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Dynamic Knowledge Support Model for Decision-Making and Sustainable Growth: An Empirical Study

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Abstract An effective knowledge-centric approach requires that tacit and explicit knowledge are mobilised, integrated, and made available to support collaboration between team members. Most knowledge management (KM) frameworks lay an emphasis on managing explicit knowledge by focussing on the processes of capture, storage, retrieval, transfer and application. Tacit knowledge, on the other hand, needs the key mechanisms of interaction and feedback for effective sharing and use. The paper presents a model validated during a case study conducted at one of the world's leading software organisations. The model addresses the need to make both tacit and explicit knowledge available and accessible for effective decision-making and sustainable development, and improved environmental impact. It makes use of the mechanisms of interaction and feedback to facilitate the flow and availability of tacit knowledge within organisational practices and routines. The paper establishes that knowledge flows between functional areas and supports tasks and activities of an organisation's development effort. The findings have longer-term implications regarding organisations' ability to manage context, provide feedback and facilitate interaction, and therefore build upon their existing knowledge resources to improve decision-making and sustainability.

Keywords Knowledge creation · Integration · Decision-making · Collaboration · Sustainable development · Feedback

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1 Introduction

Organisations function in rapidly changing and evolving environments characterised by high levels of uncertainty and ambiguity. Unpredictable and ill-structured operating conditions require dynamic resolution approaches supported by the sharing and application of tacit and explicit knowledge for creative problem solving. As organisations lay greater emphasis on people, relationships and interactions over processes and tools, knowledge increasingly underpins collaborative activities. Moreover, organisational operations are putting greater pressure on global resources requiring organisations to achieve more with less, whilst continuous discovery underpinned by sustainability has become a primary consideration. Managing knowledge effectively allows organisations to develop a long-term perspective that supports sustainable development and improves social and environmental impact.

Most work practices are increasingly being standardised to leverage existing knowledge for decision-making, but some situations require more flexibility than can be addressed by standardised processes. Rubinstein and Pfeiffer (1980) argue the ability of an organisation to innovate can be hindered by repeatedly attempting to solve problems using approaches that have been performed successfully in the past. Replication may be effective sometimes, but certain fast changing and complex situations require new approaches. Simon (1977) distinguishes between structured and non-structured situations, where repetitive and routine structured situations are addressed by standardised processes and operating procedures, while unstructured situations necessitate human judgement, insight and intuition for meaningful resolution. The complexities and unpredictability of unstructured situations require individuals' insights and tacit knowledge for effective decision-making and creative problem-solving. Standardised processes identify good practices and reduce mistakes and rework, whilst reducing an organisation's flexibility and ability to adopt new approaches for problem-solving which may result in vital learning. Tacit knowledge must therefore be available in a dynamic form to ensure that relevant shared contexts and interpretations create common knowledge and understanding in changing situations. The interaction and flow of dynamic knowledge, including tacit knowledge, is required within an organisation's core work practices to provide feedback and facilitate collaboration for decision-making, sustainable development, and innovation.

The flow of knowledge requires an effective knowledge management (KM) strategy and the mobilisation, integration, sharing, and application of tacit and explicit knowledge in a dynamic manner. However, most KM frameworks lay an emphasis on managing explicit knowledge by focussing on the processes of capture, storage, retrieval, transfer and application (Argote and Ingram 2000; Sunassee and Sewry 2002; Dyba 2003; Arling and Chun 2011). Tacit knowledge, on the other hand, needs the key mechanisms of interaction and feedback for effective sharing and use (Polanyi 1967; Nonaka and Takeuchi 1995; Kreiner 2002; Xue et al. 2011; Margaryan et al. 2011). Within a dynamic and holistic knowledge approach, the existing and created tacit and explicit knowledge are mobilised and integrated, and made available to collaborative team members. The need therefore exists for a KM framework which addresses the requirements to facilitate the exchange and application of tacit knowledge, in addition to explicit knowledge. The paper addresses this gap by presenting a model that makes tacit and explicit knowledge available for organisational practices and routines through the supporting mechanisms of interaction and feedback. Specifically, the paper investigated the research question of how knowledge generated during development activities can be leveraged and effectively applied to ensure long-term sustainability. The developed model makes available and accessible dynamic tacit and explicit knowledge that is applied for effective decision-making and problem-solving, and provides the long-term and continuous perspective for sustainable development and improved environmental impact. The proposed model was validated during a case study conducted at one of the world's leading software organisation which currently employs more than 250,000 individuals (Sandhawalia and Dalcher 2010, 2013).

The paper is organised as follows: the next section discusses the theoretical concepts of KM processes and knowledge flows, and how they influence decision-making processes; Sect. 3 presents the research methodology and provides details of the case study and the methods of data collection and analysis; Sect. 4 presents the research findings and analyses how dynamic knowledge identified in the case study organisation supports decision-making processes and helps provide a continuous perspective; Sect. 5 assesses the model and its ability to provide knowledge support for decision-making and sustainable growth; Sect. 6 presents the conclusions and implications of the research; and Sect. 7 discusses the limitations of the work done, and also highlights possibilities for future work.

