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PERSPECTIVE ON PRACTICE

Evaluating a tacit knowledge sharing initiative: a case study

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Abstract

Purpose – This paper aims to present a case study illustrating the issues involved in the tacit knowledge conversion process and to determine whether such conversion delivers value to the organisation in terms of business value and return on investment (ROI).

Design/methodology/approach – A single-case multiple baseline participants experimental design, replicated across two participants, was utilised. Aaron's KM V-model of evaluation is utilised to determine the ROI of the initiative.

Findings – While the evaluation of the tacit knowledge conversion initiative suggests positive value to the business; analysis of the conversion process also reveals a number of individual level factors, which reinforce the challenges associated with efforts to access, capture and share expert tacit knowledge.

Research limitations/implications – The results of this study may stimulate further research on tacit knowledge management processes, and specifically the influence of the individual in the success or failure of these initiatives.

Practical implications – The paper presents an actual case study situation that reveals the micro-level issues involved in converting tacit expert knowledge.

Originality/value – The paper addresses three important areas; it makes an effort to focus on tacit rather than explicit knowledge management, it takes steps to evaluate a tacit knowledge management initiative in terms of its tangible business value, and it pays attention to the influence of the individual in knowledge management processes, which are inherently driven by the individual.

Keywords Tacit knowledge, Individual factors, Return on investment, Knowledge management, Knowledge conversion, Organizational performance

Paper type Case study

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Introduction

Turning knowledge into value is widely accepted as a key source of competitive advantage for organisations (Kankanhalli *et al.*, 2007; Shih *et al.*, 2010). Tacit knowledge is key in leveraging the overall quality of knowledge (Goffee and Jones, 2007). The traditional emphasis in knowledge management has been on knowledge that is recognized and already articulated in some form, known as explicit knowledge. However there is a growing body of literature that calls for a focus on the management of tacit knowledge (Ambrosini and Bowman, 2008; Cordeiro-Nilsson and Hawamdeh, 2011). Tacit knowledge is acquired through inner individual processes such as experience, reflection, internalisation and individual talent (Haldin-Herrgard, 2000). These characteristics make tacit knowledge a source of sustainable competitive advantage because it cannot be stored and transferred easily, and thus a firm's competitors find it is difficult to imitate and copy (Ambrosini and Bowman, 2008). However, because tacit knowledge is stored in a non-verbal form, employees are often unaware of the knowledge they possess, or are incapable of expressing something that for them is natural and obvious, irrespective of their qualifications (Haldin-Herrgard, 2000). Given these difficulties, organisations are increasingly intensifying their search for ways to learn how to share and transfer tacit knowledge between their employees and teams, and prevent the loss of this knowledge through employee turnover (Nonaka and Von Krogh, 2009). Because individuals are the fundamental repositories of tacit knowledge, they are key to the success of any knowledge management initiative (Tohidinia and Mosakhani, 2010).

Organisations use both people and technology focused strategies to help the sharing of tacit knowledge. The main advantage of people-focused strategies is that they enable the sharing of more relevant tacit knowledge (Polanyi, 1983), such as employees' experiences, know-how, and other complementary expertise that is embedded in organisational practice and cannot be easily captured in documents. People focused strategies must effectively facilitate the conversion of tacit knowledge into more explicit formats where its value can be extracted and captured for use beyond a once off point-in-time social interaction between an individual or collective. To successfully optimize the way new knowledge is developed and existing knowledge is exploited, organisations need to facilitate the dynamic capabilities required for converting the knowledge available from the insights and competences of people into appropriate structures, processes, products and systems that allow the value to be exploited (McKenzie and Van Winkelen, 2004; KPMG, 2000). Thus there are two fundamental issues here; first gaining insight into the challenges associated with externalising individual's tacit knowledge and their internalising of it for application to a task; second, providing a more precise methodology as to how to measure this value and obtain some insight into the extent to which individuals competence will be impacted through sharing of tacit knowledge.

The purpose of this paper is to present an exploratory case study based on participant observation that investigated the challenges of externalising tacit knowledge and measuring its value to an organisation. The paper is structured as follows: First we discuss the challenges to tacit knowledge conversion and the issues involved in evaluating tacit knowledge management initiatives. The methodology utilised is then described in detail, followed by a description of the results. Finally, we discuss the implications of the study for the practice of training and development in organisations.

Theoretical context

Challenges to tacit knowledge conversion

The conversion of tacit knowledge is far more difficult than explicit knowledge (Argote and Ingram, 2000) because individuals are its fundamental repositories and they are active agents in its use. It is dependent on an individual's ability and willingness to engage in the knowledge transfer process. Tacit knowledge transfer requires externalisation and internalisation.

Externalisation process involves codifying and then articulating knowledge in a language that can be understood by other individuals (Balconi, 2007). Articulated knowledge is that which other individuals can recognise as codifiable and can identify the rules and code of translation whereas codified knowledge is that which is materially codified. Codification is complete if each component can be translated into a linguistic representation that successfully reflects its original meaning. Boisot (1983) suggests that the process of codifying a message involves a loss of information, which can only be recovered if the receiver associates the same cluster of meaning with the codes utilised by the sender. The codes-in-use may give rise to uncertain or ambiguous interpretations of meanings. Nonaka and Takeuchi (1995) recognised the role of language as a vector of shared meaning and interpretations. However, neither their model or related research pays sufficient attention to operationalising this process, detailing the transmission modes or the barriers experienced in the processes of externalisation, such as those associated with codifying tacit knowledge or using language as the codification medium.

