A knowledge-capture report for multidisciplinary design environments

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Abstract
Purpose – Organisations must continually innovate to remain competitive. A by-product of innovation is new knowledge. In a knowledge economy, an organisation’s ability to manage its knowledge can mean the difference between commercial success and failure. A key aspect of being able to manage knowledge is the ability to identify and capture it. This paper aims to present the development of the knowledge-capture report (KCR) and the results of its use at the third TeamWork demonstration event for collaborative working.

Design/methodology/approach – Quantifying the number of discrete pieces of knowledge captured in the KCR and categorising the type and quantity of knowledge captured demonstrate the practicality and effectiveness of the KCR in a dynamic multidisciplinary design team environment.

Findings – The different approaches that were observed and adopted by the participants using the KCR highlight a number of key issues that need to be considered when attempting to capture knowledge in a constantly evolving design environment.

Originality/value – The use of the KCR by a wide range of industry practitioners demonstrates a quick, effective and low-cost approach to capturing project knowledge and events. It could be adopted easily by the engineering and construction (AEC) industry as an entry point to managing knowledge, particularly in complex, multi-disciplinary design environments.

Keywords Knowledge management, Innovation, Project management, Research methods

Introduction
Commercial pressures have stimulated and fuelled the growth of knowledge management. A company’s ability to exploit its collective knowledge can mean the difference between commercial success and failure (Nonaka and Takeuchi, 1995). In today’s knowledge economy, knowledge is increasingly being considered as an asset that needs to be effectively managed to create added wealth.

Within the architecture, engineering and construction (AEC) industry, companies recognise they can no longer afford to reinvent the wheel, and thus must learn to better capture the knowledge accrued on projects to improve the quality and effectiveness of future projects (Egan, 1998).

Every construction project is unique with its own problems. Ideally, by carefully identifying potential problems at the planning and design stage of a project, preventive measures can be put in place. Once a problem occurs, it is the responsibility of the project team to resolve it in a quick and efficient manner. To do this, an experienced project team reflects on its past-experiences, seeking comparable problems and solutions to the current project. Some problems might be common to particular types of projects and the same solution can therefore be reused. However, when unique problems arise, it is the ability to combine and modify other solutions, to create new solutions for unique problems, that makes an experienced project team so valuable (Fong, 2003). A key factor that affects problem solving is the individuals’ or the project teams’ experience/knowledge (Salter and Gann, 2003). From
this it is clear that knowledge is built-up over time and therefore represents a considerable investment.

Traditionally, knowledge was transferred from one generation of engineers to the next over a period of time (Modesitt, 1992). However, for a number of reasons such means of knowledge transfer need to be reconsidered. For example, the declining number of graduates on engineering courses and the ageing engineering community (Construction Industry Training Board, 2002; Egan, 2002; Fairclough, 2002) renders traditional organisational learning cycles ineffective at transferring knowledge and results in an organisational “brain drain”. The short-term nature of contracts and mobile/transient project teams often means that knowledge is lost when people move company or contract (Kasvi et al., 2003). In addition, knowledge management has already been identified by a number of reports within the AEC industry as a vehicle for better project efficiency and innovation (Egan, 1998, 2002).

To address these issues effective tools that can be integrated with the design process are needed to capture and learn from the knowledge generated on projects. Virtual First, the TeamWork event organisers, approach was to produce a knowledge-capture report (KCR) that could easily be integrated into the design process and enable the project teams to capture key events, decisions and design details. The amount of detail and type of knowledge captured by the KCR drew directly from the success of the knowledge-capture form (KCF) that it had previously developed and used (TeamWork, 2001). Virtual First’s approach was then put to the test by the multidisciplinary design teams participating in the Teamwork event, who were tasked with designing and building various projects in a virtual environment.

