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IMPLEMENTATION OF A LIGHT KNOWLEDGE SHARING TOOL IN ENGINEERING DESIGN

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ABSTRACT
This paper presents an approach of implementing knowledge management within small and medium sized enterprises (SMEs). This approach proceeds iteratively (proposal for a solution, experience feedback, improvement) and takes place within an industrial partner's calculation office.
A first part of this work consists in a collaborative knowledge management system (KALIS) that meets the calculation office requirements. The main assumption of the approach is that intensive collaboration between engineers will support knowledge sharing, thus increasing the efficiency of the calculation projects.
The paper investigates integration and acceptance issues of knowledge management systems. A state of the art points out that the main barriers are the codification costs, the integration of the system within engineering activities and the management of quality regarding the content of knowledge management system. Then, propositions are given to overcome these barriers in the form of a progressive knowledge formalisation based on collaboration between engineers. The way of integrating KALIS within the activities of the company is also an important aspect of the effective acceptance. Finally, a feedback on the KALIS use within the company leads to propose a maturity assessment framework.

Keywords: Collaboration, knowledge sharing, SME, Mechanical Calculation.

1 INTRODUCTION
Nowadays, computational mechanics is an increasingly essential activity in product design. However, owing to the specific nature and complexity of the calculation activity, the current industrial trend is to outsource it, either by developing centralised and specialised in-house services or by subcontracting it to external calculation offices that are mainly small or medium-sized enterprises (SMEs). Because of their human and financial dimension, such SMEs are generally in charge of small-sized projects, which may be parts of larger ones managed by their customers. The calculation engineers working in such SMEs rely on Computer Aided Engineering (CAE) software and their job mainly consists in simulating and analysing the physical behaviour of mechanical devices under a particular focus.
Calculation providers generally present some specific characteristics as they manage projects of different sizes, involving customers from many different industrial sectors and facing a wide range of problems. It is important to note that intensive knowledge acquisition occurs through the highly cognitive tasks involved in the calculation process. This knowledge relates indiscriminately to physical modelling, customer-specific products, context, and collaboration processes.
Field studies within such calculation SMEs pointed out that calculation projects are managed independently and that each engineer is often in charge of various projects at the same time. Such companies face difficulties to create a turnover of people between projects because of a high workload of team members and short lead-time. As engineers acquire experience and skills about the expectations of the customer in terms of products, methods and inter-personal collaboration processes, they tend to become specialists of a restricted set of customers. Thus, it is difficult for another engineer to resume the work done with the customer of somebody else, because of the lack of the technical and collaboration background.
However, we observed that this individual knowledge is sometimes shared during interactions between engineers about a technical difficulty encountered by one of them. Since exchanges arise during projects, the knowledge is seldom structured nor formalized to be reusable thereafter, and

shareable in a broader way within the company. Thus, enhancing knowledge sharing is crucial for the calculation providers who are always confronted with new customers, new systems to analyse and new technical problems. Knowledge sharing appears to be a key factor for improving their reactivity and the quality and lead-times of their services.

Various knowledge management approaches such as MEREX or MASK were deployed in the industrial domain and revealed interesting results but also a number of limits such as the a limited implication of actors or the difficulties to make implicit knowledge more visible. In addition, they often require intermediaries to adapt the documentation of knowledge producers so that it can be interpreted and reused by knowledge "consumers" [1]. These intermediaries are then guaranteeing of the quality and the maintenance of information contained in knowledge management systems. Within SMEs, resources are lacking to engage such intermediaries in the engineering process. In addition, it is difficult to allocate resources to formalise knowledge when possibilities of reuse are uncertain. Consequently, the knowledge codification (formalisation) activity must be accomplished by the calculation engineers themselves when they produce this new knowledge. During the calculation process, the knowledge management system has to be integrated in the engineering practices without over-burdening the work process of these companies.

To develop a knowledge management approach adapted to the size and the requirements of these calculation offices, we do not still attempt to systematically formalise technical know-how through procedures or best practices. The present work is based on the assumption that intensive collaboration between engineers will support knowledge sharing, thus increasing calculation project efficiency. The aim is the development of systems supporting communication and exchanges between people. These knowledge management systems must enhance the awareness of information and experts that can help in the calculation projects accomplishment. In addition, to support the sharing of knowledge, it is also important to consider means to assess and to increase the quality level of the shared information.

This paper first presents a literature survey focused on the main acceptance factors of knowledge management systems. In the following part, a proposition of knowledge management approach is presented, including the concepts of KALIS, a software tool developed during this work. Then, the integration approach of KALIS within the company is presented according to the identified acceptance factors. Finally, a maturity assessment framework is proposed to support engineers in managing the content of KALIS.