The process of internalisation focuses on embodying explicit knowledge into tacit knowledge within an individual. By reading manuals about their jobs, learners can internalise the explicit knowledge written down and enrich their tacit knowledge base. Explicit knowledge can also be embodied through simulations or experiments, or anything that triggers learning by doing (Nonaka *et al.*, 2000). Venzin *et al.* (1998) have suggested that being familiar with different epistemologies means having a larger knowledge management repertoire and a better understanding of the limitations of each approach. A cognitivist epistemology suggests that when the brain is gathering knowledge from the external environment, it stores facts, relates them to existing experiences to create a picture of the world. It is about taking knowledge from the external environment and relating them to the previously acquired frames of reference, to the cognitive map (Depraz *et al.*, 2002). According to an autopoietic epistemology, knowledge gathered from the external environment is not knowledge but data i.e. data put into a certain context. This view emphasises that knowledge is not "transferred" from one individual to another, because the data has to be interpreted. Therefore, knowledge transmitted by one individual can be interpreted differently by two receiving individuals, and thus produce two different types of knowledge based on their existing knowledge. Koskinen (2000) found that similar worldviews of two individuals in a project enabled them to deal with difficulties associated with the fact that they did not speak the same native languages. Conversely, Breite *et al.* (1999) found that project metrics were not met when two individuals from different technical backgrounds could not speak the "same language" and thus had difficulties viewing the project goals in the same way.

Evaluation of tacit knowledge management initiatives

Evaluation studies to determine whether knowledge conversion and sharing initiatives, regardless of whether their focus is on explicit or tacit knowledge, produce value and whether there is a link between KM and knowledge management information system (KMIS) initiatives and performance metrics at both strategic and operational levels, are limited in number and scope (Aaron, 2009). Frequently, the best intentions, along with copious amounts of human and financial resources, are devoted to implementing KM initiatives with little or no results (Gold *et al.*, 2001).

A plethora of measurement methods exist specifically focusing on the management and measurement of explicit knowledge. However, Cohen (2006) notes that organisations fail to calculate return on investment (ROI) for KM and rely on transactional data such as the number of documents downloaded or created in information repositories. Kankanhalli and Tan (2005) categorise the multitude of metrics available for KM evaluation purposes according to the elements of evaluation necessary for KM and KMIS. The elements identified were user, system, project, process and organization. Evaluations at the user level focus on motivations of users to seek knowledge and contribute knowledge. Evaluations at the KMIS level focus on user, task, KM process and organisational outcomes for KM and KMIS. Metrics at this level include usage of and evaluation of the system (e.g. frequency of knowledge accessed, added, ease of search, ease of navigation), seekers and contributor/expert evaluations of the knowledge available/provided (e.g. quality of knowledge available, timeliness, value of knowledge, comparison to competitors), IT support for system use, level of implementation of knowledge, organisational integration of the system.

While the macro level of analysis is informative, there needs to be an improved measure of intangibles or tacit based knowledge both at a micro and macro level, particularly as good indicators at micro level enables the building of better indicators at the macro level. It is also suggested that evaluation measurements taken close to the level of implementation within the organisation better measure the impact of KM initiatives (Barua *et al.*, 1995). Knowledge management initiatives are more successful when they are implemented as a collection of smaller focused and operational-based initiatives, rather than overarching and high-level projects (Gold *et al.*, 2001; Grillitsch *et al.*, 2007). This may be due to the ability of more sophisticated, practitioner-orientated, operational level evaluation models applied at the level of implementation, to remove the impact of numerous intervening or other exogenous variables on the results (Kleist *et al.*, 2004; Barua *et al.*, 1995; DeLoone and McLean, 1992).

Evaluation of the ROI of training initiatives at an operational level is enabled through the use of evaluation models such as Kirkpatrick's (1994) and Phillips (1997). Measurement and evaluation of training is a complex process but KM metrics are particularly distinct due to the intangible nature of tacit knowledge (Glazer, 1998). As tacit knowledge is difficult to define and has multiple interpretations, it is difficult to value and measure. Aaron (2009) highlighted that the role of training is to build long-term skills and the role of KM is to provide point-of-need knowledge. Based on this premise Aaron adapted Kirkpatrick and Phillips training evaluation models to devise a model for evaluation.

Aaron's model of KM evaluation focuses on evaluating KM initiatives at a number of integrated levels of implementation to determine their direct impact on operational performance metrics for the business or element of the business to which it relates. In this regard, it adopts the operational as opposed to high level aggregate perspective on evaluation. Under Kirkpatrick's (1994) and Phillips (1997) evaluation models, direct operational data is solicited to measure learner reactions (level 1), learning behaviour (level 2), learning transfer to the workplace (level 3), impact on the business metrics (level 4) and return on investment (ROI) data (level 5). Aaron's (2009) KM V-model of evaluation comprises six levels of which levels 3 to 5 align with Kirkpatrick (1994) and Phillips (1997) models, while levels 0-2 are specific to the company's KM solutions and therefore guide the company specific metrics that need to be defined.

Aaron's KM model of evaluation defines each of the levels of evaluation as follows; Level 0 measures KM information system status in terms of the operational effectiveness of KM tools or processes such as the extent to which they perform the functions of harvesting, collecting and coding information; Level 1 measures Access to the System in terms of how users interact with the system, page hits or page visits; Level 2 measures Information Locating such as whether the KM tools or processes provide the right information to the right people at the right time. This study is not concerned with levels 0-2 due to their focus on KM tools or processes and due to the fact that the experimental conditions in place for the study override the need for the users to locate or access information as it is provided for them. This study is focused on levels 3 to 5 of the KM model of evaluation.

Level 3 refers to users applying knowledge located (similar to learning transfer) in the work setting to create value for clients. Level 4 measures business results, and is defined as the business outcome or result of applying the knowledge created or found through KM tools or processes. Level 5 is ROI and is defined as return on investment, the ratio of quantifiable business results to cost of KM tools or processes. Thus to address the second aim of this study, we utilise Aaron's KM V model as a methodology to conduct a case study evaluation (at levels 3-5) of a tacit knowledge conversion and sharing initiative (at levels 3-5).

