

# FORMATION AND CERTIFICATION OF INTEGRATED DESIGN ENGINEERING SKILLS

Andreas Riel<sup>1</sup>, Serge Tichkiewitch<sup>1</sup>, Damian Grajewski<sup>2</sup>, Zenobia Weiss<sup>2</sup>, Anca Draghici<sup>3</sup>, George Draghici<sup>3</sup>, Richard Messnarz<sup>4</sup>

(1) G-SCOP Laboratory, Grenoble University of Technology, Grenoble, France (2) Virtual Design and Automation Centre (VIDA), Poznan University of Technology, Poznan, Poland (3) Integrated Engineering Research Centre, Politehnica University of Timisoara, Timisoara, Romania (4) ISCN GmbH, Graz, Austria

## ABSTRACT

Integrated Product Development is increasingly a challenge of understanding and predicting the complete product lifecycle, and of treating the product as a whole in all phases of development. This paper points out that this trend has significant implications on the competence profiles of engineers, which are nowadays insufficiently taken into account by education and training programs, as well as skill certification schemes. It proposes a skill set of Integrated Design Engineers based on the results of collaborative research and collaborations with industrialists. Key “integrated skills” include Product Lifecycle Engineering, Innovation-driven Design, Sustainable Design, Responsible Design, Networked Collaboration, Intercultural Skills, Requirements and Knowledge Engineering. We show how the established platform and certification rules of the ECQA can be used to leverage these assets to a worldwide unique qualification and certification platform for Integrated Design with a strong international and industrial orientation.

*Keywords: Integrated Engineering, Integrated Design Engineer, System Competence, Product Development Improvement, Lifelong Learning, Certification, Professional Training*

## 1 INTRODUCTION

The design of successful and sustainable products is increasingly linked to mastering the challenge of the complexity and multidisciplinary nature of modern products in an integrated fashion from the very earliest phases of product development. Design engineers are increasingly confronted with the need to master several different engineering disciplines in order to get a sufficient understanding of a product or service. Competence in the major aspects of the whole product lifecycle is a key element of the skills they require to be able to conceive a product design that fulfils the requirements of all the different actors involved in the product’s lifecycle as well as the constraints imposed by their individual environments. Likewise, engineering teams are getting increasingly interdisciplinary, and thus there is a strong demand for a mutual understanding and collaboration between domain expert team members.

Although university curricula are starting to get adapted to this development, it is evident that there is an urgent need for interdisciplinary formation and certification programs in professional environments. While universities are supposed to educate in-depth knowledge in specific engineering areas, lifelong learning programs and curricula are needed that teach the transversal links between the different engineering disciplines according to criteria that are defined by industry. Industrialists demand for the efficient qualification and certification of these skills, as well as for their international recognition and exchangeability.

In this paper we report about first results of the iDesigner project [1], which deals with the creation of a professional modular qualification program with certification for the new job role of an Integrated Design Engineer. Chapter 2 gives an overview of the skills set that we have established as the basis of our further research. In Chapter 3 we introduce the two case studies of Sustainable Design and Automotive Powertrain Design. Chapter 4 describes the system that we are using to create and manage the skills set, the training material, and the certification process. In Chapter 5 we summarize the main points that we make in this paper.

## 2 INTEGRATED DESIGN ENGINEER SKILLS SET

The qualification and certification of Integrated Design Engineers addresses itself at experienced design engineers who want to complement and/or certify their advanced design skills. The students typically aim at a senior or principal engineer position in their design teams, but also for managing positions. The certificate, however, is not supposed to certify the student's capabilities as a design team manager. One of the biggest challenges is to conceive a training program that covers the complete skills set in a maximum of three weeks.

### 2.1 Integrated Design Engineer Skills Set Overview

The skills set of the job role of an Integrated Design Engineer provides the basis for the development of trainings and certifications. It is composed of skill units which consist of skill elements. Skill units specify a group or a domain of competences, whereas skill elements represent more specific competence areas that are related to the respective units. For each skill element so-called performance criteria have to be specified, which indicate specific competence items that a candidate has to have in order to master the element.

Training and certification can be done on a skill element level, which allows for a modular approach to getting a complete certificate of a job role.

