

A Systemic Model of Engineering Knowledge Management from the Energy Sector

Mike Colechin¹, Gillian Ragsdell²

¹Energy Technologies Institute, Holywell Park, Loughborough, Leicestershire, United Kingdom

²School of Business and Economics, Loughborough University, Leicestershire, United Kingdom

mike.colechin@eti.co.uk

g.ragsdell@lboro.ac.uk

Abstract: Knowledge management (KM) is key to the delivery of impact from the activities of any organisation. Impact is not just about delivering economic benefit but encompasses a wide range of outcomes including environmental improvement, cultural diversity and social change. While expressions of knowledge use and application often form crucial elements of models for implementing KM, it is rare to see 'impact' included within them. Some models of KM seek to address this by introducing notions of knowledge 'evaluation' and 'validation'. However, none appear to have taken the holistic approach explored in this paper, based on an ethnographic study of a knowledge intensive organisation in the energy sector.

The case study organisation, the Energy Technologies Institute (ETI), is a partnership between industry and the UK Government set up in 2007 under a ten-year operational model with an innovation budget of up to £60 M per annum. It seeks to reduce the environmental impact of energy use and production by accelerating innovation in low carbon technologies. Guided by these objectives, the models that shaped the KM practices within the ETI have developed over time. They are ultimately focussed on creating a legacy from the organisation's activities and delivering long term impact.

In its final form, the approach employed by the ETI is based around a systemic model which:

1. Takes account of the interdependencies of data creation, information architecture and knowledge management
2. Creates outcomes through the delivery of 'benefits' to 'beneficiaries'
3. Recognises that knowledge 'from' and 'about' beneficiaries is as important in the process as the creation of knowledge 'for' them

This case study shows that KM models can be highly effective when they are fully integrated into 'impact delivery' processes.

Keywords: Case study, ethnography, energy sector, impact, knowledge management model

1. Introduction

Practical application of rigorous academic study of knowledge management (KM) can make a significant difference to the outcomes an organisation delivers. This paper explores one such case in which a knowledge intensive organisation, the Energy Technologies Institute (ETI), is working with a local academic partner (Loughborough University) to develop and enhance their own strategic approach to managing the knowledge they are creating.

The increasing gap between an organisation's market value and its book value is indicative of the inability of traditional accounting methods to capture an organisation's knowledge assets. Intellectual capital (IC) reporting is a complementary approach that aims to account for intangible assets such as human capital, structural capital and relational capital; a plethora of models underpin the measurement of IC (Bontis, 2001; Alhusban and Ragsdell, 2014). While research in intellectual capital has endeavoured to assess the impact of KM activities, there is little evidence in the literature of the concept of 'impact' (a broad range of outcomes including economic benefit, environmental improvement, cultural diversity and social change) being linked to the development of effective KM tools, practices and culture within an organisation. The case study presented herein demonstrates the importance of fostering and cultivating those linkages, and captures them in a holistic model of KM.

The case study organisation is focussed on technology innovation in the energy sector; nonetheless, as will become apparent, its characteristics are broadly representative of knowledge intensive organisations and the impact they deliver. Hence, the lessons learned from this case study are transferrable to organisations in other

sectors using project-based structures to overcome inter-disciplinary challenges involving collaborative work with and for multiple stakeholders.

There are also significant advantages to be gained from the ethnographic approach adopted in this study, which acts as a very successful example of an academic institution making a significant contribution to organisational change within an industrial partner. So, not only will the case study reported in this paper contribute to the practical arena of KM, it will also make a contribution to methodological debates.

2. Case study organisation

The case study organisation, the ETI, is a partnership between industry and the UK Government set up in 2007 under a ten-year operational model with an innovation budget of up to £60 million per annum. It seeks to reduce the environmental impact of energy use and production by accelerating innovation in low carbon technologies. The ETI is hosted on Loughborough University's Science and Innovation Park, and benefits from the creation of opportunities for active engagement with other co-located organisations involved in low carbon energy innovation, including the university and its partners within the Midlands Innovation Group.

In 2011 the first author was brought into the ETI to deliver the role of Partnership Manager, acknowledging the need for the organisation to concentrate efforts and increase momentum with regard to the impact that the organisation was delivering to its funding Members and a wider community of beneficiaries. By this point the organisation had already established a strong project management and delivery ethos, and created a significant volume of project outputs. The challenge was to ensure that these outputs were seen as knowledge that could be used to generate benefits for partners from government, industry and academia involved in low carbon innovation in the energy sector.

