

# Collaborative Development of Knowledge Representations – a Novel Approach to Knowledge Elicitation and Transfer

Alexeis Garcia-Perez and Robert Ayres

Department of Information Systems, Cranfield University, UK

[a.garcia-perez@cranfield.ac.uk](mailto:a.garcia-perez@cranfield.ac.uk)

[r.ayres@cranfield.ac.uk](mailto:r.ayres@cranfield.ac.uk)

**Abstract:** Knowledge Management (KM) initiatives are driven by the need to preserve and share knowledge, in particular tacit knowledge that experts have built up in the course of doing their jobs. Such initiatives require key experts to be identified and their knowledge elicited. However, knowledge elicitation generally runs into a number of communication and motivational problems. These are well known in domains such as expert systems but it is only more recently that KM practitioners have become aware of them. Standard KM approaches separate the elicitation and, possibly, encoding of knowledge from its subsequent sharing.

This paper outlines an approach where elicitation and transfer, and possibly also creation, are carried out in one process. This involves identifying key experts and stakeholders. These two groups then work together to develop a representation of the experts' domain knowledge. The role of the KM specialist thus becomes one of facilitation rather than elicitation.

This approach has a number of advantages. It is more likely to engage the interest of experts and so avoid some of the motivational problems that are commonly encountered in knowledge elicitation. It does not rely on knowledge management specialists who do not share the experts' language, to capture and record their expertise. In particular the approach helps overcome the perceptual biases of domain experts. It is well known that perception is often selective and that judgements can be anchored on false premises. Experts are not immune from these biases but they are more likely to be eliminated as a result of the critical dialogue that occurs between experts and stakeholders using our approach.

Our approach has been developed in the course of an action research project with a major engineering company. Staff who worked on a help desk had particular expertise which was of interest to other departments, such as design and production. The research data gathered was necessarily qualitative since the focus of concern was on the richness of transfer achieved. Early results suggest that communication or motivation problems encountered by conventional approaches are avoided and that a richer transfer of knowledge results. In particular it helps to identify and capture relevant tacit knowledge. The resulting representation may also form the starting point for a knowledge base which will be available to a wider community.

**Keywords:** knowledge elicitation, knowledge creation, knowledge sharing, knowledge transfer, action research

## 1. Introduction

The ability to create and share knowledge is seen as a key factor contributing towards organisational competitiveness (Holsapple and Joshi, 2002). Most organisations which hope to improve their ability to create and exploit knowledge undertake some kind of KM initiative. In doing so, one of the problems they will encounter is how to improve the transfer of knowledge between different parts of the company.

A number of approaches to facilitating knowledge transfer can be found in the KM literature. Although well-established they do suffer from weaknesses. These approaches include:

- Directly capturing experts' knowledge and recording it in a repository which is made available to other staff. This approach is not new - its origins can be traced back to the 1980s with the development of expert systems and the need to elicit knowledge to provide a rule-base for the system.

The weakness of this approach is that it has generally been applied on the assumption that expertise could simply be extracted from an expert - "*Mining the jewels of knowledge one by one out of experts' heads*" as it is described by Feigenbaum and McCorduck (1983). However, this does not take account of the nature of expertise (Hart 1989). For example experts are often not able to explain the reasons for their actions.

- Facilitating links and conversations between experts and other employees (Davenport and Prusak 1998). The intention is that this will allow staff to discover what they know and share it with others.

Davenport and Prusak (1998) acknowledge that such ad hoc approaches may not always work. They can be affected by cognitive, psychological and communicational issues as well as practical problems such as the location of employees, or the existence of different vocabularies and frames of reference.

- The use of computer-based systems as a knowledge transfer strategy (Goh 2002).

