Integrated Engineering Skills: Improving your System Competence Level

Andreas Riel[1], Serge Tichkiewitch[1], Richard Messnarz[2]
[1]Grenoble Institute of Technology (France) and EMIRAcle AISBL
[2]ISCN GmbH (Austria) and ECQA
Andreas.Riel@inpg.fr, Serge.Tichkiewitch@inpg.fr, rmess@iscn.com

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. Building on the highly innovative and successful European-wide professional training and certification scheme of the European Certificates and Qualification Association (ECQA), it suggests a basic skill profile that is characteristic for modern job roles in Integrated Engineering, and justifies the integration into the ECQA platform. It points out that this initiative marks a major step towards the improvement of engineers' system competence levels.

Keywords

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

1 Introduction

Integrated Engineering is characterised by a highly multidisciplinary approach to product development. 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. Likewise, engineering teams are getting increasingly interdisciplinary, and thus demand for a mutual understanding and collaboration between domain expert team members [23][26].

Although university curricula are starting to get adapted to this development on an international scale, it is evident that there is an urgent need for interdisciplinary education and certification programs on a postgraduate level. 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 certification of these skills, as well as for their international recognition and exchangeability.

Today, such internationally recognized training and certification programs for job roles in modern manufacturing do not exist. This paper describes the approach that EMIRAcle (the European Manufacturing and Innovation Research Association, a cluster leading excellence – http://www.emiracle.eu) takes together with the ECQA (the European Certificates and Qualification Association – www.eu-certificates.org) in order to define and establish job roles, curricula and certifications in the domain of Integrated Engineering on a European level. The target is to define and describe the skill sets that characterises Integrated Engineering, as well as to provide skill-specific training modules and the corresponding training material. Once these are found, test questions have to be formulated, which shall provide the basis for assessment and certification of candidates.

We present the requirements to job roles in Integrated Engineering that are demanded by industry, and show how they are used to develop education and test programs, as well as certification criteria. This activity is part of the EU Certification Campus (EU Cert) initiative launched by the ECQA at the beginning of 2008, which aims at implementing a number of training and certification programs into their already well-established IT-platform, and offering those in a number of education institutions all over Europe. While ECQA members are already very active and successful in the software domain, EMIRAcle will extend their concept to the manufacturing domain with a string focus on innovation aspects. The work presented here is thus the basis for a life-long learning Integrated Engineering training and certification concept and infrastructure which are both not only worldwide unique but also heavily demanded by the industry [20].

Chapter 2 summarizes the background of the work of the ECQA. In Chapter 3 we point out the requirements to Integrated Engineering skills and we make evident that those are not sufficiently taken into account in current education schemes. Chapter 4 links aspects of improvement to system competence. Chapter 5 introduces the training, testing and certification concept that has been established by the ECQA and suggests it as the platform to implement job roles in Integrated Engineering.

2 Background

This section points out the need for job role based qualification and certification in industry.

2.1 Success Factors of Innovation

The success of an innovation or improvement is not just dependent on the correct technical approach. Instead, numerous learning strategy related aspects influences the success. This fact has been proved by the following European studies, among others:

- Study at 200 firms in 1998 [15];
- study at 128 multinational firms in 2002 [18];
- study in 59 networked European organisations in 2003 [2][8][9].

Beside top management support (26%) the studies outlined a positive learning culture (15%, learning from mistakes, team learning, knowledge sharing, etc.) and a supporting organizational infrastructure (17%) which helps with the implementation of the learning organisation [18]. A learning organisation [10][17] creates a positive learning culture and enables team learning and synergy exploitation in an organisation. By team learning knowledge is spread much more quickly and a high level of a skilled human force is maintained.

Human skills are regarded as a complementary set needed in addition to qualified processes to be successful on the market.

2.2 Processes, Job Roles, and Skills

Figure 1 illustrates that processes require roles, which need specific skills to efficiently perform the job. In ISO 15504 a capability level 3 would, for instance, require the definition of competence criteria per role. The combination of this approach with the learning organisation related approach outlined in section 2.1 leads to a framework where it becomes extremely important to think in terms of job role based qualification and skills. This concept is described in greater detail in e.g. [14].