Methodology

Study context

The study reported in this case study was conducted in a large manufacturing MNC site located in the Republic of Ireland. The experiment that is the focus of this study focused on an organisational task for which there was only one in-company technician one hundred percent competent to perform it. The task was a preventative maintenance task involving setting the correct measurements on a grinder. These measurements were designed to ensure that the grinder grinds the product smoothly and to the required dimensions and curvatures. Incorrect measurement settings would result in scrap product. The knowledge required to perform this task remained, until the commencement of this experiment, as tacit "know-how" residing with the expert technician (Engineer 1) gained through years of experience with this machine and conducting this task. In instances where Engineer 1 was unavailable to conduct this task and the task was required to be completed so as not to stop production or impact production metrics, the machine manufacturers are contacted and an engineer from the manufacturers is contracted to conduct the task. Engineer 1 therefore possessed valuable tacit knowledge not accessible by other in-company engineers and the costs to the organisation of either requiring the services of the manufacturers engineer or indeed halting or slowing production until Engineer 1 was available were a concern. To this end, the organisation saw value in engaging in a tacit knowledge conversion and sharing experiment to identify whether such an intervention would deliver worthy business value and ROI to justify repetition on other machines and with other technicians, the impact of design of this intervention on the ability of the participants to internalise and apply the tacit knowledge converted (externalised) and shared by another and the challenges associated with tacit knowledge capture and sharing interventions so as to improve future such interventions.

Engineer 1 (an Irish national, with a background in mechanical engineering, eight years experience with the company, works in maintenance area) was invited to and was provided with the time and resources during his daily work to undertake efforts to externalise his tacit knowledge with respect to this task i.e. to codify, articulate and thus convert his tacit knowledge in whatever manner he deemed suitable, possible and most effective for another engineer to utilise without his support in a verbal or visual manner. Engineer 1 therefore prepared a revision 1 and revision 2 document consisting of instructions in the form of words, numbers, symbols and images (photographs of parts of the machine) to codify and articulate his tacit knowledge. These documents were utilised to conduct the experiment as outlined below.

Experimental design and conditions

Two engineers (referred to here as Participant 1 and 2), Participant 1 (a foreign national, with a background in electronics engineering, eight years experience working with the company, works in the automation area), Participant 2 (an Irish national, with a background in mechanical engineering, works in automation area, eight years experience working with the company) with no prior training or experience with either this machine, a similar machine or a task of this nature participated in the study. Both experiments were conducted with the same machine, which was taken out of production for the duration of the study. In the pre-experiment interviews, the task was outlined and both participants were asked if they possessed knowledge or experience on how to conduct task. Both participants confirmed that they would not be able to conduct the task without a document or access to an expert. Participants were instructed to take Engineer 1's document to the machine and utilise it to conduct the task from start to finish. Participants were instructed to progress with doing the task and not to stop or ask questions of the observers or Engineer 1, whom also observed for the purposes of ensuring the safety of the participants, ensuring no damage was done to the machine and to help interpret the observations from a technical perspective. Participants were timed conducting the task and two observers recorded observations of the participants behaviours and the impact of the treatment of the provision of a document representing experts tacit knowledge (independent variable) on the participants ability to complete the task to 100 percent or part thereof and the time required to complete the task of part thereof (dependent variables). Participant 2 was requested to conduct the task only when it was evident that the treatment resulted in changes in the dependent variables for Participant 1. Engineer 1 and participants were interviewed prior to and post each and all iterations to solicit data to identify the individual level factors that influenced the results of the initiative.

Data collection process

In order to collect data to conduct the experiment which involved testing the effects of an independent variable – reading a document that provided an experts tacit knowledge on conducting a task on an inexperienced technician’s ability to conduct that task. The dependent variable for the purpose of the experiment was the effect on a technicians ability to conduct the task. We utilised interviews and observation to collect data to undertake the experiment. Study participants were interviewed prior to and on completion of the experiment.

A structured and standardised interview protocol was used in order to ascertain background information on each of the participants, their experience and training relevant to the equipment and particular task in question so as to rule out the influence of prior education, training and experience on ability to conduct the task (see Appendix). The interview schedule also contained rating scales asking the technician to rate on a scale from 1-10 their perception of how difficult the task would be with and without the documentation (converted tacit knowledge) provided by the expert technician.

All of the interviews were recorded (with prior consent and confidentiality assured). Following the transcription of the interviews, we reviewed the transcripts and consolidated findings therefore developing a profile of study participants that could be used in a non-biased manner when interpreting the experiment observations.

A structured interview schedule was considered appropriate prior to study participants undertaking the experiment, and we utilised an unstructured observational protocol for the experiments. The observation did take place within “the natural setting”, however there was one manipulation involving the introduction of the documented tacit knowledge document. Two of the researchers positioned themselves in an unobtrusive but visible position from the task at hand and independently noted down their own observations and interpretations.

Following the experiments the two researchers carried out a thematic analysis based on their documented observations with the goal of reaching inter-observer agreement (also referred to as inter-rater reliability). According to Robson (2011), inter-observer reliability is the extent to which two or more observers obtain the same results when assessing/measuring the same behaviour. The researchers compared the results of both observations, agreed on the key themes or factors and related them back to both the literature and the data collected from the interviews.

Calculating the ROI

In order to calculate the ROI for this study, these calculations were undertaken:

- *Short-term ROI calculation*: the cost of sending technicians on formal training was compared to the initial costs associated with the tacit knowledge conversion and sharing initiative i.e. time taken (costing used the technicians salary at an hourly/daily rate) to capture the experienced technicians tacit knowledge in manual format.
- *Long-term ROI calculation*: given that the tacit knowledge conversion element was conducted only once for this particular task (once the manual exists it does not have to be developed a second time unless a new machine is utilised), the long-term costs of tacit knowledge sharing were compared to the formal training costs to determine the long-term ROI.

- *Cost to business of an experienced vs an inexperienced technician*: the costs to the business of using an experienced technician (who can complete the task in less time thus representing a better return on that technicians salary and longer machine operating time and thus greater return from that machine) versus an inexperienced technician were compared to determine the ROI of using the experienced technician.
- The costs to the business of using the manufacturer's engineer (who can complete the task in less time thus suggesting a better return on a technicians salary and longer machine operating time and thus greater return from that machine) to conduct the task versus the inexperienced technician were compared to determine the ROI of using the inexperienced technician.