Computer-based systems provide a channel for knowledge transfer. However, this is not enough to guarantee that their potential for supporting transfer is exploited. Issues of motivation, trust or willingness to share can undermine technology-based strategies. An illustration of this is provided by the work of Garcia-Perez and Mitra (2007). They interviewed employees in a research organisation and found that computer-based systems could help with knowledge transfer. A knowledge-based system was developed following recommendations of the interviewees. Most employees used the system but only a fraction made significant contributions. After nine months virtually no new contributions were being made to the knowledge base.

This paper presents an approach to knowledge elicitation and transfer where domain experts and stakeholders work together to develop a representation of the experts' knowledge. We discuss how knowledge elicitation and transfer are understood within different fields. A new method of knowledge elicitation through modelling is introduced. The application of the method in a company that designs, manufactures and services gas turbines is finally described as a mechanism to assess the validity of our approach and the areas where further work is required.

## **2. Knowledge elicitation and transfer in different fields**

The need for some kind of knowledge elicitation in support of knowledge transfer initiatives is generally recognised. Different implementations of existing approaches to facilitating knowledge transfer have attempted to meet such a need, particularly by using computer-based systems or facilitating links between employees and experts. While these approaches may produce benefits for certain organisations, there is little evidence to suggest that they are effective. They rely either on the ability and willingness of experts to contribute to a knowledge base or ad-hoc discussions about the knowledge domain.

To address these limitations of knowledge elicitation and transfer, researchers in other fields have designed and implemented more controlled approaches, even before they came to be a concern in knowledge management. We can argue that:

- Knowledge elicitation was seen as a process performed by a knowledge engineer designing an expert system.

The knowledge engineer would focus on transferring experts' knowledge into a computer-based system that could perform certain tasks in a similar way to that of human expert (Burton et al. 1988).

- Requirements analysis for systems development is another domain which involves what is essentially a knowledge elicitation task.

This task is performed by an analyst, who elicits and analyses user needs to translate them into system requirements (Avison and Wood-Harper 1986).

However, methods for knowledge elicitation and transfer have had to deal with significant problems that have affected their outcomes. These include:

- Motivation: Huber (2001) highlighted motivation as the most important issue hindering knowledge transfer. Similarly, King et al. (2002) identified individuals' motivation to share their knowledge as one of the ten most important issues in knowledge management. Davis (1981) refers to motivation as one of the many behavioural limitations of the individual expert that affect their ability to share knowledge.
- Communication: Problems that occur between an expert and the knowledge specialist due to the lack of a common understanding of the knowledge domain, including both communication obstacles and psychological limitations such as human bias in selecting and using data, or human behaviour in problem-solving situations (Davis 1981).
- Disagreement between experts: Problems that emerge from differences in experts' views (e.g. when two or more users come up with conflicting views or priorities) and therefore complicate transfer. One approach to dealing with this is the use of a "referee" (Davis 1981, Valusek and Fryback 1985, Browne and Ramesh 2002).

Researchers have pointed out that these problems do not appear to have been a focus for research within the KM domain. This in spite of knowledge transfer being regarded as key to organisational survival and success (Holsapple and Joshi, 2002).

