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Abstract

Purpose – *The purpose of this paper is to explore the knowledge processes that interplay in the social construction and appropriation of knowledge and to test these constructs empirically in project teams.*

Design/methodology/approach – *Literature research and quantitative survey were used. The research identified project success, faster completion times, operational efficiency, innovation and generation of new knowledge as dominating project management expectations in the past ten years. It studied how these projects construct and appropriate knowledge within project teams to achieve these five objectives. Using a quantitative approach, data were sought from 1,000 respondents out of a population of 10,000 from 11 project management areas in eight world regions to test the conceptual model in real-world scenarios. The data gathered were analyzed using quantitative analysis tools and techniques such as reliability, correlation and regression.*

Findings – *There is a lingering difficulty within organizations on how to translate tacit knowledge into action. The transfer and utilization of tacit knowledge was shown to be embedded and nested within relationships. Innovation in projects was found to be mostly linked to replication and codification of knowledge (explicit dimension) as opposed to interpretation and assimilation (tacit dimension). Arriving at a mutual interpretation of project details and requirements does not depend on canonical (formal documentation) methods but mostly on non-canonical (informal) and relational processes embedded within the team.*

Originality/value – *This work studies, in empirical and geographical detail, the social interplay of knowledge and provided evidence relative to the appropriation of knowledge in the project organizational form, which can be extrapolated to wider contexts. The work scoped the inter-relational nature of knowledge and provided further evidence on the nebulous nature of tacit/intangible knowledge. It also proved further that organizations mostly rely on explicit knowledge to drive organizational results, as it is easily actionable and measurable.*

Keywords *Knowledge, Knowledge management, Knowledge creation, KM processes, KM strategy, Knowledge utilization*

Paper type *Research paper*

Introduction

Growing interest in knowledge management has moved the topic from a relatively new discipline to an important strategic resource for competitiveness (Prusak, 1996; Zack, 1999). The role of knowledge management in leveraging organizational performance has often been undervalued. However, recent research and practice evidence suggest that an increasing reliance on knowledge capabilities is required to garner competitive advantage (Maqsood *et al.*, 2007; Argote and Ingram, 2000; Oluikpe, 2012). The importance of knowledge management not only lies in its capabilities to enable the capture and leverage of intellectual capital but also in the deployment of this capital in a way that delivers organizational advantage.

Due to the similarities between knowledge management, information management and business management, there is some confusion as to the classification of knowledge management. Some theorists and practitioners classify knowledge management as

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"information systems", while others see it as human resource management. However, knowledge management has its roots in a number of disciplines, including: cognitive science, information science, knowledge engineering, sociology, philosophy, management, artificial intelligence, economics, and politics.

Definitions of knowledge management found in the literature come from various disciplinary perspectives such as strategic management (Wiig, 1997; Alavi and Leidner, 2001), human resources (Skyrme and Amidon, 1997; Liebowitz, 2001) and information systems (Kakabadse *et al.*, 2003; Lave, 1988; Blacker, 1995). Knowledge management has remained nebulous in terms of disciplinary categorisation and maybe this has been responsible for the difficulties in establishing a scientific approach to knowledge construction and utilization.

There are accepted knowledge construction models and frameworks in literature (Nonaka *et al.*, 1992; Demerest, 1997) but these construction and utilization models have continually come under attack. Nonaka and Takeuchi (1995) particularly, have been criticized for being too mechanistic, lacking in operationality and parsimony (McLean, 2004) and low on conceptual clarity (Gourlay, 2006; Gourlay and Nurse, 2005). Wenger (1998) has also been criticized for oversimplifying a complex problem and assuming that communities can be engineered to suit and fit into organizational management expectations (Cox, 2005).

While differences exist between the proponents and critics of these models, the commonalities lie in the recognition of the value of tacit and explicit knowledge in operationalizing knowledge. This paper proposes the CRAI Model as a knowledge construction and appropriation model.

Knowledge construction

Knowledge construction is the process of creating knowledge within a specific context, while knowledge appropriation is the process of utilizing knowledge for beneficial ends and putting this knowledge within operational contexts where it makes meaning. Furthermore, three major philosophical viewpoints dominate the theoretical and practical knowledge space. The first is the exogenic viewpoint, the second is the endogenic perspective and the third, the social construction of knowledge, seeks to marry the first two perspectives.

The exogenic (world-centred) viewpoint

This perspective could be traced to empiricist philosophies (Locke to logical positivism). This philosophy regards the world as a primary given, which is reflected in the mind. The exogenic viewpoint influences the educational pedagogy that emphasizes direct observation, experience, samples, specimens, participant observation, laboratory experiments and field trips. The exogenic viewpoint operates within the constructs of sensation and informs the mind through material reality.

According to this viewpoint, all education of the mind emanates from contact with material reality (the outside world). Gergen (1985) deconstructs this viewpoint by pointing to Rorty (1979), who argued that the problem of knowledge as a relationship between mind and world cannot be solved because it is ill-conceived from the beginning. If we set out to dichotomize what is outside and inside of the mind, we have a problem of determining how the former is accurately reflected in the latter.

The endogenic (mind-centred) viewpoint

The individual knowledge construction viewpoint is rooted in the endogenic tradition, which believes knowledge depends on processes endemic to the organism. This viewpoint advocates that the inherent tendencies to categorize and process information are responsible for the way individuals fashion knowledge.