2 ACCEPTANCE FACTORS OF KNOWLEDGE MANAGEMENT SYSTEMS

The integration of a knowledge management system (KMS) within a company implies to care about various issues. Recent empirical works, based on surveys, deal with the acceptance issue of KMS. However, very few studies exploit them. A literature review of these surveys leads to distinguish three kinds of acceptance factors. Some of them are related with the organisation, others with the integration of KMS, and last ones with the role of individuals when they use these systems.

2.1 Organisational acceptance factors

Organisational acceptance factors result from the company's organisation or the economic situation in which it evolves. Thus, these factors influence the effective deployment and use of KMS. For example, individualistic cultures inhibit sharing, ownership, and reuse, while cooperative cultures enable the creation of virtual communities [2]. Bernard [3] describes how a KMS is enacted depending on psychological safety and the rate of episodic change experienced by a team. When people feel safe within a team, they are more likely to find ways to improve their work. Kankanhalli & al. in [4] point out the importance of trust between team members and collaboration based working methods on the use of knowledge management systems. In fact, even if organisational factors (e.g. culture) are positive on the effort of users in sharing and formalising knowledge, making changes in the culture of a team is a long-time effort and remains a big challenge.

2.2 System integration acceptance factors

For King and Marks, the system integration within the activities of engineers is the most important lever of action to make it possible the use of KMS [5]. The user's acceptance is mainly conditioned by the quality and facility of use they perceive of the system [6]. For example, the perceived quality level of the content can be improved with reliable and up-to-date content. The tool integration within engineering activities can influence positively the perceived quality. The system adequacy with the engineers' activities also increases the perceived ease of use and quality. Stenmark and Lindgren [7] explain that KMS have to fit the users' activities to be invoked when knowledge is put into practice. King and Marks [5] define the supervisory control as an important integration factor, which consists in making the users acting in accordance with the company's objectives. Rewards or periodic follow-up of the system's use are examples of supervisory control that can help in obtaining critical mass of information and users.

2.3 Individual acceptance factors

In addition to organisational and integration factors, there exist individual factors, depending on the roles of KMS users. Three kinds of roles are generally distinguished: *knowledge contributors* (the ones who formalise their knowledge), *knowledge intermediaries* (the ones who prepare knowledge for reuse by eliciting it and who perform various roles in dissemination) and *knowledge seekers* (the ones who seek or reuse the content of KMS) [1]. The interests of the KMS users are different when contributing [4], or reusing [8].

When they contribute, the individuals' behaviour can be explained with social theories. Kankanhalli & al. [4] describe the influence of costs and motivations on the use of KMS. These authors consider the contribution as a voluntary act since the contributor always selects the knowledge he can formalise. Thus, the loss of power, which is often pointed out as an important issue, does not affect the use of these systems. In conclusion, they show that the codification costs seem to be the strongest contribution barrier. The impact of codification costs can be influenced by organisation factors since their negative impact is increased when trust is weak within the team. The implementation of automatic knowledge capture functionalities can overcome these codification issues. Finally, Kankanhalli & al. point out the importance of the benefits (or motivations) the users would get from their contributions as contributors generally expect to be able to "use" the knowledge produced by their colleagues.

In a reuse situation, costs and benefits in terms of social exchange are less important. The knowledge seeking activity depends on the activities the reusers are involved in ([8]). In such situation, the tool accessibility to seek for relevant information is one of the most important factors. Kankanhalli & al. [8] explain that the higher the level of implicit knowledge characterising the activity in progress is, the more it will be difficult to seek for relevant information. Finally, these authors stressed that users are strongly influenced by the quality they perceive of the system.

In conclusion, the main acceptance issues to address during the deployment of a KMS are the codification costs, the integration of the system within engineering activities and the management of quality regarding the content of the system.

3 OUR KNOWLEDGE MANAGEMENT APPROACH

Explicit knowledge is generally dinstinguished from tacit knowledge [9]. Explicit knowledge is formalised in written documents (articles, reports, books...), whereas, tacit knowledge is revealed by practice and actions. Work practices analysis [10] show how professionals use knowledge to find, use or modify information and to develop strategies of action. The assumption of these analyses is that action is the link between knowledge and information, and that knowledge can only belong to individuals. Collective knowledge can exist if members of a group of individuals share similar mental models. That can be the case when knowledge is shared by various collaborators about the basic rules of their job or in communities of practices. This collective knowledge is often internalised and embedded in the practices. Then, it is not imperative to specify the entire context of a project when group members collaborate because they already share common representations.