### 3. A new approach to knowledge elicitation and transfer in organisations

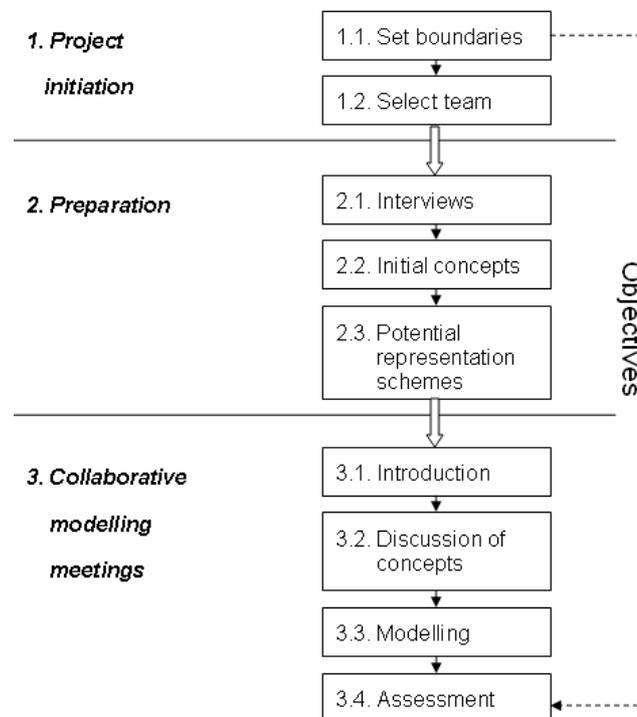
When knowledge elicitation is carried out in the context of a KM initiative the main purpose is to facilitate the transfer of knowledge. Consequently any resulting representation of experts' knowledge, although useful, is not central to the exercise. This has led the authors to develop a new approach to knowledge elicitation for knowledge transfer. In this approach experts and key employees for whom experts' knowledge might be relevant (referred to as stakeholders) are identified. They are then brought together to discuss and agree key concepts in the domain and develop some representation or model which links these concepts in a meaningful way. There are few constraints on what is used as a representation scheme provided it is useful in helping experts and stakeholders develop and refine a common understanding. It might be a concept map, spreadsheet or complex dependency diagram showing relationships between faults. The role of the Knowledge Transfer (KT) facilitator becomes one of facilitating the process of developing a common understanding among project participants through modelling the knowledge domain.

There are a number of advantages to this approach when it is applied in the KM domain:

- It has the potential to engage the interest of experts since, in developing a representation of their expertise, they will develop and refine their own knowledge. This is important since many KM initiatives fail because experts have no motivation to participate.
- It reduces communication problems due to different vocabularies - the process will expose differences of language and understanding. It will reduce the impact of any cognitive biases on the part of experts since stakeholders may have different perspectives on the domain and challenge the experts to justify their assertions.
- It ensures that the knowledge which is most useful to stakeholders will be transferred since they are directly involved in the process.

#### 3.1 Applying the collaborative transfer approach

The way we have applied this collaborative transfer approach involves three stages as outlined below and shown in Figure 1.



**Figure 1:** Key stages of the knowledge transfer mechanism.

##### 3.1.1 Project initiation

The knowledge domain to be analysed is agreed with the project sponsors. It is important that this is specified as precisely as possible and that clear objectives are set that provide a boundary to the knowledge

transfer project. Examples of objectives might be to understand how a particular kind of fault is diagnosed or to develop a model of the phases of a contract negotiation.

Project participants are selected so that there are between one and three stakeholders for every expert. This ratio guarantees that the transfer exercise does not fail due to a lack of expertise or insufficient stakeholders to challenge and question experts. There are no particular restrictions regarding the background of experts - they may have similar, complementary or even contradictory views of the domain. Indeed differences in their perspective should help to expose differences in understanding of concepts. It is important for sufficient time to be allocated to the project which may entail their attending a sequence of perhaps five or more meetings over a period of weeks.

### *3.1.2 Preparation*

The KT facilitator will interview experts and stakeholders on a one-to-one basis about the issues that are relevant to them and which need analysis. These interviews will produce questions, or suggestions for key concepts that relate to the area of interest.

The KT facilitator may extract the main questions and concepts so that they can be fed back to the participants when they meet as a group. The concepts that are relevant will vary depending on the domain. For instance if the domain of interest was that of project management then relevant concepts might be identified as project phases, completion criteria, project categories, staff roles and so on. In another domain, such as fault diagnosis, a completely different set of concepts – such as subsystem, machine status, fault category and so on – might be identified.

The KT facilitator may also select one or more knowledge representation schemes that may be appropriate to the domain. In doing this the facilitator takes into account the background of the participants. The KM specialist may also produce rough outlines of how some of the concepts could be arranged given the representation schemes selected. These outlines will become the input to the first of the series of collaborative modelling meetings.

