Knowledge creation measurement methods

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Abstract

Purpose – *This paper sets out to examine the operationalisation of knowledge creation. Given the importance of knowledge creation for national and corporate wealth, assessing its measurement is a valuable exercise; however, current research utilises a range of measures, and this lack of agreed construct operationalisation is a barrier to robust empirical investigation. This paper aims to review current measurement methods and to construct a taxonomy of knowledge creation measures.*

Design/methodology/approach – *A four-step classification method is followed. In order to generate information on the essential properties of measurement methods, relevant empirical research is reviewed and a content analysis performed on the resultant measures. The literature review includes key-term searches on bibliographic databases, yielding a sample of 63 empirical papers that incorporated knowledge creation measures. Both of the authors independently created a cognitive map of these measures based on three different attributes.*

Findings – *The main contribution of the paper is the development of a hierarchical taxonomy of knowledge creation measures. This taxonomy, in which movement up the hierarchy provides broader conceptual classification and movement down provides conceptual refinement, advances knowledge creation research by categorising measures in a way that facilitates assessment against existing comparable definitions.*

Research limitations/implications – *The limitations of the research stem from issues of bias. In addition to sampling bias, some bias may have entered the coding with respect to placement of measures into process or output categories.*

Originality/value – *The research has significant implications for future research in knowledge creation: the taxonomy facilitates consistency between knowledge construct definition and measurement, and differentiation between knowledge creation and other, related constructs, such as innovation. Such a taxonomy makes it easier to clarify similarities and differences among knowledge creation measures, develop new propositions for future investigation, and identify neglected areas of study.*

Keywords *Measurement, Knowledge organizations, Knowledge management*

Paper type *Research paper*

Creating knowledge provides value to organisations and the potential to create and sustain competitive advantage (Boisot, 1998; Bryant, 2005; Grant, 1997; Spender, 1996; Tsoukas and Mylonopoulos, 2004). The importance of knowledge creation abilities is emphasised in knowledge-based views of the organisation, advocated by researchers such as Spender (1996), which hold that the two predominant goals of organisation are the generation and application of knowledge. As noted by (Tsoukas and Mylonopoulos, 2004), an organisation that has the ability to create knowledge on an ongoing basis has developed a capability that is dynamic and unique and that potentially underpins continuous organisational learning. This is supported by empirical findings that knowledge creation is critical to a range of organisational processes supporting competitive advantage, including new product development and dynamic capability evolution (Brockman and Morgan, 2003; Smith *et al.*, 2005; Swan *et al.*, 2002, Vissers and Dankbaar, 2002; Zollo and Winter, 2002). Unlike knowledge, which is often rare for a limited period (Peteraf and Barney, 2003), as organisations develop and implement routines to create new knowledge their

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expertise becomes increasingly rare, socially complex and causally ambiguous (Coff, 2003; Lippman and Rumelt, 1982).

Since the recognition of the importance of knowledge to firm competitive advantage, several studies have been undertaken investigating knowledge management, yet while the effects of knowledge on competitive advantage (Eisenhardt and Santos, 2002; Grant, 1996), and knowledge sharing and transfer has been researched widely, there remains a dearth of information regarding knowledge creation processes (McFadyen and Cannella, 2004; Un and Cuervo-Cazurra, 2004). One of the explanations for this is the notable definitional and measurement problems that have plagued knowledge creation research (Droge *et al.*, 2003, Madhavan and Grover, 1998). Current research utilises a range of definitions and measures that encompass constructs ranging from process to outcome, and measures from interpersonal behaviour to patent citations (Almeida and Phene, 2004; Bryant, 2005; Hoegl and Schulze, 2005).

In this study, the authors attempt to advance the research on knowledge creation by responding to calls to develop a clearer conceptualisation of knowledge creation and to build consistency in its operationalisation (Lever, 2002; Malecki, 1997; Marjaro, 1988). A lack of agreed measures for knowledge creation has both research and operational implications. Agreed conceptualisation and accurate measurement facilitates robust empirical research and enables comparative analyses, and ultimately the legitimacy of research in this field is dependent upon the ability of the researcher to adequately define and measure knowledge creation (Schoenfeldt, 1984). A lack of agreed construct operationalisation leads to empirical difficulties, as research results may vary depending on the measure utilised and limit comparison between and generalisability across organisations (Droge *et al.*, 2003; Madhavan and Grover, 1998; Schriesheim *et al.*, 1993).

