of the society, and to build up solutions or artefacts of any kind to bring concrete answers to individual or social needs, mainly expressed through the market. Associated to a mastery of a sum of knowledge, know-how and various skills, engineering plays a crucial role in the development of modern economies, and appears clearly as a key factor for European countries to face growing competition from far eastern countries.

Backed up by scientific research, engineering appears for example as a privileged pathway to achieve the objectives of Lisbonne 2000 summit, where European Union members agreed to do their best to set up the first knowledge-based economy area in the world.

[……]

Importance of engineering is underlined by the continuous flow of technological breakthroughs which have to be translated into productivity gains and innovations. Beyond these contributions, engineering is also important to develop new energies, to ensure the better use of existing resources or to contribute to sustainable development.

Quality and vitality of engineering education is vital to well prepare engineers to face technological, industrial as social challenges

The aptitude of the engineering work force to face efficiently all oncoming challenges is strongly linked to an educational effort which has

- to give young engineers all necessary aptitudes, methods and body of knowledge to allow them to become quickly, in a professional context, innovative and full-qualified engineers
- to motivate and to prepare them to continuously update and improve their skills and knowledge
- to encourage their individual impetus, tenacity and personal mobility, to overcome all obstacles and to take advantage of individual abilities,
- to foster a sense of innovation and entrepreneurship

The higher education institutions (Technical universities or engineering schools) are supposed to have all necessary resources (human resources as equipment), beyond the quality of the initial scientific education, to fulfil these objectives. They have in most cases a sufficient autonomy to define by themselves their precise aims and methods.

Nevertheless it has to be reminded that the quality of the graduates relies on a chain of coherent contributions, where no weak point has to appear.

The preparation of the engineering work force is a process developed in three stages:

- through basic scientific education (in High Schools) providing a ground for future studies
- through engineering education (in technical universities or engineering schools) providing mainly scientific and technical resources in one field, corresponding to a pre-qualification phase,
- through complementary training and personal development to reach adequate qualification in a professional context.

Why a model for engineering education in Europe?

Engineering education has to keep a subtle balance between various requirements

Engineering education cannot be reduced

- to the sole acquisition of a certain amount of knowledge (pure scientific or technological approach)
- to the strict preparation to well defined jobs (professional approach) through the acquisition of well defined skills

Engineering education has to include an initiation to engineering methods used in design activities (which remain the core of engineering activities), as well as an effort in personal development and in the acquisition of elements of judgement on technological, economic and social issues.

Since a first engineering qualification may be considered as a platform enabling access to a wide variety of jobs and functions (design, building, operations supervision…), with increasing interaction with other profiles of qualification (lawyer, scientist, art designers, commercial) as well as with other specialities, engineering education has to preserve an openness and a high level of adaptation.

In a much more stable context, a current tradition has been in the past to check regularly the minimal adaptation of engineering syllabus to industrial needs, through accreditation processes, based on open judgements, historically managed by professionals.

A recent emphasis put on "learning outcomes"

A large number of initiatives have been taken in the past years (since 1990) to improve engineering education quality and to fine-tune it to economy expectations. There has been a willingness to rely more on quality procedures and to modernise accreditation.

The most recent trend has been to go beyond a "flat" description of programmes limited to subjects, and to base accreditation on a list of expected outcomes related to courses (since a reference to professional skills is not fully adequate).

This analytic approach has obvious advantages:

- on one side it helps academic managers to better define subjects of teaching and pedagogy methods meeting companies expectations (more consistency in internal choices),
- on another side it provides a better visibility of educational objectives for end-users (as for students themselves) which makes orientation debates much clearer.

Everyone agrees to see education, and particularly higher education, as a complex process, especially since it implies an active co-operation with the students. But this complexity has also to be understood as an impossibility to rely on a pure analytic description of the educational process.

The systematic reduction of the educational process to a list of outcomes has noticeable drawbacks (despite its advantages)

Although being a progress on traditional descriptions based on subjects, the "outcomes approach" has demonstrated various (and sometimes serious) weaknesses