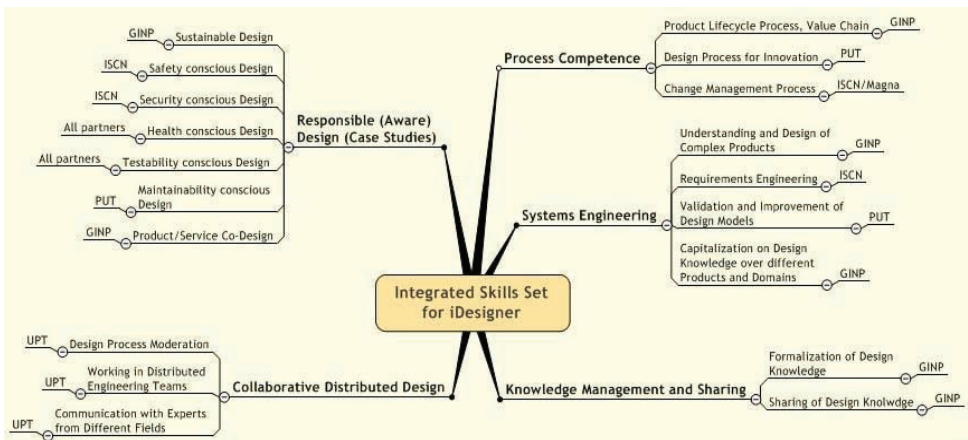


Figure 1. Basis of skills set definition of Integrated Design Engineers in the iDesigner project

Figure 1 shows a knowledge map of the skills set which provides the basis of our research and development activities. The acronyms attached to each branch indicate the partner institutions responsible for the further development of the respective skill elements, where GINP indicates the author institution (1), PUT indicates the author institution (2), UPT indicates the author institution (3), and ISCN indicates the author institution (4).

This map indicates the result of an initial consolidation of our experiences in research, education, as well as in collaboration with industry. Although we consider this skill set already quite stable, it is supposed to evolve in the course of the project as we involve experts from different industrial sectors, and get the feedback from partners in industry and academia and from students of initial training seminars. We consider the skill units Process Competence, Systems Engineering, Knowledge Management and Sharing, and Collaborative Distributed Design largely independent of specific industrial sectors, whereas under Responsible (Aware) Design we subsume more specialized skills, which are supposed to be trained using case-studies mainly. As will be pointed out in Chapter 4, the training and certification concept is modular, so that students will be able to choose those specialized skills that are relevant to their professions.

## 2.2 Systems Engineering

Many of the world's most successful brands create breakthrough ideas that are inspired by a deep understanding of consumer's lives, their needs and constraints, and use the principles of design to innovate and build value. This is crucial as innovation very often has to account for vast differences in cultural and socioeconomic conditions. In order to be able to do so, Design Engineers need to develop a good level of competence about the whole system they conceive, and about its environment.

For the classic "non-integrated" design methodology a lot of tools called "Design for ..." have been developed, which allow taking into account one specific domain (assembly, maintenance, manufacturing, etc.). Such tools are made to optimize one specific view, disregarding the fact that the global optimization of a system is in general not to be achieved by the local optimization of a series of components. Moreover, what normally has to be a constraint for the system is transformed into an objective function in these systems: Does an assembly have to be minimized, or is it sufficient to respect its operability if in another solution it can be less costly or complicated?

Integrated product design considers that the different constraints previously cited are the aim of different actors who have to control them but who "belong to the same world" [2]. The common goal is to reduce the cost, to reduce the time to market, to take into account sustainability and to increase quality. Such actors have to work in a concurrent engineering context, having access to a common product model where they can have their own contextual views. They have to respect the just need [3] which consists of giving a constraint on the system as soon as possible if such a constraint can be proved.

An application of integrated design of wood furniture can be found in [4]. It is shown how the actors of the design process have to exchange information before starting a new design in order to understand what the consequences are of the different decisions they have to make for the other actors and which information has to be propagated. Other particularly representative confirmations and urgent demands of the above issues have been published notably in the automotive industry [5][6], where product development is outstandingly multidisciplinary and interdependent.