Processes and Human Ressources

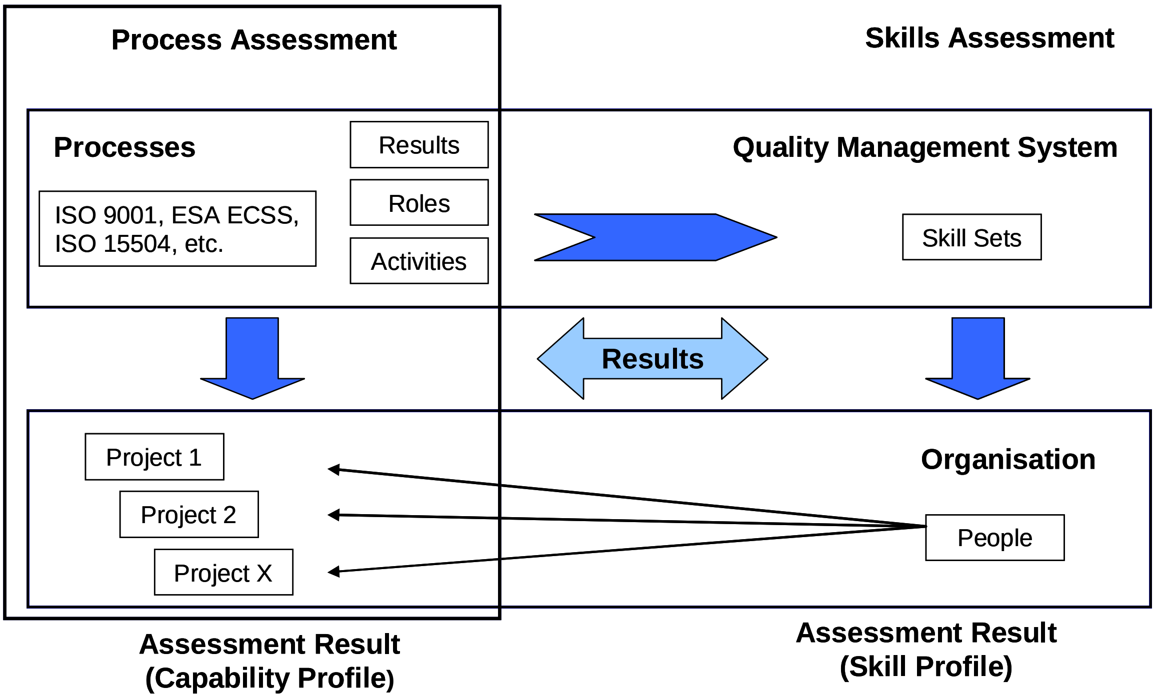

Figure 1. Integration of Process and Human Skills in an Integrated Model

3 Key Skills of Engineers in Integrated Engineering

In this section we suggest four of the key skill units which we believe should complement expert skills for job roles Integrated Engineering, with a strong focus on Integrated Design as design is at the root of every product development. The skill sets that make up this unit, as well as additional units will be developed in the frame of this research project.

3.1 Requirements Engineering

The key to making a product successful on the market is to design it according to all sorts of key requirements that come from a number of different sources. These are all the actors directly involved in the product life cycle, as well as the product's "environment", like government, laws, economy, etc. Outstanding actors and factors are

1. the target customers,
2. the manufacturing process,
3. the product's life cycle,
4. its manufacturability and maintainability,
5. the development time and costs,
6. etc.

Identifying requirements is in general a complex activity. Very often the requirements specifications that are given to designers are imprecise and/or incomplete. Knowledge about systematic requirements collection and management helps designers collect missing or incomplete requirements information.

Requirements management is a complex procedure that is difficult to carry out systematically without the use of appropriate tools. There exists already a large number of requirements management tools (about 40 are listed in [12]), which are typically specialized for use in certain domains. Even if in some (especially bigger) organizations development tools are chosen on a higher management level, it is often the engineers who are asked to propose a choice of tools.

User-centric methods like Scenario-Based Design [6] and Use Case Design [3] are becoming more and more important, as they force requirements engineers to think from a product-use point of view rather than in terms of solutions. Scenarios are important tools for exercising architecture to gain information about a system's fitness with respect to a set of desired quality attributes.

A use case is a description of a system's behaviour as it responds to a request that originates from outside of that system. The use case technique is used in software and systems engineering to capture the functional requirements of a system. Use cases describe the interaction between a primary actor—the initiator of the interaction—and the system itself, represented as a sequence of simple steps. Actors are something or someone which exist outside the system under study, and who (or which) take part in a sequence of activities in a dialogue with the system, to achieve some goal: they may be end users, other systems, or hardware devices. Each use case is a complete series of events, described from the point of view of the actor.