The study findings

We structure the findings of this experiment under three sub themes:

Subtheme 1: tacit knowledge conversion and sharing: results for change in abilities of individuals

One of the study aims involved investigating the extent to which an individuals competence is impacted through sharing of tacit knowledge. We investigated whether the provision of a tacit knowledge conversion and sharing initiative would lead to a change in the ability in the person with whom it was shared. In relation to the experiment, Table I (column 1) provides details on Engineer 1's estimate as to how long it took him to conduct the task on the first occasion. He conducted the task without documented knowledge but with a broad training provided by a machine manufacturer. It also indicates the time he took to conduct the task with experience on the machine, experience on the task and with the use of the document. Column 2 details the estimates provided by Participant 1 in the pre-experiment interview to reflect the amount of the task he perceives he could have completed and over what duration in a situation where he did not have access to the document. Column 2 also details Participant 1's actual time to complete the task during the experiment and the quantity of task completed when conducting the task in time 1 (T1) (based on revision 1 of the document) and time 2 (T2) (based on an improved revision 2 of the document). Column 3 details the estimates and actual time to complete the task during the experiment and the quantity of the task completed for Participant 2 (based on revision 2 of the document).

The results indicate that the provision of the final revision of a document representing an experts' tacit knowledge (independent variable) resulted a positive change in the ability (dependent variable) of Participants 1 and 2 from 0 per cent ability to complete the task to the ability to complete the task to 100 per cent within timeframes of 90-91 minutes.

Subtheme 2: tacit knowledge conversion and sharing: individual level influencers on the success of the conversion and sharing

Conscious of the positive impact of sharing a document, which represents converted experts tacit knowledge, on an inexperienced individual's ability to conduct a task, it was necessary to investigate the effectiveness of the codification and sharing process. The study revealed interesting findings on tacit knowledge conversion and sharing.

Table I. Timings and quantity of task completed as part of the experiment

	1 Engineer 1		2 Participant 1				3 Participant 2	
	Estimate Without “tacit” knowledge	Actual time 1 With “tacit” knowledge	Estimate Without “tacit knowledge”	Estimate With “tacit” knowledge	Actual time 1 With “tacit” knowledge	Actual time 2 With “tacit” knowledge	Estimate Without “tacit” knowledge	Actual time 1 With “tacit” knowledge
Time to do task	120 mins	46 mins	Could not complete	120 mins	82 mins	91 mins	Could not complete	90 mins
Percentage of task completed	100%	100%	0%	100%	30%	100%	0%	100%
Change in time to do task			11 per cent increase in time taken to do task in T2 over T1 T2 a 70 per cent increase in the quantity of the task that could be completed					

Differences in interpretation of the codes in use. As inexperienced technicians read the codes utilised by the expert in his document and attempted to apply the knowledge to conduct the task, Participant 1 attached a different meaning to some of the words in the text than was intended. As an illustration, one incidence of this was where the text gave instructions and computer code with which to run the computer. It stated "'Sample Program' LOOP G1 G28 F310 X0 X0 X0, Insert sample program and test machine limits". Participant 1 perceived that he was to insert this exact code into the computer whereas the expert provided this text only as an example; further instruction as to which code was to be utilised was provided later in the document. This issue may have occurred due to the challenge of codifying and articulating knowledge or due to differences in how individuals process information. Specifically with regard to information processing, there were evidence of individual preferences. The experienced engineer presented his knowledge in a document incorporating words, numbers, symbols and images where he felt these would best illustrate the part of the machine to which he was referring in the text. During the experiment we observed that the inexperienced technician had a preference to refer firstly to the images and/or simply skim read the text. The result was that on occasion the inexperienced technician tried to conduct the task without having absorbed sufficient information. On more than two occasions this resulted in the inexperienced technician progressing to a step in the task prematurely and incorrectly and upon seeing error messages on the computer or upon being unable to conduct that step he had to stop and refer to the document again to read the text completely. As an illustration the text stated "Put a; in front of any line you wish the machine not to read (see below)", however the inexperienced technician skim read this line and did not process the words "not". Consequently, he input ";" in front of all lines of code instead of the code which he wanted the machine not to read.

Determining which components of tacit knowledge require conversion. In the process of enabling tacit knowledge sharing, an expert engineer needs to determine which components of his "know-how" or tacit knowledge require conversion and capture, so that the inexperienced technician will have sufficient knowledge to be in a position to conduct the task. Observation of the inexperienced technician's use of revision 1 of the document revealed that the expert had neglected to capture some components of the task. It emerged therefore that some knowledge had become truly tacit, automatic and engrained in his subconscious and only became re-apparent to the expert upon observing the inexperienced technician skipping steps or making errors. The expert acknowledged that these errors, which were not due to the inexperienced technician but due to an incomplete tacit knowledge capture.

An individuals prior knowledge. On occasion the inexperienced technician manipulated the machine using techniques he would normally apply on other machines with which he had experience. His prior knowledge suggested to him that the same techniques would apply to this machine. This prior knowledge was not appropriate for use on this machine. A lack of prior knowledge of relevance to this task also caused challenges. One inexperienced technician had a background in electronics and not mechanics and so the need to engage in physical manipulation of large machine parts was a new skill for him. A lack of experience with computer panels and keyboards posed challenges in ways such as locating specific keys on the keyboard and ignoring warning signals flashing on the computer screen as these had no meaning for him. This prior knowledge was not included in the document. In a similar vein, the expert made a deduction, based on his experience, as to how much of his tacit knowledge was required in this document to facilitate another persons understanding for the purposes of transfer. In face-to-face interactions an inexperienced person has the opportunity to pose questions until such time as he obtains a sufficient amount of knowledge from the expert with which to understand and apply that knowledge. In this experiment such questioning was not possible. Consequently, the inexperienced technician found that he experienced some confusion as to the purpose and context of conducting some steps suggested in the document and the consequences of not conducting these tasks exactly as indicated. To illustrate, the document stated "Press pedal full to the floor". The inexperienced technician felt a need to know why this step was required and the consequences of not pressing the pedal full to the floor. In interpreting the instruction the inexperienced technician placed emphasis on the word "full" thus causing him to question whether there would be consequences. Such concerns are understandable given the emphasis in environments such as this on safety and the costs of damage to these machines. These insights illuminate the role of contextual knowledge and prior knowledge in enabling interpretation and knowledge transfer.

