AN INTEGRATED CDIO - EQF ENGINEERING FRAMEWORK FOR EUROPE

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ABSTRACT

The paper describes the results of a recent project entitled "DOCET - *EQF-CDIO Correspondence Model for the Recognition and Enhancement of Engineering Degrees".*
In Europe, the recent changes in the educational systems, as well as in the international macroeconomic contexts, bring about the need of enhancing engineering curricula as well as increasing their transparency. In this scenario, any tool able to help Universities revise "in real time" their programs and transfer innovation into courses will be an important support. A first prerequisite of such a tool is to be based on a "common language", shared by the higher education national systems and stakeholders (both within Europe and globally).
The new European Qualifications Framework (EQF) aims to provide a common reference system to build qualifications readable across Europe, and not linked to any specific disciplinary areas of engineering. The CDIO Syllabus already represents a world-wide reference for the design of engineering programs and for their evaluation. Its development involved stakeholders from industry and so it could speed up the mutual transfer of innovation between Universities and businesses. Both the EQF and CDIO Syllabus are based on the same learning outcomes (objectives) based approach.
Accordingly, the DOCET project aimed to build a correspondence model between CDIO syllabus and the EQF, mapping the CDIO outcomes onto the 8 EQF levels. The learning outcome - based descriptors the EQF provides for Knowledge, Skills and Competence at different levels (and its other qualifiers such as *autonomy and responsibility*, *context*, *action verbs*) have been combined with the *engineering content* provided by the CDIO Syllabus in a

set of tools that can help the negotiation and definition of shared and transparent goals for engineering education.

KEYWORDS

EQF, European Qualification Framework, CDIO, Learning outcomes, Transparency, Recognition

INTRODUCTION: THE CONTEXT AND OBJECTIVES OF THE DOCET PROJECT

In Europe, the recent changes in the educational systems, as well as in the international macroeconomic contexts, bring about the need of enhancing engineering curricula as well as increasing their transparency. At the end of the nineties, the so called “Bologna Declaration” [1] was signed by 29 European countries. Its aim was “to adopt a system of easily readable and comparable degrees”. From a general point of view, it expressed the programmatic intention of generating “a new enhanced European cooperation” especially focused on higher education and employability, to support the greater international mobility of engineering students and graduates and the globalisation of the labour market demand.

In fact, the European engineering higher education area is not yet homogeneous: the processes of implementation of the BMD (Bachelor – Master – Doctorate) schema and the use of the ECTS (European Credit Transfer System) still aren’t completed. There are deep differences among the EU member states about the meaning of the term “engineer” and if the Bologna Declaration initiated a reform, it is still not fully implemented by all European Countries.

Consequently, how can we foster mobility, better employment, competences growth Europe-wide and the attractiveness of the European higher education area in the engineering field, if it is difficult for all the actors involved to recognise degrees and competences?

Moreover, the engineering Universities are required to foster the collaboration with enterprises and to update continuously their programs to support the rapid development of business context. The requirement is more and more important also in countries with a long tradition of cooperation between technical Universities and businesses (such as France).
It appears so evident that any tool able to help Universities revise “in real time” their programs and transfer innovation into courses will be an important source of support and instrument for change.

In this scenario, the objectives of the project “DOCET - *EQF-CDIO Correspondence Model for the Recognition and Enhancement of Engineering Degrees”* (a project funded with the support of the European Commission under the Erasmus Mundus Programme, action 4, selection 2008) can be summarized as follows:

1) Enhancing the attractiveness of the European Higher Education Area and improving its value, with the development and a pilot implementation of model and tools for the recognition of European higher engineering degrees by worldwide students and universities easily “portable” in several disciplinary areas and based on the EQF (European Qualifications Framework [2]) , CDIO [4] [5] and ECTS;

2) Strengthening the links between the University and the labour market, with the improvement of the visibility and recognition of degrees both by Universities and businesses;
3) Promotion of the use of the EQF for the recognition of engineering degrees and qualifications among targeted European countries.