Integrated Product Design thus does not seek to optimize one single objective, but rather aims at finding the best compromise solution under multiple, often coupled restrictions that are imposed by the actors and environments of the whole product lifecycle. They typically concern issues like producability, assembly/disassembly, modularity, testability, product variant creation, environmental sustainability, product-service optimization, maintainability, cost minimization, etc. It goes without saying that Integrated Design Engineers are not supposed to master all the associated complex disciplines by themselves. They should, however, be able to understand domain experts, and be able to translate their requirements into their design tasks.

## 2.3 Process Competence

In addition to having a thorough understanding of the system, Integrated Design Engineers need to have competence about the processes of product creation, usage, and disposal, as integrated product design has to take into consideration all the stages of the product life cycle.

Although a product lifecycle is specific to a product, there are some basic facts, aspects, and phases that are common to almost any type of product [7]. An Integrated Design Engineer needs this basic knowledge in order to be able to analyse and understand specific product lifecycles. The reality is however much more complex, people and departments cannot perform their tasks in isolation and one activity cannot simply finish and the next activity start. Design is an iterative process, often designs need to be modified due to manufacturing constraints or conflicting requirements.

Companies that design successfully have carefully crafted Product Creation Processes (PCP) that extend over all phases of product development from initial planning to customer follow-up. Their PCP is their plan for continuous improvement. The decision to develop and operate under a PCP is a corporate one. Successful operation of a PCP requires extensive cooperation among a firm's marketing and sales, financial, design, and manufacturing organizations. In the idealized account of the PCP, everyone cooperates, desired quality is achieved, and the product succeeds in the marketplace. In practice, the process is difficult and full of conflict and risk. Converting a concept into a complex, multitechnology product involves many steps of refinement. The design process requires a great deal of analysis, investigation of basic physical processes, experimental verification, complex tradeoffs between conflicting elements, and difficult decisions. Satisfying the different and conflicting needs of function, manufacturing, use, and support requires a great deal of knowledge and skill.

## 2.4 Collaborative Distributed Design

In technical terms, collaborative product development in terms of the system- and process-oriented view elaborated in the previous chapters is based on the integration of Product Lifecycle Management (PLM), Enterprise Resource Planning (ERP), Supply Chain Management (SCM) and Customer Relationship Management (CRM) solutions [8] (Figure 3). Integrated Design Engineers not only have to be able to work with these tools, but they also need to understand how they link the different teams and actors that are involved in the product lifecycle.



Figure 2. Integration of PLM, ERP, SCM and CRM

Although in human terms collaborative engineering is based on the support of the organization, it is very much facilitated by the awareness of each engineer about his role in the process, as well as the roles of others. Collaborative design involves product designers, manufacturing engineers, and representatives of purchasing, marketing, and field service in the early stages of design in order to reduce cycle time and improve manufacturability. This practice helps resolve what is often called the designer's dilemma, the fact that most of product cost, quality, and manufacturability are committed very early in design before more detailed information has been developed.

The key to the successful use of collaborative design concepts is the ability to organize and manage concurrent processes and cross-functional and typically distributed teams effectively. Obtaining this know-how is not a matter of studying textbooks but it rather demands a balanced blend of solid experience and of theoretical background. This is what the professional seminar program to be conceived in this research shall convey in sector- and national-specific contexts.

## 2.5 Knowledge Management and Sharing

Knowledge management is globally a subject of the whole organization, which is under the responsibility of the management levels. However, understanding the purposes and challenges of knowledge management and knowledge capitalization, as well as the concept of typical knowledge management and knowledge modeling tools, is an important prerequisite for the participation of Integrated Design Engineers in the related efforts of an organization.

## 2.6 Responsible (Aware) Design

In the initial skill set definition of an Integrated Design Engineer we are dealing with some special issues of Product Lifecycle Engineering for which we see a high demand in the market and in the society in general, and which can be realized successfully only by conceiving products (from whatever industrial sector) with integrated product lifecycle-related competences. In this context, we have published one related case study of safety engineering in automotive [9], and we are working on others, always looking out for close collaboration with industry. In the following chapter we introduce two examples in sustainable design, and in automotive powertrain engineering.

### 3. EXAMPLES OF CASE STUDIES

In this chapter we point out two examples of case-study based qualification modules: Sustainable Design and Integrated Model-Based Automotive Powertrain Design.