Polanyi (1958) is probably one of the greatest proponents of personal knowledge. He proposed that "all knowledge is personal". However, the individual knowledge construction viewpoint has been criticized for fostering a self-contained (me-alone) and fundamental isolation view, which has spawned a secular society where individualism, rather than collectivism, pervades. The impact this viewpoint could have on knowledge sharing and knowledge management programmes in organizations could only be envisaged. In a scathing attack on individualism, Gergen (1985) contends that the *locus* of scientific rationality lies not within individual minds but within the social aggregate and that what is rational is a result of negotiated intelligibility.

Social construction viewpoint

Gergen (1985) advocated a social construction of knowledge viewpoint. He sees this as necessary because the mind/world dualism fostered by the endo/exogenic conceptions of knowledge have been rendered vulnerable by previous intellectual debates, especially that of Rorty (1979). According to Gergen (1985) social construction of knowledge deals with "explicating the process by which people come to describe, explain or otherwise account for the world (including themselves) in which they live".

Gergen *et al.* (1973) described the social construction process of knowledge and opined that knowledge construction from this viewpoint is not value neutral, indicating that different individuals and groups construct reality from their unique contexts and backgrounds. For example, a bottle of water would represent different values for environmentalists, religionists, chemists and oceanographers alike.

Many theorists believe that knowledge is socially constructed (Demerest, 1997; Wenger, 2003; Oluikpe, 2012). Gergen himself opined that the degree to which a given form of understanding prevails, or is sustained across time, is not fundamentally dependent on the empirical validity of the perspective in question but on the vicissitudes of social processes (e.g. communication, negotiation, conflict and rhetoric). von Krogh *et al.* (1994) advanced the notion that "knowledge development at the individual level resembles knowledge development at the social level", thereby situating the individual as an integral of the social, hence bridging the dualisms of the empiricist and rationalist perspectives. Constructionism moves beyond the dualisms to which these traditions are committed and attempts to situate knowledge within the process of social interchange.

Construct variables derived from the social construction of knowledge

The author derived four construct variables as Interpretation, Assimilation, Reproduction and Codification from Gergen's social construction of knowledge viewpoint. In developing

"Project teams tend to utilize knowledge that has a common/collective interpretation over knowledge obtained from elsewhere."

the CRAI Model, the author recognizes the four KM success factors of people, culture, technology and strategy in project management teams. However, these success factors are not the subject of this paper and would be explored in a subsequent paper. The model is specifically focussed at exploring knowledge construction and appropriation enabled by social interaction in project teams and their relationship with project outcomes such as project success, innovation, operational efficiency, completion times and generation of new knowledge. The CRAI Model is outlined in Figures 1 and 2.

Interpretation

This variable deals with the level of understanding required in social interchange to foster a common understanding and collective enterprise. Interpretation involves sense-making (Hmelo-Silver, 2003) where learners can construct representations that they use as tools in their thinking. These tools can be used to negotiate meaning and production of visual representations that reflect their intermediate understandings.

A German sociologist, Oevermann (1973/2001a) described a pattern of interpretation involving complex, collectively shared mind-sets and mutual rules, which are neither accidental ideas nor selective individual opinions. Recently, Deloitte (2014) has utilized

Figure 1 The CRAI Model of knowledge construction and appropriation

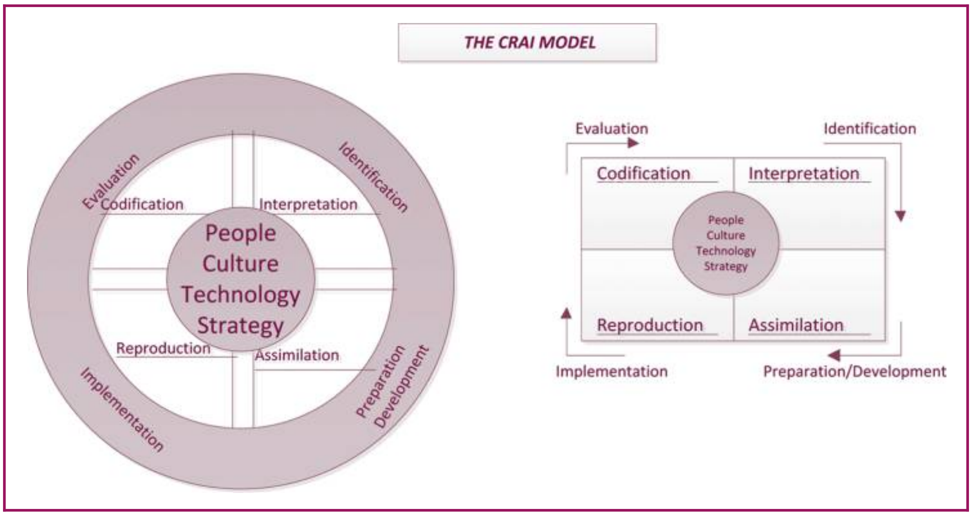

Figure 2 Model constructs

Four Stages of Project Knowledge	
Codified Knowledge Knowledge output of the whole project needing to be captured, codified and stored. • Evaluation • Analyse results • Lessons learnt • Impact assessment	**Interpretative Knowledge** *Immediate and remote knowledge available at the time of project identification needing interpretation to aid project decision* • *Experience* • *Org. Knowledge* • *Documentation* • *Decision Support* • Staff
Reproductive Knowledge *Knowledge assimilated needs to be reproduced on implementation. Project results are direct reproductions of project knowledge assimilated.* • *Refine knowledge* • *Utilise Knowledge* • *Finished product* • *Progress review*	**Assimilative Knowledge** *Knowledge created during interaction/team formation need to be assimilated for project purposes.* • *COPs/Social capital* • *Progress meetings* • *Networks* • *Collaboration* • *Process*

> “**Project learning (organizational learning) is linked with knowledge replication and codification.**”

shared identity and shared interpretation as symbols in the knowledge construction loop in organizations. von Krogh *et al.* (1994) redefined the notion of information as a process of interpretation by which knowledge is acquired.