- whatever efforts are made, outcomes lists do not manage to grasp in depth the reality of educational processes: the role of the host institution (department) is sent in the background, and important dimensions (values, fostering of individual attitudes) are more or less forgotten.
- Even defined in relation with the workplace, outcomes lists remain much too general to fit to professional needs (job descriptions), which give a much larger place to precise abilities. This trend to rely on quite general formulation is symptomatic in the most general grids (Dublin indicators) which have been proposed to distinguish the two first Bologna levels: they are not easy to translate into operational actions.
- There is a conceptual gap between presented list of outcomes and actual programmes, (subjects which are actually taught)
  - which creates a double description and two different ways of understanding what is done in an engineering course
  - which force to introduce two forms of assessment, which are not fully compatible
- In most cases no clear indication is given on the actual level of achievement in expected outcomes,
  - because assessment methods have not been defined (outcomes remain too general to be assessed)
  - because no choice has been made between a pass or failed approach and a more flexible way to combine marks (compromise asked by the student body).
- List of outcomes don't integrate well what is needed to ensure a continuous adaptation of the programmes
- Lists of outcomes are defined in an analytical spirit: although all expected abilities may be considered as useful (and necessary), they can hardly be considered as sufficient. The list give the impression that the final efficiency may simply result of a sum of elementary capacities (that is not true).
- Having a tendency to become prescriptive (to appear as norms) and coherent with minimum standards externally defined by accreditation bodies, list of outcomes may hinder initiatives, and don't well integrate feed back experience.

These weaknesses often neutralise each other: when an expected outcome is expressed in very general terms, it is hard to considered it has an actual prescriptive effect. In that sense outcomes list may be presented only as guidelines.

What for a model?

The need for a broader model

Queste project has been defined to foster excellence in engineering education, through the granting of a label, to be considered as a distinction of a higher level of achievement, above existing common standards, checked by accreditation bodies.

The judgement which has to be expressed in that context has to be based to a certain extent on a referential, which may be considered more or less as the expression of a "model".

This is the rationale for the proposed new model, which is defined here to give a concrete support to this ambition.

Several uses

This model is supposed

- to give a more satisfactory description of the educational process,
  - by being useful for internal management and syllabus choices
  - by being useful for communication
- to propose an adequate frame
  - for internal control and improvement
  - for external assessment (base for the QUESTE label)
  - for a continuous dialogue between the academic and corporate world.

How to design a model

A delicate exercise to meet several conditions

The definition of a new model is not free from constraints, since it is no a "building from scratch" exercise. Indeed several conditions have to be met

- it has to be compatible- or at least consistent - with existing models, which have been developed after an important "in-depth" work
  - ACQUA by Dutch universities (stress on academic dimension and preparation to design)
  - Qualification frameworks by EPC and QAA (focus on abilities to handle modelling)
  - Qualification profiles from IDEA League
  - Accreditation frameworks of reference, as they may be consider as the expression of minimum standards
- It has to overcome experienced limits of existing outcomes systems
- It has not to be normative, keeping the door open to a flexible use (in comparison with accreditation standards)
- it has, above all, to be useful, and not only an intellectual construction, especially in two crucial dimensions (which will be used to grant the QUESTE label)
  - to ensure a high level of quality (conformity with engagements and efforts towards excellence)
  - to ensure an actual dynamic adaptation based on an open partnership with the corporate world.

A meta model

For all these reasons, the adequate way is to define a broad model, indeed a kind of "meta-model", which could be used as a common frame for existing or future referential, and express a common philosophy shared by "best" engineering educational programmes.

Discussions which have been organised with some of the best experts of this question have confirmed the interest of such an initiative and its feasibility.

The starting point of the proposed model is to see any engineering programme, more than an educational process precisely defined in an analytical way, but as the production of a social entity (the educational institution where various stake-holders interact, such as faculty or students) and as the expression of its capacities, history and values and strategical choices.

Even if it remains still acceptable (and interesting) to describe and to characterise a programme through a list of features (f.e. taught subjects) or objectives to achieve (learning outcomes) or indirect achievements (employment, professional performances), we propose here to balance this analytical approach, which infers a kind of mechanical relationship (one property being an answer to an expectation, with a kind of adequationism) by a more systemic (holistic) view, emphasising more upon strategy and reactivity.

Our model may be presented as a meta-model, offering a common description framework for more specific models, with the capacity to well translate their diversity.

Four general principles

Following the general philosophy, just introduced above, the model is based on four main options (which appear to some extend in the above mentioned models) :

- **holistic view**: Any programme will be always analysed and understood in close link with the supporting organisation (social entity).

  It seems indeed artificial to separate the institution as a support and programme as a process: the institution has the responsibility of long term views and of the strategical choices which shape the programme.
- **Finality:** A first attention will be given to the motivation (why) and the ambition (what for) expressed by the supporting organisation through the setting-up of any programme. This explicit finality would include
  - The underlying vision of the targeted engineering profile (engineer in general, specific profile)
  - A presentation of specific ambitions and local options (strategies)
  - Reference to values
- **Reactivity**: although analytical assessment has not to be left aside (check of separate features), main attention will be given to a global assessment: each strategical option should be assessed globally through the pertinence of the observed response
- **Hierarchical view**: all items , strategical options, subjects or teaching options, will be addressed through their hierarchical structure.
  For instance two main dimensions will be put at the top,
  - quality
  - adaptive process

  , which may be declined in various actions.

