Industrial Knowledge Management Tools Applied to Engineering Education

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Abstract. Knowledge is a major source of competitive advantage. Hence, industry has developed tools to capture and reuse its knowledge in the development of new projects and products. Information practices and learning strategies, as Knowledge Management, are gaining acceptance also in the field of education. However, the use of these tools are limited to staff applications and they are not being employed in the university core business: education. This paper shows how a tool to build and validate internal combustion engines, developed in industry, has been successfully integrated into a university course. The learning process has being greatly enriched by the use of this application. Evidence on the planned improvements are also presented.

Keywords: Knowledge management; engineering education; internal combustion engines,

1. Introduction

The dynamism of the new market has created a competitive incentive among many companies to consolidate their knowledge assets as a means of creating value that is sustainable over time [1]. Since knowledge resides within the brain of employees, firms have developed various strategies to create organizational knowledge through leveraging employees' knowledge [2]. Among them, Knowledge Management (KM) involves any activity related to the capture, use and sharing of knowledge by the organisation [3]. KM practices can include the handling of key documents, expertise directories, lessons-learned databases, best practices and communities of practice that reflect and deliver knowledge to learners at a particular time of need [4].

The enterprise final objective is to build and deliver great products that customers are excited to buy. In the actual global conditions, companies have to fulfil many market requirements and some of them are in conflict with each other, for example car manufacturers have to design new engines with increased power that satisfy stricter pollution standards. Therefore, it is important to develop and validate, during the product conceptual phase, several product alternatives that take into account those conflicts and to select the optimal solution. The decision making process needs to be supported with IT tools.

In this contribution, the innovative principles of a tool to design and validate internal combustion engines are presented. The tool has been developed using a KM method in an industrial environment. Nonetheless, it is of primary importance to introduce automotive engineering students to the same industrial methods and to the use of the same tools. Therefore, the KM-based tool has be introduced in a university course.

The remainder of this paper is structured as follows: section 2 presents the revision of the state of the art of KM tools in industry and education. Next, the innovative principles embedded in the tool, Engine Paradigm (EP), are summarized in section 3. In section 4, a description of the activities necessary for the correct introduction of the tool in a university curricula is provided. The course deployment and results are discussed in section 5 and 6 respectively. Finally, conclusive remarks are discussed in section 7.

2. State of the art

KM is a trend topic and it has been extensively used in industry. There is evidence of its recent successful application in sectors such as aerospace [5], shipbuilding [6], wind generation and naval engineering [7]. In particular, KM has undoubtedly made strong inroads in the automobile industry [8]. In 2004 FIAT (now FCA Group) started a research to capture designer's knowledge in the first steps of engine concept design. The resulting tool, EP, is a knowledge driven accelerator conceived for developing diesel and gasoline engines.

Even if initially KM appeared to be adopted only in large, multinational and international companies [9], now it has become the underlying source for successful organisations regardless of their size and geographical locations [10]. KM is beneficial in fields such as banking, telecommunications, production, manufacturing, and even the public sectors [11]. There is even evidence of the use of KM in the management of cultural heritage [12]. Among all these sectors, higher education institutions are exposed increasingly to marketplace pressures similarly to other industrial businesses. Hence, information practices and learning strategies, as KM, are gaining acceptance in education [13]. However, KM practices in universities are often limited to the storage and dissemination of lecture slides and other relevant materials in virtual learning environments [14]. Universities have not employed KM in its core business: education.

Politecnico di Torino has introduced KM to the issues related to automotive engine design. The course of Powertrain Components Design provides students with the necessary knowledge for the structural design, sizing and verification of main engine components by using analytical, semi-empirical and numerical approaches. These tasks allow students to perform calculations, but they might not have a graphical representation of their analysis. Modelling all the elements of the engine would become a time consuming task, focused on calculation rather than designing activities; further, students may lose the global picture of the designer activity.