Dimensions of tacit knowledge that could not be codified. Fourth, as is expected due to the "stickiness" of tacit knowledge, some steps of the task could not be codified in the form of words, symbols, code or images. It was suggested that video may have been helpful but would still have been incomplete. As an illustration, one step required the inexperienced technician to remove a long solid metal bar from the machine. This bar was securely in place and required a degree of strength and physical manipulation to remove it. The text stated "remove", however the experienced technician revealed that to do so required that you give the bar "a wiggle". It was not evident to the inexperienced technician from reading the document how much force he should exert to remove the bar. Again, with concern for damage to expensive machine parts prevalent, it is likely that he would not use significant force, would not be aware that it required "a wiggle" and consequently would be slow in completing this step in the task. A demonstration from the experienced technician is most likely required here due to the psychomotor nature of this tacit knowledge.

Subtheme 3: tacit knowledge conversion and sharing: results of estimations of business value and ROI

The business value and ROI were calculated using the metrics of 'time to complete task' utilised for the first part of the experiment and as per the methods used by Phillips (1997) in evaluating training interventions. Five ROI calculation scenarios are presented:

(1) the short-term formal/informal training ROI is based on "the cost of learning the task through formal training" by comparison to "the cost to the business of conducting the tacit knowledge conversion and sharing initiative";

(2) the long-term formal/informal training ROI is based on "the cost of learning the task through formal training" by comparison to "the cost to the business of conducting the tacit knowledge conversion and sharing initiative minus the original once-off cost of tacit knowledge conversion into a document";

(3) the short-term use of competent/less competent personnel ROI is based on comparing "the cost to the business of using an experienced formally trained

technician to conduct the task" to "the cost of using an inexperienced technician who leverages the tacit knowledge document"

(4) the long term use of competent/less competent personnel ROI is based on comparing "the cost to the business of using the manufacturers technician (when the experienced technician is not available for which the case site gave an estimate based on the previous year of ten occurrences)" to "the cost of using an inexperienced technician whom leverages the tacit knowledge document".

(5) The potential ROI.

Table II presents a comparison of the costs of "learning the task by sending a technician on a formal training programme" to the "cost to the business of the tacit knowledge conversion and sharing initiative". The cost to the business of the tacit knowledge conversion and sharing initiative ultimately includes the initial costs associated with the expert spending time in tacit knowledge conversion. However, so as to present a conservative ROI estimate and to respond to the results from the observations such as the inability to codify all tacit knowledge and some gaps in the documents, the inexperienced technicians prior knowledge and a need for contextual knowledge, we include the cost of a support or mentor technician whom can fill in this gaps in tacit knowledge codification. We costed this using the time taken by the inexperienced technicians during the experiment to conduct the task without support i.e. we provide them with ninety-one minutes of support. We also include the cost to the business of the inexperienced technician being away from his job while learning. The initial ROI is calculated by comparing the costs of formal training to those of the tacit knowledge conversion and sharing initiative and based on this is 36 per cent.

The long-term ROI is calculated using the same metrics but as the tacit knowledge conversion and capture initiative is complete, the associated costs are no longer charged. The long-term ROI compares the costs of formal training to those of the tacit knowledge conversion and sharing initiative, based on this is 94 per cent.

Table III presents the ROI of provision of tacit knowledge to an inexperienced technician such that he can conduct the task versus utilising an experienced technician to conduct the task. The results reveal that due to the inexperienced technician requiring more time to conduct the task, the business incurs a 98 per cent loss. However, in incidences where the experienced technician is not available, an engineer from the machine manufacturer needs to be utilised. A comparison of the cost of utilising the manufacturer's technician with that of using the in-house inexperienced technician reveals a future ROI of 1,474 per cent.

Table IV assumes that the inexperienced technician increases his speed to conduct the task at a rate of five minutes each time he gets to the conduct the task. This is considered, by the experienced technician whom was involved in this experiment, to be a conservative estimate. Table IV illustrates that, using this rate of increase, the inexperienced technician would be performing at the same speed as an experienced technician after 11 opportunities to conduct the task (note that this task occurs on average in the company 24 times per year on one machine and there are 13 machines on this site). After 16 opportunities to conduct this task, the inexperienced technician is delivering a sustainable positive ROI to the business as a result of leveraging from the tacit knowledge conversion and sharing initiative.

Table II. Financial savings: learning task: formal training vs tacit knowledge leverage

	Itemised costs/benefits	
Formal training costs for measurement/alignment task for grinder	Cost of sending 1 technician on training course for the measurement task (€4500-900 (flights and accommodation)/3 = 1/3 of full cost[a])	€1,200
	Flights and accommodation	€900
	Technician salary (€450 daily rate × four days/3 = 1/3 of full cost)	€600
	Total cost	€2,700
Knowledge capture, sharing and learning on measurement/alignment task	Cost of documenting the tacit knowledge (once off cost) (technician salary €450 daily rate × three-and-half days to write up)	€1,575
	Cost of supporting inexperienced technician T2 on task (technician hourly rate €50 × 91 mins T2)	€76
	Cost of inexperienced technician T2 on task (technician hourly rate €50 × 91mins T2)	€76
	Total cost	€1,727
Initial: tacit knowledge management vs formal training	Initial saving	€973
	Initial ROI (%)	36
Future: knowledge capture, sharing and learning on measurement/alignment task	Cost of documenting the tacit knowledge (once off cost)	€0
	Cost of supporting inexperienced technician T2 on task (technician hourly rate €50 × 91 mins T2)	€76
	Cost of inexperienced technician T2 on task (technician hourly rate €50 × 91 mins T2)	€76
	Total cost	€152
Future potential: knowledge capture, sharing and learning on measurement/alignment task	Future potential saving	€2,548
	Future potential ROI (%)	94

Notes: [a]Estimated by project sponsor to be 45 per cent of the training programme; it is costed here at 33 per cent of the training programme so a more conservative estimate is provided

Table III.
Financial savings: conducting PM task – tacit knowledge leveraging technician vs formally trained technicians