The work to overcome this challenge has supported and underpinned a wider communications objective of the organisation – to be seen as a 'rational voice of reason' in the energy debate, recognised for pragmatic, practical arguments. This has been developed and delivered by encouraging the organisation to be more open and transparent, becoming a widely recognised self-publisher of its knowledge.

Ultimately, the organisation was set up to deliver outcomes that make a difference to society as a whole ie to create impact. Examples of these include:

- A major impact on policy development - project outputs to inform future policy/regulation/legislation, particularly around climate change and economic development.
- Supporting the development of critical supply chains - investment in the capability that leads to commercial development of key services, systems and component technologies for use in the UK and globally
- Increasing investor and industry confidence - system and sub-system demonstrations that deliver market confidence and encourage future investment

It was recognised that delivering these impacts would require changes in the way that the ETI was managing its knowledge. In 2012 the organisation approached Loughborough University to seek support with the on-going development of their strategy in this regard, building on the relationship that had already been established with the ETI's host institution. The decision to work with Loughborough University was taken based on a competitive tendering process, identifying the university as providing the best value for money and most appropriate capability for the task to be undertaken.

The first step in this process of support was the design and delivery of a bespoke knowledge audit, described in Ragsdell *et al* (2014). There were three objectives of the knowledge audit - the first two involved the mapping of critical knowledge in the organisation and the determination of what knowledge assets were crucial in supporting specific organisational activities. These two objectives led to the third that required the identification of any knowledge gaps and bottlenecks. The audit took a holistic approach, playing into the overarching philosophy of the ETI of considering all of its activities within a wider systems context. Qualitative data was gathered via interviews with employees from four departments. Questions were asked about employees' roles, procedures and knowledge needs; their department's knowledge requirements; and about knowledge

interfaces with external partners. Views about the culture and structure of the organisation were also sought. Analysis of the data led to the formation of two knowledge maps per department (one each for internal and external knowledge flows) followed by in-depth analysis of the maps to surface strengths and weaknesses of each department’s knowledge activities. Finally, a cross-department comparison was undertaken so as to identify best practices and organisational-wide KM opportunities.

At both an organisational and departmental level the knowledge audit highlighted various strengths of the ETI. These included storage of individuals’ information on shared drives, plans for engagement with funding Members, staff working closely with the organisation’s Communications Team to deliver accurate messages, and individuals describing the organisation’s culture as ‘open’ and ‘open-minded’.

The audit also identified two key issues for the organisation: the importance of providing additional support to an emerging knowledge culture; and the need to improve information management practices before moving ahead with the development and implementation of a full KM strategy.

After the audit various improvements were implemented, and the ETI continued to work with Loughborough University on its KM journey as illustrated in Figure 1.