THE PILLARS: EQF AND CDIO

A first prerequisite of such set a tools is the use of a “common language”, shared by all the European national higher education systems, understood by enterprises, and recognisable by students, universities and business stakeholders outside Europe.

The new European Qualifications Framework (EQF) aims to provide such a common “currency”, a reference system to build qualifications readable across Europe. The EQF has been introduced as “a common European reference framework which links countries’ qualifications systems together, acting as a translation device to make qualifications more readable and understandable across different countries and systems in Europe. It has two principal aims: to promote citizens’ mobility between countries and to facilitate their lifelong learning” [2].

From an operational point of view, the EQF introduces *8 reference levels*, spanning the full scale of qualifications acquired in general, vocational as well as academic education and training, from basic levels (e.g. Level 1 for school leaving certificates) to advanced levels (e.g. Level 8, nominally for example Doctoral degrees); each level is described in term of *learning outcomes*, defined as “*a statement* of what a learner knows, understands and is able to do on completion of a learning process”.

Moreover, for each of the 8 levels, learning outcomes are specified in three categories:

- *Knowledge (K),* described as theoretical and/or factual;
- *Skills (S),* described as cognitive (involving the use of logical, intuitive and creative thinking) and practical (involving manual dexterity and the use of methods, materials, tools and instruments);
- *Competence (C)*, described in terms of responsibility and autonomy.

As an example, Table 1 shows the descriptors provided at levels from 4th to 8th. However the levels the European Commission directly relates to the Framework for Qualifications of the European Higher Education Area range from 5th to 8th, where “Each cycle descriptor offers generic statement of typical expectations of achievements and abilities associated with qualifications that represent the end of that <higher education> cycle”.

Table 1
EQF descriptors (levels 5 – 8)

EQF Level	Knowledge	Skills	Competence
8	Knowledge at the most advanced frontier of a field of work or study and at the interface between fields	The most advanced and specialised skills and techniques, including synthesis and evaluation, required to solve critical problems in research and/or innovation and to extend and redefine existing knowledge or professional practice	Demonstrate substantial authority, innovation, autonomy, scholarly and professional integrity and sustained commitment to the development of new ideas or processes at the forefront of work or study contexts including research
7	• Highly specialized knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research • Critical awareness of knowledge issues in a field and at the interface between different fields	Specialised problem-solving skills required in research and/or innovation in order to develop new knowledge and procedures and to Integrate knowledge from different fields	• Manage and transform work or study contexts that are complex, unpredictable and require new strategic approaches • Take responsibility for contributing to professional knowledge and practice and/or for reviewing the strategic performance of teams
6	Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles	Advanced skills, demonstrating mastery and innovation, required to solve complex and unpredictable problems in a specialized field of work or study	• Manage complex technical or professional activities or projects, taking responsibility for decision making in unpredictable work or study contexts • Take responsibility for managing professional development of individuals and groups
5	Comprehensive, specialized, factual and theoretical knowledge within a field of work or study and an awareness of the boundaries of that knowledge	A comprehensive range of cognitive and practical skills required to develop creative solutions to abstract problems	• Exercise management and supervision in contexts of work or study activities where there is unpredictable change • Review and develop performance of self and others
4	Factual and theoretical knowledge in broad contexts within a field of work or study	A range of cognitive and practical skills required to generate solutions to specific problems in a field of work or study	• Exercise self-management within the guidelines of work or study contexts that are usually predictable, but are subject to change • Supervise the routine work of

			others, taking some responsibility for the evaluation and improvement of work or study activities

It is plain that the descriptors provided by the EQF are general and not linked yet to any specific discipline. Nonetheless, the Recommendation of the European Parliament and of the Council of 23 April 2008 [3] sets 2010 as the target date for countries to relate their national qualifications systems to the EQF. In addition, various initiatives to develop sectoral framework based on the EQF have been begun. In fact the general descriptors embed a set of *dimensions* (see next paragraph) able to guide the definition of specific learning outcomes in a transparent way, an essential requirement to "facilitate comparison and transfer of qualifications between countries, systems and institutions".