2 Theoretical Background

Many organisational operations are considered straight forward processes of planned, monitored, and controlled activities in a disciplined, orderly and methodical way. Dalcher (2003a, b) argues that a control perspective offers short-term focus with a limited emphasis on growth, improvement or the long-term accumulation of knowledge, reflection, experience or wisdom. Shifting attention towards a knowledge-based economy, emphasises continuous discovery and the creation, integration and application of knowledge. Knowledge creation, and its integration, can be viewed as collective processes of constructing, articulating and redefining shared beliefs and mental models through social interaction that help manage complex tasks and activities during collaboration, (Grant 1996; Huang 2000; Chang et al. 2012). However, Huang et al. (2001) argue that current conceptualisation of how knowledge is integrated and made available within the context of coordinating specialised expertise and tasks remains limited. It is therefore important to explore the dynamics of knowledge integration while performing collaborative activities such as decision-making which further generate ideas through collective input.

Work has previously been done to understand the theory of organisational knowledge creation. Nonaka and Takeuchi (1995) proposed a theory to explain the phenomenon of knowledge creation through the phases of socialisation, externalisation, combination and internalisation. The subsequent works of Von Krogh et al. (2000) and Nonaka et al. (2001) built upon Nonaka and Takeuchi's (ibid) theory, and these combined works conform to Gregor's (2006) view of theories as statements providing a lens for viewing or explaining the world. Senge et al. (1994) assert that a theory is a fundamental set of propositions of how the world works, which have been subjected to repeated tests and in which we gained some confidence. Further, Lynham's (2002) method of theory building consists of the five phases of conceptual development, operationalisation, confirmation or disconfirmation, application, and continuous refinement and development. Based on the propositions of Nonaka and Takeuchi's (ibid) work, Alavi and Leidner (2001) developed a KM framework that defined processes for the creation, storage, retrieval, transfer and application of knowledge. This paper attempts to operationalise the main concepts of Nonaka and Takeuchi's (ibid) and Alavi and Leidner's (ibid) work and apply them to understand the role of knowledge integration, flows, and collaboration in leveraging long term sustainability for development tasks and activities.

The ability to create, store, integrate, disseminate, and utilise knowledge and expertise has become a primary way to compete (Hayashi 2004). Amassing and synthesising specialised knowledge from multiple sources is an integral factor during decision-making processes. The importation of new knowledge coupled with the recombination of existing knowledge provides information and knowledge that can be leveraged to improve decision-making, and lower performance risk. Decision-making is often compromised when team members fall victim to the fallacy where benefits are overestimated and costs are underestimated. Knowledge provides tacit insights and judgment, and forms the basis for better decision making. Moreover, the knowledge integration process involves social interactions among individuals using internal communication channels for knowledge transfer to arrive at a common perspective for problem-solving. Collaborative linkages are the primary means of transferring specialised knowledge (Tasi 2001), which facilitates knowledge reuse, and the recombination of existing knowledge is an important antecedent of uncertainty resolution and innovation (Marjchrzak et al. 2004; Terwiesch and Loch 1999).

Newell et al. (2004) state that objective measures and collaboration strongly influence the creation of common knowledge. Measures provide tangible benefits to be gained by creating common knowledge and people working together need to be able to identify the value gained by creating common knowledge, and therefore learn and contribute to the effort. Furthermore, collaborative activities form ties and are important for knowledge integration and researchers have long recognised the need for people to collaborate in order to sustain innovation (Davenport 1993; Van De Ven 1986). Dougherty and Hardy (1996) confirm that collaborative structures of cross-functional teams and processes of decision-making are important for sustained innovation.

An effective collaborative mechanism for achieving knowledge integration is to facilitate the flow of knowledge and make it available to coordinate the planning of interdependent work process strategies (Styhre 2003). Prior research indicates that knowledge integration can be achieved when people are involved early in the work process (Boynton et al. 1994). Mutual consideration of work process strengths and weaknesses allows individuals to identify requirements and capabilities for targeted work processes, predict what resources are needed to fulfil the requirements, and determine how best to deploy resources to optimise performance and minimise delays (Mitchell and Zmud 1999). The act of coordination is a knowledge integration process that facilitates a common understanding of task objectives and the means to reach those objectives (Reich and Benbasat 1996).

Tasks that require knowledge integration are communal, and the flow of knowledge between individuals is essential to facilitate collaborative activities and foster complex knowledge transfer. The transfer process can slow down where the complexity of knowledge is determined by the degree to which it is tacit, and whether an individual is dependent on another for the transfer and acquisition of knowledge (McKenzie and van Winkelen 2004). Effective knowledge flows provide integrated, task relevant knowledge support from appropriate competence areas to balance multiple perspectives and stakeholder interests. Thus available knowledge and consequent collaboration help create a sense-making community who understand the interactions and synergy of workflows through a multi-perspective view of diverse knowledge competence areas.