Note that the preparation phase is intended to set a clear focus for the rest of the project in terms of its scope and participants. Although the knowledge sharing requirements of the organisation are analysed, this phase is different from what is understood as requirement analysis for systems development.

### *3.1.3 Collaborative modelling*

When the project preparation is completed, a series of structured meetings are carried out, in which collaborative modelling of the knowledge domain takes place. Each one of these meetings usually lasts between one and two hours. The KT facilitator will run these meetings and ensure that they are divided into the following phases:

- Introduction – the current state of the project and its objectives are briefly reviewed and the structure for the meeting set out.
- Discussion of concepts – participants discuss whether the concepts are viewed in the same way and whether any concepts or questions should be modified.
- Modelling – the participants select a representation scheme and use it to model the relationships between key concepts.
- Assessment – a brief review is carried out at the end of the meeting in which participants can decide whether they have yet achieved the objectives originally set for the transfer project.

After each meeting the KT facilitator will document the outcomes (the current set of concepts and representation) to be circulated before the next meeting. This record will then provide the starting point for the next collaborative modelling meeting.

The first time a meeting takes place the KT facilitator will use the results from the preparation step to provide an initial set of concepts and questions to be discussed. If participants have trouble suggesting an appropriate representation scheme then the facilitator may step in with specific suggestions based on the background preparation carried out for the first meeting.

The discussion meetings will occur at regular intervals until the participants feel that the overall objectives have been met. Of course it is quite possible that new questions and issues will arise in the course of the

meetings. These may lead to further transfer exercises being carried out. It is preferable to keep each knowledge transfer exercise focussed on its objectives since different experts or stakeholders may become appropriate should the objectives be modified.

This stage of the method benefits from experience of specific data collection tools such as group interviews or focus groups. However, it is different to these approaches. While group interviews are tools designed for a researcher to collect data (Stewart and Shamdasani, 1990), our method aims at facilitating interaction between participants and, as a side effect, relevant knowledge can be captured.

#### **4. Methodology**

The method for knowledge elicitation and transfer outlined in this paper has been developed as part of an action research project concerned with looking at knowledge-related processes. This project was carried out in a gas turbine manufacturer where:

- knowledge was considered a key resource;
- there was no formal mechanism in place for the transfer of knowledge between employees or units; and
- there was an awareness of the problems arising from the lack of knowledge transfer.

An action research project involves a cyclical process of identifying or defining a problem, considering alternative courses of action for solving the problem, selecting the best course of action, studying the consequences of such actions and identifying general findings (Susman and Evered 1978). These five stages were fully implemented in a project that ran between April 2007 and October 2007. During those six months we collected data through different means and in different formats. Data collection mechanisms included:

- Observing existing mechanisms to transfer knowledge between experts, customers and other employees;
- E-mail communication between the researchers and the project teams;
- Working notes taken during the process and in project meetings;
- Interviews with project participants at different stages of the development of the project.

Recordings were made of those meetings and interviews where participants agreed.

#### **5. Knowledge elicitation and transfer at a gas turbine manufacturer**

Gas Turbines Ltd. (GTL) is a supplier of gas turbines with expertise that has been built up over decades. It has many thousand staff including professionals from a range of engineering disciplines. Although GTL has a range of standard turbines, most of those that are installed have been customised in some way. It generally takes about 10 months from receipt of order until a turbine is installed in the field. During this time the turbine will be designed, built, tested on a special test-bed and, finally, installed and commissioned. A maintenance department provides a support service, including a help desk, for installed turbines. Once installed a turbine may run for many years – some gas turbines that were originally installed in the 1950s are still in operation.

Those employees who work on the help desk providing customer support, accumulate the largest amount of expertise about machine operation. The help desk has about 20 staff some with as much as 20 years experience in diagnosing faults and fixing turbines. Their expertise is an extremely valuable resource, not just for helping to keep customers' machines operating but also as a source of advice and information to other GTL departments.