On the other hand, the CDIO (Conceive, Design, Implement, Operate) approach for the rethinking of engineering education has developed a common syllabus for the design of engineering programs and degrees and for their evaluation, and it is based on the same learning outcomes (objectives) approach used by the EQF. These suggested learning outcomes for engineering students are enumerated within the document entitled *CDIO Syllabus – A Statement of Goals for Undergraduate Engineering Education* [8]. The *CDIO Syllabus* was developed through discussions with focus groups comprised of various stakeholders, and by reference to other documentation of the time. This process included participants from industry, so that its adoption could speed up the mutual transfer of innovation between Universities and businesses. Furthermore, CDIO is an approach adopted by worldwide engineering universities, and the CDIO Syllabus has been translated into French, Swedish, Spanish, Chinese and Vietnamese.

As shown in Table 2, the CDIO Syllabus classifies learning outcomes into four high-level categories: technical knowledge, personal attributes, interpersonal skills, and the skills specific to the engineering profession. The content of each section was expanded in the CDIO Syllabus to a second level (also shown in Table 2), to a third and fourth level, (available at http://www.cdio.org). To ensure comprehensiveness, the Syllabus was explicitly correlated with key documents listing engineering education requirements and desired attributes. As a result of this development process, the CDIO Syllabus emerged in 2001 as a rational and consistent set of skills, derived from an understanding of needs, that stakeholders would expect from graduating students.

Thus CDIO Syllabus can provide the EQF with the sectoral, specific engineering "content" that the EQF itself misses, while the EQF can provide the CDIO' syllabus with levels, categories and descriptors (with embedded additional dimensions) that can be used to express the learning outcomes in a fully transparent and definite way.

Table 2
CDIO Syllabus at the Second Level of Detail

1 TECHNICAL KNOWLEDGE AND REASONING 1.1 KNOWLEDGE OF UNDERLYING SCIENCE 1.2 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE 1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE **2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES** 2.1 ENGINEERING REASONING AND PROBLEM SOLVING 2.2 EXPERIMENTATION AND KNOWLEDGE DISCOVERY 2.3 SYSTEM THINKING 2.4 PERSONAL SKILLS AND ATTITUDES 2.5 PROFESSIONAL SKILLS AND ATTITUDES	**3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION** 3.1 MULTI-DISCIPLINARY TEAMWORK 3.2 COMMUNICATIONS 3.3 COMMUNICATIONS IN FOREIGN LANGUAGES **4 CONCEIVING, DESIGNING, IMPLEMENTING, AND OPERATING SYSTEMS IN THE ENTERPRISE AND SOCIETAL CONTEXT** 4.1 EXTERNAL AND SOCIETAL CONTEXT 4.2 ENTERPRISE AND BUSINESS CONTEXT 4.3 CONCEIVING AND ENGINEERING SYSTEMS 4.4 DESIGNING 4.5 IMPLEMENTING 4.6 OPERATING

METHOD AND APPROACH

Accordingly, the project aimed to build a model able to integrate and relate the CDIO Syllabus and the EQF, mapping the CDIO syllabus on the 8 EQF levels. For this purpose, previous results coming from studies aimed at finding objective and transparent ways of Knowledge, Skills, and Competence levelling have been considered together with the works developed by B. Bloom [6] and B. Mansfield [7]. In-the-field surveys have also provided pragmatic feedbacks to revise the developed correspondence model.

Thus an approach to provide guidelines to develop Learning Outcomes transparently and systematically has been developed following five steps:

1) Identification of the main *dimensions* embedded in the EQF level descriptors;
2) Identification of the *general descriptions* the EQF provides for each dimension (from level 4th to 8th);
3) Extraction of the main areas of Knowledge/Skills/Competencies an engineer should master from the CDIO Syllabus ("*what*" in the final model);
4) Definition of *engineering specific descriptions* for each dimension and level (for EQF levels 4 – 8);
5) Development of the final model, providing a *standard set of tools and tables* combining the levels and engineering-related specific descriptions in line with the EQF and the topics of the CDIO syllabus.