#### 3.1 Sustainable Design

Integration of environmental considerations as early as possible into the product design is extremely beneficial, as all decisions at this phase have significant impacts on the long-term product improvement and functionality. This concerns not only new products but also existing products, improvement of branding and company image. Standards like ISO-14062 specify the systematic integration of environment considerations in to design process. Results of each stage of the planning process are fed back into other stages and given to designers. In practice companies employ different approaches and tools to design and develop products. Different products also have their own specific characteristics, which is why there is no single standard way of integrating environment considerations into design processes.

A starting point for the eco-design process can be an existing product, a prototype, a concept or an idea to meet a particular customer's requirement. Basically, the earlier ecological improvements can be dealt with in the product development process, the more effective the results and the lower the implementation costs will be. Therefore, environmental concerns should be systematically incorporated into the earlier phases of the product development process. The graphic below illustrates a proposal for a methodical procedure in relation to ISO14062 (Figure 4).

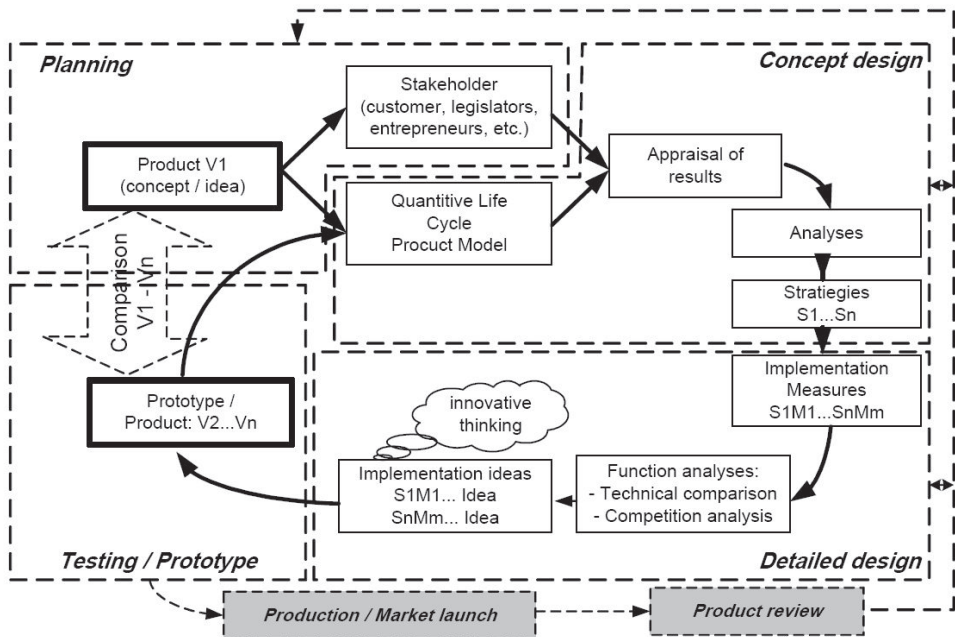


Figure 3. Systematic procedure for sustainable design [10]

In order to offer a successful and environmentally sound product on the market, the expectations of potential customers, the legal framework (both existing and projected), internal corporate interests and the entire product lifespan and its environmental impact must first be acknowledged (the planning stage of ISO14062). The analysis of all these factors forms a basis for further developmental stages, such as realization of strategies (concept design), and subsequently, the formulation of concrete measures until implementation ideas have been determined (detailed design). At the end of this chain, a new and improved product proposal, prototype or a new idea will result, that will be compared with the original concept under the existing criteria (customer expectations, legislative, environmental impact, etc.) (testing/prototype).

Depending on the result of the comparison, the eco-design process cycle can be redeveloped from scratch and repeated as often as needed until a satisfactory result is achieved (feedback/continuous improvement). The individual stages of the process depicted in Figure 4 are described in [10]. The message we want to give in the context of this paper is that design engineers have the most crucial role in the control loop that leads to a sustainable product with respect to its whole lifecycle.

### 3.2 Integrated Model-Based Automotive Powertrain Design

Integrated Engineering by its very definition covers multiple expert domains and thus usually separate and specific threads of communication, specific wordings, different understandings of terms, etc. Classic product development organizations typically resemble expert domains in their departmental and/or project structures, thus further intensifying and augmenting the difficulties of realizing integrated engineering. With increasing system complexity, obtaining the competence of the whole final product as a system and as a result of a networked system of development tasks has become practically impossible in such environments.