Further, effective knowledge flows are critical for interaction and sustaining knowledge integration. Briggs et al. (2003) report on the value of facilitating interaction and accomplishing organisational tasks, and how in the case of inter-organisational collaboration, knowledge flows support significantly complex tasks when goals are to be accomplished by teams whose members do not share culture, communication and coordination processes. Gladstein (1984), Hackman (1987), and McGrath (1984) argue that performance is a result of the interactions and dynamics among team members, and Argote and Ingram (2000) state that the utilisation of knowledge embedded within a team's interactions and tasks is the key to achieving better performance. Several researchers have investigated the importance of team work as members with diverse skills, knowledge, experiences, and expertise are required to work together to resolve the issues or problems encountered during project execution. However, a focus on how knowledge flows and supports collaboration and knowledge integration appears to be limited.

Knowledge flows influence the efficiency and scope of knowledge integration which Grant (1996) identified as critical for organisational competitiveness. Effective knowledge flows facilitate the generation of common knowledge and its seamless coordination between team members. The flow of knowledge within an organisation helps attain a level of integration efficiency relative to the scope of integration required, and facilitates the ability to continuously innovate and maintain competitive advantage. Knowledge flows enable the diverse pool of team members to access, share and discuss knowledge uniquely distinct to each member, thus creating knowledge not possessed before which is vital for creativity, innovation, and developing solutions. Knowledge integration is realised by synthesising different perspectives and expertise during decision-making processes, and enables different views to be incorporated. Team members bring different sets of assumptions about optimal ways to proceed, prioritising different values and perspectives, which are integrated in the process to develop required solutions. With decision-making being central to their work, team members recognise that failure is an opportunity for understanding and learning to avoid mistakes, and it is therefore imperative to make an effort to support collective reflection.

Distinct expertise needs to be shared between diverse team members with a sufficient level of congruence to enable individuals to understand each other and work together towards their common goals from different perspectives (Xue et al. 2011). Combining previously unconnected aspects or recombining previously associated aspects creates common knowledge (Leonard-Barton 1992), as team members realise that tasks are better achieved through dynamic interaction and feedback. In this way

Table 1 Knowledge management life cycle model

Model	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase6
Despres and Chauvel (1999)	Create	Map/bundle	Store	Share/ transfer	Reuse	Evolve
Gartner Group (1998)	Create	Organise	Capture	Access	Use	
Davenport and Prusak (1998)	Generate		Codify	Transfer		
Nissen et al. (2000)	Capture	Organise	Formalise	Distribute	Apply	
Amalgamated	Create	Organise	Formalise	Distribute	Apply	Evolve

Adapted from Nissen et al. (2000)

teams are likely to create new and common knowledge and engage in effective sharing and integration of knowledge to achieve their predefined goals. To study how this dynamic knowledge is created, integrated and shared while performing collaborative tasks, the research focused on identifying how knowledge flows during the development processes.

Previous studies and work have tried to determine the effectiveness of knowledge flows within the lifecycle of KM frameworks. Serenko et al. (2007) suggest that as organisations increase in size, the effectiveness of internal knowledge dramatically diminishes and the degree of intra-organisational knowledge sharing decreases. Based on a survey of different models available in the literature, Nissen et al. (2000) present a KM lifecycle model that identifies the different phases within which a sense of knowledge flows can be perceived. They identify the creation of knowledge as the first phase, followed by mapping or bundling as the activities in the second phase. Codification and storage of knowledge are the activities of the next phase, while the following three phases refer to the transfer, sharing, application, reuse and evolution of knowledge within organisations. Table 1 below presents Nissen et al.'s (ibid) KM life cycle model.

The above model attempts to identify the phases where knowledge flow activities occur but does not articulate how knowledge flows during organisational processes, practices and routines of development. This study aims to analyse how knowledge flows during development activities and its impact on the distributed work practices of large organisations to address the limitations of the above mentioned studies.

3 Case Study

An extended case study was conducted at a large consultancy organisation that develops software and employs more than 250,000 individuals to examine how knowledge flow supports knowledge creation and integration and collaboration within its processes. Exceptional access negotiated for this research provided an opportunity to study and analyse the well established and highly mature work methods practised in the organisation. The research propositions required the study, analysis and identification of the flow of knowledge between the functional areas of the development effort.

3.1 Data Collection

The data was collected over a period of 26 months, through interviews, questionnaire and observation which were conducted in parallel to enable researchers to confirm key phrases, events, instances and insights and provide a degree of clarification and ensure triangulation.

3.1.1 Observation

The researchers observed the work practices and process areas within the organisation, and the functioning of teams in their collaborative work environment. The observations were carried out by ensuring that each field visit was for a minimum of 3 weeks. This was done to ensure that after the initial observation session, individual team members were familiar and comfortable with the researchers being present during such meetings and sessions. Team members were made aware of the research being conducted, and this benefited the researchers by enabling them to conduct interactive group discussions, and also obtain confirmation and feedback about the observations at the end of each session. The interactive group discussions played a part in strengthening the value and perceived importance of the trends that were observed and enabled early clarification of issues. The researchers observed various meetings including weekly reviews, design, project start-up, closure, and conference calls with on-site developers and clients, in addition to software development activities and daily team interactions. Weekly review meetings lasted on average between an hour and a half to about 2 h, while project start-up, closure and design meetings were considerably longer. Most design meetings lasted a minimum of a half day (4 h), with some meetings lasting for three-quarters of a day or even a complete day (8 h). Certain design meetings required to be resumed the next working day. Focused project start up meetings that involved initial stakeholders would typically last for half a day, while the same was the case for project closure meetings.