	Itemised costs/Benefits	
Experienced technician	Technician salary (€50p/hr) × time to do task (46 mins)	€38
	Machine downtime costs (€1000 p/hr) × time to do task (46 mins)	€767
	Total cost of conducting task**	€805
	× No. of occurrences in 12 month period (14 times actual)	× 14
	Total cost	€11,270
Inexperienced technician	Technician salary (€50p/hr) × time to do task (91 mins)	€76
	Machine downtime costs (€1000 p/hr) × time to do task (91 mins)	€1,517
	Total cost of conducting task*	€1,593
	× No. of occurrences in 12 month period (14 times actual)	× 14
	Total cost	€22,302
Initial: tacit knowledge leverage technician vs formal trained technician	Initial loss	€11,032
	Initial loss (%)	98
Future: manufacturer technician	Manufacturer technician on-site × 1 day	€871
	Flight	€382
	Accommodation	€50
	Machine downtime costs (€1000 p/hr) × time to do task (46 mins)	€767
	Machine downtime costs (€1,000 p/hr; operates 23hrs a day) × time waiting for manufacturer technician (24hrs)	€23,000
	Total cost of conducting task	€25,070
	× No. of occurrences in 12 months (ten times actual)	€250,200
	Total cost	€250,700
Future: Inexperienced technician	Total cost of conducting task (from above*)	€1,593
	× No. of occurrences in 12 months (ten times actual)	× 10
	Total cost	€15,930
Future potential: knowledge capture, sharing and learning on measurement/alignment task	Future potential saving	€234,770
	Future potential ROI (%)	1,474

Number of times to conduct task (T = time)	Time taken to conduct task @ increasing levels of proficiency	Points to note	Cost of inexperienced technician @ €1,593[a]	Cost of using manufacturers technician @ €2,070[b] over inexperienced technician	ROI on using inexperienced technician over manufacturers technician	Cost of using experienced technician @ €805[c]	ROI on using inexperienced technician over experienced technician
T3	86 minutes		€1,506	€564 +	27%	€701 − [d]	87%
T4	81 minutes		€1,419	€651 +	31%	€614 −	76% −
T5	76 minutes		€1,332	€738 +	35%	€527 −	65% −
T6	71 minutes		€1,245	€825 +	40%	€440 −	55% −
T7	66 minutes		€1,158	€912 +	44%	€353 −	44% −
T8	61 minutes		€1,071	€999 +	48%	€266 −	33% −
T9	56 minutes		€984	€1,086 +	52%	€179 −	22% −
T10	51 minutes		€897	€1,173 +	57%	€92 −	11% −
T11	46 minutes	Inexperienced technician operating at same time proficiency as experienced technician	€810			€5 +	1% +
T12-T15		Positive ROI in using the inexperienced technician over experienced and manufacturer technician					

Notes: [a]cost of inexperienced technician conducting task as per * in Table IV; [b]this is the basic cost of one day on-site, flights, accommodation & machine downtime for 46 mins. It does not include time waiting for the technician to travel from Germany, thereby presenting a conservative ROI; [c]cost of experienced technician conducting task as per ** in Table IV; [d]denotes a loss to the business of using the inexperienced technician instead of the experienced technician

Table IV. ROI of TK initiative for inexperienced technician vs utilising experienced technician or manufacturers technician

Discussion

The case study outlined in this paper provides a useful insight into the issues involved capturing in capturing tacit knowledge and its value to a business. Our study reveals a number of significant challenges involved in tacit knowledge conversion and sharing. On the issue of externalisation, it is recognising that codification and articulation of tacit knowledge is prone to challenges, errors and loss of knowledge but precise insights and potential causes of these challenges with which to inform solutions is limited.

The specific challenges revealed in this case study include differences across individuals in their communication code preferences and information processing preferences. Previous research reveals that there is agreement that the basic steps used to process information are consistent but the skills, goals, prior knowledge and strategies used by individuals can vary significantly (Sojka and Giese, 1997). Some people rely more on images to learn while others learn better from verbal material and some are mixed processors whom can learn from either format (Ong and Milech, 2001). Thus while the process of codification is challenging to the extent of identifying codes that best represent the intended meaning, an additional challenge is to utilise codes that in tandem match the information processing preference of the individual whom is receiving the code. As revealed in this case, some steps of the task could not be codified in the form of words, symbols, code or images and efforts were made to use metaphor to articulate the intended meaning, for example "wiggle". Metaphors aim to fill gaps in our language and transfer meaning by utilizing a metaphor which fits the characteristics of the concept that the individual wishes to highlight (Oswick and Jones, 2006) or metaphors can add new meanings to both the source and target concepts (Cornelissen, 2004) and thus they can facilitate articulation of that which is less amenable to articulation such as higher levels of tacit knowledge on the Ambrosini and Bowman (2001) scale of tacitness. However, metaphors only generate partial "truths" as if they are taken literally or to an extreme they are distorted and false. Not every aspect of the metaphor in use transfers to every aspect of the concept being described and so metaphors hide some features of the concept they are applied to and highlight others (Goatly, 1997). Because metaphors are partial, several are needed to provide a richer description of a concept; each metaphor highlighting different features of the same concept (Short, 2001). Therefore, in the process of externalizing tacit knowledge in the form of documents in a manufacturing environment metaphors for all their advantages are equally prone to multiple interpretations and therefore error. Equally, if the response of both technicians is interpreted according to autopoietic epistemology and based on how they interpreted the codes provided based on their existing knowledge, it is possible that the different worldviews (electrical by comparison mechanical) of both inexperienced technicians (mechanical and electrical) and the expert (mechanical) will produce different responses to the instruction "wiggle" due to differing interpretations. Electronics tends to consist of small delicate objects by comparison to mechanics consists of large strong objects and thus they require a different level of psychomotor strength in response to an instruction "wiggle".

Our case study illustrates that the knowledge provider experienced difficulties in determining the quantity of tacit knowledge to give the receiver so that he could understand the content and be in a position to apply it. Knowledge retention over time will be higher for those given system/general knowledge rather than those given procedural/task knowledge. However, the amount of knowledge increased over time for both those initially provided with task and those provided with general knowledge (Annett, 1989; Rose, 1989). However, the decision with regard to how much of his knowledge an expert should provide is also based on the prior knowledge and skills of the receiver of the knowledge and so some degree of customisation would be required to meet all the knowledge requirements of all receivers of tacit knowledge.