Use case design thus enables engineers and anyone else concerned with the product to adopt an application and user-oriented viewpoint which largely facilitates the derivation of the detailed functional requirements to the product.

3.2 Integrated Product Design

Current design methodology developed a lot of tools called "Design for …", in order to take 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" [4]. 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 [5] 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 [19]. 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. Choosing an assembly system for joining two boards is directly guided by a quality requirement but also has consequences on the mechanical models used to determine the deflections of the boards and on the manufacturing features to be realized (and therefore also on the cost). The assembly set can be considered as an intermediate object for the communication between people in charge of assembly, mechanical behaviour and manufacturing. As such it acts as a vehicular object (as opposed to a vernacular one). At the same time, however, this assembly set cannot be sized without knowing the thickness of the board that depends on the model used. We saw that an interactive process between the assembly actor and the people in charge of mechanics must arise during the design activity. This interactive process is a way to solve imaginary complexity.

Other particularly representative confirmations and urgent demands of the above issues have been published notably in the automotive industry [13][20], where product development is outstandingly multidisciplinary and interdependent.

According to the above, product design does not seek to optimize one single objective, but rather aims at finding the best compromise solution under multiple, often coupled restrictions like the following:

- Producability,
- Assembly/Disassembly,
- Modularity,
- Testability,
- Product Variant Creation,
- Environmental Sustainability,
- Product-Service Optimization,
- Maintainability,
- Cost Minimization,
- etc.

Certainly an Integrated Design Engineer cannot master all the associated complex disciplines by himself in general. He should, however, be able to understand domain experts, and be able to translate their requirements into his design task.

3.3 Product Lifecycle Engineering and Management

Integrated Engineering is synonym for well understanding the product and the way it is created, used, disposed, and recycled. Product Lifecycle Management (PLM) is the process of managing the entire lifecycle of a product from its conception, through design and manufacture, to service and disposal [24]. It is one of the four cornerstones of a corporation's information technology structure. All companies need to manage communications and information with their customers (CRM-Customer Relationship Management) and their suppliers (SCM-Supply Chain Management) and the resources within the enterprise (ERP-Enterprise Resource Planning). In addition, manufacturing engineering companies must also develop, describe, manage and communicate information about their products (PDM).

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. An Integrated Design Engineer needs this basic knowledge in order to be able to analyse and understand specific product lifecycles.

The core of PLM is in the creation and central management of all product data and the technology used to access this information and knowledge. PLM as a discipline emerged from tools such as CAD, CAM and PDM, but can be viewed as the integration of these tools with methods, people and the processes through all stages of a product’s life. It is not just about software technology but is also a business strategy.

For simplicity the stages described are listed below in a traditional sequential engineering workflow. The exact order of event and tasks will vary according to the product and industry in question but the main processes are:

- Conception,
- Specification,
- Concept Design,
- Design,
- Detailed Design,
- Validation and Analysis (Simulation),
- Tool Design,
- Realization,
- Plan Manufacturing,
- Manufacturing,
- Build/Assembly,
- Test (Quality Check),
- Service,
- Selling and Delivery,
- Usage,
- Maintainance and Support,
- Disposal and Recycling.

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.

Although 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.

3.4 Networked Collaboration

Due to the involvement of many different experts, Integrated Product Design can only be done in teams, which are inherently heterogeneous and also increasingly international. Although design tools support this collaborative work increasingly better, Integrated Design Engineers need to have skills that go beyond tool operation in order to be successful collaborative engineering tasks. We list below the ones that we will focus on in the development of the Integrated Design Engineer's profile:

1. Teamworking skills,
2. Intercultural skills,
3. Knowledge Management,
4. Knowledge Capitalisation,
5. Knowledge Sharing.

Teamworking and intercultural skills are indispensible in modern international engineering teams. Knowledge management is certainly a subject of the whole organisation, which is under the responsibility of the management levels. Understanding the purposes and challenges of knowledge management and knowledge capitalisation, as well as the concept of typical knowledge management and knowledge modelling tools, is an important prerequisite for the participation of Integrated Design Engineers in the related efforts of an organisation [7].

4 Improvement of and by System Competence

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 organisations 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 [20], and their implications on the need for integrated engineering skills to attain and improve system competence.

4.1 Example: The Automotive Powertrain Development Process

Figure 2 shows the most essential phases of the powertrain development process [20]. 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 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.