This paper describes the development of the KCR, the report’s approach to capturing knowledge and presents the results of its use in the third TeamWork event organized by Virtual First. Two key questions, were initially addressed in developing the KCR:

1. What constitutes knowledge and knowledge management?

2. How can knowledge be captured effectively?

Knowledge and knowledge management

Knowledge creation is an ongoing process derived from a cycle of socialising, externalisation, combination and internalisation (Nonaka and Takeuchi, 1995). Knowledge management supports the creation process by putting in place processes, or mechanisms, to: identify, capture and leverage knowledge (Manasco, 1996). In order to do this it is essential to identify what knowledge should be captured, why it is of value, how can it be captured, how can it be stored, how can it be retrieved, and how will it be used. Defining the aims of the knowledge management initiative by answering these questions increases the initiative’s overall chances of success (McCampbell et al., 1999).

The identification of knowledge, however, is not straightforward. According to Nonaka and Takeuchi (1995) there are two forms of knowledge: “explicit” and “tacit”. Snowden (1998) illustrates the difference between the two with the following example:

The map [information] is an artefact created by explicit knowledge and provides a series of routes and options that can be taken for a journey. The guide can use the map but also use the tacit knowledge which he/she possesses. However, a client could challenge the received wisdom of the guide through “curiosity and naivety” which may lead to the discovery of a new route.

Ward’s (1998) list of knowledge sources further illustrates Nonaka and Takeuchi’s (1995) two forms of knowledge: Presentations, reports, journals, databanks, manuals and training materials being examples of “explicit” knowledge; and individual ability, memory, know-how, experience, teams, and networks examples of “tacit” knowledge. However, Bollinger and Smith’s (2001) definition of knowledge as: “the understanding, awareness, or familiarity acquired through study, investigation, observation, or experience over the course of time” which is personal to an individual, would regard Ward’s (1998) explicit list as information.

The concept of a knowledge creation cycle and the contrasting definitions of what knowledge is, results in a vague definition making it difficult to distinguish between knowledge and information, illustrating why the identification of knowledge is not straightforward. The practical
implication of this is that to identify knowledge it must be recognised that knowledge can manifest itself in many different forms, sources and locations.

Having identified the nature and location of the knowledge sought, consideration should then be given to capturing it. Garza and Ibbs (1992) outlined four knowledge-acquisition techniques, each suited to capturing different types of knowledge:

1. **Analysis of the public domain knowledge**: allows the knowledge capturer to familiarise himself/herself with the current thoughts on a particular subject.

2. **Interviews**: these can be unstructured or structured. The advantage of unstructured interviews is that they allow the knowledge holder (the person being interviewed) to explain freely what they feel are key elements in their work that if missed or not given attention, will affect the end result. Such information can then be refined and probed further with structured interviews. The disadvantage of unstructured interviews is that the knowledge holder may digress from the problem being addressed.

The opposite is the case for structured interviews, however, the disadvantage is that important points are not covered due to the way the interview is structured. The advantage is that the points that the knowledge capturer (the interviewer) wants to address are covered.

An important point to bear in mind with interviews is that “Uncued recall of something that has never been specifically memorised is notoriously bad. A classic example of this is remembering the design on the back of a coin – hardly anyone can produce anything more than a rough idea of it, even though they have seen the design hundreds of time and could recognise the correct design instantly” (Welbank, 1983).

3. **Observation**: these techniques can be broken down into four categories: observation of familiar tasks; observation of tasks with limited information; observation of tasks with constrained processing; observation of specific tasks. The first category offers the most freedom to the knowledge holder to perform the task but this might not be that interesting to the knowledge capturer as it may mean re-visiting routine tasks that are already documented. Observation of tasks with limited information places some restriction on the knowledge holder, to prompt some form of response/assumption. Processes can then be restricted to see what is important by the sequence of decisions made. The final observation technique of specific tasks would include tasks like emergency procedures, that might never occur, but where it is critical to know the outcome.