3.1 The basis of the approach

Hansen & al. [11] define codification and personalisation approaches as the two main knowledge management strategies. On the one hand, the codification strategy is based on knowledge formalisation and relies on knowledge repositories which enable users to access codified knowledge. On the other hand, the personalisation strategy is centred on tacit knowledge, enhances knowledge sharing through a socialisation process and is based on knowledge networks.

Some approaches combine both the personalisation and the codification strategies in associating knowledge repositories and knowledge networks [12]. However, these systems are complex and expensive to develop. Thus, few approaches integrate these strategies in a same and simple system to benefit of the efficiency of knowledge sharing through collaboration and of the long-term interest of knowledge codification.

We argue that knowledge management within small enterprises can rely on the creation of a knowledge sharing culture and on the provision of simple tools, which combine both the codification and personalisation approaches in a relevant manner. The knowledge codification process has to be as simple as possible and formalise just enough knowledge to foster information identification. To support information exchange and collaboration, these systems should encourage actors to be aware that helpful information and experts are available during a project.

Many field studies carried out in the CSCW domain concern awareness and collaboration issues and are relevant to set our approach. In particular, Ackermann and Halverson, investigating the process of sharing boundary objects, argue that information is easily reused when provenance context of use, and trajectory of use is provided [13]. They also point out that boundary objects are simultaneously embedded in many organizational and individual processes and evolves during their sharing.

We carried out a field study in a calculation SME and our observations led to note that the collaboration (self-organisation, spatial proximity…) ways within the calculation department were similar to those encountered in communities of practices as defined by Wenger [14]. We identified that many technical objects were shared between engineers and reused in other projects. More precisely, when these objects are shared, knowledge about the working methods is also shared by discussion (socialisation) between colleagues regarding these objects, which can be calculation worksheets, standards, procedures, etc [15]. They bring a support to calculation engineers during a project, thus, we defined them as Support Data [16]. They embed formalised knowledge and can reveal know-how related to the calculation domain. For the engineers, these Support Data appeared to be very important for carrying out their calculation job, however, no management method of these data was defined within the company.

The method and supporting tool that we propose are supposed to help engineers in managing Support Data and people (engineers) interactions related with these data. By fostering collaboration between engineers and making them aware of the Support Data items owned by their colleagues, we believe it is possible to overcome a number of reuse issues.

Obviously, it is not possible to formalise engineers' complete knowledge about a given Support Data item, the objective is rather supporting the progressive formalisation of a part of their knowledge about the object and its context of use [16]. The context of use can be defined with three levels:

- the **Project** level to identify the project and the customer…
- the **Study level** to specify the lead engineer, the scientific domain of the study…
- the **Activity** level to characterize the current activity and its objective…

Although, knowledge reuse is strongly influenced by the quality of information, we noticed that few knowledge management systems provide users with an evaluation of the quality of their content. Our aim is to provide users with quality indicators to both enhance the quality of formalised knowledge, and help reusers to identify reliable Support Data.

To support this approach, we developed a software tool called KALIS (*Knowledge about Activities as a Link to Information Sharing*) that combines both personalisation and codification strategies. KALIS is defined as a mean to manage and formalise knowledge about Support Data in a progressive manner. Il also aims at promoting their sharing between calculation engineers.

3.2 KALIS, a tool to support knowledge sharing

KALIS proposes a simple and progressive knowledge codification approach based on pooling, within a repository, useful Support Data for calculation projects accomplishment. The documentation of Support Data is based on a characterisation of the context about the study undertaken by an engineer and, makes it possible to identify the knowledge sources for other engineers. This is the basis of the personalisation strategy of KALIS as it can facilitate the identification of experts.

KALIS provides access to various kinds of information via an Intranet in which users can build, modify, download, or exchange Support Data items during the calculation projects. In KALIS, the description of Support Data is based on free-form text fields where diagrams or pictures can be added. Each actor can update the description text, depending on his knowledge about the Support Data, in a quick and straightforward manner as in can be done in “Wikies” [17].

The indexation method of information within KALIS links activity context descriptors with Support Data items during their use. The context of use relies on a taxonomy of the calculation activities that can be undertaken during a project [16]. This link is intended to increase the awareness between collaborators as it makes it possible to identify both the purpose a Support Data item and the kind of studies undertaken during projects.
A history of interventions (creation, consultation, documentation, modification, verification and validation) provides users with the opportunity of viewing the evolutions of a Support data item. It can also help to identify Support Data validity, similar projects or related experts. Being able to track the support data used during a project can also help engineers in identifying similar calculation studies (cf Figure 1).