Each project begins with an interpretation, analysis and detailed consideration of project information, requirements and specifications. To deliver a project well, one must understand why it is needed and what it is for at the start of the planning process. At this stage, documentation, organisational knowledge, staff experience, decision support tools and technologies are used to enable project managers to make decisions. The client explains their requirements; stakeholders are able to get across their views about the project and what they require. This stage is the preliminary stage of interpretation and planning (Muriithi and Crawford, 2003), where things are made clear.

Assimilation

This is the process of configuring and aligning new information to fit with pre-existing schemas and mental models (Piaget, 1970). It is an integration process. An individual or group digest and reify new knowledge in an internalization process aimed at structuring the information based on existing schemas (Tsai and Lei, 2006; Chang Lee *et al.*, 2005). Without this structuring process, it is difficult to utilize such information. The author refers to this as a “conformation process”. Assimilation as a process has been referenced by Nonaka and Takeuchi (1995) as internalization, von Krogh *et al.* (1994) as assimilation relating to learning in the cognitivist perspective. This implies that the individual “more accurately obtains representations of the world through assimilating new experiences[. . .] and relating incoming information to a previously acquired psychological frame of reference” (von Krogh *et al.*, 1994).

This process depends more on the reflective and endogenic qualities of the individual. At the assimilative stage, the various day-to-day interactions taking place between new project team members and experienced team members yield a measure of knowledge previously unavailable to individual members of the team on their own. Even new members of a team bring views that make experienced project managers learn. The various tools that foster assimilation of knowledge about a project include emails, face-to-face interaction, mentorship, groupware, telephone conversations and chat.

At this stage of the project, the information presented in documentation at the interpretation stage is assimilated through everyday interaction, questioning, dialogue, explanations from team managers, group discussions and stakeholder meetings. In the process of assimilation, information is converted into knowledge and tacit knowledge is exchanged among team members. A mutual understanding about the project develops. The knowledge acquired and shared in this process is useful for achieving project objectives.

Research has linked a projects information utilization capacity to the existence of group mechanisms (Galbraith, 1973; Gupta and Govindarajan, 2000). It has also been said that innovation flows more efficiently through relationships in and outside a project (Tushman and Scanlan, 1977; Ghoshal and Bartlett, 1988; Nobel and Birkinshaw, 1998; Hansen, 1999), and best practices are transferred more easily when there is a relationship between two parties to knowledge transfer (Szulanski, 1996). Hansen (2002) researched on knowledge sharing between project teams and linked project completion time to the rate of knowledge sharing among teams.

Reproduction

The third variable, reproduction, concerns itself with the ability of actors in a social space to deploy knowledge acquired during interchange in meaningful enterprise. It is not enough to internalize knowledge but it is important to also replicate the knowledge and put it to productive use.

Competent workers are often classified by the ability to recall and apply knowledge in context-specific circumstances. Collins (1978) referred to this as the process of explicating tacit knowledge, Nonaka and Takeuchi (1995) as externalization and Rivkin (2001) described the process of knowledge replication in organizational context. More recently, organizations have shown interest in knowledge reproduction as beneficial in expanding their frontiers Winter *et al.* (2012).

The reproduction process coincides with, but is not exclusive to, the project implementation stage. At this stage, knowledge residing in design details and in the heads of team members is made tangible. The project outcome (infrastructure) is the product of the combination of tacit and explicit knowledge. Tacit knowledge which is in a state of doing (empirical) and explicit knowledge which is in a state of being (idealist) are combined and reproduced into project outputs. Knowledge creation in itself is not profitable if it is not translated into project outcomes. At this stage, the core competencies (entrepreneurial, technical, evaluative and relational competencies) of project management (PM) as identified by Lampel (2001) are translated to tangible outcomes.

Codification

In every cultural milieu, a social system often conserves its body of knowledge through various means, most commonly, knowledge repositories of some form.

Codification is a process of making tacit knowledge explicit (Oluikpe *et al.*, 2010). Nonaka and Takeuchi's (1995) knowledge spiral or SECI Model expostulated the concept of tacit and explicit knowledge and the interplay of both in knowledge work. Boisot's (1987) model yielded some distinctions between codified and uncodified knowledge, in an approach similar to the tacit–explicit continuum of Nonaka and Takeuchi (1995).

In the model the author is proposing, codification is not a sequential process, but could occur in any of the stages of the model. However, the author opines that at the end of the knowledge process, a codification of the knowledge generated during the process also should happen in some sort. The codification stage of the CRAI Model is the evaluation stage of the PM process. Towards the conclusion of a project, relevant knowledge and information are documented and passed on as evaluation reports, summaries of project activity, appraisals, project brief and debriefings (Schindler and Eppler, 2003). These documentations attempt to capture the knowledge of staff who worked on these projects. Post-project reviews (PPR) have been recognized as strategies for capturing and codifying project knowledge (Carrillo, 2005). Although documentation may contain project knowledge, they are often not in readily usable format to enable decision-making. Research

"Despite the abundance of research evidence that companies and teams should value tacit knowledge much more, it is very difficult to conceptualize any framework that would effectively explicate tacit knowledge."