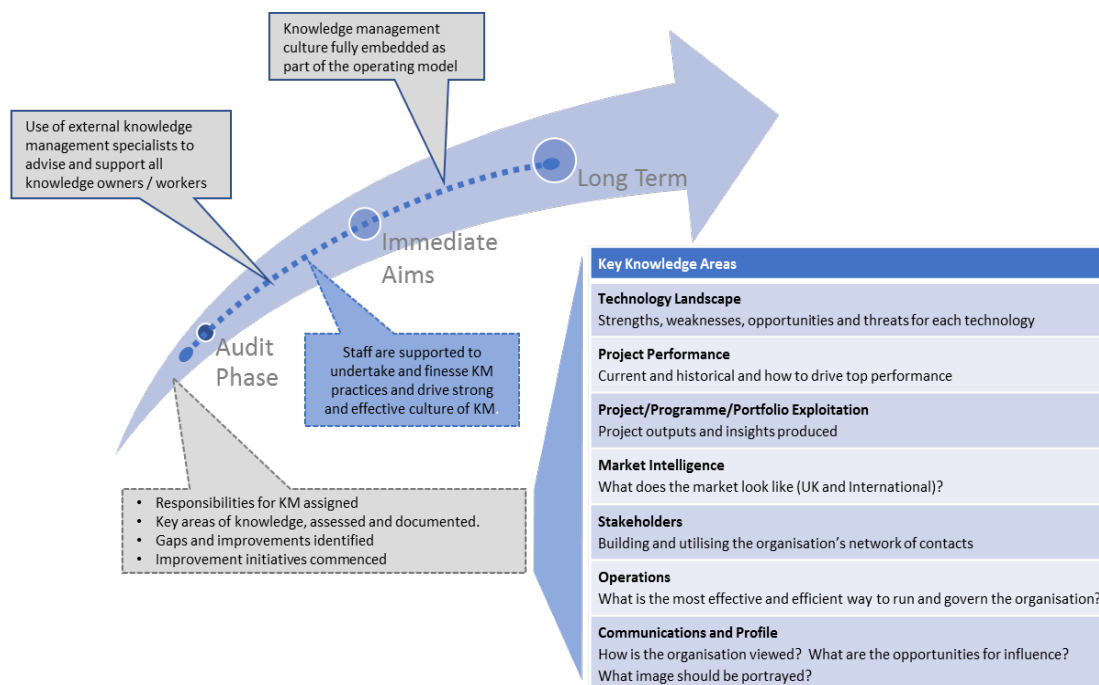


Figure 1: KM Strategy

The relationship between the ETI’s management team and the university continued to develop through an ethnographic approach.

3. Ethnography

The holistic philosophy of the ETI’s approach to the energy sector had not only been complemented by the philosophy of the knowledge audit, but was also upheld via the research methodology that underpinned the next stage of the organisation’s KM journey. Ethnography was adopted to build a deeper understanding of the needs of the organisation; an ethnographic study, that called for the researcher to be embedded ‘in the field’, i.e. within the ETI, was designed.

With its roots in anthropological studies, ethnography is a qualitative approach that emphasises social phenomena and the understanding of behaviour and culture. The ontological and epistemological positions of ethnographic case studies may not seem to align with the positivist stance generally associated with the science

and engineering expertise of the ETI. Nonetheless, their value has been appreciated in sectors such as software engineering, construction and aerospace (Elliot *et al*, 2000; Rooke *et al*, 2004; Baird *et al*, 2000). So, the decision to introduce ethnography to the ETI was not without supporting evidence of its effectiveness in related settings.

Further, ethnography is gaining traction in KM studies with Schulz's (2000) seminal study that embraced three sets of knowledge workers and, a little later, Davey and London's (2005) study in the Australian construction industry, and Gabbay and Le May's (2004) work in the health sector. With recognition of the changing focus of KM from explicit to tacit knowledge, Kane *et al*'s (2006, p149) claim that "Ethnography as a method of research to better understand tacit knowledge also potentially aids knowledge management in practical terms" was intended to trigger contemporary KM researchers to engage more fully with the approach. It was not long before the experiences of Quinlan (2009), Nycyk (2011), Gentry (2013) and Stadler and Fullagar (2013, 2016) were captured. This study will add to that collection of empirical work.

The cited examples of practice demonstrate different forms of ethnography with a variety of corresponding levels of participation from the researcher. A successful application to the Royal Academy of Engineering's Industrial Secondment Scheme enabled the second author to work as a Knowledge Manager alongside the ETI's Partnership Manager (the first author) to accelerate the implementation of the KM strategy that had been developed. This financial support afforded the opportunity to undertake an ethnographic study with the maximum level of participation – to undertake fieldwork consisting "mostly of ongoing interaction with the targets of study on their home ground" (Van Maanen, 2011, p2) as a researcher who also had responsibility in the organisation of study.

Thus, the ethnographic approach supported the development of a strong working relationship between the co-authors and with other ETI employees, creating high levels of trust and mutual respect, often quoted as crucial elements of an effective KM culture (Soliman and Spooner, 2000; Oliver and Kandadi, 2006; Chang and Lin 2015). The secondment also complemented two ETI co-funded PhD studentships (in related but discrete aspects of KM) that helped to further inform the implementation phase. There were additional favourable consequences since the ethnographic approach assisted the university in creating a direct outlet for delivering benefits from the outputs of its research, creating measurable impact and generating a change in the case study organisation's culture.