4. **Induction**: allows governing rules and gaps in existing rules to be identified by the analysis of case studies. By documenting the factors that result in different outcomes, governing rules can be developed. For example, if one house was built with foundations and a second without, if the house without foundation collapsed, the governing rule could be: houses with no foundations collapse. However, if further cases were examined gaps/flaws in the governing rules might be identified which would require the rule to be reassessed and further factors that influence the outcome to be analysed. A disadvantage with this approach is the difficulty in detecting subtle differences between the case studies and how these affect the rules.
Background to Virtual First and the TeamWork events

Virtual First is a government and industry sponsored educational initiative. Its mission is “to provide an education focus for the construction and facilities management industries to deliver built facilities which meet client needs through effective team working across all design, construction and operation activities, using IT for virtual prototyping . . . to build before we build, to occupy before we’ve built” (TeamWork, 2002).

The TeamWork events organised by Virtual First offer the participants, ranging from architects, to engineers, to fabricators, to suppliers, a unique opportunity to work in teams to realise the virtual construction of a number of buildings. The virtual construction projects allow the teams to test and develop new collaborative processes and innovative design concepts, effectively “learning by doing” (TeamWork, 2000; Nonaka and Takeuchi, 1995). To date, the events have explored a number of issues such as: the single building model, supply chain integration and multidisciplinary collaboration (respectively, TeamWork, 2000, 2001, 2002).

For each event, a record of the achievements, lessons learned and recommendations is produced by Virtual First. Their approach to capturing this information and knowledge has evolved with the growing size and scope of each event.

The first TeamWork event required no formal knowledge capture due to there being only 29 participants, nine of whom were from Virtual First. However, the substantial increase in the number of participants to 57 (ten of whom were from Virtual First) coupled with the fact that the Virtual First team was not going to be actively involved with any project work required a practical and effective knowledge capture methodology to be developed for the second event.

The approach adopted by Virtual First for the second TeamWork event was to create a knowledge capture team consisting of five knowledge reporters. The team was responsible for capturing and documenting events, data, information and knowledge created in the development of the virtual design and construction of a north London secondary school, as these arose throughout the event.

To help with the capture process, a KCF was developed. This contained five items of information: discipline area/subject heading, date/time of the event captured, reporter’s name, interviewee’s name and the description/notes of the event which generally also included a screen shot. The description and screen shot conveyed the interviewees’ interpretation of what he/she was doing and its importance (see Figure 1).

Virtual First’s use of the KCF enabled sufficient knowledge to be captured to prepare the presentation on the last day of the event and produce the second TeamWork (2001) report. The success of the KCF demonstrated the feasibility of the form as a method for ‘capturing knowledge’. The main conclusion of the report concerning the KCF was that although it successfully achieved its objectives, it could be further improved before the third event by addressing the following weaknesses:

- the reliance on knowledge reporters: relying on reporters to be in the right place, at the right time, to capture events, meant that important events were possibly missed;

Figure 1  Example of a KCF entry

| Subject: Supply chain integration |
| Date: 2001-09-25 captured at 17:00 |
| Reporter: [Name] |
| Interviewee: [Name] |
| Note: A dxf format was used to get info from Nemetschek into the Powerwall software. This info was then used as the boundary condition, which was filled with the cladding system. The Powerwall software also allows fabrication schedules to be produced. |
the number of knowledge reporters limited the total number of events that could be captured; and
the subjective decision of the knowledge reporter as to what he/she chose and chose not to capture meant that certain events were unfortunately overlooked by the reporters.

The KCR

To address the weaknesses identified with the KCF in the second TeamWork event and ensure sufficient knowledge was captured in a consistent manner, the knowledge capture team revised the KCF and developed the KCR for use at the third event.

To increase the capture of useful knowledge in a consistent manner the KCR included additional elements; for example the concept, scheme and detailed design options sections. One of the reasons for adding new sections was to support teams in capturing their own knowledge, to ensure a range of knowledge accrued on their projects was captured and reduce the risk of good quality information being overlooked.