Therefore, as first attempt, an instrument to generate a 3D parametric CAD model was developed; it provides the designer with a first simplified vision of the engine components [15]. However, even if this solution was a promising method, it presented some drawbacks. As a matter of fact, the developed software was devoted to teaching purposes and lacked completely industrial practical knowledge.

In the next sections, this paper presents the tool and implementation in a university course.

3. Engine Paradigm

A paradigm is a set of assumptions, concepts, values, and practices that constitute a way of viewing reality for the community that shares them, especially in an intellectual discipline [16]. Figure 1 shows the general paradigm process that has served as a framework for the study of the design practice in FCA. The model consists, firstly, in capturing knowledge by analysing previous projects. Next, it is necessary to formalize and store the common knowledge. Then, the final aim of the framework is to reuse the captured knowledge in new projects. However, in order to keep the knowledge at the state of the art, the model needs to be updated frequently.

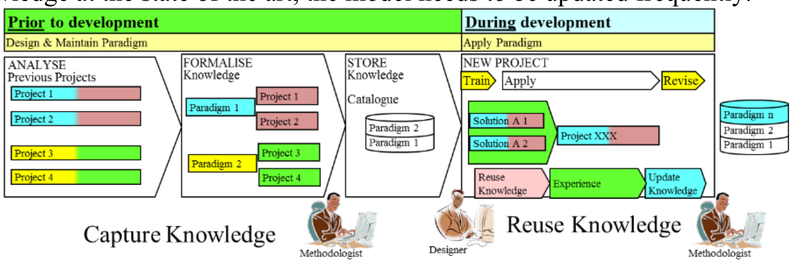


Figure 1. Paradigm approach

The paradigm approach has been applied to organize and capture the "technical skills" of people during the product development process of FCA, with the aim of increasing their average performance without blocking individual creativity. It is an infrastructure built and integrated into the CAD software Nx. It was developed by Vittorio Romagnoli (former FGA worker) and Domenico Giannetto (SIEMENS Industry Software – Italy). The development process of an engine was thoroughly studied, a group of 8 people (consisting in developers and expert designers) met one or two times per week over a period of 5 years. The study resulted in an infrastructure that allows to easily to conceive, validate and compare several combustion engine alternatives. The same principles were employed in the development of Die Paradigm (DP), which is currently being used by FCA. The main objectives of EP are twofold: first, to model directly the key components of an engine; second, to define and validate several product alternatives.

Modelling

The EP application is installed as an add-on of the CAD software and it requires a special license for its use. The EP assembly is made up of simplified components. The management of these components (insertion/removal in the assembly, control of their size and characteristics) is performed via defined User Interfaces (UI). At first, the components are created as copies (templates) of parts that exist in a library. Both the part library and UI can be easily modified and/or extended.

The main engine assembly consists of four functional groups (FG). Each FG is built by adding the parts that conforms the sub-assembly. Furthermore, each part is composed of smaller modules. In Figure 2 the FG crankshaft-conrod is presented. It is composed by four modules: counterweight (shown in orange), no counterweight, distribution terminal and flywheel. The modular strategy allows the system to easily respond to modifications. The actual configuration is a 4 cylinder engine and if the number of cylinders is extended or reduced the system automatically adds or eliminates modules.