Beginning with the first step, the analysis carried out showed that the EQF suggests three main dimensions to characterize different levels of learning outcomes: the *Autonomy and Responsibility* to be demonstrated in accomplishing tasks or performing various activities; the

Context in which Knowledge, Skills, and Competencies are applied to/in; a set of *Action Verbs*, expressing the ability to apply Knowledge and Skills, and demonstrate Competencies.

The *general descriptors* provided for each dimensions by the EQF were identified in the second step, and range:

- From “Within the guidelines” (level 4) to “With autonomy, authority, commitment” (level 8) for the dimension *Autonomy and responsibility*;
- From “Predictable; Within a field” (level 4) to “Forefront context; Critical problems” (level 8) for the dimension *Context*;
- From “Exercise; Improve” (level 4) to “Synthesize; Evaluate; Innovate” (level 8) for the *Action verbs* (along with statements “suggesting” action verbs, which are in *italic* in Table 3).

Table 3 reports the full set of descriptors for EQF levels 4 – 8.

Table 3
EQF general descriptors for the dimensions *Autonomy and Responsibility*, *Context*, *Action Verbs* (for EQF levels 4 – 8)

EQF Level	Autonomy and Responsibility	Context	Action Verbs
8	With autonomy, authority, commitment	Forefront context; Critical problems	• **Skills:** Synthesize, Evaluate, Solve, Innovate, Extend and Redefine *knowledge* • **Competence:** Demonstrate, Develop *new ideas and processes*
7	Independently	Unpredictable and complex context / problems; Interface between fields	• **Knowledge**: *Original thinking, critical awareness* • **Skills**: Solve *problems (Problem solving*), Innovate, Develop, Integrate • **Competence**: Manage, Transform, Reviewing *performance*
6	Taking responsibility; On his/her own with responsibility	Unpredictable projects / processes; Specialized field	• **Knowledge**: *Critical Understanding* • **Skills**: Innovate, Solve • **Competence**: Manage, Make *decisions (Decision making)*
5	Under general supervision; On his/her own with confidence	Unpredictable activities / specific problems; Abstract problems	• **Knowledge**: Awareness • **Skills**: Develop • **Competence**: Exercise, Review, Develop
4	Within the guidelines	Predictable; Within a field	• **Skills**: Generate *solutions* • **Competence**: Exercise, Supervise, Improve

The guidance to identify a full list of knowledge/skill/competence areas that every engineer should master (the *what*) has been provided by the CDIO Syllabus as the third step. These outcomes offer a set of goals not only for the undergraduate engineering studies but also in a lifelong learning perspective. The CDIO Syllabus represents these outcomes at four levels of detail, from the four broad areas in Table 2, to the 17 topics in Table 2 at the second or “X.X” level, to about a hundred topics at the third level and hundreds at the fourth level. The second or “X.X” level of Knowledge/Skills/Competencies was selected as the one at which to establish the correspondence with EQF. This was done: in order to reach a good balance between synthesis and granularity; so that there was comparable in detail in the EQF descriptors and topics; and because this is a level at which university program learning outcomes are often written (note that course and lecture level outcomes would be at considerable more detailed level, but could be derived using the same approach). In the correspondence framework below, the “X.X.X” level topic has been included for a few items when the meaning of the “X.X” level topic is not immediately obvious.

As the fourth step, the *engineering-related specific descriptors* have been elaborated starting from the previous mentioned dimensions and their general descriptors (see step 2), trying to answer the question “how can they be formulated in order to embed specific features of the engineering field and combined with the “X.X” items of the CDIO Syllabus to build up learning outcomes?”.

The descriptors for *Autonomy and Responsibility* have been enriched by an iteration process that placed them more in a context of engineering; they are summarized in Table 4 and they can be applied to all sections of the CDIO Syllabus. They can be compared with the more generic descriptors of the EQF in the second column of Table 3.