The development process of automotive powertrains is a stereotype example for this problem. The automotive industry is one of the most highly innovation-driven industries. This chapter presents selected results of a detailed analysis of this process [5], and their implications on the need for integrated engineering skills to attain and improve system competence.

#### The Automotive Powertrain Development Process

Figure 5 shows the most essential phases of the powertrain development process [5]. The engine and transmission development processes run in parallel in very similar phases and they are closely linked by consecutive “vertical” tasks if the powertrain is developed in a holistic way. The horizontal line arcs indicate the various horizontal activities that need to be carried out ideally throughout the whole process, as they are all closely linked to the performance and quality of the final product. Most of them, however, require the whole powertrain and/or the vehicle to be available before they have actually been built. This is especially true for the engine and powertrain electronic control units (ECU – Engine Control Unit, TCU – Transmission Control Unit). In the traditional approach, prototypes of the missing parts are manufactured, or they are used from a suitable predecessor model.

In the modern, still heavily researched approach, simulation models with different levels of detail are used to mimic real components that are not yet available, from concept simulation via tests and

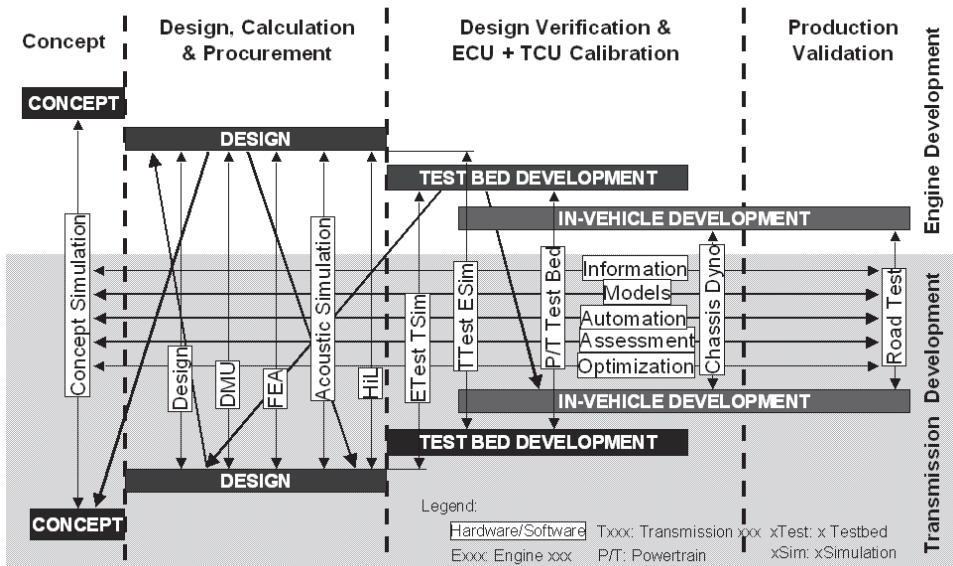


Figure 4. Automotive Powertrain Development Process

calibrations on various kinds of testbeds to the phase with the vehicle prototype on the chassis dynamometer. This enables “front-loading” development activities to the early phases of the process, which are mostly linked to design. In this scenario, it may well happen that the transmission exists before the engine has been built and vice versa.

Both these approaches, and any approach in between, represent cases in need of intensive integrated engineering and system competence on an individual engineer’s level as well as on a distributed team level. They involve engineers with several different education and expertise profiles, who all have to work towards the same final targets, which are all linked to the global performance of the whole vehicle, mainly in terms of drivability (specific “feeling”), fuel consumption and emissions. The inputs of one activity depend on the results of several other activities, which are all linked to different domain experts. [3][12][13] treat this subjects exhaustively, with special regard to its implications on integrated design. [5] develops the so-called Behavioral Mock-Up (BMU) concept that extends the well-established Digital Mock-Up (DMU) concept to support the entire development process.

The permanent interactions and synchronizations between the two processes are sketched with the inclined arrows in Figure 5. Networking the engine and transmission development processes can be achieved by the seamless use of simulation tools and consistent simulation models. Closely connected to this is the process of collecting all the data that are required for the models used [5]. Primarily due to the stringent demands imposed by quality assurance, member of the different, typically distributed engineering teams, need to have comparable levels of engineering skills on a system level. Because it is on a system level where the teams’ tasks are linked and have their dependencies: Engine and transmission, control electronics and powertrain, comfort electronics and cabin, etc. to name a few.