So, ethnography enabled the second author to be embedded in the ETI in order to study its behaviour over an extended period: part time for a year. The focus was on the gathering of unstructured data. The location of the second author in the ETI's building for half of the working week enabled a wide variety of data collection tools to be used, including observation and interviews. Both informal, *ad hoc* and formal, scheduled data collection took place as she went about her duties as a Knowledge Manager. Daily personal memos and notes were kept, as well as minutes of meetings. These tools allowed for a deep exploration and description of behaviour in context, and triggered an in-depth understanding of ETI's culture that a less participative approach would not have achieved. Overall, the study increased the ability to work more closely on tacit aspects of organisational and personal knowledge. These were aspects that could be captured in ETI's KM model.

4. Knowledge management models

In attempts to investigate, understand and articulate KM, models can be useful aids. They capture and express a wealth of complex ideas and information in a simplified arrangement. As Wilson (1990, p8) states "A model is the explicit interpretation of one's understanding of a situation, or merely of one's ideas about that situation. It can be expressed in mathematics, symbols or words, but it is essentially a description of entities, process or attributes and the relationships between them. It may be prescriptive or illustrative, but above all, it must be useful." With the wide variety of contributors to KM, from both research and practice, it is not surprising that KM models have their roots in a range of disciplines and take on an assortment of forms.

Key KM concepts are represented in a plethora of KM models that, from time to time, have been organised and critiqued to increase the clarity of their contribution. McAdam and McCreedy's (1999) early identification of three types of models – knowledge categorising, intellectual capital and socially constructed models – has continued to be supported (Haslinda and Sarinah, 2009; Mittal 2016) despite the regular addition of models to the portfolio. It is also not surprising that, facilitated by increasing granularity of data, some models focus on

particular processes in KM eg knowledge creation (Nonaka, 1994), sharing (Ipe, 2003) and use (Menon and Varadarajan, 1992), and factors that affect these processes, rather than on KM as a whole.

As the ETI sought to develop a more holistic KM strategy it recognised the need to develop a KM model that was shaped by the organisation's commitment to adding value and delivering effective outcomes. Immersion of the second author in the organisation and a shared commitment to the implementation of the ETI's KM strategy led to the authors' realisation that, despite the numerous KM models reported in the literature, none were truly representative of the ETI's approach to managing its knowledge. None seemed to explicitly capture two key elements for the ETI – the impact element and the focus on management of knowledge for stakeholders.

4.1 Impact

Contemporary use of 'impact' is not just about delivering economic benefit but encompasses a wide range of outcomes including environmental improvement, cultural diversity and social change. Rich's (1997, p15)) distinctions between 'use', 'utility', 'influence' and 'impact' of information are helpful in appreciating the subtleties in the context of knowledge. 'Use' is concerned with the receipt of knowledge and its possible application whereas knowledge creates 'impact' when it has been received, understood and resulted in policy action. Using (or synonyms thereof) knowledge does not equate with creating impact.

Models that capture KM processes do not explicitly support the delivery of impact. Instead, models that capture a KM cycle tend to include processes such as knowledge generation, capture, sharing and use, articulated with a range of terminology. So, while expressions of knowledge use and application often form crucial elements, it is rare to see Rich's (1997) higher levels of utilization, including the highest level of 'impact', even implicitly, within them. (It is however noted that Boisot's i-space model (1997) does include reference to impact, but it is not in the sense expressed in this paper. There is discussion of abstract knowledge becoming embedded in concrete practices.)

The outcomes and impacts that the ETI seeks to deliver have already been described in section 2; the omission of the notion of impact in KM models was an important issue for the ETI's model to address as was the recognition of the ETI's stakeholders.

4.2 Customer Knowledge Management

Knowledge management, and the relationships with users and beneficiaries that it enables, is key to the ETI's delivery of any of its impacts. The notion of customer knowledge management (CKM) (García-Murillo and Annabi, (2002), and Gibbert et al (2002)) was therefore an important foundation for an ETI-tailored KM model. A theoretical framework was drawn from the early work previously cited coupled with insights from utilisation of CKM in settings such as libraries (Daneshgar and Bosanquet, 2010) and health care (recently reported in McCracken and Edwards, 2017). Much of the detail of CKM was gleaned from Zanjani et al's (2008) conceptual model as shown in Figure 2.



Figure 2 – Conceptual Model for Customer Knowledge Management (Zanjani et al 2008, p305).