In addition to constraining research progress, the absence of agreed knowledge creation measures leads to important operational difficulties. Evaluating knowledge creation competence is a significant and complex demand for many organisations, and it relies on the ability to measure the activities and factors that comprise and influence knowledge creation capabilities (Frenkel *et al.*, 2000). However, the complexities embodied in knowledge work significantly constrain the ability of organisations to manage knowledge creation, which is largely related to the nebulous and contentious nature of knowledge and knowledge creation.

Knowledge possesses specific characteristics, including tacitness, subjectivity and embeddedness, that impose barriers to its identification and evaluation (Chua and Goh, 2008). The processes involved in knowledge creation are not only organisation-specific, but also socially complex (Coff, 2003). The highly tacit and causally ambiguous nature of knowledge creation makes the causal link between components, behaviour and performance difficult to identify, and therefore imposes limitations on measurement (Lippman and Rumelt, 1982). In addition, the process of knowledge creation – symbolic analysis (Reich, 1993) – means that the employee controls and owns the means of production (Drucker, 1998). While these complexities bestow competitive advantage, they also present significant management challenges because the process of knowledge creation is almost impossible to monitor and, therefore, to influence effectively (Despres and Hiltrop, 1995). Typically, the response to situations such as these is to establish contracts that include rewards for achieving desired outputs and penalties for acting in ways that do not progress the organisation's goals (Jensen and Meckling, 1976), however a lack of agreed measures limits management ability to specify requirements regarding knowledge creation outputs or outcomes.

This paper's objective is to categorise the methods utilised in knowledge creation research, with the dual aim of clarifying the range of concepts that are investigated as knowledge creation, and facilitating consistency between definition and measurement. These aims are achieved by undertaking a review of literature relevant to the operationalisation of knowledge creation and developing a taxonomy for measures of knowledge creation. While a range of different measures for knowledge creation have been developed and utilised, no

taxonomy has been developed that categorises the array of extant measures and specifies distinctions among them. The explosion in, and diversity of knowledge creation research (McFadyen and Cannella, 2004; Un and Cuervo-Cazurra, 2004) and the acknowledged role of taxonomies in the advancement of understanding (Merton, 1964), indicates the need for a comprehensive taxonomy of knowledge creation measures.

A framework for investigating knowledge creation measurement

In order to provide a basis for reviewing knowledge creation measures, a definitional framework must be agreed that reflects the theoretical content domain of the construct (Anastasi, 1982; Nunnally, 1978; Nunnally and Bernstein, 1994). A clear specification of the total content universe that is relevant to knowledge creation allows for representative measures to reflect the meaning of each knowledge creation dimension (Carmines and Zeller, 1979; Nunnally, 1978). However, the term knowledge creation is both ambiguous and lacks a single agreed definition. Much of the relevant theoretical and empirical research into knowledge creation is developed from a conceptualisation of knowledge and does not define knowledge creation separately (Droge *et al.*, 2003; Kess and Haapasalo, 2002; Smith *et al.*, 2005). This reference does little to aid the operationalisation of knowledge creation, as the definition of knowledge remains the subject of debates delving into the rationalistic utilisation of the word ''knowledge'' as a noun to identify an objectively-knowable factual object versus the word ''knowing'' as a verb to identify a socially constructed, performative concept (Brown and Duguid, 2001; Piaget, 1969; Spender, 1996), as well as debates on the difference between knowledge-that, reflecting knowledge that can be represented in objects such as documents and other ''repositories'', and knowledge-how, encompassing knowledge as interpretation, process and relationship, and largely not symbolically representable (Argote and Ingram, 2000; Garavelli *et al.*, 2002; Gourlay, 2006; Kakihara and Sorensen, 2002).

Research studies that do include a definition of knowledge creation demonstrate a wide-ranging conceptual coverage, depicting knowledge creation as a series of activities or process, as the output of such processes, or as a value-adding outcome such as an exploited new product, service or process.