##### **5.1 The knowledge elicitation and transfer project**

After initial meetings between one of the researchers and GTL staff it was agreed that the knowledge of the help desk was not only superior to that of any other department, but it was also unique by its nature and was needed throughout the organisation. The analysis highlighted the absence of an established knowledge sharing mechanism that included the help desk. Both parties understood that such a mechanism could improve organisational performance and competitiveness.

The project is described in terms of the three main phases of initiation, preparation, and modelling outlined previously. These phases had not been formally defined when the project began but the work carried out naturally fits into this framework.

### *5.1.1 Initiation*

It was agreed that the focus of knowledge transfer for the project would be fault diagnosis in gas turbines. Given the time constraints, the project focussed on one particular fault which occurs when there is insufficient lubricating oil being supplied to the moving parts of the turbine. This was a topic of interest to all the technical departments in GTL.

Three help desk staff were selected as experts and a further six staff from other departments as stakeholders to participate in the project team. One of the researchers acted as the facilitator to help with the knowledge transfer process.

### *5.1.2 Preparation*

Prior to the first collaborative meeting of the project team some of the key concepts relating to the diagnosis of turbine faults were extracted from documentation. This was done with the assistance of a member of GTL staff who was able to explain concepts and direct the researcher to useful documents. A set of concepts was produced relating to the workings and modes of failure of a gas turbine. Messages from operating and error logs were also extracted to provide data relating to certain faults and associated sequences of messages. (The turbines generate status and error messages during operation and these are automatically transmitted to a GTL computer.)

The researcher used the data collected to produce a tabular representation showing how certain faults appeared to be associated with particular modes of failure and operating messages which were indicative of these failures.

### *5.1.3 Collaborative modelling meetings*

A series of four meetings, lasting between forty minutes and slightly more than two hours was held over the course of several days. The objective of these meetings was to discuss and agree the patterns of error messages which were associated with particular faults. This would help to understand how those faults could be diagnosed. Participants agreed about the concepts that were relevant in describing turbine faults and their causes and little time was spent on these. The patterns of messages, and the origins of some faults, on the other hand gave rise to considerable discussion. It became clear that staff from other departments often had little idea of the relative frequency of faults nor of the ways in which help desk staff generally resolved these faults.

The sequence of meetings ended when the participants agreed that the essential information on faults and how to diagnose them from message logs had been captured. The representation scheme used for fault information which had been proposed by one of the researchers was not changed as a result of these meetings. However, the information on the faults and how they could be diagnosed was substantially revised.

Comments made to the researcher when the meetings ended, and at other times by those involved, suggested that the participants found the experience interesting and engaging. Several of them said, without prompting, that they found the meetings very useful and that such elicitation exercises should be carried out more often.

Once the collaborative modelling meetings had ended work carried on to produce a knowledge based system using the results. Information gathered from the meetings was used to produce a Bayesian network which related error messages to failure modes and observed faults. Further work was carried out with some of the help desk staff to assign appropriate probabilities to the links in the Bayesian network. Once the network was complete it was used to implement a system which diagnosed faults on the basis of messages received. This further work was carried out as part of the original agreement with GTL but was distinct from the knowledge transfer which had been achieved through the collaborative modelling meetings.

## **5.2 Evaluation from applying the method at GTL**

The project at GTL was expected to produce two main outcomes – a knowledge base of turbine faults and a transfer of knowledge between staff in different departments. The knowledge base was used as the basis for an automatic fault detection system which was assessed on the proportion of faults that it diagnosed. This system was considered to be successful but is not discussed further here.