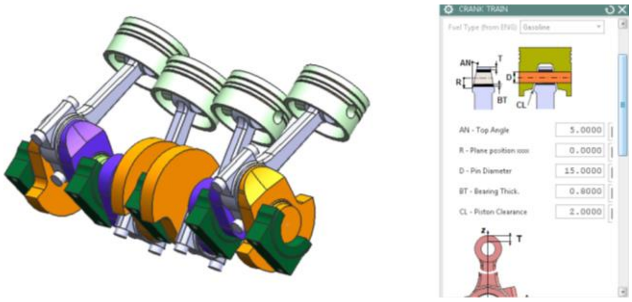


Figure 2. User Interface and functional groups

EP makes extensive use of parametric models that are computer representations of a design constructed with geometrical entities. Each entity has several attributes (properties): some of them are fixed (constraints); others can vary (parameters) [17]. The generation of a geometry defined by dimensions, parameters, attributes and rules keep the coherence of the design. This information is used, at a higher level, to propagate data between different layers of the assembly (interpart expressions) and to create associative copies of geometry between parts (wave links). EP consistently supports the parametric design of parts and assemblies: its structure allows keeping the design consistent with the constraints and thus increasing the designer ability to explore ideas by reducing the tedium of rework. The system allows creating the geometry of a complete engine from a scratch in a matter of minutes (a skilled user employs 15 min. while a new user requires 3 hours). Figure 3 shows a complete example of an engine developed with the support of EP.

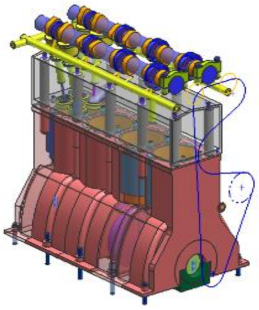


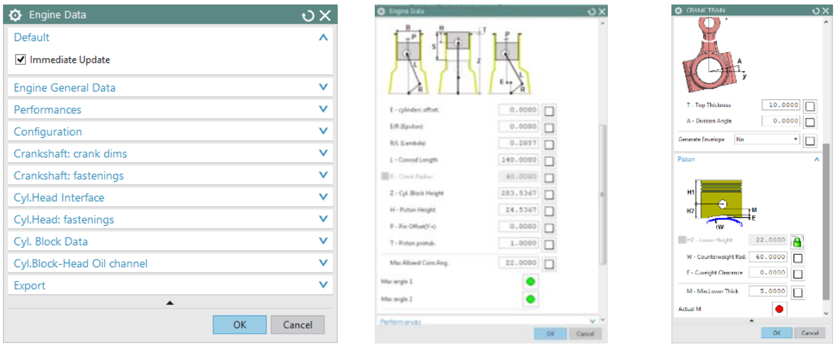
Figure 3. Engine Paradigm

Product Validation

Once the geometry has been created, the concept of the best engine configuration amongst several options must be validated. Starting from the preliminary product requirements, designers follow their train of thought, perform calculations and use technical languages to describe a potential solution. The design process is iterative and reaches the final solution after several loops, as part of the required data is not available at the beginning. At this stage the designer needs a project dashboard that monitors the current status of the product alternatives in terms of values and checks performed.

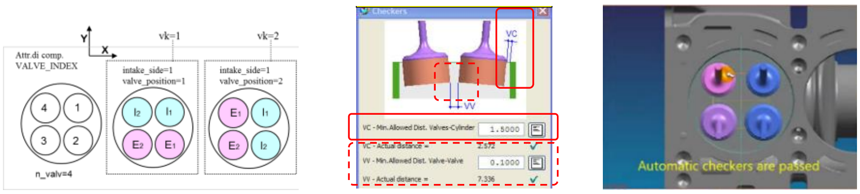
EP is able to control and maintain the consistency between several part-sketches belonging to different parts managed in the product study. Figure 4.a shows the main Engine data dashboard that contains all the information that can be modified at the main assembly level. Figure 4.b presents a particular frame of the Engine General Data. The designer can change the values of all the different parameters. Some of these inputs are not independent with each other; the unconstrained changes may lead to a condition where constraints are not respected. Hence, a set of checkers (green circle in the picture) have been implemented to help the designer to quickly evaluate if entered values are meaningful. Moreover, it is possible to fix the value of an important parameter (see the green lock of Figure 4.c) once it has been determined. In this case, the designer can continue to explore solutions with the certainty that this input cannot be changed.