  If international is introduced as a strategy and it will be developed in a second stage in sub strategies in languages, international placements…

Overall structure of the model: first element of design and use

In its simple form the proposed model will appear as a matrix (or a table), with the would-be development of some cells in more detailed matrix. Each rank could have following structure:

Dimension	Expression (Item)	Explicit aims, challenge to face…

For practical reason the third column will be omitted in the first developments.

Model structure: general level

Dimension	Expression
Identity features and strategical options	1. Vision of engineering in present world and developed societies (to be updated every 5 years or more?) 2. Specific targeted engineering profile 3. Education strategy, interacting with educational objectives - stable choices (/identity) - adjustable choices (/environment) 4. (Values)
Matrix of educational objectives (learning outcomes and complementary conditions)	
Basic requirements Immediate outcomes Dynamic dimensions	5. Learning outcomes Scientific and technical knowledge Methods and environment Transverse competencies
Student personal development	6. Extra activities, coaching…
Control and steering (management)	7. quality insurance 8. adjustment procedures (feedback process)

This table may be understood and used

1) as the support of declarative information giving a description of a programme
2) as on opportunity to check internally the consistency and the realism of all options (introduction on data on resources)
3) as a base for an external judgement and the granting of a label

It is interesting to note that the descriptive function of this table brings elements for a typology work (distinction of rather homogenous categories).

Quick analysis of all dimensions

1) Vision of engineering today and in the future

Such a vision will remain declarative: it will only be the sign of an internal reflection on the issue, with mandatory consultations of the corporate world and analysis of prospective studies. It will likely be shared by groups of institutions, if not all in a national context, and will appear as an element of identity.

It may interfere with ethics issues and push towards specific strategy (sustainable development, water resources,…)

2) Targeted profile

This issue is crucial for the right definition of an educational programme. Two main options are open:

- the targeted profile may be quite well identified (with the possibility to propose some jobs descriptions) that lead to a professional -oriented curriculum, with some limits.
- the targeted profile may be kept quite open, with an emphasis put on general capacities an resources,

Choices have to be confronted with actual positions of former graduates. Choices may be prepared by joint committees with firms.

3) Education strategies

The increasing importance of strategical issues is linked to the fact that higher institutions are more and more free of their choices, as far as they are consistent by themselves and with their human and equipment resources.

In comparison with list of learning outcomes, which express immediate objectives (relevant for accreditation processes), strategical options reveal to a certain extend, a willingness to differentiate from others and to build up a specific identity

Strategical objectives may be developed as a tree structure, from general items to more detailed ones. It seems nevertheless sensible to ensure that there are not too many strategical options, since they must be considered as priorities

examples of strategies related to internal choices (expression of an identity)

- Special stress on future adaptation of graduates (strong scientific base, methods, opening, ability to address complexity…)
- Fostering of an international dimension
- Stress on personal development of the students
- Stress on specific Professional profile (f.e. Architect, client manager, marketing…)
- Fine mastery of technological aspect in one domain
- Stress on the interdisciplinary approaches
- Special effort to develop an innovation spirit
- Preparation to handle complexity
- Opening on other kind of knowledge (Law, social sciences, economy…)

Strategies related to external priorities

Another form of strategies is constituted by the effect oft external priorities linked to public policies. Several example may illustrate such cases

- New attention to sustainable development
- Urgent need to train engineers in nuclear engineering
- New attention to give to OSH aspects (occupational safety and health)

All these strategies are declarative (even as output of internal debates). But their realism and consistency may be checked through the effects they have on learning outcomes.

Such a check may be illustrated by this general table:

Learning outcomes	Strategy “xxx xxx xxx”
- Knowledge	
- Methods	

Learning outcomes	Strategy "xxx xxx xxx"
- Experience of environment	
- Transverse skills	
- individual development (intellectual profile, personal profile, values)	

4) Values

Although scientific circles may consider the reference to value as a bit formal, it has indeed an importance, since it has an influence on all other action.

The definition of values may be considered as purely internal.

5) Educational objectives (learning outcomes)

Much work has been done on list of learning outcomes, which has to be used here.