4.3 Integrating impact and CKM

The coupling of an intent to deliver outcomes that make a difference to society as a whole ie that create impact, and the appreciation of the need to understand stakeholder needs was encapsulated by the ETI as shown in Figure 3.



Figure 3: Delivering 'impact' as part of the KM process

This understanding of delivering impact was integrated into the ETI's KM model and, as will be seen in Figures 4 and 5, underpins the creation of an important feedback loop that enables impact to inform KM practices in the organisation. Thus the ETI's model of KM goes beyond the static reporting of the impact of KM practices commonly recorded in IC annual reports.

5. Development of the ETI's knowledge management model

It was important for the ETI to articulate the organisational conceptualisation of KM. Although various academic contributions have already been mentioned, undoubtedly the development of the ETI KM model was also subconsciously influenced by the authors' contact with other models. Collection and analysis of data from the fieldwork of the ethnographic study aided the process and a normative model was developed.

When the audit of the ETI's knowledge related activities was undertaken, their historical approach had been data driven, focussing on the acquisition and organisation of experimental data and project outputs. They had begun to establish an information architecture approach, ensuring that the data was not only stored effectively but also accessible to and disseminated to a wider audience. The model adopted by the ETI built on the standard KM hierarchy approach (see Figure 4), advancing from 'data creation', through 'information architecture' and ultimately delivering knowledge management, by closing the loop on knowledge creation and utilisation.

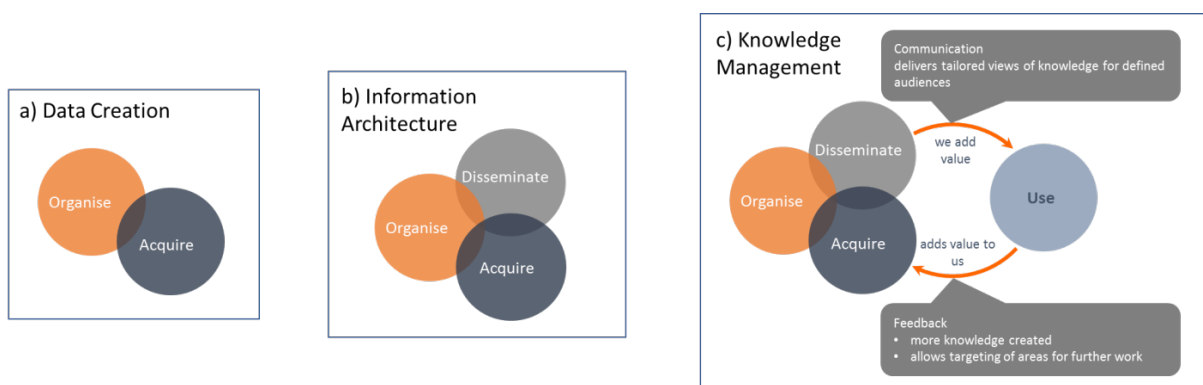


Figure 4: The transition from 'data creation', through 'information architecture' to 'knowledge management'

In seeking to adopt a true ‘knowledge management’ approach, with effective delivery of impact, there was an appreciation of the need to target outputs at specific user groups and learn from those groups as the benefits of the ETI’s work were delivered (see Figure 5).