### Model-based Integrated Development

In the ideal model-based integrated development process, sketched in Figure 6, the early CAE-models act as the single source of data for all the later models. This assures the consistency of all the models.

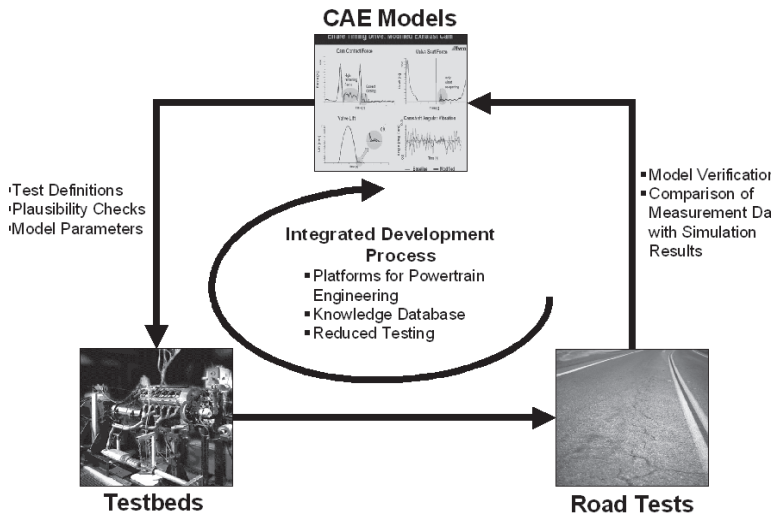


Figure 5. Model-based Integrated Development

Real-time models are derived from CAE-models by target-oriented simplification or re-structuring, which typically includes the replacement of analytical calculations by pre-calculated maps and the exclusive use of fixed-step solvers. CAD/CAE data and models are used for test planning and definition, and a seamless feedback loop from the testing environment has to be established for model verification and improvement. A practical example can be found in [14]. This engineering “control loop” relies on a working flow of vehicular knowledge between the involved groups and departments. Realizing such a loop relies on system competence of the engineers involved, as each part of this loop has to understand what the others need in terms of the characteristics of the system models, the parameters and the data.

### 3 QUALIFICATION AND CERTIFICATION OF INTEGRATED DESIGN ENGINEERING SKILLS

This chapter gives an overview of the system and the platform proposed and implemented by the ECQA [11]. One of the major aims of this research is to show that both their system and their platform are very well suited to specify, implement and roll out the qualification and certification of modern job roles in Integrated Engineering environments.

#### 3.1 Skills Acquisition with the ECQA Platform

The ECQA has set up a partnership of experienced partners in 18 European countries to create a pool of knowledge for specific professions. This pool can be extended to further professions. All the professions that have been configured in this system up to now, are based in the ICT area, and are thus closely related to Software Development. As integrated product development processes are increasingly related and/or linked to software development, new job roles from the Integrated Engineering domain will profit from this sound basis [15].