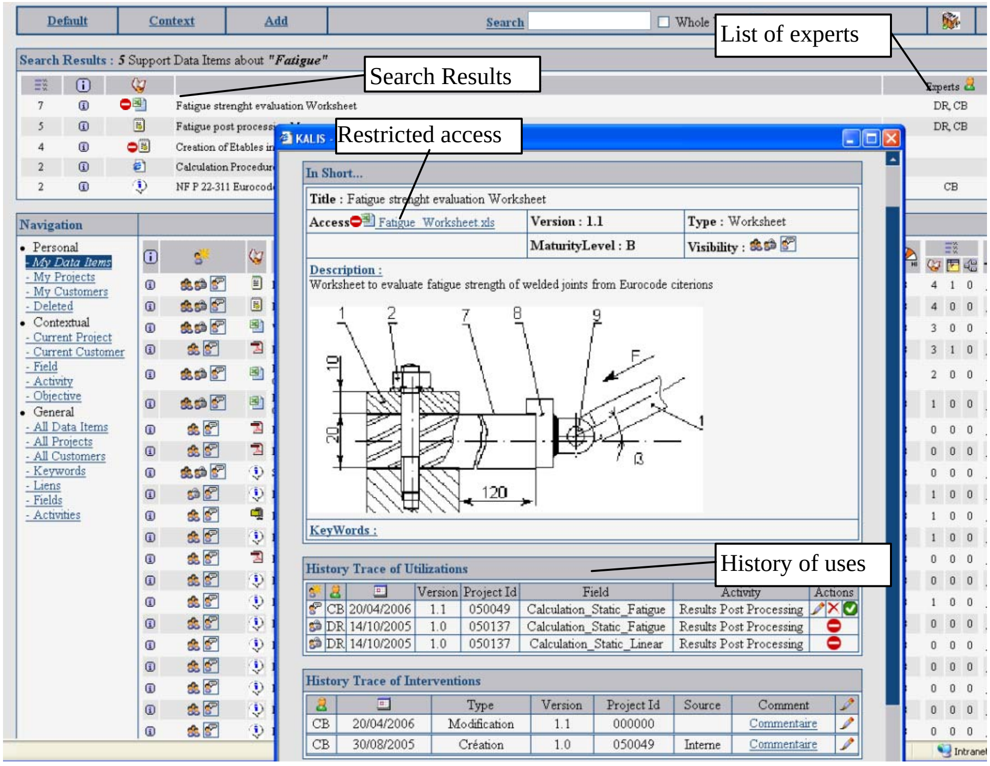

Figure 1. Detailed Description And History Trace Of Support Data.

In KALIS, progressive development of Support Data is supported by the way of a three kinds of workspaces framework that matches the three treatment levels of knowledge defined by Girod: individual, collective decentralised and collective centralised [18].

- A private workspace contains information that can only be accessed by its creator and fits the individual knowledge treatment level. The owners of the Support Data items manage information content according to their own methods.
- A proximity-based workspace corresponds to the collective decentralised knowledge treatment level as it contains information shared by a restricted number of engineers within the organisation. As in communities of practice, the Support Data in proximity-based workspaces belong to the engineers who readily work together on specific topics. Proximity-based workspace content is the result of interactions between actors and reflects collective knowledge. Within a proximity workspace, each member can modify information. Consequently, trust is a crucial condition and the wiki self-regulating principle is well suited to this kind of workspace.
- A public workspace contains public information accessible by each member of an organisation. In this workspace, the reliability and validity of information have to be carefully considered. Consequently, a manager is required to coordinate and validate information content and development.

In addition to this three–workspaces framework, a showroom concept is proposed in order to foster local knowledge sharing between engineers by making engineers aware of relevant information in colleagues' workspaces. The principle is to associate with each Support Data item a short description of its contents. In the showroom, this description is visible by every engineer, even if his access rights do not allow him to use the Support Data item directly. Consequently, it makes it possible to identify information through restricted access workspaces.

3.3 The evolution of Support Data items

Complex Support Data items are developed in several steps, which involves sometimes participation of several engineers. Table 1 presents the case of a calculation macro created when KALIS was deployed (2005-08-22). Each line represents an intervention on the macro, so one can know details about the context of intervention on a Support Data item like who made the intervention, the date and the project identifier... In Table 1, we see that the considered macro was progressively shared between users A, B and C who needed it during projects 1, 2, 3 and 4. In KALIS, the macro progressively moved from the private workspace of user A to the proximity-based workspace of A and B, and then to the proximity-based workspace of A, B and C.