> **"The usefulness of the CRAI Model in knowledge construction and appropriation has been highlighted and tested by this research, especially in the project management context."**

has been carried out in the area of learning from PPRs (Terry, 2004; Carrillo, 2005). PPR meetings, evaluation reports and lessons learned databases offer a rich source of knowledge for projects if they have the time to analyze them. In theory, organisations have PPR and review meetings, but in practice, they are frequently not in place (von Zedtwitz, 2003). This makes organisations miss the opportunity to learn from important mistakes or successes of a project. Capturing and codifying project knowledge throughout the project process will lead to the generation of new knowledge if the captured knowledge is subsequently analyzed and utilized (Argyris, 1999; Disterer, 2002; Bowen *et al.*, 1994).

Testing and operationalizing the model

To test the assumptions behind the CRAI Model (a social construction of knowledge model), the author chose to operationalize the constructs within Project Management contexts using a survey. The survey was chosen to measure the impact of the model on five critical outcomes of projects identified from Crawford *et al.* (2006):

1. Innovation (Harkema, 2003; Coleman, 1999; Wheatley, 1992; Samid, 2003).
2. Completion times (Ancona and Caldwell, 1992; Eisenhardt and Tabrizi, 1995).
3. Project success (Dalgleish, 2003).
4. Operational efficiency (Paul, 1987).
5. Generation of new knowledge/project learning (Schindler and Eppler, 2003).

Methodology

The study identified a potential study population of 10,000 people and then narrowed to a sample size of 1,000, using a stratified random sampling technique. Projects were selected based on a review of three project databases, which covered 11 project areas selected for the study. These databases were secured from an academic institution in the UK, a British construction and design company and an international online development project directory.

Project selection

Project management classifies the status of projects as ongoing, completed and abandoned (Baker, 2000, World Bank, 2002). The author decided to use ongoing and completed projects for this study. Ongoing projects provide the opportunity for answering questions on the usefulness of knowledge from previous projects. They are also more likely to be adopting new and current practices. The rationale for using ongoing projects is because it is felt that they could offer information in the interpretation and assimilation boxes of the model which completed projects might have forgotten. Therefore, to gather useful and recent information on interpretation and assimilation perspectives of the model, the author felt ongoing projects were a good fit.

Completed projects were used for this study because aspects such as codification of knowledge are considered by the author as more applicable to projects which are completed or are near completion. This is due to a practice prevalent in project management where projects are most often evaluated at the end of the project rather than in-between phases. Project success is also much more measurable with a completed project than with an ongoing project. Projects were also selected according to type or subjects covered. Two criteria of selection are:

1. Frequent reoccurrence of a project area in the directories and databases.
2. Utilization of project management processes for design and implementation of projects.

The following shows the selected project types for the survey:

- Construction.
- Water and Sanitation.
- Education.
- Social services (health, etc.).
- Sustainability.
- Information.
- Women Welfare.
- Children and Youth Services.
- New Product Development.
- Design.

Project region

The World Bank (2005) regional classification of projects was used as a standard. The survey was designed to be executed in 12 regional divisions of the world. This decision was made for ease of classification of data and also for clarity and detail in analysis. The following section shows the regional classification of projects:

- Europe.
- North America.
- Latin America.
- The Caribbean.
- Sub-Saharan Africa.
- North Africa.
- East Asia.
- The Pacific.
- Central Asia.
- South Asia.
- Australia.
- Middle East.

Questionnaire design

The author developed a web questionnaire to enable faster collection of information. The questionnaire was structured on a six-point Likert scale ranging from strongly disagree to strongly agree. Questions were placed randomly in the questionnaire to avoid response bias. The questionnaire was coded with options to add to the fields of project management through a free-text tool, as long as respondents were working in these unlisted areas. On a general note, the areas listed above were very representative of current day project areas.

Population

About 10,000 projects were selected for this study. From this population, a sample size of 1,000 was drawn. The stratified random sampling method was used to select projects to be surveyed (Table I).

The number of projects selected from each region was arrived at based on the total number of projects from a region represented in the total population. There were more projects from Europe and North America than other regions, and using the stratified random sampling technique, 15 per cent of projects were selected from Europe and North America.

Question coding

Section A of the questionnaire has 11 background questions, which dealt with the general features of the project. The questions in this section explored the following areas:

- project region;
- size;
- number of staff;
- duration of project;
- communication tools;
- project roles of respondent;
- knowledge management tools used;
- email contacts for feedback; and
- project type (Table II).

Survey administration

The questionnaire was loaded on a website and administered to each project contact using email. A link to the questionnaire was provided on the email, after introducing the research.

Over a period of five months, responses were received from different project contacts. The response rate was 303, which represents 30.3 per cent of the sample size. This response rate is high considering that some studies are of the view that a good response rate is in the region of 20 per cent and above (Kardas and Milford, 1996) (Table III).