The system also allows to quickly configure products alternatives while assuring compliance with international standards or industrial best practices. Figure 5.a shows two possible valve arrangements; the designer will choose the best solution according to the intake/exhaust location. Once the general schema has been defined, the distance between valves and between valves and engine head walls must be considered. This particular requirement is regulated by a FCA best practice. The system automatically calculates such distance (which is the result of the valve's angle) and shows a green flag (Figure 5.b) if the requirement is met. Finally, the 3D geometry is regenerated (Figure 5.c).



a) b) c)

Figure 4. a) Main engine data. **b)** Engine general data overview **c)** Checker



a) b) c)

Figure 5. a) Valve arrangement **b)** Valve angle checker **c)** Regenerated model

4. System upgrading and pilot test

EP was originally developed in a previous Nx version (Unigraphics) and, since the development was stopped in 2009, it was not sustained over time. It was then necessary to analyse the porting of the old structure to a newer version. As stated before, a similar tool, Die Paradigm (DP), was developed soon after EP ended. It was decided to use the existing DP infrastructure in order to reduce the development time. Several meetings were necessary to agree the best strategy both from the technical point of view, with SIEMENS Industry Software – Italy, and from the property rights, with FCA. The complete updating of the tool took over three months.

After the successful EP upgrading, training on the use of the tool was necessary for all the stakeholders that participate to the project. The training consisted in two phases. The former included the complete development of an engine using EP. The overall behaviour of the structure was tested and several issues were identified and corrected. The latter consisted in the development of a custom example using the same structure. This was done to allow a better comprehension on the basic function of the tool. The tool was then installed and distributed in the laboratories.

5. Deployment in a university course

The M.Sc. course of Powertrain Components Design is included in the 2nd year of the automotive engineering curriculum in Politecnico di Torino. Approximately 40 students attend it each year. The course has a total duration of 100 hours. Approximately, 60 hours are used for theoretical aspects concerning engine and transmission design, while the remaining time is employed for laboratory activities. The laboratory practice is divided in the course's main topics: 20 hours for powertrain concepts and 20 hours for components design. EP is used in the latter section.

Students that attend this course come from different universities, different countries and different backgrounds (mechanical engineering, automotive engineering, production systems, etc.).

The goal of the practice is to design an engine while respecting the following constrains: i) 4 cylinder gasoline engine, ii) overall displacement around 1.2 litres and iii) power delivery 70 kW. Moreover, the development of the engine should take place as it is done in actual industrial practices, thus collaborative work is required. Students are requested to create a common engine; still each student faces different challenges and responsibilities. The group division and assignments are reported in table 1. The course chair defined the group division randomly. The only driving criterion was to avoid more than three people from the same country, in order to allow student's interaction and integration.

Table 1. Group subdivision for engine design practice

Group	Goals	People
Project management	Definition of the engine layout and management of the group activities.	2
Piston	Design of the piston, evaluation of piston slap, thermal analysis of the piston for defining the proper size, rings conformability	6
Piston Pin	Design of the pin. Static and fatigue verification	2
Connecting rod	Design of con-rod, considering bearing and screws	6
Crankshaft	Flywheel, crank, check, crank pin and journal pin. Analytical analysis of torsional behaviour, potential mass damper usage, lubrication, drawing of the solution. Static and modal finite element verification. Definition of journal bearing.	12
Crankcase	Definition of the geometry and of the construction philosophy, evaluation of water circuit, drawing and static verification. Liner dimensioning	5
Oil pan	Drawing, modal analysis, optimization procedure	4
Cylinder head	Dimensioning and drawing, static analysis. Definition of the valvetrain and drivetrain system, valve spring definition	5
Manifold	Design of intake and exhaust manifold, computation of exhaust manifold	3

6. Results

At the end of the course, students presented their results. The evaluation of this presentation counts for a third of the final score. Additionally, direct student interview was performed to obtain feedback on the course. An interesting and useful discussion took place and pros and cons were highlighted.