Table 4
Engineering specific descriptors – *Autonomy and Responsibility*

EQF Level	Autonomy and responsibility (can be applied to all Sections of CDIO Syllabus)
8	With substantial autonomy, authority and wide responsibility
7	With autonomy and responsibility
6	Taking responsibility, on his/her own with responsibility
5	Under general supervision, on his/her own with confidence
4	Within the guidelines, under direct supervision

New descriptions of the *Context* dimension have been provided (see Tables 5 and 6). These are the specialization of the generic EQF context of the third column of Table 3 to engineering. Specific categories have been formulated that apply to different sections of the CDIO Syllabus: a) Context of Knowledge and Personal Skills (Syllabus Section 1 and 2); b) Context of Interpersonal Skills (Syllabus Section 3); c) Context of Society (Syllabus Section 4.1); d) Context of Enterprise (Syllabus Section 4.2); and e) Context of Engineering (Syllabus Section 4.3-4.6).

Table 5
Engineering specific descriptors – *Context* (section 1, 2 and 3 of the CDIO Syllabus)

EQF Level	Context of Knowledge and Personal Skills (Syllabus Section 1 and 2)	Context of Interpersonal Skills (Syllabus Section 3)
8	Strategic and forefront problems; of substantial uncertainty requiring complete integration of disciplines	Large / multi-cultural / heterogeneous audience or group
7	Complex and uncertain context /problems which require integration of various disciplines or deep knowledge of a field	Large / heterogeneous audience or group
6	Open ended context / problems which require integration of various disciplines	Medium size / homogeneous audience or group
5	Context / problems with some degree of uncertainty which require consideration of various disciplines	Small / local audience or group
4	Largely specified problems within a field	Small / established audience or group

Table 6
Engineering specific descriptors – *Context* (section 4 of the CDIO Syllabus)

EQF Level	Context of Society (Syllabus Section 4.1)	Context of Enterprise (Syllabus Section 4.2)	Context of Engineering (Syllabus Section 4.3-6)
8	In a totally integrated dynamic global environmental and societal context.	In a dynamic multi-national effort requiring integration of many enterprises	Strategic and forefront problems; of substantial uncertainty requiring complete integration of engineering and other disciplines
7	In a changing global environmental and societal context.	In a rapidly evolving multi-national effort requiring coordination among many enterprises	Complex and uncertain context /problems which require integration of engineering disciplines, extensive consideration of other fields, or deep knowledge of a field
6	In an evolving regional environmental and societal context	In an evolving regional effort requiring broad integration with an enterprise	Open ended context / problems which require integration of various engineering disciplines and consideration of other fields
5	In a local environmental and societal context	In a effort within an enterprise requiring coordination among groups	Context / problems with some degree of uncertainty which require consideration of various engineering disciplines
4	In a stable local environmental or societal context	In stable small groups within an enterprise	Largely specified problems within a field of engineering

The final *engineering specific descriptor* is the list of Action Verbs to be used to describe learning outcomes. A correspondence among the action verbs extracted from the EQF (Table 3, fourth column) and a subset of the action verbs from Bloom's taxonomy (used in CDIO) has been developed. The starting point for establishing this correspondence was the five point Bloom-based scale already used to collect program data on the expected competence of engineering graduates in CDIO Syllabus topics at a number of Engineering programs world-wide [4] (see Table 7). On this scale, level 1 is called “Exposure”, which corresponds to no Bloom level. CDIO level 2 is Knowledge, and level 3 is Comprehension. Level 4 combines Application and Analysis, while level 5 similarly merges Analysis and Synthesis.