The KCR contained eight sections:

- **Section 1: project team and project summary information.** Documented the team members, contact addresses, their roles, an overview of the team's project and their objectives for the event.
- **Section 2: technical information and technical interaction.** Listed the different computer software applications used by the team, what they were being used for, and any interaction that took place between them.
- **Section 3: team interaction.** Reported the communication/interaction that took place both internally and externally to the team.
- **Section 4: project specification.** Developed at the start of the event by each team set out the desired functional design criteria. This was used subsequently at the end of the event to measure how well the final design met the original design criteria.
- **Sections 5-7: concept, scheme and detailed design options considered.** Captured options considered at different stages of the projects development and the reasoning behind the preferred design option.
- **Section 8: additional information.** Allowed the team to capture/highlight any additional key events, issues and design features that they felt were important to the project.

The key purpose of the KCR was to capture knowledge and information, to enable problems and solutions, and key lessons and events, to be documented in a consistent format. This would then allow external team members and observers to browse through the KCR and understand at a glance each team's projects, the events that formed the project, and any other additional information relevant to the project. The Virtual First team reviewed all the KCRs and presentations when bringing together the experiences and lessons learned for the final TeamWork report.

To help the teams understand how the KCR should be used, a blank report was filled in with the information and knowledge captured from the first two events. The background, importance and purpose of the KCR, and how the KCR would help the teams through the event were discussed with each team at a series of meetings arranged by Virtual First. Teams were also advised on how to approach the knowledge capture process, and given the incentive of winning the TeamWork knowledge capture prize. The two main pieces of advice given were to:

1. appoint one of the team as a knowledge reporter, responsible for completing the KCR; and
2. capture information and knowledge as it happened and on a regular basis.
Analysis and discussion of the KCR’s usage

Altogether, 47 industry practitioners from a range of disciplines in the AEC industry participated in the third TeamWork event. They were divided into six teams of approximately equal size. Each adopted a different methodology within the overall framework of the KCR to capture what they were doing and complete the knowledge capture exercise.

Teams A and B used the KCR as intended, completing nearly all the sections. Team A, put more emphasis on the overall development of the project and created an extensive storyboard containing 54 images of the project development (see Figure 2). Team B placed more emphasis on the different options explored and additional features considered by the team.

Teams C and D used the KCR as a starting point and supplemented it with additional sections and reports to capture greater detail. Team C did this by expanding the KCR, creating a new section (whole life cost model, environmental design and process and sustainability) and using certain sections as repositories for technical data and information. Team D supplemented the KCR with detailed reports on specific elements of the project (one of which detailed the progress of different elements of the buildings structural designs and another detailed the effect of collaborative working).

Teams E and F only partially used the KCR, waiting until the end of the event to produce polished presentations detailing what they had achieved.

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**Figure 2** Extract from team A’s project summary information KCR section

<table>
<thead>
<tr>
<th>Date</th>
<th>Title</th>
<th>Comment</th>
<th>Platform</th>
<th>By</th>
</tr>
</thead>
<tbody>
<tr>
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<td>Family &amp; Parks Spec</td>
<td></td>
<td>Tifforma</td>
<td>LG</td>
</tr>
<tr>
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<td>Base support</td>
<td>Tifforma</td>
<td>TA</td>
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<td>Model or key</td>
<td>Tifforma</td>
<td>TA</td>
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<td>11/06/02</td>
<td>Pre LiveWeek</td>
<td>Pre LiveWeek</td>
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</table>

<table>
<thead>
<tr>
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<th>Title</th>
<th>Comment</th>
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<th>By</th>
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</thead>
<tbody>
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<td>TA</td>
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<tr>
<td>12/06/02</td>
<td>Concept options</td>
<td>Pavilion</td>
<td>Paper</td>
<td>MB</td>
</tr>
<tr>
<td>12/06/02</td>
<td>Live Week brief</td>
<td>It’s a box</td>
<td>Internal planning</td>
<td>MB</td>
</tr>
<tr>
<td>12/06/02</td>
<td>Structural grid</td>
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<td>TA, MB &amp; JPC</td>
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</table>
To further examine and quantify the success of the knowledge capture exercise by each team, the completion of the different sections of the KCR, non-KCR reports and the teams’ final presentation were tabulated and assessed against a basic marking system (see Table I).