Table 1. History of the evolutions of Support Data

Date	Action	User	Project	Scientific Field	Current Activity
2005-08-22	Create	A	1		
2005-08-22	Use	A	1	Static Calculation	Loads Application
2005-08-24	Modify	A	1		
2005-08-29	Document	A			
2005-10-12	Use	B	2	Static Calculation	Boundary conditions specification
2005-10-14	Document	B	0		
2006-02-06	Use	C	3	Static Calculation	Boundary conditions specification
2006-02-24	Use	A	0	Static Calculation	Boundary conditions specification
2006-02-27	Modify	C	0		
2006-05-02	Use	B	4	Linear Static Calculation	Boundary conditions specification
2006-06-06	Use	B	5	Static Calculation	

Figure 2 summarises the main concepts of KALIS described in this part. Through the three kinds of workspaces, the objective is to support the progressive development of Support Data and formalise their description. When an engineer puts a new Support Data into the system, it is stored by KALIS within the private workspace of this engineer. This information will join proximity-based workspaces when it becomes shared by several engineers. In private or proximity-based workspaces, Support Data sharing occurs locally in an informal manner between the owners and the ones who wish to use it during a project. Then, some Support Data can be moved in a public workspace if they are considered to be sufficiently interesting and mature. In fact, not all Support Data are appropriate for publication in a public workspace. The identification of useful information is based on maturity indicators that can be the number of users, the number of project where a support data where used…

In such knowledge management approach, KALIS is supposed to enhance the sharing and the development of knowledge objects in a progressive manner. Thanks to the showroom concept, interpersonal exchanges are fostered to promote the creation a knowledge sharing culture. The deployment and integration method is also an important factor in constructing this knowledge sharing culture.

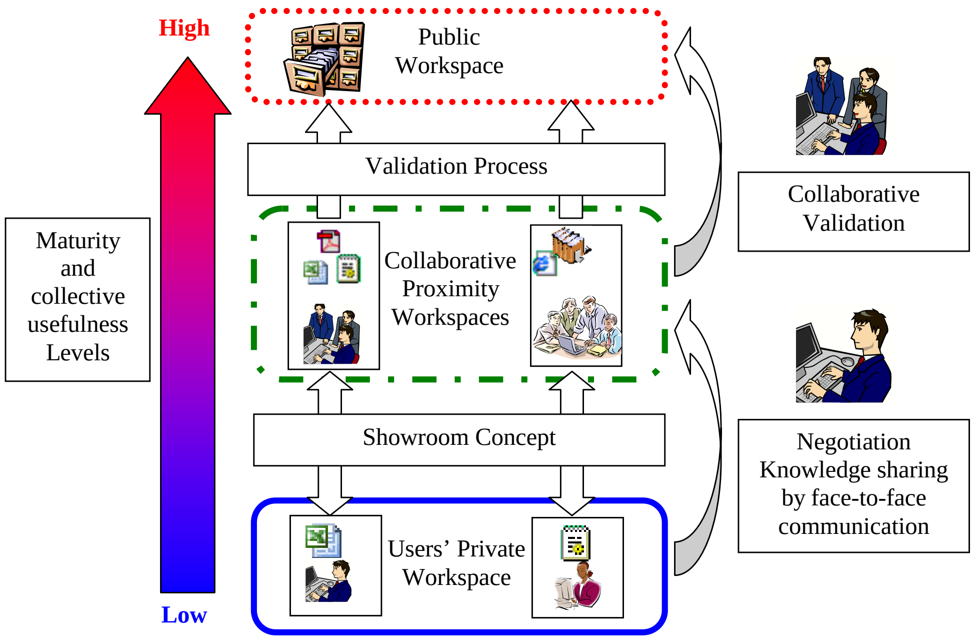

Figure 2. KALIS' Progressive Knowledge Formalisation Process.

4 DEPLOYMENT OF THE KNOWLEDGE MANAGEMENT SYSTEM

Knowledge management can be deployed within SMEs following a pragmatic approach that consists in a step-by-step development of the knowledge management system (tool, method and team organisation) [19]. This kind of iterative approach aims at deploying solutions related with a limited part of the problem. This allows a faster deployment of these solutions, which makes it possible to get rapidly a relevant feedback. Some improvements and also new issues can thus be identified from the new situation.

During the development of KALIS, the issue of constructing a knowledge sharing culture has been strongly considered. This construction has been mainly influenced by the commitment of engineers in the design of the system and the approach of integrating the system in their working environment.