Table I Stratified random sampling of projects

Regions	*No. selected*	*(%)*
Europe	150	15
North America	150	15
Latin America	70	7
The Caribbean	70	7
Sub-Saharan Africa	70	7
North Africa	70	7
East Asia	70	7
The Pacific	70	7
Central Asia	70	7
Australia	70	7
Middle East	70	7
South Asia	70	7

Table II Questionnaire variables

Section A: general	Section B: projects
Project region	Interpretation
Project size	Assimilation
Project type	Reproduction
Project duration	Codification
Number of staff on project	Project completion time
Project role of staff	Project success
Project communication tools	Best practices
Knowledge sharing tools	Innovation
	Operational efficiency
	Generation of new knowledge

Table III Response rates

Project area	Number	Duration (years)	Number	Region	Number
Construction	45	Under 1	74	Europe	100
Water	11	1	65	North America	66
Education	52	2	87	Latin America	28
Technology	54	3	46	The Caribbean	6
Social	20	4	17	Sub-Saharan Africa	10
Sustainability	13	5	9	North Africa	12
Information	58	5+	4	East Asia	11
Women welfare	9	Total	302	The Pacific	14
Children	6	System	1	Central Asia	6
New product development	25			South Asia	19
Design	10			Australia	15
				Middle East	16
Total	303		303		303

Data analysis

Reliability. The questionnaire items on Interpretation (ten items), Assimilation (six items), Reproduction (ten items) and Codification (five items) were tested for reliability using SPSS scale (reliability analysis function). The measurement criteria selected is the Cronbach's alpha, which measures internal consistency. The items under each construct were entered into the SPSS scale (reliability analysis function) and computed for Cronbach's alpha (Table IV).

The reliability of the model constructs are as follows: Interpretation (0.628 alpha), Assimilation (0.816) and Reproduction (0.719), while Codification has 0.731 alpha.

These results are high and indicate that the constructs measure the population they are meant to measure. The validity of the constructs such as their convergent, discriminant and nomological validity is less easy to determine apart from using the correlation findings in Table V. Evidence demonstrating validity would be easier if such constructs were already operationalized within the literature and could be used as part of the questionnaire. This was not the case (Table V).

Correlation analysis

Table V shows the correlations of the variables with each other. Project success strongly correlates with innovation, assimilation and reproduction. This indicates that the way teams share knowledge (assimilation) and innovate is linked to a replication of the knowledge shared during the implementation period.

Completion times are strongly correlated with interpretation and reproduction, indicating that the way projects are planned at the beginning (interpretation) and the way they are executed (reproduction) affect their completion on schedule.

Table IV Reliability statistics

Model constructs	Count	Mean statistic	SD	Cronbach's alpha
Interpretation	303	19.2	3.1	0.628
Assimmilation	303	20.3	2.4	0.816
Reprodroduction	303	24.5	2.9	0.719
Codification	303	19.8	2.4	0.731
Project success	303	4.9	1.1	0.79
Innovation	303	4.8	1.2	0.63
Completion times	303	4.9	1.1	0.60
Operational efficiency	303	5.2	0.97	0.62
Knowledge generation	303	5.1	1.1	0.76

Table V Correlation of variables

Model constructs	Y_1	Y_2	Y_3	Y_4	Y_5	X_1	X_2	X_3	X_4
Y_1: Project success	1	0.36	0.15	0.06	0.01	0.04	0.59	0.25	0.01
Y_2: Innovation	0.36	1	0.15	0.13	0.02	0.01	0.33	0.51	0.06
Y_3: Completion times	0.15	0.15	1	0.01	0.05	0.28	0.10	0.44	0.02
Y_4: Operational efficiency	0.06	0.13	1.3	1	0.01	0.00	0.48	0.05	0.00
Y_5: Generation of new knowledge	0.00	0.02	0.05	0.01	1	0.05	−0.00	0.36	0.51
X_1: Interpretation	0.04	0.01	0.28	0.00	0.05	1	0.07	0.11	0.10
X_2: Assimilation	0.59	0.33	0.10	0.48	0.00	0.07	1	0.24	0.09
X_3: Reproduction	0.25	0.51	0.44	0.05	0.36	0.10	0.11	1	0.42
X_4: Codification	0.01	0.06	0.02	0.00	0.51	0.10	0.09	0.42	1

Generation of new knowledge has strong correlations with reproduction and codification, implying that new knowledge is realized (codified) during the implementation and winding up stages of the project. This does not mean a strictly sequential process of new knowledge realization, as it is well known that knowledge can be realized at any stage of a project. Knowledge utilization is at its peak during the implementation (reproductive) stage, and it is often harvested and made tangible during the review and evaluation stage (codification) (Table VI).

Regression analysis

The elements of the model used in the regression analysis include Interpretation, Assimilation, Reproduction and Codification. The dependent variables are project success, innovation, completion times, operational efficiency and generation of new knowledge.

In analyzing the regression of the CRAI Model against the five dependent variables (project success, innovation, completion times, operational efficiency and generation of new knowledge), multiple regression was applied using the stepwise selection method. The criterion used for entry into the regression equation was the computed probability of the *F* statistic (Probability of *F*-to-enter [PIN]) is less than 0.05.

Table VI Regression analysis

Variables	B	β	t
Constant	0.69		0.99
Project success	1.05	0.05	1.52
Innovation	1.11	0.46	4.6
Completion times	0.69	0.18	0.99
Operational efficiency	1.94	0.62	3.11
Generation of new knowledge	8.24	0.12	1.22
R	0.561		
R^2(Square)	0.314		
F Statistic	34.17		
Significance	0.000		
df	4		

The first independent variable was examined for removal as in backward elimination using the POUT (probability of *F*-to-remove) criteria of 0.10. This process was continued with all the variables in the equation and provided the results shown in Table VI. The R^2 of 0.314 indicates that the model fits the data well, and almost 31 per cent of the variability in the data can be explained by the above regression equation.