Observations and lessons learned

The total mark for each of the teams in Table I further highlights the variation in the overall extent of the knowledge capture and the success of the different KCR sections. These variations can be attributed to a number of factors.

Although it was suggested at the start of the event that each team appoint a knowledge reporter, actively encouraging all team members to be responsible for capturing what they were doing was found to be a more successful approach. By involving the whole team, a much broader overview of their work was captured.

The next key factor determining the team’s knowledge capture success, was their ability to integrate the knowledge capture activity with their project process. The teams that saw the capture activity as an integral part of the project process and updated the KCR regularly made the activity seem effortless. An additional benefit of this approach was the projects’ development being tracked in real time and could thus be used to overcome the issue of engineers not being easily able to describe where they were in the design process; an issue identified previously in the TeamWork 2001 event (TeamWork, 2001).

Variation in the usage of the different KCR sections appeared to be based on the type of information that the participants needed to capture. The KCR captured two types of information. The “Form information” sections of the KCR were the more successful of the two, capturing concise factual information (e.g. name, telephone number, email address) which required little effort to complete. In contrast, “Free information” sections were less restrictive and left to the user to decide what knowledge they should capture and how much detail they should go into. Although the “Free information” sections were used the least they were the more valuable to the teams that completed these sections, and likewise to the Virtual First team in reporting the teams’ activities. The value of the “free information” was that it documented the evolution of the design and the project. How a solution is developed/derived may be more important than the solution itself. Documenting the questions asked and decisions made at different stages of the project and how they affected the final solution allows a project audit trail to be developed which the reader can use as “sign post” of events to:

- obtain an overview of the project’s evolution;
- contact the people associated with particular events/activities;

<table>
<thead>
<tr>
<th>Table I</th>
<th>Summary of KCR section usage</th>
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</thead>
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<tr>
<td>KCF sections</td>
<td>A</td>
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<tr>
<td>Project team information</td>
<td>✔+</td>
</tr>
<tr>
<td>Project summary information</td>
<td>✔−</td>
</tr>
<tr>
<td>Technological information</td>
<td>✔−</td>
</tr>
<tr>
<td>Technological interaction</td>
<td>✔−</td>
</tr>
<tr>
<td>Team interaction</td>
<td>✔−</td>
</tr>
<tr>
<td>Project specification</td>
<td>✔−</td>
</tr>
<tr>
<td>Concept options considered</td>
<td>✔−</td>
</tr>
<tr>
<td>Scheme options considered</td>
<td>✔−</td>
</tr>
<tr>
<td>Detail options considered</td>
<td>✔−</td>
</tr>
<tr>
<td>Additional information</td>
<td>✔−</td>
</tr>
<tr>
<td>Additional knowledge reports</td>
<td>✔−</td>
</tr>
<tr>
<td>Presentation</td>
<td>✔+</td>
</tr>
<tr>
<td>Total (out of 12)</td>
<td>10.2</td>
</tr>
</tbody>
</table>

Note: ✔ = completed; + = high level of detail; − = not used
go directly to specific non-KCR explanations/reports embedded in the KCR as hyperlinks; and
support the decision making process on future projects.

The amount of detail captured in the “free information” sections of the KCR varied from a few
lines of text and an image, to detailed reports for example on structural design progress. The
strength of the detailed reports was their depth and focus on specific issues; their
weaknesses were the time needed to review the knowledge they contained, and the high
cost of the capture process.

The strength of the brief text and images were their breadth, allowing the end user to get a
quick overview of the project and its evolution, and low cost to capture; their weakness was
the ambiguity in what the author was trying to communicate.