Positive Aspects
Mainly, the course achieved its objectives satisfactorily and the contents of the course were considered original by the majority of students. The teaching method and material given were highly appreciated. EP allowed the students of the group to provide a complete assembly of the engine in less than 4 weeks. The main constraints, described in section 5 were respected. All the groups successfully developed the requested tasks on time. The obtained result is visible in Figure 6.

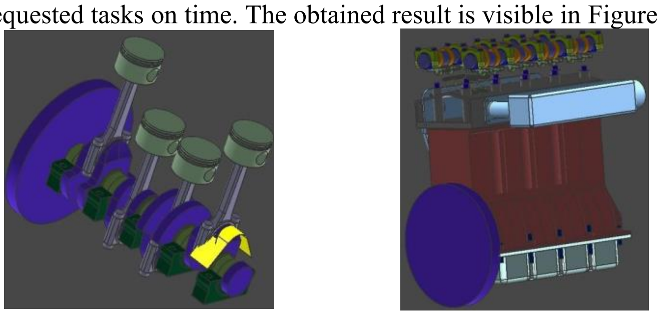


Figure 6. Engine designed by the students

EP allowed the students to reach a first design attempt of the overall engine in the established 20 hours of laboratory. On the contrary, the practice on powertrain concepts did not reach similar results, even if the same amount of time to this task were employed. This fact highlights the didactic relevance of EP.

In addition, students appreciated the easy and fast mounting of parts thanks to templates. The easiness of the UI was also greatly appreciated. Though, the most relevant aspect was the possibility to rapidly change all important engine parameters.

Future improvements
The laboratory infrastructure is only composed by 32-bits computers while the CAD system requires exclusively 64-bits machines. In order to by-pass this problem, a set of virtual machines were installed and distributed over the 32-bit machines. The infrastructure worked correctly but performed rather slow, especially when working with big assemblies.

One non-technological aspect that affected the development of the exercise is the previous knowledge on the CAD system. The M.Sc. course is attended by students that have heterogeneous education and not all of them were confident with the use of the CAD tool. Such students tried to develop their parts in other systems and they found difficult the integration with EP.

Another issue that restrains the didactic objectives it the engine architecture: EP is limited to in-line engines because when it was created, there were no plans of developing other kinds of engines. Moreover, EP lacks of some important components such as the oil pan, intake and exhaust manifolds, valvetrain activation systems and oil pump. It is important to highlight that these components were designed by the students and they can be now imported to the EP library and to the UI. In addition, some sketches of the existing components must be changed in order to increase the geometrical control. For example, the counterweight opening angle should be included in the UI in order to quickly modify the counterweight mass.

The most important aspect regards the collaborative work. At this stage, EP works in a standalone version and it is not integrated to any Product Lifecyle Management (PLM) system. For this reason, each group worked independently and, after completing the study, communicated the final information to the project management team. This is a major issue that needs to be addressed immediately to assure a correct working method.

7. Conclusions

In this paper the introduction of an industrial Knowledge Management tool in a high level education institution was presented. This contribution extends the state of the art by showing evidence that the tool has been employed for didactic purposes and not only in staff applications. In fact, the use of Engine Paradigm in the course of Powertrain Components Design allowed students to take effective decisions while developing an engine. Students were exposed to the complexity of developing a product with the help of an actual industrial application. The tool facilitated the evaluation of several design alternatives while reducing the tedium of rework. The results obtained, compared to a similar exercise performed in the same course (same students), are really promising.

The experience gained in this first application has allowed authors to identify strengths, weaknesses and improvement opportunities. On one hand, positive aspects assures the goodness of the teaching strategies. On the other hand, the identified opportunities are now being studied. The proposed improvements comes from both students and professors. The embedded knowledge defined by its creators it is now being enriched with the actual requirements of the university.

References

[1] A. H. Gold, A. Malhotra and A. H. Segars, "Knowledge Management: An Organizational Capabilities Perspective," *Journal of Management Information Systems,* vol. 18, no. 1, pp. 185-214, 2015. doi: 10.1080/07421222.2001.11045669.