When defined as a process, knowledge creation refers to the initiatives and activities undertaken towards the generation of new ideas or objects, for example, Styhre *et al.* (2002) describe knowledge creation as the utilisation of complex and discontinuous events and phenomena to deal with collectively defined problems. Knowledge creation as a process is defined in terms of the method or means through which knowledge is created and can be differentiated from the end result, or output. When defined as an output, knowledge creation refers to the development of new ideas that reflect a significant elaboration or enrichment of existing knowing (Parent and Gallupe, 2000); for example, Johnson (2002) describes knowledge creation as the difference between what is known and what must be known for project success. Knowledge creation as an output is defined in terms of an immediate product of the knowledge creation process, such as the representation of an idea, and can be differentiated from its impact on the organisational system, or outcome. Knowledge creation as an outcome means that new knowledge is diffused, adopted and embedded as new products, services and systems (Argyris and Schön, 1996; Nonaka, 1994; Phan and Peridis, 2000); for example, the assimilation from the outside of new codes and routines

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(Phan and Peridis, 2000). Knowledge creation as an outcome is defined in terms of a value-adding object.

Definitions of knowledge creation as a process, output and outcome reflect models of a knowledge creation value chain in which each sequence in the chain contributes additional value in terms of organisational performance and competitive advantage (Carlucci *et al.*, 2004; Cooke, 2005; Holsapple and Singh, 2004; Lee and Yang, 2000). In developing a framework for investigating knowledge creation measurement, the authors chose to adopt the most inclusive definition, capable of accommodating each sequence in the knowledge value chain and therefore the range of knowledge creation efforts that may be expected in an organisation. To achieve this, the authors developed a single integrated definition knowledge creation, and separate component definitions of knowledge creation as a process, output and outcome. The definition of knowledge creation as chosen to guide this review was ''the generation, development, implementation and exploitation of new ideas''. This definition captures the initiatives and activities undertaken towards the generation of new ideas, assessed as significantly different from extant knowledge, which, in turn, provide a conceptual basis for the generation of value-adding objects such as routines, products, publications or services. Within this single integrated definition, the process component of knowledge creation is defined as ''the method through which new ideas are generated, incorporating activities, interactions and other organisational mechanisms'' (Styhre *et al.*, 2002). The output component of knowledge creation is defined as ''the generation of enriched new ideas, manifest as, for example, a description, graphic or verbal depiction''(Johnson, 2002; Parent and Gallupe, 2000), and the outcome component is defined as ''the generation of an object, which is demonstrable, such as a routine, prototype or publication, and which represents the realisation of a new idea'' (McFadyen and Cannella, 2004; Nonaka *et al.*, 1994).

Method

Research on systematic review and classification directed the method used in this study. Systematic review, defined as an exhaustive literature search of topic relevant studies, plays a significant role in evidence-based practices and is regarded as a fundamental research activity (Denyer and Neely, 2004). The components of a successful review include the development of clear objectives and methods, search of all potentially relevant articles, the use of specified criteria in the selection of articles for inclusion and synthesis of individual studies using an explicitly analytic framework (Tranfield *et al.*, 2003). With reference to the latter component, Fleishman and Mumford (1991) describe four steps required to generate a framework:

1. Specification of the domain of objects to be classified.
2. Definition of the essential properties of objects lying in this domain.
3. Appraisal of the relative similarity of these objects to each other on the basis of the properties identified.
4. Specification of processes for determining assignment to a category.

The domain of in this research is methods used to measure knowledge creation, and the objective is the development of a taxonomy of measurement methods. In order to generate information on the essential properties of knowledge creation measurement methods, the relevant empirical research was reviewed and a content analysis performed on the resultant measures. A summary of the review steps is presented in Table I. The literature review included key-term searches on the following bibliographic databases:

- Emerald Library;
- ABI Inform;
- Business Source Premier;
- JSTOR;

Table I Review strategy

Step 1	Establish the domain of objects to be reviewed and the objectives of the review
Step 2	Undertake search of electronic databases
Step 3	Content analysis of data set
Step 4	Specification and confirmation of taxonomic categories
Step 5	Specification of criteria for assignment to categories. Sorting of measures.
Step 6	Review measures against taxonomic framework

- ScienceDirect;
- PsychINFO; and
- Wiley Interscience.

The two main criteria for selection were:

1. that the research study specifically describes knowledge creation as a key issue for investigation; and
2. that the research study incorporate the description and utilisation of a method to operationalise intra- or inter-organisational knowledge creation.

Decisions were made to omit conceptual papers and methods that were not clearly specified.