While observing the functioning of teams within their work environment, the researchers were present within the coded access areas of their workplace for a half day session at each instance, and were able to observe, examine and make notes of team interaction, and work methods and practices. The researchers were also invited to observe senior management interactions for extended sessions, for example 8 a.m.–2 p.m., and make notes of work routines and problem solving methods. In total, the researchers observed 97 meetings, which were of 11 different types, yielding 340 h of observation, and the summary is provided in Table 2.

3.1.2 Interviews

Thirty-eight open-ended interviews were conducted with individuals within the organisation and included an Executive Vice President, the second most senior executive within the organisation, a Vice President, Consultants, Researchers, Project Managers, Project Leads, and members of the Software Engineering Process Group (SEPG). The depth in organisational hierarchy represented in the cross-section of individuals interviewed helped ensure that the interview data collected did not have an over-reliance

Table 2 Summary of observation hours

No.	Type of meeting	Meeting function	Number of meetings observed	Average hours per meeting	Total number of observation hours
1	Project start-up	Project management	3	4 1/2	13 1/2
2	Design	Software development	4	7 1/2	30
3	Weekly review	Review	18	2	36
4	Conference calls with clients and on-site developers	Project management and development	5	Approximate 2 3/4 (one call was long = 4 1/2 h)	18 1/2
5	Software development activities	Software development (observation time)	11	Approximate 3	33
6	Team interactions	Project management	15	2 3/4	36
7	Coding	Software development	15	Approximate 2 1/2	35
8	Quality review	Quality (software development)	6	Approximate 3	18
9	Project closure	Project management	4	Approximate 10	40
10	Maintenance	Software development	6	Approximate 3 1/2	20
11	Interaction with Principal Consultant and Project Managers	Project management	10	6	60
Total			97		340

Table 3 Interviews

No.	Designation	Number of individuals interviewed	Number of interviews conducted	Total number of interview hours (approximate)
1	Executive Vice President	1	1	3
2	Vice President	1	4	5
3	Senior Researchers	2	2	4
4	SEPG Members	3	5	8
5	Principal Consultants	2	12	30
6	Group Leads	3	4	6
7	Project Managers	13	18	26
8	Project Leads	6	8	10
9	Developers	7	8	8
		38	62	100

Table 4 Questionnaires

No.	Designation	Number of questionnaires sent	Number of responses received
1	Project Manager	5	4
2	Project Lead	12	9
3	Developer	7	7
		24	20

on either easily accessible or elite respondents, as suggested by Miles and Huberman (1994). A total of 62 interviews were conducted involving 38 individuals with varying levels of seniority and experience lasting a total of 100 h, and the summary is provided in Table 3.

3.1.3 Questionnaires

A detailed survey questionnaire was administered primarily to obtain responses from a wider cross section of respondents within the distributed organisation. The researchers were able to get views and opinions of on-site team members, that is, those team members who were based on clients' site and consequently not available for interviews at the organisation's premises. The questionnaire provided access to employees working on the projects being examined and analysed and who were not available for a face-to-face interview. A total of 24 questionnaires were sent out of which 20 individuals responded; that is a response rate of 83 %. The researchers were subsequently able to communicate with the respondents via email to seek clarifications and further discuss relevant issues related to the research, thus extending the questionnaire instrument into a more dynamic information gathering tool from remote subjects, and summary is provided in Table 4.

The interview and survey questions were developed to determine and gain a clear understanding of the: organisation's knowledge strategy, with a particular focus on the:

- primary vision for the knowledge strategy
- issues and barriers faced while implementing the strategy
- flow of knowledge within the processes and functional areas of the organisation
- requirements to facilitate a smooth flow of knowledge
- modes and channels of communication and coordination within the organisation
- mode of facilitation of tacit knowledge within the organisation
- roles and responsibilities
- impact of use of knowledge tools and assets on work practices, project management processes and software development processes, and methods to measure the same if any exist
- organisation's knowledge strategy review process and ability to learn continuously, identify patterns, and formalise routines
- development of the organisation's knowledge culture
- influence of knowledge infrastructure and processes on organisational maturity
- role of knowledge infrastructure and processes on decision-making within the organisation and impact on problem-solving
- important and integral areas of decision-making
- decision-making tools, inputs and resources
- role of knowledge flows on quality and testing and
- use of knowledge and experience in subsequent projects, especially in the decision-making process