Both approaches were invaluable in producing the TeamWork report but, within the context of
a real project, the value of the knowledge captured needs to be weighed up against the cost of
the capture process. Determining the appropriate amount of effort and detail that should go
into the knowledge capture process is critical to maximising its overall value and success.

One of the weakest areas of the KCR was the team interaction section and its ability to
capture soft issues. For example all the participants agreed that multidisciplinary team
working was important but no precise knowledge was captured by the KCR that might lead
to a better understanding of the different factors that contributed to the successful
integration of the different engineering disciplines in order to apply these on future projects.
A useful modification to the KCR in the future would be to amend this section so that it
involved a two-stage process. Firstly, using “form information” to initiate the capture process
by documenting meetings dates and attendees, and the second requiring each participant
to write a paragraph on how they felt the meeting went or explain what happened.

The KCR was intended to provide the reader with an instant understanding of the projects.
This was achieved by allowing the reader to use the different sections of the report as a
framework for directing their enquiries and using the documented project events as “sign
posts” to relevant people and detailed reports on specific issues. There was however, some
inconsistency in the form’s use; nevertheless, those who captured and reported events
using the KCR clearly demonstrated its value.

Conclusions and recommendations
To capture the knowledge generated by the six multidisciplinary teams participating in the
third TeamWork event, designing and building projects in a virtual environment, Virtual First
developed the KCR. The development of the KCR drew on the success of the KCF that
Virtual First had developed and used the previous years.

The KCR’s eight sections were developed based on the different categories of project
knowledge generated during the previous years TeamWork event. The structure of the
individual KCR sections and the amount of detail to be captured for particular items of
project knowledge again drew on the KCF format and usage.

The eight sections of the KCR enabled various types of knowledge to be captured that
collectively present a holistic overview of the team’s project. How the six teams approached
using the KCR, and the knowledge they captured, highlight strengths and weakness that
have resulted in a number of recommendations.

The range of approaches used by the teams demonstrates that there is no definitive way to
capture knowledge; it is therefore essential to allow a certain amount of flexibility in the
capture process. However, it is clear that if key sections are not completed the knowledge
accrued from a team’s work may be lost.

The following approaches were demonstrated to be practical and successful:

- all team members should be encouraged to participate in the knowledge capture process;
- the knowledge capture process should be integrated with the overall project processes;
- the KCR should be considered as a minimum requirement;
teams should be encouraged to tailor the capture methods to suit their needs; and

- the KCR should remain a high-level overview document from which one can drill down into the detail.

The use of the KCR by a wide range of industry practitioners demonstrates a quick, effective and low-cost approach to capturing project knowledge and events. It could be adopted easily by the AEC industry as an entry point to managing knowledge, particularly in complex, multi-disciplinary design environments. Once a number of the KCRs are completed by an organisation on real projects, the true value of the knowledge captured will become apparent to the organisation and allow it to make a considered business assessment of the necessary level of detail the reports should go into to achieve maximum return on the investment in this process.

This paper and the KCR have focused on the capture part of the whole knowledge management process. The development and use of the KCR by the participating teams allowed Virtual First to capture both a global overview of each team’s project, philosophy, design process and project evolution as well as in depth details on particular aspects of their design. These various levels of information capture were then used to produce the TeamWork (2002) report. For the teams, the KCR was a permanent record of their project and achievements that they could share with others.

Further work is required to better understand how the knowledge contained within the KCR is retrieved and used. This would help indicate KCR refinements that would ensure the right level of detail and type of knowledge is captured.

The construction industry invests considerable time and money in finding solutions to problems. But this can only be considered an investment if lessons are learned and are applied to avoid repeating the problems, otherwise it should be simply considered as a cost. Organisational knowledge is becoming a key factor in determining competitive success. This will therefore continue to increase the relevance of finding more effective knowledge management systems in the future.

References