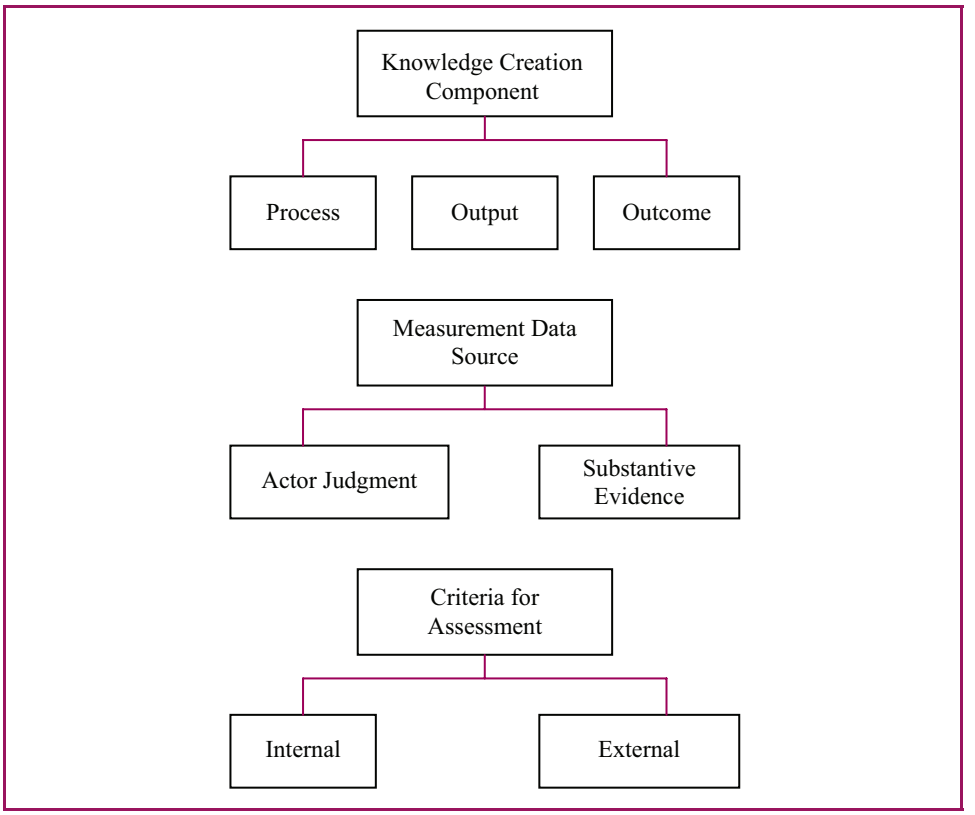
The sample consisted of 63 empirical studies investigating knowledge creation. The criteria of ''theoretical saturation'' was adopted to guide sampling decisions, which directs the researchers to extend their sample until they are confident that no additional data can be found that contributes to the development of properties of a category (Adams *et al.*, 2006, Glaser and Strauss, 1967). The review process was continued until the contribution of further studies was perceived to add insignificant value. Research grounded solely in one type of journal was perceived as a threat to the generalisability of findings and therefore the sample was taken from empirical research reported in publications from diverse management streams published between 1994 and 2007. With this heterogeneous sample, an array of knowledge creation measures were captured and analysed and a broad range of different measurement types were identified. Knowledge creation researchers designed and employed a variety of survey instruments and interview schedules to measure knowledge creation process, many of which utilised Nonaka's (1991) socialisation-externalisation-combination-internalisation model (Camelo-Ordaz *et al.*, 2004; Chou and He, 2004; Nonaka *et al.*, 1994, Schulze and Hoegl, 2006; Teerajetgul and Chaoenngam, 2006).

Case study methods were also used to analyse inter- and intra-organisational knowledge creation processes (Inkpen, 1996; Sherif and Xing, 2006). Knowledge creation outputs were measured as enriched, unique new ideas, design options, alternative future scenarios and problem solutions (Beech *et al.*, 2002, Bergman *et al.*, 2004, Bryant, 2005, Fong, 2003). Researchers used a range of factors to measure knowledge creation outcomes including successful patent applications and citations, publications in scholarly journals and journal impact factors, new products, prototypes and routines (Almeida and Phene, 2004; Malhotra and Majchrzak, 2004; Matusik and Heeley, 2005; McFadyen and Cannella, 2004; Sigurdson, 2000; Styhre *et al.*, 2002).