3.2 Data Analysis

The collected data provided a rich empirical basis to analyse the flow of knowledge and its dynamic creation and integration during decision-making and problem-solving throughout the development effort. The large volume of data was examined, reviewed and checked to ensure accuracy. Data reduction and display techniques were applied in systematic ways as suggested by Miles and Huberman (1994) to categorise the data in groups based on their attributes that adhered to the theoretical propositions and orientation of the research. The groups and attributes were placed in multiple columns and rows matrix to enable analysis and identify similarities, interactions and relationships, and form impressions. An iterative process of ongoing analysis based on reformulation of ideas and emerging insights provided the basis for reliability in the qualitative approach suggested by Yin (2003). Specifically, the study relied upon the theoretical propositions to ensure validity, guide the analysis, and help focus certain data to define explanations and alternatives, Yin (2003: 112). The data collected was triangulated to reduce research bias and ensure its validity, integrity and reliability, and conclusions were drawn based upon theoretical concepts and assumptions developed. Triangulation was ensured by using multiple sources of evidence, namely, data collected from interviews, questionnaires and observation. The multiple sources of evidence allowed confirmation of different attitudinal and behavioral issues and perspectives, and their

Table 5 Data reduction, display, and columns for Knowledge

No.	Group/category	Attributes	Comment (text)
3	Knowledge	Interaction—team members, customers	With whom—who are the individuals involved; where does this interaction take place; how does this interaction affect and influence project outcome?
		Reusability and lesser development time	Benefit of knowledge and its flow; can this benefit be measured; how is the organisation sure that this benefit exists?
		Process owners and process improvement proposals	Who are the process owners—teams or individuals? What review and validity checks exist for such proposals?
		Lessons learned and best practices	How are these transferred and applied? Who is responsible for their integrity, validity and redundancy?
		Explicit and Tacit knowledge	Is there too much emphasis on explicit knowledge? What about dialogue and interactive problem solving?

interpretation. The collected data reflect different sources of information and allow the presentation of converging lines of inquiry.

Silverman (2005) states that "data analysis does not happen only after all the data has been safely gathered." Insights were gained and sense made of the data while the interviews, discussions and observations were being conducted. The large volume of data collected through the interviews, questionnaires and observations was examined and reviewed to ensure data accuracy. Clarifications were sought to reconfirm the accuracy and relevance of key events, phrases and instances, thereby beginning the process of checking and verification early in the analysis and conceptualisation stage of the research. The collected data was transcribed and coded, highlighting the relevant words, phrases, and events, as suggested by Yin (2003). Readings of the data helped assign specific codes to the pieces of text that represented important concepts and distinct responses during observations and interviews. Following the qualitative data analysis protocols suggested by Miles and Huberman (1994), the coded data was put into groups or categories resulting in 29 groups, and adhering to the theoretical propositions and orientation of the research, attributes from within the data were assigned to each group based upon their relevance to the group. The groups and their attributes were placed in a table to compare and identify similar attributes within the groups. The process highlighted data groups with certain similarities and themes and made it possible to further group the data in fewer groups or categories with consolidated attributes, resulting in twelve categories. Subsequent coding, groupings and assigning attributes were done using NUDIST software to display 'group nodes' and the data associated with them. Table 5 provides an example of data analysis for the knowledge category.

The data was conceptualised by a mapping process where themes were identified and related. The categories formed through this process were further examined to assign attributes that enable the flow of knowledge within the development projects of the organisation. Following Miles and Huberman (1994) suggestion, the following four criteria were adopted while determining and assigning attributes to each category during coding.

(i) Each attribute must be mentioned and supported by at least two respondents during the interviews.
(ii) Respondents should have provided instances of how a particular attribute influenced their work methods
(iii) Each attribute should have significant relevance within the literature to its assigned category, and thereby adhere to the theoretical propositions of the research, or should offer new insight into the research because of its relevance
(iv) The interview data supporting each attribute is supported in unison by the data collected through observation, and vice versa.

The research primarily followed the preferred strategy of 'relying upon theoretical propositions' recommended by Yin (2003) and Miles and Huberman (1994), to develop the categories and their attributes, and compare them iteratively for similarities, interactions, and relationships. An evaluation and analysis of the categories and their attributes based upon emerging themes, combined with insights gained while conducting the case study, provided a rich empirical basis to analyse and present the flow of knowledge while implementing development processes within an organisation.

4 Findings

The case study provided evidence of the flow of knowledge during collaborative tasks in the development processes. The researchers established the mechanisms of feedback and interaction that facilitate the flow of knowledge by identifying the activities, tasks, and actors involved in the development processes. The effects of interaction and feedback, and the tacit and explicit dimensions of knowledge flows, were determined by analysing the knowledge input, executed tasks, and outcomes, of collaborative activities. The collective team performance, output, and experience was further analysed to identify the specific knowledge created and integrated during the development process and applied for decision-making.

The researchers analysed how knowledge was dynamically created and made available to team members within the functional areas of the development effort. The interactions between the knowledge flows and functional areas were identified and depicted the overall complexity of the development effort. The case study analysis confirms the existing knowledge of team members is applied, and further knowledge created during problem-solving and engagement in development activities within the technical area. This process of knowledge creation and integration, creates process and product specific knowledge, and also enhances the individual and collective team experience. This was confirmed by a developer's response quoted from a questionnaire that "knowledge about the product and domain is acquired during the technical development of software," while a project manager's response was that "experience helps in understanding problems and creating effective solutions." Thus the output flow from the technical area is the creation of new product knowledge and an enhancement of individual and team experience.