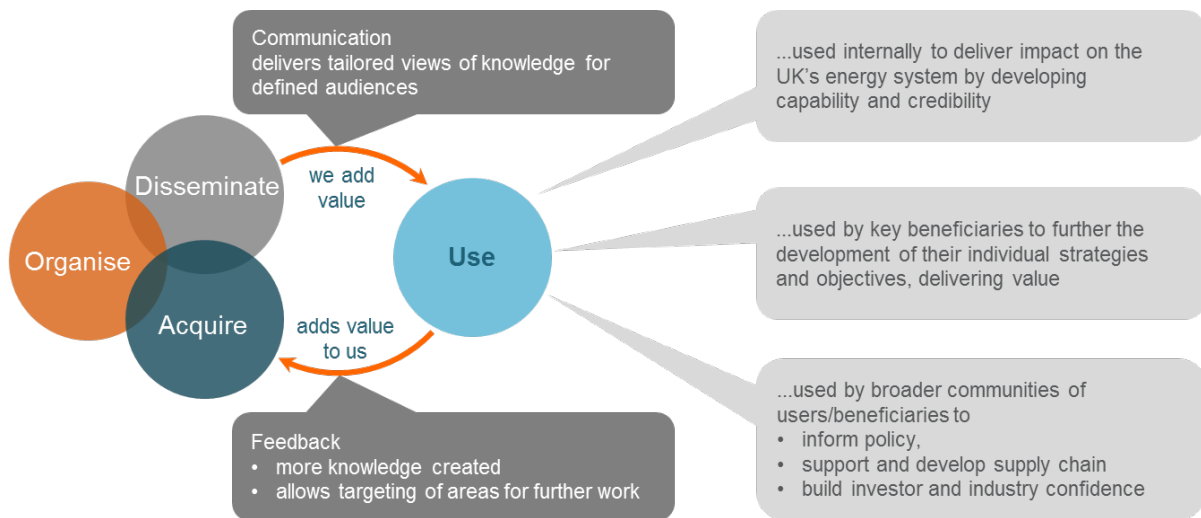


Figure 5: ETI’s KM model

In its final form, the approach employed by the ETI is based around a systemic model which:

1. Takes account of the interdependencies of data creation, information architecture and knowledge management;
2. Creates outcomes through the delivery of ‘benefits’ to ‘beneficiaries’;
3. Recognises that knowledge ‘from’ and ‘about’ beneficiaries is as important in the process as the creation of knowledge ‘for’ them.

Various indicators have been used to monitor the cultural change within the organisation as a result of implementing this model and the associated KM strategy. Over the period of the study the ETI has moved from one focussed primarily on the delivery of project outputs to one that is focussed on the achievement of outcomes and the creation of a long-term legacy from the investment that has been made in the organisation. This has required a more detailed understanding of the ETI’s stakeholders and the tailoring of knowledge to deliver targeted communication to specific user groups. The ‘openness’ identified during the knowledge audit has been further developed to make the organisation responsive to feedback from the use of their knowledge to further develop and improve their offering, becoming more transparent and making a far greater proportion of their knowledge available in the public domain.

6. Conclusions

This case study has sought to redress the lack of evidence in the literature for the benefits that can be derived from linking the concept of ‘impact’ to the development of effective KM tools, practices and culture within an organisation, and of fostering and cultivating those linkages by capturing them in a holistic model of KM.

The concept of impact encompasses a broad range of outcomes including economic benefit, environmental improvement, cultural diversity and social change. Consequently, an integrated approach needs to take account of the interdependencies of data creation, information architecture and knowledge management to create such outcomes through the delivery of ‘benefits’ to ‘beneficiaries’. It also needs to recognise that knowledge ‘from’ and ‘about’ beneficiaries is as important in the process as the creation of knowledge ‘for’ them.

The model adopted by the ETI took these concepts into account by building on the standard KM hierarchy – advancing from ‘data creation’, through ‘information architecture’ and ultimately delivered knowledge

management, by 'closing the loop' on knowledge creation and utilisation. Over the period of the study various metrics indicated that this approach had a positive impact on the culture of the organisation, moving it from one focussed primarily on the delivery of project outputs to one seeking to achieve specific outcomes and create a long-term legacy and return on investment.

Strategically, this change has supported and underpinned a wider communications objective of the organisation – to be seen as a 'rational voice of reason' in wider societal discourse (around energy), recognised for pragmatic, practical arguments. This has been developed and delivered by encouraging the organisation to be more open and transparent, becoming a widely recognised self-publisher of its knowledge.

This case study shows that KM models can be highly effective when they are fully integrated into the 'impact delivery' processes of a knowledge intensive organisation. These lessons can be transferred to organisations in sectors as diverse as construction, health and academia that use project-based structures to overcome interdisciplinary challenges involving collaborative work with and for multiple stakeholders.

In this specific case the application of KM has been significantly enhanced through the use of an ethnographic approach, building on previous studies which had demonstrated that such approaches can successfully be applied in positivist settings. Following an early piece of consultative research procured from the university, the 'embedded' role that the lead researcher took on within the case study organisation created high levels of trust and mutual respect. This greatly enhanced the benefit of the work to both organisations, demonstrating the benefit that academic research into KM can have in establishing models and concepts that can then be successfully applied in a practical setting to improve an organisation.

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