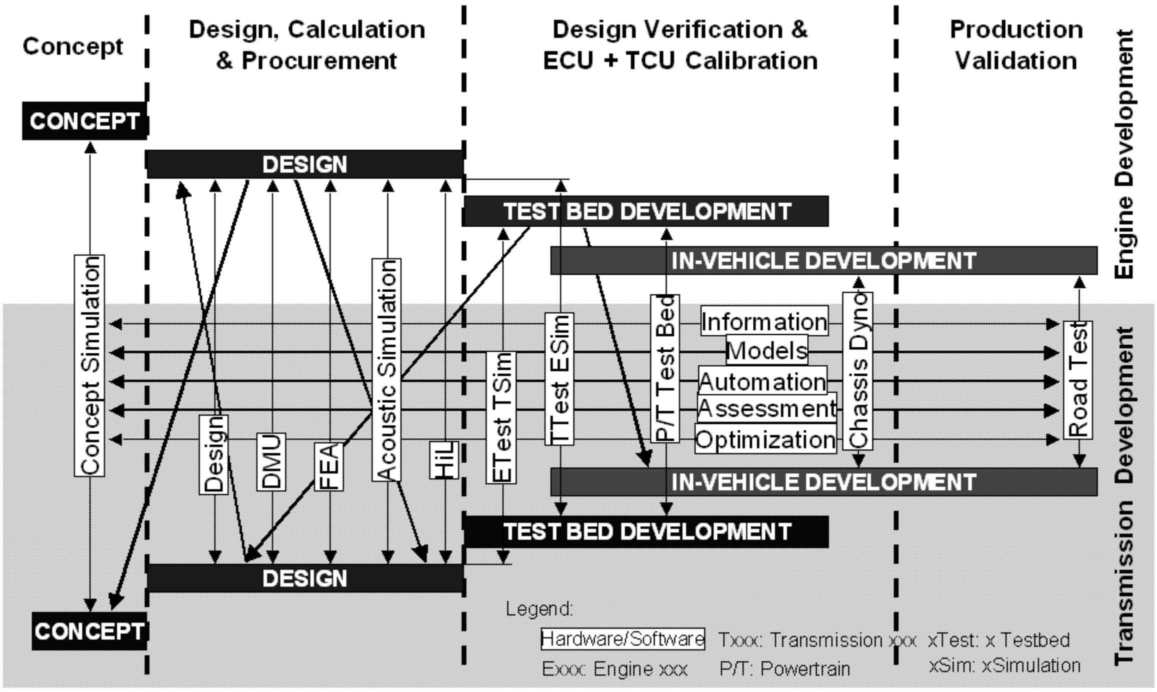

Figure 2. . Automotive Powertrain Development Process

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. [5][7][26] treat this subjects exhaustively, with special regard to its implications on integrated design. [20] develops the so-called Behavioural 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 1. 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 [20]. 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 only a few.

4.2 Model-Based Integrated Development

In the ideal model-based integrated development process, sketched in Figure 3, the early CAE-models act as the single source of data for all the later models. This assures the consistency of all the models.

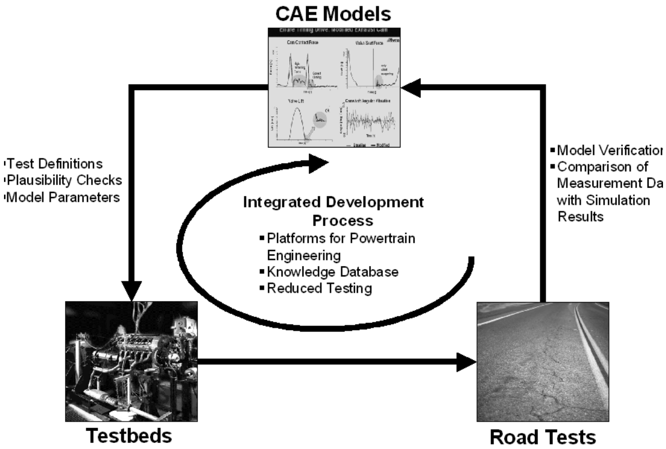

Figure 3. Model-based Integrated Development

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 [21]. 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: Each part of this loop has to understand what the other parts need in terms of the characteristics of the system models, the parameters and the data.