The analysis further confirmed the product specific knowledge flows to the quality area where it is applied to identify mismatches and detect defects in the product. New learning emerges in this area when errors are corrected, and knowledge is also created while analysing the defects to ensure that the product conforms to the required specifications. The view is supported by a project manager's response that "impact of the modification done after addressing mismatches is accessed on the whole system and the changes are made throughout the system to minimise further mismatch issues on implementation". The new knowledge created further integrates with the existing knowledge when updating checklists and performing causal analysis, and this was confirmed during observations and survey questionnaires. Thus the quality area benefits from the product specific knowledge created in the technical area and provides further learning and reflection (Dyba 2003).

Analysis of the data establishes that the functional area where project management tasks are performed benefits from enhanced experience gained in the technical area, and from the further reflection provided by the quality area. The project management area integrates such experience and reflection by updating project management templates and modules to ensure more effective planning, control and monitoring of projects. Integrating experience and reflection creates further dynamic knowledge, which the project management area is able to transfer to the decision-making area. Responses received during interviews and in the questionnaire state that "reviews" and "experience gained" while implementing a project help "improve project management processes" for subsequent projects.

The functional area for decision making benefits from product specific learning from the quality focus and the dynamic knowledge from the project management area. This enables more effective decision making that is applied within the technical area for current and subsequent projects. For example, as questionnaire respondents state that "knowledge acquired" while implementing a project enables "better planning" and "better software designs" in future projects. The literature confirms that knowledge is applied for effective decision making while making sense of uncertain and unstructured situations (Simon 1977; Nutt 1989; Gruenfeld et al. 1996; Politis 2003). Observation confirmed the application of knowledge available from the quality and project management areas was applied for decision-making.

Table 6 below provides a summary of the relationships between the functional areas and the knowledge flows as analysed in the previous section along with the actions that link them. However, it is important to note that the activities attributed to each functional area are not exclusive to that area, but depict a relationship where the emphasis on that activity is greater than other activities, within that particular area.

The above discussion analyses the flow of knowledge within the functional areas of the development process and their inter-relationships. The flow is iterative, and the continuous inflows and outflows of knowledge from the individual areas confirm the non-linear relationships and interactions between them. The relationships present in the form of closed and continuous loops of knowledge flows, and depict the interactions and feedback of the development process as established by Abdel-Hamid and Madnick (1991). The loops ensure that new knowledge integrates with existing knowledge in a

Table 6 Relationship between knowledge flows and functional areas

Actions	Technical development	Quality	Project management	Decision making
Knowledge creation	*	*		
Learning		*		*
Reflection		*	*	
Knowledge transfer			*	*
Knowledge application	*			*
Experience	*		*	

dynamic manner, and allow experience gained while executing collaborative tasks to be effectively transferred and applied in the decision-making process. The continuous view provided by the feedback loops is modelled to represent the dynamic flow of tacit and explicit knowledge within the functional areas of the development effort and is termed the Knowledge-Dynamic Feedback model (K-DFM), and is presented in Fig. 1.

The K-DFM presents the flow of knowledge between an organisation's functional areas of project management, technical development, quality assurance, and decision-making. The model balances the interactions and interdependencies between the different functional areas and provides a complete picture of how the problem-solving requirements of an organisation are addressed. The K-DFM addresses the knowledge needs of organisations and provides the framework that ensures both tacit and explicit knowledge are made available to the right person at the right time and place. In other words, the model depicts how knowledge is made available throughout the development processes of the organisation, and is not located in a single place.

5 Assessing the K-DFM

Rubenstein-Montano et al. (2000) recommend that a knowledge management framework should:

- be both prescriptive and descriptive, that is a combination of the two approaches
- be consistent with systems thinking
- link knowledge management to organisational goals and strategies
- be planned before the knowledge management activities take place
- acknowledge the organisational culture, and the knowledge management practices must be compatible with the culture
- direct knowledge management through learning and feedback loops

The K-DFM is a dynamic model that presents the flow of knowledge between the functional areas of project management, decision-making, technical development, and quality, through feedback loops. The model is descriptive in its depiction of the flow of knowledge between the four functional areas, and is not prescriptive. The model