Further stepwise multiple regression analyses were carried out on the five PM expectations, and the results are expressed below.

Tables VII and VIII highlight a stepwise multiple regression of the model and project outcomes and the collinearity statistics of the model construct. The collinearity test was carried out to ascertain that the problem of multicollinearity among the model variables is not present. As seen in Table VIII, the tolerance figure for each model construct is above 0.20, meaning that there are no concerns of multicollinearity of the variables. We now go ahead to analyze the results of the stepwise multiple regression.

In a hierarchical multiple regression, Interpretation and Assimilation were entered in the first step and explained about 34.9 per cent of the variance in project success ($F2,300 = 80.467$, $p < 0.05$), 11.4 per cent of the variation in innovation ($F2,300 = 86.979$, $p < 0.05$), 8.9 per cent of the variation in completion times ($F2,300 = 14.71$, $p < 0.05$), 24 per cent ($F2, 300 = 47.41$, $p < 0.05$) of the variation in operational efficiency and 0.03 per cent of the new knowledge, each explaining a similar proportion of the variance.

Reproduction was entered second and explained a further 1.2 per cent ($F1,299 = 5.816$, $p < 0.05$) of the variance in project success, 20 per cent ($F1,299 = 86.98$, $p < 0.05$) of the variation in innovation, 16.3 per cent of the variation ($F1,299 = 65.11$, $p < 0.05$) in completion times, an insignificant effect on operational efficiency and 14.5 per cent ($F1, 299 = 51.08$, $p < 0.05$) of the variability observed in generation of new knowledge.

Codification was entered third and explained another 0.9 per cent ($F1,298 = 4.167$, $p < 0.05$) of the variance in project success, 2.8 per cent ($F1,298 = 12.9$, $p < 0.05$) of the variation in innovation, 6.2 per cent of the variation in completion times ($F1,298 = 27.11$, $p < 0.05$), insignificant effect on operational efficiency and 16.5 per cent ($F1, 298 = 71.42$, $p < 0.05$) of the variability observed in generation of new knowledge. Ideally, the author would have liked to explain most, if not all, of the variations in the variables as outlined above. However, the results above establish a positive link between the model and the variables.

Discussion

Based on the data analyzed, the author found that project teams tend to utilize knowledge that has a common/collective interpretation over knowledge obtained from elsewhere. In

Table VII Stepwise multiple regression of variables

Variables	*Interpretation + (Rsq) assimilation*	*Reproduction (RSq)*	*Codification (Rsq)*	*Significance*	*Durbin – Watson statistic*
Project success	0.349	0.012	0.009	0.05	1.780
Innovation	0.114	0.200	0.028	0.05	1.680
Completion times	0.089	0.163	0.062	0.05	1.924
Operational Efficiency	0.240	0.000	0.000	0.240	1.932
G. of new knowledge	0.003	0.145	0.165	0.05	1.861

Table VIII Collinearity statistics: tolerance and variance inflation factor

Statistics	*Interpretation*	*Assimilation*	*Reproduction*	*Codification*
Tolerance	0.981	0.936	0.770	0.813
Variable inflation factor	1.020	1.068	1.299	1.229

effect, they adopt a low-risk strategy to knowledge application. Knowledge seeping into the team from external sources first undergoes a transformation and a conformation process before being deployed. This is because common interpretation is necessary to further project objectives.

This result is not surprising, as it is known that project teams share common processes and values which provide a framework for interpreting and internalizing project knowledge (Dhanaraj *et al.*, 2004; Bouwen, 2001). Project staff depend on a shared context, shared identity and common interpretation to make sense of project information. These interpretive processes often do not depend on canonical knowledge (manuals, project documentation) alone, but on non-canonical knowledge (web of relationships, collectivity, situational learning, improvisation, narratives) that exist in the team (Brown and Duguid, 1991). Although Zhou (2014) found relational ties to inhibit knowledge acquisition in buyer–supplier relationships, we think that contextually, this is different from project teams where individuals deal with each other on a much more closer, non-competitive and non-adversarial basis. For supplier–buyer relationships, the tendency to outwit, and drive a hard bargain might overcome the need for cooperation.

Again, Dhanaraj *et al.* (2004) provides evidence relative to the positive impact of relational embeddedness in improving the transfer and utilization of tacit knowledge. The results are consistent with Lave and Wenger (1991) seminal viewpoint on situated learning where informality, task orientation, observation, participation and identity are important elements of a social construction of knowledge system.

The results find that project learning (organizational learning) is linked with knowledge replication and codification. What has not been utilized cannot be reconfigured in different ways. Lessons cannot be learned except where implementation has taken place. At codification, those lessons are made explicit and preserved for future learning and utilization. Interpretation and assimilation do not contribute as much as reproduction (application) in creating new knowledge, according to the results. It is easy to see how this result conflicts with conventional knowledge theory but is consistent with actual knowledge practice. Most knowledge management theorists place much premium on tacit knowledge as the source of competitive advantage. It is considered as the purest and highest form of knowing and that within this domain, innovation is spurned. What is most often missed is that “flexibility comes with use”. Knowing without doing cannot result to innovation. To support this line of thinking, we cite a strategy management maxim that “a mediocre strategy expertly executed is better than a profound strategy that never left the shelf”.