Table 7
CDIO Learning Outcome scale and related Verbs from Bloom’s Taxonomy

	Level	Group	Verbs
	Knowledge	Recognize	Label, Name, Recognize, Recall, Underline
Level 2		List	List, Record, Repeat, Reproduce, State
		Describe	Define, Describe
		Match	Arrange, Match, Order, Relate
	Comprehension	Locate and classify	Arrange, Classify, Identify, Indicate, Locate, Sort
Level 3		Explain	Discuss, Explain, Express, Give examples, Report, Summarize
		Translate	Convert, Interpret, Paraphrase, Restate, Translate
		Interpolate	Interpolate, Infer
		Extrapolate	Extend, Extrapolate, Generalize
	Application	Prepare	Choose, Prepare, Schedule, Select, Sketch
		Use	Apply, Change, Employ, Manipulate, Modify, operate, Use, Utilize
		Practice	Demonstrate, Execute, Illustrate, Practice, Show
Level 4		Resolve	Compute, Measure, Solve
	Analysis	Analyze and test	Analyze, Appraise, Calculate, Elicit, Examine, Experiment, Question, Test
		Categorize	Breakdown, Categorize, Diagram, Inventory, Outline, Separate, Subdivide
		Discriminate	Compare, Differentiate, Distinguish, Discriminate, Reconcile
	Synthesis	Plan	Collect, Plan, Propose
		Create	Compose, Create, Design, Devise, Formulate, Generate, Set up, Tell, Write
Level 5		Construct	Arrange, Assemble, Construct, Combine, Compiles, Manage, Organize, Synthesize, Set up
		Rearrange	Modify, Rearrange, Reconstruct, Reorganize, Revise, Rewrite
	Evaluation	Assess	Assess, Conclude, Estimate, Predict, Rate, Score
		Evaluate	Attack, Criticize, Critique, Evaluate, Value
		Defend	Argue, Defend, Justify, Support

University engineering program information on expected learning outcomes is already available, and has been collected over the years by the CDIO collaborative through surveys addressed to faculty members, industries and alumni [5]. This data shows that the absolute level of expectation for the “core engineering topics” (e.g. engineering problem solving, communications, design, etc.) is, on the CDIO/Bloom scale:

- About 3.5 for Bachelor level experiences;
- About 4 for Masters level experiences.

This implies an absolute correspondence between the CDIO/Bloom scale and degree programs, and indicates about a half level increase in expected competence is obtained by the Master students compared to those completing Bachelor level degrees.

Comparing the action verbs elicited from the EQF at level 4-8 and verbs included in the Bloom’s Taxonomy, a strong relation can be built and numerous common points can be identified; these relations can be summarized as shown in Table 8. This table is read by starting on the left with the EQF level, and its associated Action Verbs from Table 3. The Bloom verbs that correspond directly or indirectly to the bolded EQF verbs are in the third column, along with their corresponding CDIO level (Table 7). The trend in these levels suggests the CDIO level shown in the right most column of Table 8.

With reference to the table and the above discussed data, it follows that the implied correspondence from expected proficiency at the time of a degree (3.5 for Bachelors, 4 for Masters) to CDIO/Bloom scale to EQF is that a Bachelors degree preparation produces an EQF of 5, and a Masters produces about a 6, in contrast to European policy statements that suggest a Bachelors should be a 6 and a Masters a 7. We think this is due to misalignment of the EQF descriptors with the reality of engineering education.

Table 8
Relation among EQF' and Bloom's *Action verbs*

EQF Level	EQF Verbs (and Verb Phrases)	Bloom Verbs	CDIO Level
8	Skills: **Synthesize**, **Evaluate**, **Solve**, **Innovate**, **Extend and Redefine Knowledge** Competence: Demonstrate, **Develop new ideas and processes**	Synthesize (5), Evaluate (5), Solve (4), Create (5), Improve (5), Compose (5)	5
7	Knowledge: Original thinking, **critical awareness** Skills: Problem **solving**, Innovate, **Develop**, Integrate Competence: **Manage**, **Transform**, **Reviewing** Performance	Critique (5), Solve (4), Formulate (5), Manage (5), Modify (4), Appraise (4)	4-5
6	Knowledge: Critical **understanding** Skills: **Innovate**, **Solve** Competence: **Manage, Decision Making**	Comprehend (3), Devise (5), Solve (4), Manage (5), Select (4)	4
5	Knowledge: **Awareness** Skills: **Develop** Competence: **Exercise**, **Review**, Develop	Interpret (3), Prepare (4), Utilize (4), Examine (4)	3-4
4	Skills: Generate **solutions** Competence: **Exercise**, Supervise, **Improve**	Solve (4), Employ (4), Extend (3)	3-4

A final list of *Action Verbs* were selected to align with the Bloom levels for Comprehension, Application, Analysis, Synthesis and Evaluation, with the EQF levels 4-8, as shown in Table 9. There are no outcomes implied in the EQF Levels 4-8 that are only at a Bloom level of Knowledge.