4.1 Involving actors in the knowledge management system design

The research method followed to design the KMS switched between participative observation phases within the partner company, and analysis phases within the research laboratory. This type of research approach enables a fine understanding of calculation office activities and of the main issues in the company. Then, the implication of the engineers could begin by communicating on the objectives of the knowledge management approach.

The fine understanding of calculation activities made it possible to design the framework of KALIS to support an already existing practice within the company. In fact, a number Support Data were already shared in an informal manner between calculation engineers. Now, the weaknesses due to the absence of management and valorisation of Support Data have been addressed in fitting the framework of KALIS to the requirements of existing practices. In addition, it helps the engineers in the acceptance of KALIS, as it does not change deeply the engineering practices.

The implication of the engineers in the approach was increased during the deployment of KALIS. The development phase took place in collaboration with an engineer inside the design office of the company. Moreover, KALIS was directly trained on real projects and a number of functionalities were improved to fit the engineering practices. This training period was also the opportunity to let engineers discovering the tool functioning principles. The training of KALIS on real cases was accompanied with a phase of identification of the Support Data already used in the calculation office. Then a critical mass of relevant information could be stored in KALIS in the objective if increasing its perceived quality.

When the system was deployed in the whole calculation office, the engineers already knew the main principles of KALIS. In addition, they could appropriate it thanks to the examples of the real projects added during the test phase. We also took care of the integration of KALIS in the engineering practices of the calculations engineers.

4.2 Integrating KALIS in the engineers' working environment

Our field studies also helped in understanding the engineers working environment, consequently, we could link KALIS with a project management system already used in the day-to-day activities of the calculations engineers. This connection between KALIS and the project management system enables to capture some context descriptors automatically when the users log in and interact with the project management system. In addition, it contributes to place explicitly the KMS within the calculation processes. After interviews with users, it is possible to say that the automatic capture of information about the activities carried out during projects increase the KALIS' perceived ease of use as context is captured without over-burdening the work process. In addition, the perceived usefulness has also been reinforced because providing context with Support Data items increased the efficiency of the seeking for Support Data.

Finally, an organisational control was put in place in the form of an integration of KALIS within the company's quality management system (ISO 9001:2000). During the calculation project validation phase, a procedure was defined to verify the Support Data used. When the verification engineer checks the project calculation studies, he also checks if the related Support Data have been stored in KALIS (or updated). Then, he verifies if the context of use of these objects has been documented.

4.3 Evaluating the use and the integration of KALIS

Once the tool was deployed, we investigated both the activities carried out and the Support Data used during projects. Then we interacted with the engineers as they could understand the benefits they could withdraw from sharing and documenting their Support Data.

Then, we followed during a year the integration of KALIS within the calculation office by monitoring its use with quantitative indicators such as the frequency of access, the number of support data created, used or modified… We observed that four calculation engineers out of the five working in the calculation office use KALIS to share a total of 150 Support Data items. Some were added during the test period but most of them were created by the engineers as they managed their projects. KALIS content is currently growing (at the rhythm of a new Support Data item per week) and mainly comprises technical standards, calculation worksheets and FEA-specific macros. At the first sight, the amount of Support Data stored and used with KALIS confirms its acceptance by calculation engineers.

In the mean time, we analysed the content of KALIS with a qualitative point of view. Firstly, the history of using the different Support Data has been monitored to analyse the lifecycle of these data (the creation, the different uses and the modifications, etc.).

Initially, we defined these indicators to follow-up the evolution of formalisation and sharing of knowledge about Support Data. The example of the FEA specific Macro given in Table 1 presents a feedback of this observation. During a first time period, the Support Data was not stable (it was modified every time it was used) as it changed though the interactions between the various engineers. In fact, engineers modified the macro itself to make it more suitable to the encountered problems and improved its description. We noticed that a part of knowledge exchanged during discussions between the owners and the engineers wishing to use it, was formalised thereafter in KALIS, which was one of our goals. This tends to validate the hypothesis that Support Data can be developed progressively and collectively.

Afterwards, other indicators about the amount of Support Data stored in each kind of workspaces were developed to provide a feedback about real knowledge sharing and reuse situations. We noticed that the description of Support Data items in KALIS mainly relates to declarative knowledge (about what is the Support Data, the context of use) that just permits their identification by calculation engineers. Procedural knowledge about Support Data appears to be mainly shared during direct interactions between calculation engineers but remains seldom formalised within KALIS. These assessments point out the need to improve the support of engineers when formalising procedural knowledge.