4.3 IT-Infrastructure in Integrated Engineering Organizations

A fundamental requirement to integrated engineering support systems is to neatly integrate into existing IT infrastructures. Both manufacturers and suppliers have invested a lot in their tool- and IT-infrastructures. CAD, ERP and PDM systems are more or less the three IT “pillars” within a product development enterprise [20]. Figure 4 shows the close relationships between the integrated engineering environment (here represented by the BMU) and all the other important complementary information sources within the enterprise.

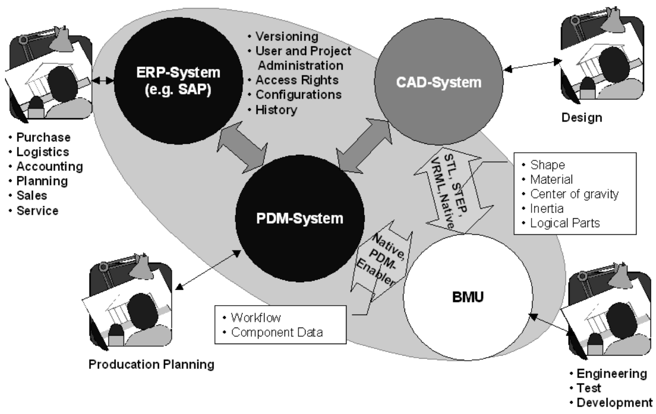

Figure 4. Networked Integrated Engineering

Integrated Engineers have to understand the role of each system in order to be able to use the whole IT infrastructure in way that it can leverage the work of all the concerned engineering teams. Once more he has to be aware of the fact he is one part in a highly networked, dependent and complex system, in which his work depends on that of others and vice versa [25].

5 Qualification and Certification of Integrated Engineering Skills

We are fundamentally convinced that the system and the platform proposed and implemented by the ECQA [14] is very well suited to specify, implement and roll out the qualification and certification of modern job roles in Integrated Engineering environments.

5.1 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, we believe that new job roles from the Integrated Engineering domain will profit from this basis [22].

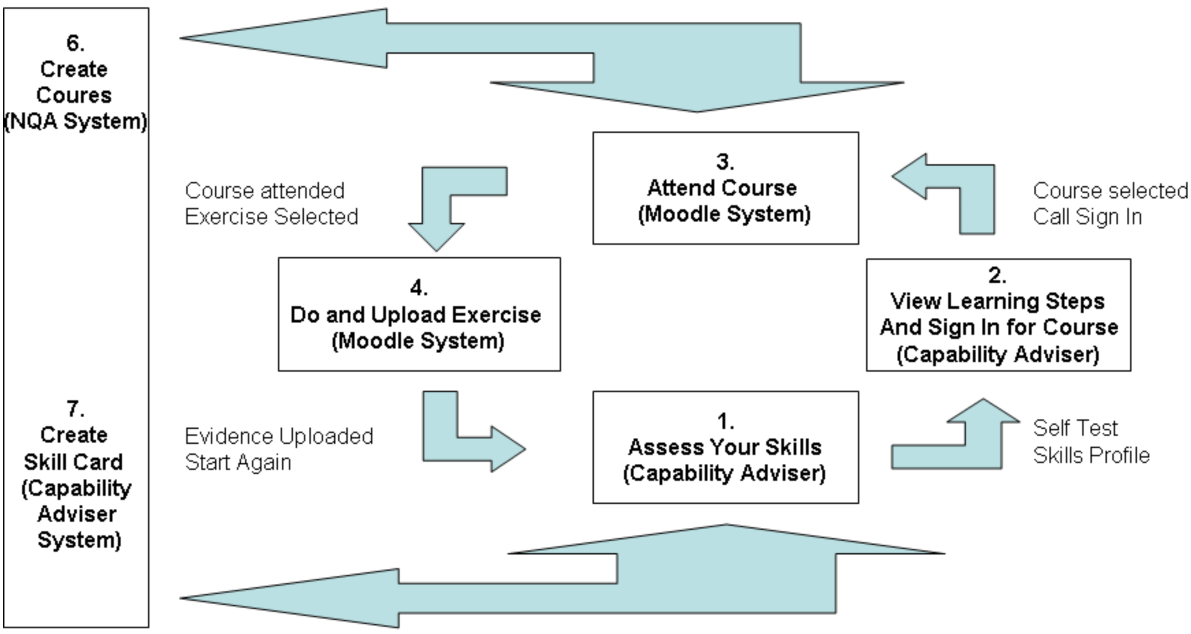

Figure 5. The Integrated European Skills Acquisition System

Figure 5 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 [16]. 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). 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 [16].