In detail, EQF level 8 draws its verbs exclusively from the "stronger verbs" of Bloom Synthesis and Evaluation (CDIO level 5). EQF level 7 gets its verbs from some of the "weaker" verbs from CDIO/Bloom level 5 plus some of the "stronger" verbs from CDIO/Bloom level 4, in order to place it between 4 and 5 on the CDIO/Bloom scale. Likewise for EQF level 5 using verbs from CDIO/Bloom levels 3 and 4.

The final list of chosen *Action Verbs* are listed in Table 9. It should be noted that, in order to avoid confusion, there is no verb that is shared by two EQF levels. This list will be used in the subsequent detailed tables and examples of learning outcomes.

Table 9
Selected Final Bloom Verbs and EQF/Bloom/CDIO Correspondence

	CDIO 5 Level Scale					
	2	*3*	*4*	*4*	*5*	*5*
	Bloom Verbs					
EQF	*Knowledge*	*Comprehension*	*Application*	*Analysis*	*Synthesis*	*Evaluation*
8					Create Synthesize Improve	Evaluate
7				Appraise	Revise Propose Formulate Plan Design Manage	Critique Defend
6			Select Apply Conduct Execute Demonstrate	Analyze		
5		Classify Discuss Interpret	Utilize Prepare Practice	Compare		
4		Identify Explain Locate Report	Employ			

As a set of summary remarks on the engineering specific descriptors for *Action Verbs*, it should be emphasized that:

- The set of key action verbs identified characterize the various levels;
- Each level inherits the contents at lower levels;
- Descriptions of learning outcomes associated to a level have to include at least one of the action verbs characterizing that level;
- It is recommended that descriptions of learning outcomes associated to a level don’t include a large number of action verbs belonging to different levels.

THE FINAL MODEL

The model created by the DOCET project combines the above discussed dimensions in order to provide a standard process (guidelines and set of tools) that can be used in order to describe engineering learning outcomes in a transparent way and to assign them levels according to the EQF. Thus it combines *EQF levels* (from 4 to 8), *Action Verbs*, the “*What*” dimension (the engineering content), and *Context* and *Autonomy*. These dimensions have been combined for each CDIO item at level “X.X” (i.e. “1.1 Knowledge of underlying sciences”, “1.2 Core engineering fundamental knowledge”, “1.3 Advanced engineering fundamental knowledge”, etc). The Table 10 shows an example for the item “2.2 Experimentation and knowledge discovery”.

Table 10
Final model – Example for the CDIO item "2.2 Experimentation and knowledge discovery"

EQF Level	CDIO level	Bloom verb	What (Knowledge / Skill / Attitude)	Autonomy	Context
8	5	Create (5) / Synthesize (5) / Evaluate (5)	Experimentation and knowledge discovery	With substantial autonomy, authority and wide responsibility	Strategic and forefront problems; of substantial uncertainty requiring complete integration of disciplines
7	4-5	Plan (5) / Design (5) / Appraise (4)	Experimentation and knowledge discovery	With autonomy and responsibility	Complex and uncertain context /problems which require integration of various disciplines or deep knowledge of a field
6	4	Select (4) / Conduct (4) / Analyze (4)	Experimentation and knowledge discovery	Taking responsibility, on his/her own with responsibility	Open ended context / problems which require integration of various disciplines
5	3-4	Prepare (4) / Utilize (4) / Interpret (3)	Experimentation and knowledge discovery	Under general supervision, on his/her own with confidence	Context / problems with some degree of uncertainty which require consideration of various disciplines
4	3-4	Employ (4) / Report (3)	Experimentation and knowledge discovery	Within the guidelines, under direct supervision	Largely specific problems within a field