Although many Support Data are shared by several engineers and have been used in various projects, approximately a half of the Support Data items contained in KALIS have never been noted as used. This observation points out that some questions are still unresolved as regards the management of KALIS' content.

The quality of the knowledge management systems' content was pointed out as an important acceptance factor, which affects the behaviour of both knowledge producers and knowledge seekers. As a consequence, since KALIS seems to be well integrated in the calculation activities, it is now important to provide the engineers with a simple quality content management support.

5 MATURITY EVALUATION OF THE CONTENT TO IMPROVE THE PERCEIVED QUALITY

As soon as the tool was deployed, the engineers started to create and store their own Support Data, and we observed that they did it with a long-term focus. For example, a calculation worksheet created for a single use was, before KALIS, less sophisticated than the ones currently being developed. In Table 1, we have presented an example of evolution of Support Data uses and pointed out that some of them were shared, within groups of increasing size in time. This widening is generally accompanied by modifications and enrichment of Support Data.

Thus, the participative observations made it possible to conclude that the progressive knowledge formalisation about Support Data is related with the development of knowledge within the company. As the maturity of objects evolves, the maturity of engineering practices is also improved.

We propose to assess the maturity of those objects to increase the overall quality of the KMS. Moreover, this assessment could increase the confidence of knowledge seekers when they use the KMS.

5.1 Our definition of maturity

During the development process of a Support Data item, the maturity level evolves. This evolution can be assessed in comparing the current characteristics of the information item with objective quality indicators. When the objective quality indicators are reached, the information item could be considered as mature.

In the concurrent engineering domain, some authors worked on the evaluation of preliminary information maturity. For Saint-Marc & al. [20], when exchanging information, the maturity is valuated through the provider and the receiver's point of view: the provider expresses the maturity with four criteria (precise, complete, final and consolidated); the recipients judge the maturity with their own criteria (comprehensive, consistent, exploitable, actual and acceptable). Grebici & al. [21] consider the evaluation of the maturity of preliminary information by qualifying indicators about the exchanged data. These indicators have to be chosen beforehand by the actors, depending on the culture of the company.

According to these studies, the maturity assessment of Support Data items can be based on predefined indicators that are valuated during the exchange. However, the context of the proposed approach differs from the concurrent engineering because the social context of the exchange is not the same: knowledge contributors and seekers do not directly depend on each other to perform the project activities. Stvilia & al. [22] propose a quality assessment framework that provides a quality mark to the wikipedia articles at three levels: intrinsic, contextual or relational, and reputation or confidence. The evaluation proposed by Stvilia & al. just helps to compare the relative quality of the articles between each other. Culley & al. [23] also investigated the quality of many kinds of information sources with four dimensions (authority, validity, relevance and structure). They assess the average quality level and a quality range for a number of types of information sources. These studies can be adapted in the proposed framework as the contexts are effectively similar with the knowledge management approach presented here. In the present study, assessing the maturity consists in evaluating a number of information quality indicators to point up the development stage of a Support Data item.

5.2 Investigating the development process of Support Data items

Because of the SME structure, lead engineers develop Support Data during the projects accomplishment. Consequently, the hypotheses underlying the Support Data are only validated under the particular conditions of the project. Lead time pressures have consequences on this development, as it is difficult to allocate a project task and time to develop and test a Support Data item with various hypotheses as it could done be in R&D or Advanced calculation department. During the projects, the engineers have to test the candidate Support Data item until it can be considered as reliable enough to be used in the study. In fact, even if users assess information as being reliable as it was tested over a