One reason for the foregoing result might be the oft-quoted difficulty of “harvesting tacit knowledge and making it explicit”. Knowledge that has been made explicit is mostly useful for project teams. Little wonder the results also show that innovation in project teams is mostly linked to knowledge replication (reproduction). Knowledge can emerge in new ways (reconfigured, reconstituted and recombined) at the point of usage and application. Project teams make decisions to utilize knowledge in ways suitable for that project and not necessarily in the form the knowledge was received. The results show that innovation is made tangible and possible at the point of application. It is not surprising that most advances in science and engineering in the past 50 years have been incremental, reinforcing the notion that existing (explicit) knowledge is reconfigured in the innovation process.

Most software and technology companies which thrive on imitation and replication are successful in replicating products and making it a success because they refuse to play in the interpretation and assimilation box (tacit knowledge) but rather play in the reproduction/codification box (explicit knowledge). This reinforces the notion that what has not been made explicit cannot be internalized or reconfigured. The results are consistent with those of the study by Dhanaraj *et al.* (2004) which reported a positive relationship between explicit knowledge and performance due to its ease and low cost of transfer, actionability and clarity. We surmise that although tacit knowledge is more valuable (Polanyi, 1966), explicit knowledge can be exploited more easily and deployed to organizational advantage.

What the results demonstrate is that the age-old difficulty of what to do with tacit knowledge is yet to abate. Despite the abundance of research evidence that companies and teams should value tacit knowledge much more, it is very difficult to conceptualize any framework that would effectively explicate tacit knowledge. Perhaps, more qualitative study, as a follow-up to this research, could help situate this problem within discursive scenarios for better insight as opposed to the detached and dispassionate feature of quantitative research.

Conclusions

This paper postulates a theoretical and operational framework for explicating, appropriating and operationalizing knowledge using the project management life cycle.

The theoretical framework is grounded in the social construction of knowledge viewpoint. Using literature, the paper grounded four constructs of interpretation, assimilation, reproduction and codification as knowledge processes evident in typical social interplay involving the generation and utilization of knowledge.

It also operationalized these constructs within the industry using an empirical survey methodology that sought data from projects from 12 selected regions and 11 project areas. A population of 10,000 projects was initially earmarked, and a sample size of 1,000 was selected for the study. A 30.3 per cent response rate was achieved, and data were analyzed using correlation, regression and stepwise regression models.

Implications of the study for researchers and practitioners

Research into knowledge management frameworks and processes are abundant in literature, but very few have studied in granular detail, depth and coverage, the empirical implications of social interchange in knowledge creation and utilization.

Most research have been ethnographic and qualitative, providing very little objective statistical links between knowledge and its application in real contexts. This work contributes to fill the gap.

A lot has been written in the literature on the interplay between tacit and explicit knowledge and the contexts of their application in organizations. Theoretically, it has been well established that there is still the persistent difficulty of explicating tacit knowledge and putting it in contexts where it makes meaning for organizational exploitation. It is necessary to keep building on this theoretical foundation and to empirically validate approaches to knowledge explication by providing evidence relative to their operationalization.

As such, this work helps towards the effort to close the gap between academia and industry. Researchers can build on this research through further tests and validation. For practitioners, the results linked to knowledge replication, innovation and creation of new knowledge within the reproduction–codification loop will generate understanding about where the focus should be in collaborative knowledge work.

The usefulness of the CRAI Model in knowledge construction and appropriation has been highlighted and tested by this research, especially in the project management context. Organizations, especially project management organizations should adopt the model to leverage knowledge producing activities, as it would enable them deepen expertise, leverage competencies and enable learning. The relevance of the CRAI Model mostly lies in its ability to situate and contextualize knowledge in collaborative contexts while enabling the application of that knowledge and its retention in codified form.

The CRAI Model evolved from the social construction of knowledge paradigm; hence, its application should be within collaborative contexts such as project teams, task groups, work groupings and networks of practice. The assumption made in developing the model is that knowledge is socially constructed and an item of knowledge derives its meaning in a collective context with common understanding.

The following conclusions are drawn from the results of the study:

- New knowledge in project management contexts can be realized mostly during the reproductive (implementation) and the codification (evaluation) stages of the project as our results demonstrate. The implication is that project teams and organizations by generalization should focus more on the implementation and evaluation stages of the project to harvest new knowledge. Project managers should begin to focus on codification processes that highlight new knowledge such as after-action reviews, PPRs and lessons learned systems. This will enable knowledge discovery. Choudhary *et al.* (2009) highlighted the usefulness of PPRs in knowledge discovery using data mining techniques.
- Project teams value explicit knowledge more than tacit knowledge. This reflects the state of the practice and mirrors the pragmatic and realistic orientation of project teams and not necessarily a judgment on theoretical assumptions about the value of tacit knowledge. The consequence of this finding for practice is that project teams, to deliver results, need to focus more on applying knowledge. Whether this should be applicable in other organizational forms such as communities of practice and task groups should be a subject of future research. For example, other organizational forms may focus more on the interpretative and assimilative (tacit) dimensions.
- The innovative capabilities of project teams are mostly exploited during the assimilative (preparation) and reproductive (implementation) stages. By implication, project managers should implement project techniques that transition and embed group and individual knowledge into everyday project processes to spurn innovation. Team members should capture knowledge on the go using project tools, and ensure they are shared widely to enhance knowledge diffusion in the project team.