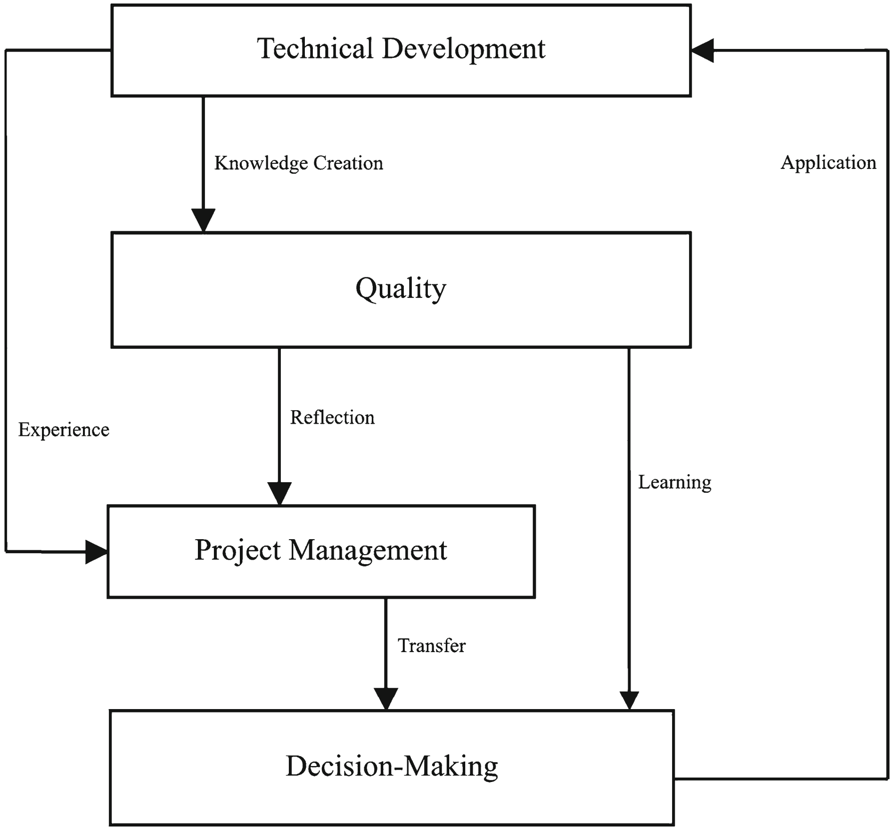

Fig. 1 Knowledge-Dynamic Feedback model (K-DFM)

highlights the flow of knowledge and using a systems approach, depicts the relationships and interactions of project management, the development effort, and knowledge management. In doing so, the K-DFM highlights the fact that consideration must be given to non-technical aspects of any development effort. The function of the decision-making area is to integrate different perspectives and considerations, and make sense of the knowledge that is created and emerges from the functional areas and flows through the feedback loops, thereby making the K-DFM consistent with systems thinking and satisfying all the criteria of the Rubenstein-Montano et al.'s (2000) framework.

By presenting the flow of knowledge through the feedback loops, the K-DFM provides the organisation with the ability to provide knowledge management support to its development processes in a continuous manner. The K-DFM provides the infrastructure that facilitates the long-term flow of knowledge and hence supports knowledge sharing activities. Thus the model provides the framework that links knowledge management to an organisation's goal and strategy of continuously improving its processes in order to make them more efficient, effective and sustainable.

Sustainability has often been mentioned as a goal of organisations during the past two decades, but measuring the degree to which organisations are being sustainable or pursuing sustainable growth is difficult. Elkington (1994) developed the concept of 'Triple Bottom Line' (TBL) performance along the interrelated dimensions of profits, people and the planet in an attempt to extend value beyond financial objectives and measure sustainability and social support. Many organisations have adopted the TBL sustainability framework to evaluate their performance and incorporate the social, environmental and financial dimensions of performance. However, monetisation of all dimensions of the TBL, including social welfare or environmental damage, has been argued on philosophical grounds (Hacking and Guthrie 2008; De Ridder et al. 2007). The concept of sustainable development is an approach that seeks to balance different needs of competing environmental, social and economic factors. A key strength of the K-DFM is that it gives consideration to the non-technical aspects of the development effort and acknowledges the important role of dynamic knowledge to support a continuous perspective that extends beyond immediate operational focus or the temporal limitations of singular efforts and projects. Indeed, it is a feature that is missing from most technical development and project management models. The continuous perspective facilitated by the K-DFM allows the gathering of knowledge after completion and delivery of the product or artefact, and ensures its continuous application to support factors of sustainable growth in on-going fashion. Moreover, the K-DFM enables organisations to balance the interactions of functional areas and capture and build on knowledge beyond the development effort to underpin the on going intelligent utilisation of available resources. Thus knowledge creation, learning, reflection, and the integration of various considerations facilitated by the K-DFM, allows organisations to develop sustainable development and growth and improve social and environmental impact in the long term. The K-DFM supports an organisation's sustainable growth in the following manner:

- **Organisational Context** The project management functional area of the K-DFM addresses how sustainability factors are influenced within an organisation's context, and addresses the objectives of environmental and social aspects. Questions such as the influence and relevance of sustainability factors and the answers are translated and integrated into more innovative operational processes with implications for the future.
- **Long-Term Perspective** The adoption of a long-term perspective as advocated by the K-DFM, underpins the shift from short-term considerations typical in single projects to a better-informed global and sustainable point of view. Global developments can consequently be considered from a wider perspective that eschews temporal concerns in favour of wider and longer-term considerations encompassing investments, benefits, outcomes, priorities, preferences and concerns.
- **Stakeholders** The K-DFM helps organisations manage and balance competing and conflicting interests and considerations. The model provides a long-term perspective to a large and ever-increasing number of stakeholders within global organisations, specifically those concerned with balancing social, environmental, and economic interests.
- **Business Case** The K-DFM supports the inclusion of non-technical and non-financial factors such as social and environmental issues and helps justify the organisation's business case and purpose from a sustainability perspective. Knowl-

edge gained through the K-DFM supports work practices that address business case objectives in a coordinated and effective manner.