Evaluation of the knowledge transfer was harder since there were no objective tests that could be applied. The approach which was adopted was to visit GTL some time after the original meetings of the project team and interview participants about the impact that the exercise had had on their way of working. Interviews were carried out on a one-to-one basis with those who had participated in the original exercise and were structured – there was a predetermined set of questions that were asked though the interviewer allowed participants to expand on other points that the interviewee felt were relevant. Considerable care was taken to design these questions so that they did not suggest particular answers. The interviewees were not told that knowledge transfer was a focus of interest; they were asked questions like “*What recollection do you now have of the project which you participated in?*” and “*Can you think of any change that has resulted from this project?*”

The original project meetings were held in June 2007. One of the researchers returned just over 6 months later, in early 2008, to carry out the interviews. It turned out to be possible to interview only one of the help desk staff who had participated. This expert was very positive about the project. He said that his participation had given others access to his “*first-hand experience about gas turbine operation*”. Furthermore the project gave him the chance to “*express what is in his mind*” and had helped him to structure his understanding of the failure modes discussed.

Of the six staff from other departments who had participated it was possible to interview four. Three of them gave very positive feedback. Although their participation in the project did not change the way they worked, it improved the outcomes of their everyday job. They mentioned that it had given them the only chance they had had to get extensive access to the knowledge of experts. They asserted that they learned by participating in the project. Finally, they would encourage the organisation to have someone responsible for “knowledge transfer” through a similar project on a permanent basis and would participate in any similar initiative. The fourth person interviewed did not report any benefits from the project. However, this person had changed his role shortly after the completion of the project and this may have made it less relevant to his work.

One further stakeholder who had left the company was contacted by e-mail. He acknowledged that being part of the knowledge transfer project was “*the best experience*” he had had during his time at GTL because of the amount he learned during the process.

The experience from applying this approach to knowledge elicitation and transfer at GTL showed that:

- Experts were highly motivated and found the project engaging.
- The direct communication between experts and stakeholders helped both sides to develop their understanding of the domain.
- The project focussed on issues which were of importance to all the participants.

These factors clearly contributed to the perception of GTL staff that the project was a success.

There had been an initial concern at GTL with regard to the amount of time that experts would need to spend in the project meetings. However, only two days were needed for the collaborative modelling of the knowledge domain, where knowledge elicitation and transfer took place. Thus, by having only a small number of meetings the method avoided two common problems that affect KM initiatives: limited availability of experts and using too much of their time. Having realised the advantages of applying this method, the project sponsor now hopes to go through a similar process on a regular basis.

## **6. Conclusions and further work**

Knowledge elicitation has not been a major focus of research in knowledge management even though transferring knowledge is a key issue. Existing approaches to knowledge elicitation and transfer within organisations depend on either ad-hoc or technology-based mechanisms for sharing knowledge and personal experience. Research in other fields has identified a number of difficulties of such approaches that include communication and motivational issues. Our research has been concerned with addressing these problems when facilitating the transfer of knowledge within organisations. This has led to an approach to knowledge transfer which involves bringing experts and key stakeholders together to collaborate in modelling important features of the domain.

Using this approach many of the motivational and communications problems that have previously been identified in research on knowledge elicitation were avoided or reduced. A KM expert that may not be fully

aware of the language related to the knowledge domain will facilitate the application of the method. Communicational problems are minimised because the main interaction will take place between domain experts and their stakeholders. Also, discussion of their own experience with colleagues through a process of modelling their expertise significantly increases experts' motivation to share knowledge. The method also benefits from its focus on transfer of knowledge rather than the construction of a knowledge base.

Although the authors are confident that the general approach to knowledge transfer outlined in this paper is effective, further work is required to refine the method for applying it. One issue relates to the appropriate timing and spacing of meetings. Meetings should be long enough to be useful but not so long as to cause some participants to lose interest. Meetings also need to be sufficiently far apart to give people some time to reflect on the issues discussed.

The nature of expertise is another area which needs investigation. Traditionally knowledge elicitation research has been concerned with eliciting knowledge from people with a high level of expertise. In the context of knowledge management it is likely that many of the "experts" that may participate in a knowledge transfer exercise may not have highly developed expertise. They may have experience in work which is highly relevant to other departments in the organisation but this does not mean that they will have developed a deep understanding of what they do. This implies the need for some framework to classify the kinds and levels of expertise. It may be that different approaches are required for dealing with different groups in terms of the nature or level of their expertise.

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