5.2 Provision of Skill Sets

The ECQA platform of knowledge is enhanced on an annual basis. Existing skills sets are being re-worked and new skills sets are added. Joint knowledge is being configured in form of a job role with standard content structures [8][17] 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.

5.3 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, and a common set of certificate levels and a common process to issue certificates.

The partners collaborated on the development of the quality criteria consisting of: Quality criteria to accept new job roles in the ECQA, quality criteria to accredit training organisations and certify trainers promoted by the ECQA, and quality criteria and test processes to certify attendees who have run through the training of a specific job role.

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 SW Quality Institute, www.isqi.org).

6 Conclusion

This paper points out that there is a strong industry need for international training, qualification and certification of modern job roles in Integrated Engineering. 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. We have started related activities for two specific job roles which are already very demanded in various industrial sectors: Integrated Design Engineer and Innovation Manager in Engineering and Production.

Acknowledgements

This project is the first in the long-term lifelong learning strategy of the EMIRAcle association, which is well-aligned with the strategic objectives of the European Technology Platform in Manufacturing ManuFuture (www.manufuture.org). The launching activities have been supported by the European Commission under the contract NMP2-CT-2004-507487 of the Network of Excellence in FP6 VRL-KCiP. We are currently supported by the EU in the Leonardo da Vinci project LLP-1-2007-AT-KA3-KA3MP (EU Cert - EU Certification Campus) of the Lifelong Learning Program.

Literature

1. Ameri F., Dutta D., Product Lifecycle Management: Closing the Knowledge Loops, Computer-Aided Design & Applications, Vol. 2, No. 5, 2005, pp 577-590
2. Biro M., Messnarz R., Davison A., The Impact of National Cultures on the Effectiveness of Improvement methods – The Third Dimension, in Software Quality Professional, Volume Four, Issue Four, 2002, American Society for Quality
3. Bittner K., Spence I., Use Case Modeling. Addison Wesley Professional, 2-3. ISBN 0-201-70913-9, 2002
4. Boltanski L., Thevenot L., De la justification, les économies de grandeur, Gallimard, 1991
5. Brissaud D., Tichkiewitch S., “Innovation and manufacturability analysis in an integrated design context”, in Computers in Industry, 43, 2000, pp 111-121
6. Carroll J.M., Five Reasons for Scenario-Based Design, in: Proceedings of the 32nd Hawaii International Conference on System Science, Hawaii, IEEE No. 0-7695-0001-3/99, 1999
7. Draghici G., Brissaud D., Modélisation de la connaissance pour la conception et la fabrication integrées, Editura Mirton, Timisoara, 2000
8. Feuer E., Messnarz R., Best Practices in E-Commerce: Strategies, Skills, and Processes, in: Proceedings of the E2002 Conference, E-Business and E-Work, Novel solutions for a global networked economy, eds. Brian Stanford Smith, Enrica Chiozza, IOS Press, Amsterdam, Berlin, Oxford, Tokyo, Washington, 2002
9. Feuer E., Messnarz R., Wittenbrink H., Experiences With Managing Social Patterns in Defined Distributed Working Processes, in: Proceedings of the EuroSPI 2003 Conference, 10-12 December 2003, FTI Verlag, ISBN 3-901351-84-1, 2003
10. Gemünden H.G., Ritter T., Inter-organisational Relationships and Networks, Journal of Business Research, 2001
11. Hua C., Chao L., Yan C., Rujia Z., Xu Q., Co-operative design based on multi-agent systems. In: Cheng K., Webb D., Marsh R. (eds.): Advances in e-Engineering and Digital Enterprise Technology: Proceedings of the 4th International Conference on E-Engineering and Digital Enterprise, Wiley, 2007, Wiley, 2007
12. Ludwig, J.I., Requirements Management Tools, available at: http://www.jiludwig.com/Requirements_Management_Tools.html, Accessed: 2008-04-14
13. Menne R., Ford: teach integrated engineering, in: Automotive Engineer, December 2007, Professional Engineering Publishing Limited, London, UK, p. 5, 2007
14. Messnarz R. et al., The EQN Guide. Graz, Austria, 2008
15. Messnarz R., Stöckler C., Velasco G., O'Suilleabhain G., A Learning Organisation Approach for Process Improvement in the Service Sector, in: Proceedings of the EuroSPI 1999 Conference, 25-27 October 1999, Pori, Finland, 1999
16. Messnarz R., Stubenrauch R., Melcher M., Bernhard R., Network Based Quality Assurance, in: Proceedings of the 6th European Conference on Quality Assurance, 10-12 April 1999, Vienna, Austria, 1999
17. Messnarz R., Nadasi G., O'Leary E., Foley B., Experience with Teamwork in Distributed Work Environments, in: Proceedings of the E2001 Conference, E-Work and E-commerce, Novel solutions for a global networked economy, eds. Brian Stanford Smith, Enrica Chiozza, IOS Press, Amsterdam, Berlin, Oxford, Tokyo, Washington, 2001
18. O'Keeffe, T., Harrington D., Learning to Learn: An Examination of Organisational Learning in Selected Irish Multinationals. Journal of European Industrial Training, MCB University Press, Vol. 25: Number 2/3/4, 2001
19. Pimapunsri K., Tichkiewitch S., Butdee S., “Collaborative negotiation between designers and manufacturers in the wood furniture industry using particleboard and fibreboard”, Design Synthesis, CIRP Design Conference, Enschede, CD-ROM, 2008
20. Riel A., From DMU to BMU: Towards Simulation-Guided Automotive Powertrain Development. Thèse de Docteur Ingénieur, Université de Technologie de Vienne, Vienna, Austria, 2005
21. Riel A.; Brenner E., Shape to Function: From DMU to BMU, in: Experiences from the Future. New Methods and Applications in Simulation for Production and Logistics. Fraunhofer IRB Verlag, Stuttgart , ISBN 3-8167-6640-4, 2004, pp 275-288, 2004