- **Success** The inclusion and justification of sustainability factors within the business process of the organisation, helps reflect the environmental and social aspects in the definition of organisational success, and addresses the pressure on organisations to integrate them in terms of business value. Indeed it provides a wider lens for appraising the success of organisational undertakings. The knowledge flows facilitated by the K-DFM help integrate the sustainability factors and added value to the success criteria with long-term implications for organisational vision.
- **Reporting** The definition of scope, objective, success factors, business case of organisations are supported by the K-DFM, and provide the structure of progress reports that depict the influence and relevance of sustainability factors.
- **Risk Management** Inclusion of environmental and social factors requires their assessment and mitigation during risk planning and management. The K-DFM provides the holistic view and dynamic knowledge to facilitate risk management that integrates the sustainability factors with operational objectives whilst allowing a deeper interest in opportunities and their utilisation.
- **Organisational Learning** The dynamic learning and reflection supported and facilitated by the K-DFM includes the impact of sustainability and improved use of resources in the long term.

6 Conclusions and Implications

The paper presents a long-term perspective for effective decision-making in organisations operating in environments of rapid and unprecedented change encouraging thinking beyond discrete projects and undertakings. The paper establishes that knowledge flows between functional areas can support tasks and activities of the development effort. The K-DFM presents a framework that emphasises dynamic knowledge support, especially tacit knowledge support in the form of human judgement, insight, intuition, and experience, for decision making in the non-structured situations identified by Simon (1977). The feedback loops presented in the model support collaboration, and integration of knowledge to create new common knowledge which is further applied in improving decision-making. The paper confirms the processual nature of knowledge as argued by Styhre (2003), which exists throughout an organisation and is not located at one single instance of time or space. Moreover, it helps to identify the distinction between product-oriented processes (and knowledge), which occur as part of the elaboration and creation of the product of the technical development, and the managerial processes required to describe, underpin and organise the work of the project. The model has been validated by successful implementation in an organisation that employs more than 250,000 individuals and therefore addresses the limitations of Serenko et al.'s (2007) study which identified the decreased effectiveness of knowledge flow and sharing with an increased organisational size. The model is distinct from Nissen et al's (2000) lifecycle model as it depicts and balances the interactions and relationships between knowledge flows and functional areas through dynamic feedback loops.

The processual nature of knowledge and its flow have implications for a large part of management literature that focuses on how to make knowledge more manageable.

Managing knowledge provides a connotation of control and ownership where the first step is to establish its ownership. However, it is difficult to assign ownership, and store and retrieve something that is abstract and elusive in nature. Knowledge is considered tacit by nature, that is, implied and understood implicitly in the situation, without being definable and visible. Furthermore, as the research shows knowledge exists in distinct groupings and organisational functions; capturing tacit knowledge is viewed as a challenge by organisations that need to spread knowledge for better decision-making and greater innovation. This research presents an approach where the flow of knowledge supports collaborative tasks and activities in areas where the knowledge is required and applied within a context. The approach considers knowledge as something that is made resourceful by being competently mobilised and utilised, and consequently new knowledge is created by improving the ability to facilitate, mobilise and utilise existing knowledge.

For organisations this paper's findings have implications regarding their ability to manage context, provide feedback and facilitate interaction, and therefore build upon their existing knowledge resources to improve problem-solving and sustainability. The research provides organisations with a perspective that would help them achieve excellence and sustainable growth not only through integrating various considerations for effective decision-making, but also through knowledge creation and sharing. The K-DFM's focus on supporting the flow of knowledge, learning, experience and reflection within the functional areas provides organisations with the benefits of continuous process improvements and competitive advantage. Thus the research presents an approach to ensure that the right knowledge is available to the right person at the right time during the decision-making process and throughout the extended life cycle of knowledge utilisation. This provides a starting point in the quest to address the requirements of effective problem-solving for sustainable development.

7 Limitations and Future Work

The research has some limitations and several possibilities for future work emerge from the results of the current study. The case study is located within a single organisation. The study did not attempt to isolate specific conditions that may tend to moderate the findings within a single organisation. A focused study within several organisations, combined with an objective evaluation of the flow of knowledge and capability support within the various knowledge management initiatives, would provide useful follow-up research. Interesting research possibilities exist to extend and test the model within other developmental domains and industrial sectors. Therefore further studies need to be conducted to look at organisations in other areas and domains to determine if the same practices apply.

There was no attempt to categorise the findings based on the size of the organisation. Opportunities for similar research appear to exist in this area, to determine if the research factors differ based on organisation size or structure. While this study was focused on the flow of knowledge within collaborative activities, there is evidence in the literature that effective knowledge management strategies may tend to enhance the flow of knowledge. Therefore, a longer-term study examining changes in the flow of knowledge before and after performing collaborative activities would yield useful and interesting results.

Finally, further work is required to develop measures to determine the flow of knowledge while performing the above mentioned collaborative activities. Such research will help determine, establish and confirm the benefit and impact knowledge flows have on work practices and resources of an organisation. Assuming that access for this research can be negotiated, the researchers hope to be able to build further on the findings offered through this research.

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