Limitations of the study

This work has focussed only on projects. There are many organizational forms, aside from the project organization. It is possible that the results of this study, and what has been found to be applicable to project teams, might not hold for other work groupings such as task groups, meetings, communities of practice and other collaborative forms. It has been noted elsewhere in literature that knowledge management implementation is context-specific (Inkpen and Dinur, 1998; Thompson and Walsham, 2004; Tuomi, 1999; Nonaka *et al.*, 2000), therefore requiring that organizations adapt models to suit the peculiarities of their organization. However, the results of this study require closer attention by these other organizational forms, as there could be comparable features that could be extrapolatable to their contexts especially given the wide geographical coverage of this research.

Second, the data collected and analyzed are entirely quantitative and have no qualitative features. It is possible to have assigned objective measures entirely to things which are subjective. In that sense, there was no way to have explored these subjective dimensions. However, one strength and relevance of this quantitative study is that it fills the gap in literature and enriches the quantitative and empirical basis for the tacit–explicit categorization of knowledge, and the social construction of knowledge where in the past, quantitative research on this subject have been few and far between.

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Appendix 1

Table AI Model constructs/questionnaire items

Category	*Alignment to project cycle*	*Definition*	*Questionnaire items*
Interpretation	Identification	This is the stage at which project teams are constituted, brought together to achieve a specific objective. Project ideas, principles, objectives are put on the table for common interpretation. Common interpretation is the platform for the project	We consider a knowledge management process at the initial stage of the project Change management is a factor in our project planning We conduct a risk analysis of our project at the planning stage We estimate the time necessary for completing various aspects of the project Our project defines what constitutes success for this particular project We reviewed similar project reports/lessons learnt in the past before planning this project We also conduct feasibility studies at the commencement of the project We consider the experience and qualifications of staff seriously before assigning them to any project Best practices are a very important aspect of our project considerations We had information management plans put into place at the beginning of the project
Assimilation	Preparation/ development	Project team members collaborate and work with commonly accepted (interpreted) symbols, mental models, frameworks and principles. These are internalized (assimilated), even if temporarily, to implement the project	There was/is a lot of team work during the project Team members helped each other learn on the project and newcomers especially were able to learn from others on the job We held/hold regular progress meetings to review work done, brainstorm and to correct mistakes and also plan ahead for the project There was the presence of informal groups/communities within the project Team members are also allowed and encouraged to communicate with other similar external projects to gain knowledge Project team members are encouraged to share what they know and there are technologies that encourage them to document and share (please also complete the knowledge management technologies section)
Reproduction	Implementation	This is the stage at which the project is implemented using knowledge resident in the project and team members. The unique feature of this stage is the replication of knowledge (utilization)	Knowledge gained from group collaboration, discussions and sharing were critical to executing this project There were attempts to translate innovative ideas into practical equivalents during the execution In my estimation, our project created new knowledge during its lifecycle The project leadership was very critical to its success The team work on this particular project was adequate in helping project delivery There was an issues management process which enabled project staff to identify concerns and raise them appropriately to leadership for necessary action

(*continued*)

Table AI

Category	*Alignment to project cycle*	*Definition*	*Questionnaire items*
			We had a quality management procedure in place to ensure the project adhered to accepted standards There was also a Work Breakdown Structure in place to ensure that various aspects of the project were successfully assigned to competent staff I would consider our project a success from the point of the stated objectives at the commencement of the project The project also met the cost, schedule and time requirements of the stakeholders
Codification	Evaluation	Here, the knowledge used during the project and lessons learned are documented (codified). Project reports, lessons learned reports, repositories, FAQs, blogs, success stories and many other outputs from projects constituted useful project knowledge in codified form	The project was analyzed at the end against stated objectives and stakeholders views We have a system/process put into place to review our projects We maintain a repository/documentation/reports detailing the activities that went on from the identification to the evaluation stage of the project This report is available for project members and other interested parties Staff who have been reassigned to other projects could also be reached when questions regarding the project come up

Appendix 2

Table AII Project outcomes/questionnaire items

Category	*Alignment to project cycle*	*Definition*	*Questionnaire items*
Innovation	All stages of the cycle	This variable explores new things (ideas, products, processes and outcomes) that happen in the project as a result of collaboration	We usually generate new ideas on a project We often stumble on new things as a result of relating with our team members New ideas are welcome and implemented in the team by team leaders
Project success	All stages of the cycle	This variable explores the linkages between social (team) collaboration and the successful outcome of the project	Our project succeeded because of collaboration among team members We attribute the project's success to knowledge sharing and collaboration among team members In my opinion, I can say that our project succeeded
Operational efficiency	All stages of the cycle	This variable explores project's perception of how better their processes are running due to increased collaboration and knowledge utilization	Our projects complete on time because of team cooperation Our project met the specific timelines given by the stakeholders
Generation of new knowledge	All stages of the cycle	This variable explores project's perception about the generation of new knowledge from collaboration	Team relationships impact on the quality of work we deliver on the project Our processes run efficiently and is understood by majority team members
Timely completion	All stages of the cycle	This variable explores the impact of collaboration and knowledge sharing on timely completion of projects	We have learnt new things on this project which we can transfer to future projects We document lessons learned in order to adjust future work The lessons learned are made accessible to all stakeholders

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