The extent of prior knowledge and skills possessed by the inexperienced technicians also revealed some other internalisation challenges. There was a tendency for an inexperienced technician to reference his prior knowledge to help him conduct the task or conduct the task without reading the document. This behaviour, if interpreted through cognitivist epistemology, is suggestive of the inexperience technician gathering knowledge from the external environment and relating them to previously acquired frames of reference, to his cognitive map. In this case study, the inexperienced technician, on occasion incorrectly perceived his prior knowledge to be of the same model and therefore relevant to use in this task. Instructional design theory applied to real world tasks recommends training on tasks by sequentially increasing the complexity of the task while ensuring the knowledge and skill components of the tasks are the same or similar (Merrill, 2007). However, in this instance the machines appeared similar but the tasks were different thus requiring the technician to recognise this fact and then "forget" or unlearn previous methods, or in others words, devise a updated cognitive map. Equally, the inexperienced technician experienced some challenges utilising the experts know-how due to lack of prior knowledge and skills which were pertinent to the task, e.g. system understanding and keyboard skills. In this instance it suggests that he lacked a cognitive map with which to relate the new knowledge and so had to devise one.

The difficulties of an information provider accessing his/her or being aware of his/her own subconscious tacit knowledge also emerged. Some tacit knowledge is articulable where the source is asked the right questions. Therefore in scenarios such as this it is possible that the involvement of an interviewer with significantly developing interviewing skills should be able to surface the tacit knowledge held in the subconscious.

Our study findings highlight a number of important practice implications. The process of capturing tacit knowledge and ensuring its conversion is both complex and time consuming. Therefore organisations need to demonstrate a sense of realism concerning the types of knowledge that are amenable to the use of people focused as opposed to technology focused strategies. Our case study does reveal the potential to calculate ROI. Such a calculation requires the careful gathering of cost and benefit data and the need to convince senior management of the value of such tacit knowledge conversion and sharing initiatives. Effective tacit knowledge conversion may ultimately be best achieved through analogies, metaphors and stories. We highlight that these aspects are problematic in an expert knowledge sharing context, but that the ROI of such initiatives may be significant.

References

Aaron, B. (2009), "Determining the business impact of knowledge management", *Performance Improvement*, Vol. 48 No. 4, pp. 35-45.

Ambrosini, V. and Bowman, C. (2001), "Tacit knowledge: some suggestions for operationalization", *Journal of Management Studies*, Vol. 38, pp. 811-29.

Ambrosini, V. and Bowman, C. (2008), "Surfacing tacit sources of success", *International Small Business Journal*, Vol. 26 No. 4, pp. 403-31.

Annett, J. (1989), "Trained skilled performance", in Colley, A.M. and Beech, J.R. (Eds), *Acquisition and Performance of Cognitive Skills*, Wiley, Chichester.

Argote, L. and Ingram, P. (2000), "Knowledge transfer: a basis for competitive advantage in firms", *Organizational Behavior and Human Decision Processes*, Vol. 82 No. 1, pp. 150-69.

Balconi, M. (2007), "Codification of technological knowledge, firm boundaries, and "cognitive" barriers to entry", unpublished manuscript, Università di Pavia, Pavia.

Barua, A., Kriebel, C. and Mukhopadhyay, T. (1995), "Information technologies and business value: an analytic and empirical investigation", *Information Systems Research*, Vol. 6 No. 1, pp. 1-23.

Breite, R., Koskinen, K.U., Pihlanto, P. and Vanharanta, H. (1999), "To what extent does the tacit knowledge embodied in a technology product limit its electronic commerce potential?", *Proceedings of the 22nd Information Systems Research Seminar in Scandinavia (IRIS22), Keuruu*.

Boisot, M. (1983), "Convergence revisited: the codification and diffusion of knowledge in a British and a Japanese firm", *Journal of Management Studies*, Vol. 20 No. 2, pp. 159-90.

Cohen, D. (2006), "What's your return on knowledge?", *Harvard Business Review*, December.

Cordeiro-Nilsson, C.M. and Hawamdeh, S. (2011), "Leveraging socio-culturally situated tacit knowledge", *Journal of Knowledge Management*, Vol. 15 No. 1, pp. 88-103.

Cornelissen, J.P. (2004), "What are we playing at? Theatre, organization, and the use of metaphor", *Organization Studies*, Vol. 25, pp. 705-26.

DeLoone, W.H. and McLean, E.R. (1992), "Information systems success: the quest for the dependent variable", *Information Systems Research*, Vol. 3 No. 1, pp. 60-95.

Depraz, N., Varela, F. and Vermersch, P. (2002), *On Becoming Aware: The Pragmatics of Experiencing*, John Benjamins Press, Amsterdam.

Glazer, R. (1998), "Measuring the knower: towards a theory of knowledge equity", *California Management Review*, Vol. 40 No. 3, pp. 175-94.

Goatly, A. (1997), *The Language of Metaphor*, Routledge, London.

Goffee, R. and Jones, G. (2007), "Leading clever people", *Harvard Business Review*, March, pp. 1-16.

Gold, A.H., Malhotra, A. and Segars, A. (2001), "Knowledge management: an organisational capabilities perspective", *Journal of Management Information Systems*, Vol. 18 No. 1, pp. 185-214.

Grillitsch, W., Muller-Stingl, . and Neumann, R. (2007), "Successful sharing of project knowledge: initiation, implementation and institutionalisation", *Electronic Journal of Knowledge Management*, Vol. 5 No. 1, pp. 19-28.

Haldin-Herrgard, T. (2000), "Difficulties in diffusion of tacit knowledge in organizations", *Journal of Intellectual Capital*, Vol. 1 No. 4, pp. 357-65.

Kankanhalli, A. and Tan, B.C.Y. (2005), "Knowledge management metrics: a review and direction for future research", *International Journal of Knowledge Management*, Vol. 1 No. 2, pp. 20-32.