Both of the authors independently created a cognitive map of these measures. This map established three different attributes on the basis of which measures differed (Figure 1).

On the basis of these attributes, the authors established the dimensions of a working taxonomic framework. Once the taxonomy was established, two coders independently assigned each of the knowledge creation measures to a taxonomic category. The authors trained the two independent coders in the nature and use of the knowledge creation measures classification scheme. The coders worked separately and categorised each measure according to each dimension of the taxonomy. To check for coding reliability, the measures were split into two groups. Agreement between the two coders was

Figure 1 Cognitive map of measurement method attributes



assessed for the first 24 measures and then for the remaining 39 measures. Agreement between the two authors for coding of the first group was 83 per cent and for the second group it was 90 per cent.

Taxonomy of knowledge creation measures

The taxonomy incorporates measurement classifications nested under three hierarchical levels (Table II). The first attribute distinguishes between knowledge creation measured as a process, output or outcome, and was identified a priori on the basis of the existing definitions of knowledge creation. This attribute, termed ''knowledge creation component'', differentiates measures on the basis of the element, or sequence in the knowledge creation value chain (Holsapple and Singh, 2004), at which they are directed.

As a process, knowledge creation is measured in terms of the means through which knowledge is generated and can be differentiated from the end result, or output. Measures oriented to capture knowledge creation as a process assess the steps or activities undertaken in pursuit of new knowledge, such as, for example, the use of metaphors to externalise knowledge (Teerajetgul and Chaoenngam, 2006). As an output, knowledge creation is measured in terms of an immediate product of the knowledge creation process, such as the representation of an idea, and can be differentiated from its impact on the organisational system, or outcome. Measures oriented to capture knowledge creation as an output assess the immediate product of knowledge creation efforts such as, for example, a spoken idea (Beech *et al.*, 2002). Knowledge creation as an outcome is measured in terms of a value-adding object. Measures oriented to capture knowledge creation as an outcome assess the manifestation of an object, such as a changed routine or product prototype (Malhotra and Majchrzak, 2004).

Table II Taxonomy of knowledge creation measures

Knowledge creation component	*Data source*	*Criteria*	*Definition*	*Example*
Process measures	Actor judgment	External	Measures based on non-participant categorisation of processes associated with knowledge creation	Observational assessment of actor participation in knowledge-creating processes (Nonaka, 1994)
		Internal	Measures based on participants' subjective categorisation of the immediate output of knowledge creation processes	Participant interviews assessing knowledge-creating processes in joint ventures including technology transfer, joint venture parent interactions and personnel movements (Inkpen, 1996)
Output measures	Actor judgment	External	Measures based on non-participant categorisation of the immediate output of knowledge creation processes	Enriched ideas coded by experienced research- and hypothesis-blind researchers (Parent and Gallupe, 2000)
		Internal	Measures based on participants' subjective categorisation of the immediate output of knowledge creation processes	Telemedicine consultations coded as knowledge creating (Paul, 2006)
Outcome measures	Substantive evidence	Internal	Measures based on an internal organisational assessment of new operational resources including new product, service, routine or document	New product prototype development (Schulze and Hoegl, 2006)
		External	Measure based on external criteria argued to reflect knowledge creation – often argued to indicate value of knowledge created	Journal impact data (McFadyen and Cannella, 2004)

Two additional attributes emerged a posteriori on the basis of analysis of the data generated through the literature review, which is a valid method for constructing typologies (Rich, 1992).

The second attribute, termed measurement data source, differentiates measures based on whether the source of data is substantive or based on actor judgment. This attribute distinguishes between knowledge creation measures on the basis of the source of the information used to categorise events as knowledge creation. Measures based on actor judgment assess knowledge creation on the basis of individual or group perception of, for example, the generation of knowledge in the form of ideas (Un and Cuervo-Cazurra, 2004). Measures based on substantive evidence assess knowledge creation on the basis of the existence of a tangible or verifiable object or change such as a new product or a new routine (Hoegl and Schulze, 2005). Measures of knowledge creation process and output are based on actor judgment. Outcome-oriented measures are based on substantive evidence in terms of data source. Within both of these (data source) categories, a third attribute differentiates measures based on whether the criteria for assessing knowledge creation is internal or external.