22. Riel A., "EU Certificates and Knowledge Communities in Europe: An unbeatable Symbiosis", Keynote at "EQN Founding and Dissemination Conference", Krems, Austria, CD-ROM, 2006

23. Riel A., Tichkiewitch S., Molcho G., Shpitalni M., Uys W., Uys E., du Preez N., Improving Product Development Organisations using Knowledge Mining: Requirements, Methods and Tools. Knowledge Management in Product Development, Proceedings, Enschede, CD-ROM, 2008

24. Saaksvuori A., Product Lifecycle Management. Springer, ISBN 3540257314, 2005

25. Schmidt C., Temple B.K., McCready A., Newman J., Kinzler S.C., Virtuality-based understanding scheme (VirUS) – a holistic typecast supporting research and behaviour-oriented management of virtual teams. In: Cheng K., Webb D., Marsh R. (eds.): Advances in e-Engineering and Digital Enterprise Technology: Proceedings of the 4th International Conference on E-Engineering and Digital Enterprise, Wiley, 2007

26. Tichkiewitch S., Brissaud D., Methods and Tools for Co-operative and Integrated Design, Kluwer, Academic Publishers, ISBN 1-4020-1889-4, 2004, pp. 488.

Author CVs

Andreas Riel

Doctor Andreas Riel is General Manager of the EMIRAcle association, and is mainly responsible for external communication and transfer to industry. He has ten years of professional work experience 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 been certified as European Innovation Manager and Trainer; Andreas.Riel@inpg.fr

Serge Tichkiewitch

Professor Serge Tichkiewitch is currently the Scientific Coordinator of the Network of Excellence "Virtual Research Lab for a Knowledge Community in Production" and has been elected as the President of the EMIRAcle association. He has been the former Director of the Industrial Engineering and Management School of Engineers at National Polytechnic Institute of Grenoble. He was the initiator and director of the Integrated Design team of the 3S Laboratory, composed of 40 persons and the first General Director and founder of the French PRIMECA network. He has supported 20 PhD thesis, published more than 130 papers in journals, books or proceedings of international conferences. His research interest is the methodologies and the tools for integrated and innovative design and the modelling of the forging process; Serge.Tichkiewitch@inpg.fr

Richard Messnarz

Doctor Richard Messnarz has 16 years industry experience and is the chairman of EuroSPI, the coordinator of the EU Certified Innovation manager, the coordinator of the European Qualification Network, the moderator of task forces of 24 leading German companies, the editor of 7 books (IEEE, Wiley, Springer) on process improvement, and the director of ISCN since 1997. He is a principal ISO 15504 assessor working for firms like ZF Friedrichshafen AG, Magna, Continental, T-Systems, Giesecke & Devrient, etc.; rmess@iscn.com