Kankanhalli, A., Pee, L.G. and Tan, B.C.Y. (2007), "Evaluation of knowledge management: a review and agenda for future research", in Jennex, M.E. (Ed.), *Knowledge Management in Modern Organisations*, Idea Group Publishing, Hershey, PA.

Kirkpatrick, D.L. (1994), *Evaluating Training Programs. The Four Levels*, Berrett-Koehler, San Francisco, CA.

Kleist, V.F., Williams, L. and Peace, A.G. (2004), "A performance evaluation framework for a public university knowledge management system", *Journal of Computer Information Systems*, Spring, pp. 9-16.

Koskinen, K.U. (2000), "Tacit knowledge as a promoter of project success", *European Journal of Purchasing and Supply Management*, Vol. 6, pp. 41-7.

KPMG (2000), *Knowledge Management Research Report*, KPMG, pp. 1-13.

Merrill, M.D. (2007), "A task-centred instructional strategy", *Journal of Research on Technology in Education*, Vol. 40 No. 1, pp. 5-22.

McKenzie, J. and Van Winkelen, C. (2004), *Understanding the Knowledgeable Organization: Nurturing Knowledge Competence*, Thomson, London.

Nonaka, I. and Von Krogh, G. (2009), "Tacit knowledge and knowledge conversion: controversy and advancement in organizational knowledge creation theory", *Organization Science*, Vol. 20 No. 3, pp. 635-52.

Nonaka, I. and Takeuchi, H. (1995), *The Knowledge-creating Company: How Japanese Companies Create the Dynamics of Innovation*, Oxford University Press, New York, NY.

Nonaka, I., Toyama, R. and Nagata, A. (2000), "A firm as a knowledge creating entity: a new perspective on the theory of the firm", *Industrial and Corporate Change*, Vol. 9 No. 1, pp. 1-20.

Ong, Y.W. and Milech, D. (2001), "The style of processing scale: normative and reliability data", *Perceptual and Motor Skills*, Vol. 93, pp. 595-8.

Oswick, C. and Jones, P. (2006), "Dialogue", *Academy of Management Review*, Vol. 31 No. 2, pp. 483-5.

Phillips, J.J. (1997), *Return on Investment*, Gulf Publishing Co., Houston, TX.

Polanyi, M. (1983), *The Tacit Dimension*, Doubleday, New York, NY.

Robson, C. (2011), *Real World Research: A Resource for Social Scientists and Practitioner-Researchers*, 3rd ed., Wiley, New York, NY.

Rose, A.M. (1989), "Acquisition and retention of skills", in McMillan, G.R., Beevis, D., Salas, E., Strub, M.H., Sutton, R. and Vanbreda, L. (Eds), *Applications of Human Performance Models to System Design*, Plenum, New York, NY.

Shih, K., Chang, C. and Lin, B. (2010), "Assessing knowledge creation and intellectual capital in banking industry", *Journal of Intellectual Capital*, Vol. 11 No. 1, pp. 74-89.

Short, D.C. (2001), "Strategies for applying metaphor in HRD research, practice, and education", *Advances in Development Human Resources*, Vol. 3 No. 3, pp. 379-96.

Sojka, J.Z. and Giese, J.L. (1997), "Thinking and/or feeling: an examination of interaction between processing styles", *Advances in Consumer Research*, Vol. 24, pp. 438-42.

Tohidinia, Z. and Mosakhani, M. (2010), "Knowledge sharing behaviour and its predictors", *Industrial Management & Data Systems*, Vol. 110 No. 4, pp. 611-31.

Venzin, M., von Krogh, G. and Roos, J. (1998), "Future research into knowledge management", in von Krogh, G.R., Johan, R. and Kleine, D. (Eds), *Knowing in Firms: Understanding, Managing and Measuring Knowledge*, Sage, London, pp. 26-66.

Further reading

Brown, J.S. and Duguid, P. (1996), "Organisational learning and communities of practice: toward a unified view of working, learning and innovation", in Cohen, M.D. and Sproull, L.S. (Eds), *Organizational Learning*, Sage, Thousand Oaks, CA, pp. 58-82.

Appendix. Pre and post experiment interview schedule

Pre-experiment

(1) What is your role?

(2) How long are you in company?

(3) What is your background in the company?

(4) How long in current technician role?

(5) How did you first learn how to do this job?

(6) What does a technician do?

(7) How familiar are you with conducting tasks like this one? (on a scale of 1-10 with 10 being very familiar with doing this task)

(8) What competencies (technical and non-technical) do you believe are required to conduct this task?

(9) To what extent on a scale of 1-10 do you feel you possess these competencies?

(10) How far would you get in this task without the "how to" document? What percentage of the task do you estimate you could complete without the "how to" document? Explain

(11) How long do you estimate it would take you to do this task? How long do you estimate it would take you to do this task as far as the percentage you indicated?

(12) How long do you estimate it would take you to do this task with the "how to" document?

(13) How far would you get in this task with the "how to" document? What percentage of this task do you estimate you could complete with the "how to" document?

(14) How easy on a scale of 1-10 (10 representing difficult) do you think it is to conduct this task?

Post-experiment

(1) How far did you get in the task with the "how to" document? (The answer to this question also incorporated the experienced technicians answer as an observer to the experiment). What percentage of the task did you complete?

(2) How long did it take you to complete this task as far as the percentage you conducted? (The answer to this was ultimately based on time taken on the stopwatch).

(3) Evaluate the how to' document?

- Was there other information you required and if so what was it?
- Was there other knowledge you required and if so what was it?
- How easy on a scale of 1-10 (10 representing difficult) was it to use this "how to" document to conduct this task?
- Explain – what was easy?; what was difficult?
- How easy on a scale of 1-10 (10 representing difficult) was it to find the information you needed to conduct this task in the "how to" document?
- In this section of the interview, the observers also asked unstructured questions relating to their observations, for example:

- Where the inexperienced technician made an error during the task, he was post experiment asked to comment on how the error occurred.
- Where the inexperienced technician paused during the task, he was post experiment ask to explain the reason for the pause.

(4) How easy on a scale of 1-10 (10 representing difficult) was it to conduct this task?

(5) How could help from an individual/expert have enabled you to conduct this task more effectively, efficiently or with more confidence?

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