[2] M. Birasnav, “Knowledge management and organizational performance in the service industry: The role of transformational leadership beyond the effects of transactional leadership,” *Journal of Business Research,* vol. 67, pp. 1622-1629, 2014. doi:10.1016/j.jbusres.2013.09.006.

[3] Organisation for Economic Co-operation and Development, “Oslo Manual - Guidelies for collecting and interpreting innovation data,” 3rd edition, OECD and Eurostat, 2005. ISBN 92-64-01308-3.

[4] L. Bielawsky and D. Metcalf, Blended elearning: Integrating Knowledge, Performance Support, and Online Learning, HRD press, 2002. ISBN 978-0874258608

[5] G. La Rocca and M. J. L. van Tooren, “Knowledge-based engineering to support aircraft multidisciplinary design and optimization,” *Proceedings of the Institution of Mechanical Engineers, Part G: Journal of Aerospace Engineering,* vol. 224, no. 9, pp. 1041-1055, 2010. doi: 10.1243/09544100JAERO592

[6] K. Hiekata, M. Grau and J. Stjepandić, “Cross-Domain Collaboration in Shipbuilding,” in *The IFIP WG5.1 11th International Conference on Product Lifecycle Management – PLM14,* Yokohama, Japan, 2014.

[7] G. Ford, J. Igba, C. McMahon, K. Alemzadeh, C. Rowley and K. Henningsen, “Knowledge Management: A Cross Sectorial Comparison of Wind Generation and Naval Engineering,” in *11th IFIP WG 5.1 International Conference, PLM 2014*, Yokohama, Japan, 2014. doi: 10.1007/978-3-662-45937-9_14

[8] S. Sukumaran and M. V. Shetty, “Knowledge Managementm in automobile: Application of a value chain approach using KM tools,” in *Internet Technology and Secured Transactions*, London, 2009. doi: 10.1109/ICITST.2009.5402554

[9] K. Y. Wong, “Critical success factors for implementing knowledge management in small and medium enterprises,” *Industrial Management & Data Systems,* vol. 105, no. 3, pp. 261-279, 2005. doi: 10.1108/02635570510590101

[10] A. Okunoye and H. Karsten, “Where the global needs the local: variation in enablers in the knowledge management process,” *Journal of Global Information Technology Management,* vol. 5, no. 3, pp. 12-31, 2002. doi: 10.1080/1097198X.2002.10856329

[11] F. O. Omotayo, “Knowledge Management as an important tool in in Organisational Management: A Review of Literature,” *Library Philosophy and Practice,* 2015.

[12] B. Hervy, F. Laroche, A. Bernard and J.-L. Kerouanton, “Co-working for knowledge management in cultural heritage: towards a PLM for museum,” in *10th IFIP WG 5.1 International Conference, PLM 2013,* Nantes, 2013. doi: 10.1007/978-3-642-41501-2_32

[13] L. A. Petrides and T. R. Nodine, “Knowledge management in education: defining the landscape,” Institute for the study of Knowledge Management in Education, Half Moon Bay, 2003.

[14] N. Leung, H. Shamsub, N. Tsang and B. Au, “Enhancing learning experience of coursework students in higher education: a knowledge management methodology,” in *EDULEARN14 Proceedings*, 2014. http://hdl.handle.net/1959.3/397253

[15] C. Rosso, C. Delprete, E. Bonisoli and S. Tornincasa, “Integrated CAD/CAE Functional Design for Engine Components and Assembly,” *SAE Technical Paper,* p. 12, 2011. doi: 10.4271/2011-01-1071

[16] T. S. Kuhn, The Structure of Scientific Revolutions, The University of Chicago, 1962. ISBN: 978-0226458083

[17] C. R. Barrios-Hernandez, “Thinking parametric design: introducing parametric Gaudi,” *Design Studies,* vol. 21, no. 2, pp. 99-107, 2006. doi:10.1016/j.destud.2005.11.006