Learning outcomes can be easily elicited from the tables, by combining an Action Verb, Knowledge/Skill/Attitude Topic, an indication of Autonomy and Context. Even with all of this prescribed, there is still a great deal of interpretation and selection that can be done to develop a set of program level outcomes. For example, for the CDIO Syllabus topic 2.2 of Experimentation and knowledge discovery, program outcomes might be:

- A graduate at EQF level 6 is able to conduct experiments in open-ended contexts that require the integration of multiple disciplines, taking responsibility for the approach and the results.
- A graduate at EQF level 5 is able to utilize experiments to gain knowledge on a phenomena that require consideration of more than one engineering discipline and, under general supervision, interpret the results of the experiments.
- A graduate at EQF level 4 is able to Employ established guidelines and procedures in experimentation and knowledge discovery in a specific field of engineering.

GENERAL REMARKS: HOW TO USE THE MODEL

The analysis carried out by the DOCET group and the results of an open consultation (organized in the first quarter of 2010 and involving Professors, representatives from Business and company Associations, people involved in the CDIO community) have pointed out that:

- The EQF can be used not only to classify full degree qualifications, but it also provides the basic elements to define learning outcomes and levels within qualifications.

- The stakeholders interviewed generally don't feel comfortable when a degree and an EQF (or other) level of qualification are explicitly linked. They observe that the correspondence between EQF levels and HE Full Qualifications (EQF 6 = Bachelor; EQF 7 = Master; EQF 8 = PhD) is not aligned based on the current definition of generic EQF descriptors. Furthermore, within engineering, the "real" EQF levels to be considered are lower especially when considering "non-core" engineering learning outcomes.
- Since the learning outcomes defining the curricula can have different positions within EQF levels, the levels assigned to qualifications are the result of an "average" among the levels assigned to learning outcomes. On the whole, the criterion to assign the level to a full qualification that has learning outcomes at different EQF levels is based on negotiation. However, as general rule, at least the set of learning outcomes related to the key topic of the reference qualification has to be positioned at the same level as the full qualification. Moreover these general rules are to be the basis for transparency.

The relations among EQF levels and degrees of the European Higher Education Area (Bachelor, Master, PhD) have been thus removed from the tables: in fact, it appears unrealistic that a single set of learning outcomes (i.e. a single final profile for a degree) exists for each level (Bachelor, Master, PhD) of all engineering programmes. Thus the correct relation should be established by the engineering Universities considering: 1) the environment of the University; 2) the desired profile of learning outcomes the University designs for the various programmes offered. The model could in this sense provide a repository of standard learning outcomes and their basic descriptors-level indicators (allowing the creation and updating of dynamic databases and related semantic information systems) that each Institution must customize.

The use of the model should help the process that universities, companies, and stakeholders follow to define and "negotiate" transparently the learning objectives of the engineering education. It also facilitate the comparison (and the improvement) between curricula, the communication addressed to students and the recognition of credits and curricula among different countries.

Outside the university environment, this model should help small and medium enterprises to understand and position someone's competences, especially if this someone came from a different country (and different university system).

With this model, labour and student mobility can be improved with a transparency model of studies recognition.

CONCLUSIONS

The paper described the results and model developed by the DOCET project, sponsored by the European Union. The model, combining the general descriptors and levels of Knowledge, Skills and Competence provided by the EQF and the "engineering content" suggested by the CDIO Syllabus, defines a set of reference tools that can be used to define learning outcomes associated with engineering programmes in a transparent way.

Universities, businesses and students can benefit from the model, the use of which can improve the recognition and transparency of curricula, the improvement of their quality (facilitating the process of continuous comparison) and the negotiation of engineering goals by the interested stakeholders.

ACKNOWLEDGEMENTS

This project has been funded with support from the European Commission. This publication reflects the views only of the author, and the Commission cannot be held responsible for any use which may be made of the information contained therein.
The support of the European Commission funding the DOCET project is gratefully acknowledged.

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