simple mechanical case, it is difficult to consider it as being generic until it was used in several others situations.
A fine analysis of KALIS' content led us to identify four typical situations encountered during the development of a Support Data item.
The first situation is encountered when Support Data have never been used through KALIS. We pointed out that about a half of Support Data item were simply stored. When considering never used Support Data many questions raise as regards their usefulness. If Support Data are stored in KALIS, it is because someone thought that they might be useful. A knowledge seeker accessing these Support Data for the first time could not assess easily their effective maturity. In a knowledge contribution focus, if Support Data remains not used for a long period, it is necessary to look at their purpose. Then, the creator of the Support Data item or a group of experts can decide to remove it from the database.
The second situation is when used Support Data have never been especially tested. The FEA-specific calculation macro in Table 1 is a relevant example of such a situation in which users can change Support Data as and when interacting between each others. Thus, knowledge seekers cannot trust in the reliability of the Support Data. However, the amount of engineers sharing and using a Support Data item in their projects can indicate its usefulness. In the case of contributors, the possible actions can consist in testing the Support Data under many hypotheses to make it more reliable.
The third situation occurs when Support Data are recognised as useful. Then, the reliability of Support Data becomes an important aspect. In such a situation, contributors have to collaborate with the objective of making the Support Data reliable. A number of actions are possible such as verifying if the Support Data item fits a set of quality requirements (validity of hypothesis, Currency – when the article was updated the last time, …). The stability and the amount of engineers who have already reviewed a Support Data item since the last time it was modified can make knowledge seekers more confident in using a Support Data item.
The last observed situation concerns the Support Data that have been recognised as reliable (Support Data item recognised to be useful, stable and reviewed by several engineers). In a knowledge-seeking context, engineers can be confident on the reliability of Support Data. The remaining actions for contributors consist in improving the quality of the Support Data items' documentation to make it more understandable and free of errors. The structure of the documentation has also to be improved to fit the requirements and provide Support Data with a formalisation of declarative, procedural and motivational knowledge.
These four observed situations of evolution the Support Data can indicate to users the maturity of Support Data and the actions to undertake for continuing their development. Thus, we propose now a maturity assessment framework, which is based on the characteristics of these four situations.

5.3 First steps toward a framework of maturity assessment of KALIS' content

The maturity assessment framework intends to support engineers during the collaborative development of Support Data. By this manner, the target is the improvement of the global quality level of the KALIS' content.
The framework shares characteristics with the CMMI, which is based on several levels indicating the maturity of processes [24]. In one hand, knowledge seekers could have an idea of the risks taken when using a Support Data by assessing the reliability of objects and practices. In another hand, knowledge contributors are interested in knowing the current development phase of a Support Data item, and the possible actions to undertake in order to improve the maturity. Within the framework, each maturity level is composed of indicators identified as the most relevant ones for a particular development phase of a Support Data item. Some of these indicators can be assessed automatically and others can result from actions of knowledge contributors during the development of a Support Data item.
Table 2 describes the framework and the associated indicators. It shows also how these indicators are associated with the four situations described above. The indicators of each maturity level intend to help knowledge seekers when assessing the maturity of Support Data. The aim of the right hand column is to guide knowledge contributors in the way of improving the maturity of the Support Data item. Once the required action has been performed, the indicators of each maturity level are updated. The values of the indicators determine the global maturity level of a Support Data. The current maturity level can indicate both the maturity of a Support Data itself or the maturity of practices related with the Support Data item within the company (when using a standard for instance).

Table 2. Support Data maturity assessment framework

Maturity Level		Indicators	Description	Actions
0	Simple storage		No specific particularities are needed to reach this level The Support Data item has never been used.	To Be Stored
1	Usefulness revealing	Use	Indicate the amount of effective use of Support Data items.	To Be Used
		Share	Indicate the number of engineers who worked with the Support Data item	To Be Shared
2	Reliabilization	Verification	Indicate if the Support Data item has been verified since the last modification	To Be Verified
		Revision	Indicate the number of reviewers of the Support Data item since it was verified	To Be Reviewed
		Stability	Indicate the stability of the Support Data item	To Be Stabilised
3	Consolidation	Documentation	Indicate if the documentation of the Support Data item is comprehensible, exhaustive and structured	To Be Documented
		Validation	Indicate if the Support Data Item is validated by an expert	To Be Validated

6 CONCLUSIONS

The challenge of our knowledge management approach is to fit the size and the requirements of calculation offices. Thus, we propose a collaborative knowledge management system in the aim to overcome KMS main acceptance issues as their codification costs, their integration within engineering activities and the management of the quality of such system's content.
Feedbacks on the deployment of our system in an industrial context return positive results about the codification costs and the system's integration issue addressed by our approach.
To overcome the codification issue, KALIS propose to formalise only crucial knowledge. In addition, the framework of KALIS enables a collaborative and distributed knowledge formalisation process.
The integration issue was being addressed with the implication of engineers in the design of KALIS and in integrating the system in the working environment of calculation engineers.
Finally, it is stressed in this paper that the quality issue of knowledge management systems' content affects both knowledge seekers and contributors. Thus, an investigation of the evolution of Support Data within KALIS leads to the identification of four typical situations revealing their maturity and the proposal of a four level maturity assessment framework. In one hand, this framework indicates knowledge seekers the quality of support data. In the other hand, the maturity level helps knowledge contributors in improving the quality of the knowledge management system's content.
The presented approach could be expanded to others profession of the product design domain as it fits the collaborative behaviour of communities of practices. KALIS enables the progressive formalisation of knowledge and fosters the collaboration, which lead to improve the quality of formalised knowledge.

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