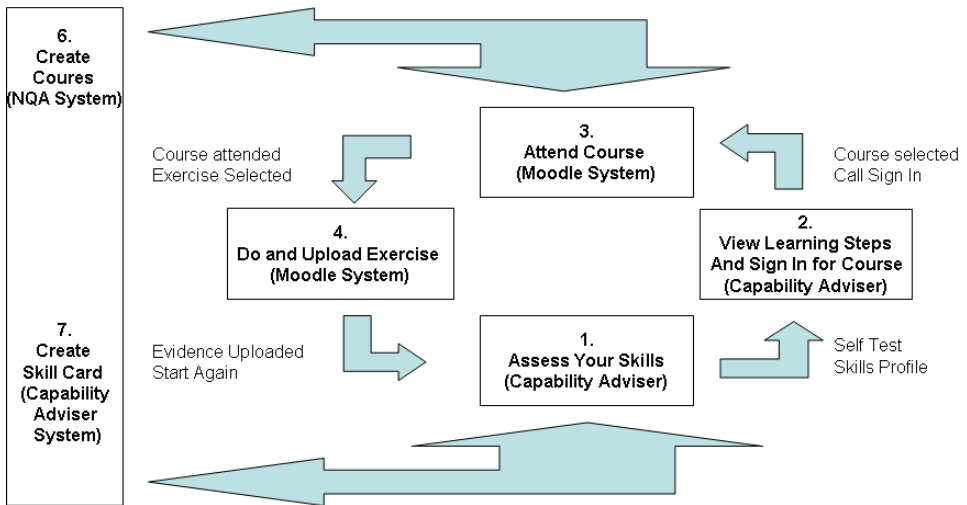


Figure 7. The Integrated European Skills Acquisition System of the ECQA

Figure 7 gives an overview of the uncomplicated but efficient skill acquisition process supported by the ECQA platform: If there is a need a person can attend a course for a specific job role online through an advanced learning infrastructure. The student starts with a self assessment against the skills. Then she can sign into an online course. Here he is guided by a tutor and does a homework which is corrected by the tutor. Finally the homework and the real work done in her project are sufficient to demonstrate the skills. The learning platform is based on the web based public domain learning management system Moodle ([www.moodle.com](http://www.moodle.com)). The assessment process is supported by the so-called Capability Adviser, which is a web based assessment portal system with a defined database interface to connect the systems. Network Quality Assurance NQA is a web based team working tool which was developed in the EU IST 2000 28162 project.

#### 3.2 Provision of Skill Sets

The ECQA platform of knowledge is enhanced on an annual basis. Existing skills sets are being reworked and new skills sets are added. Joint knowledge is being configured in form of a job role with standard content structures like skills set, syllabus, learning materials and online configuration, as well as sets of test questions.

So-called Job Role Committees decide upon the content for a specific skills set. These committees are composed of academics and industrialists. The job role committee for the Innovation Manager, for



instance, created a skills set of an innovation manager together with a set of online courses etc. People can register from their work places.

### 3.3 Qualification and Certification

Nowadays and according to the Bologna Process, it is very important that training courses are internationally recognized, and that successful course attendees receive certificates that are valid for all European countries. The EU supported the establishment of the European Qualification Network (EQN), from which the ECQA has evolved, with exactly this target in mind. This has resulted in a pool of professions in which a high level of European comparability has been achieved by a Europe wide agreed syllabus and skills set, a European test questions pool and European exam (computer automated by portals) systems, a common set of certificate levels and a common process to issue certificates.

Quality criteria to accept new job roles in the ECQA, to accredit training organizations and certify trainers, as well as to certify attendees have been developed. The existing skills assessment portals (already used by more than 5000 students in different learning initiatives) are extended to cover the new requirements of the ISO 17024 (General Requirements for Bodies operating Certification of Persons) standard. Among the international certification organizations that provide ECQA-compliant certification is the ISQI (International Software Quality Institute, [www.isqi.org](http://www.isqi.org)).

## 4. SUMMARY

This paper points out that there is a strong industry need for international training, qualification and certification of modern job roles in Integrated Engineering, like Integrated Design Engineering. It also makes evident the important relationship between professional training and university education to achieve this aim. We found that the lifelong learning concept of the ECQA, which is already very well established in the ICT domain and set a European-wide standard there, is highly suitable for this purpose. Moreover, the ECQA provides a strong IT platform with all the applications required for learning, testing, and certification already in place.

## 5. ACKNOWLEDGEMENTS

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Contact: A.E. Riel  
Grenoble University of Technology  
G-SCOP Laboratory  
46, av. Félix Viallet  
38031, Grenoble  
France  
Tel.: +33 4 76825156  
FAX: +33 4 76874695  
email: [andreas.riel@inpg.fr](mailto:andreas.riel@inpg.fr)  
URL: [www.g-scop.inpg.fr](http://www.g-scop.inpg.fr), [www.emiracle.eu](http://www.emiracle.eu)

Andreas Riel is a contractual researcher at Grenoble University of Technology, as well as the General Manager of the EMIRAcle association ([www.emiracle.eu](http://www.emiracle.eu)). He has ten years of professional work experience in development, research and innovation management in the automotive industry, and two years of experience in the management of the European Network of Excellence VRL-KCiP, which is at the origin of EMIRAcle. Over the recent years he has gained vast experience in innovation management in both product development and manufacturing, and he has focused his research activities on Integrated Design.