Our most original option is to insert educational objectives (slightly beyond learning outcomes) refer to a basic 3x4 matrix, in comparison with accreditation lists which focus on a 2x4 matrix, or even a 1x4 matrix (grey cells with red borders):

	bases to master (prerequisite before starting studies)	**Expected outcomes** immediate aims	**Elements of adaptability** skills for the future
Knowledge	Bases of sciences	- scientific knowledge, - technology, - mathematics	Ability to master new knowledge, ability to transfer
Methods linked to practical and contextual actions	…	- Art of engineer, design, industrial management - Scientific research	opening to new domains
Experience of scientific, technological economical and social context	…	- understanding of business models - awareness of industrial challenges - ideas of orders of magnitude	
Transverse skills	…	communication abilities	transculturality
Individual development (not to be assessed)	form of intelligence curiosity, leadership, tolerance	logical reasoning	personal project

The key question, which has been addressed by the Dutch document, is to set up of list of outcomes

- which is understandable by faculty
- which may be translated into concrete choice
    - subjects
    - pedagogy
    - assessment

Special attention to of objectives linked to the field of technical competencies

The need may appear at this stage to introduce qualification profiles. Anyway there is an Interest to separate

- fundamentals
    - fine description

to develop further

6) Students development

Although student personal development is not directly assessed, this dimension plays an important role in the appreciation of young graduates by companies. This is a good reason not to stay passive.

- opportunities offered to students (creative activities, junior consulting)
- animation of student life
- coaching

to develop further

7) Quality insurance

The increasing interest borne to quality procedures is a direct consequence of the growing autonomy, which requires new forms of control.

Two directions

1) Conformity to announced engagements
2) Efforts to be at he best level

This effort will rely on

- educational outcomes put as objectives
- graduates performances (placement, career, jobs)

to develop

3) Policies adjustment procedures

The so-called policy adjustment procedures are supposed to provide elements

- For the strategical options (What for, = finality)
- For the objectives options (What we do…)

It will rely on a dialogue with the corporate world and some feed back studies. Two main questions have to be solved:

- How to get the right message from employers, who have mainly short terms problems?
- How to extract messages from alumni experience

to develop

How to use it

The three main utilities of the model

The presented model has three main utilities

- It may be considered as a self description tool, useful for communication (and promotion?) and a possible base for a typology.
- It may appear as a tool for internal management (place given to long-term options, consistency) especially to check
  - quality
  - permanent adaptability
- It may be used as the base for an external judgement

Realistic and idealistic view

Our model has been designed according to internal choices, covering the definition of an identity, strategical choices and concrete objectives. It may appears as an idealistic view of the reality, and not as a good description of reality. To address this objection it seems necessary to confront the model

- to constraints of resources
- to actual achievements

This leads to a three component structure as:

	Institution policy	
Resources <-----	Choices (model core)	----->Achievements

In assessment procedures attention will be given to realism and consistency (Resources/ choices) and to existing gaps between objectives and actual achievements.

The model as a support for information

It may be presented as a support for clarification, more than the evidence of an effort of transparency.

Clarification will be higher if several institutions accept the same referential and the same vocabulary.

Such a work should help to define a suitable typology and could lead to a kind of register (CLAIU project). To facilitate this typology it would be better to define "landmarks" (could QUESTE project do that?)

- **What is missing (could be added?)**
  - details on admissions procedures and prerequisites
  - details on careers

The model as a tool for internal management

The framework which has been presented appears as kind of check list for educational managers, who are eager not to forget anything.

The model may be seen as a source of synthetic indicators, giving a rather fine picture of important points and choices.

Attention should be given to assessment procedures (level of achievement, measures)

How to express judgements (inside or outside)

The model has a vocation to be used as a support for assessment of excellence, with the advantage to address dimensions, which do not appear in accreditation standards.

The process could be threefold

- first level: understand and check consistency of objectives and options
- second level: check pertinence
- third level :check actions (level of excellence)

The “devil advocate”

Would be weak points of the proposal

It is always useful to review all counter arguments (to be the devil advocate) to better locate weak points of the project.

1) Where is the source of differentiation? A basic motivation is to give a solid support to differentiation. But this differentiation may simply come from structural features:
   - higher budgets
   - “better” teachers
   - “better” students

   more than from strategy and smart objectives.
2) Since the basic matter is declarative, much energy may be spent to give a rosy approach of the reality: how to neutralise this attitude?
3) The choice made to favour synthetic approach will be understood if the formulation is quite relevant
4) More attention should be given to effective results of the programme: time to find a job, suitability to the studies, salaries…