The third attribute, termed measurement criteria, differentiates measures based on whether knowledge creation is determined with reference to criteria independent of, or internal to, the knowledge creation event or organisation. When measures are based on actor judgment, this attribute distinguishes between measures based on actors that were internal to the knowledge creation events and measures based on actors that were independent of the knowledge creation events (objective actors, often research and hypothesis-blind).). When measures are based on substantive evidence, the measurement criteria attribute distinguishes between measures based on evidence that is internal to the organisation, such as the embedding of a new routine, and measures based on evidence that is independent of the organisation such as patent citations.

The three attributes are partially nested. Each measure can be categorised based on the primary attribute of knowledge creation component, either process, output or outcome.

Within this category, measures can be further classified in terms of the data source utilised, actor judgment or substantive object, and criteria for assessment, internal or external.

Process-oriented measures are based on an assessment of engagement in defined knowledge creating processes. Process-oriented measures reviewed were all based on actor judgment. These measures were either based on the judgment of actors internal to the knowledge creation event or external actors. The former category of measures utilised participants' subjective determination of their involvement in knowledge creating activities; for example, Nonaka (1994) utilised 38 items to measure managerial self-reported involvement in processes of knowledge creation incorporating socialisation, externalisation, combination and internalisation. The latter category of measures utilised non-participant investigators' objective determination of actor involvement in knowledge creating activities; for example, Nonaka and Takeuchi's (1995) observation of a bread-maker's failure to externalise tacit knowledge.

Output-oriented measures assess the immediate end result of knowledge creation process and utilised either actor judgment or substantive evidence as their data source (Bryant, 2005; Cross *et al.*, 2001, Styhre *et al.*, 2002). Measures based on actor judgment either utilised measures based on the judgment of actors internal to the knowledge creation event or external actors. The former category of utilised participants subjective determination of knowledge created; for example, Paul's (2006) assessment of telemedicine consultation as knowledge transfer, knowledge discovery or knowledge creation involved coding data from transcribed interviews with multiple key informants who participated in the consultations as either clinicians, administrators or IT professionals. Other studies attempt to objectify perceptual assessment, for example, Parent and Gallupe's (2000) experimental study into focus groups used the number of enriched ideas generated as the measure of knowledge creation. Enriched ideas were coded by experienced, research- and hypothesis-blind researchers, who were not involved in the consultations and judged as capable of providing an objective assessment. Subjective perception-based measures include, for example, Fong *et al.*'s (2007) investigation into design options for the refurbishment of a reservoir, which assessed participants' perceptions of enriched, unique ideas.

Outcome-oriented measures assess the value-adding objects or changes resultant from knowledge creation and are classified as operational in terms of data source. Operational measures determine knowledge creation either on the basis of internal, organisational criteria or external criteria. The former category use the development of new products, services and routines to assess knowledge created, for example, new product prototypes and new supply chain management services (Arnulf *et al.*, 2005; Cardinal and Hatfield, 2000; Kodama, 2007; Salisbury, 2001). The second category of operational measures employs an external frame of reference and determines knowledge creation based on criteria that are often also argued to provide a foundation for assessing the value of knowledge created. For example, McFadyen and Cannella (2004) utilised journal impact factor as a measure of the quality of knowledge created in scientific journal publications, arguing that frequent citations reflect the value of a publication to the scientific community, which can be extrapolated to reflect the quality or level of knowledge created. Similarly, patent citation rate has been used as a proxy for knowledge creation in a number of studies in which it is argued that successful patent applications ensure the knowledge is deemed valuable by qualified assessors (Ibert, 2006; Robertson *et al.*, 2003; Sigurdson, 2000).

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Implications, conclusions and future research

This paper provides a review of recent efforts to operationalise knowledge creation. The main contribution of this paper is the development of a hierarchical taxonomy of knowledge creation measures. In this study, the authors took the initiative by exploring the different measures currently used to investigate knowledge creation. This study is the first to review and categorise knowledge measures in response to calls for measurement consistency, and generated data leading to the development of three measurement orientations:

1. process;
2. output; and
3. outcome.

Knowledge creation is thus measured as:

- initiatives and activities undertaken towards the generation of new ideas or objects;
- new ideas that reflect a significant elaboration or enrichment of existing knowing; or
- knowledge that is diffused, adopted and embedded as new products, services and systems.

These categories can be divided on the basis of whether the source of data used to determine knowledge creation is actor perception or a substantive object or change, and further on the basis of whether knowledge creation is determined with reference to criteria external or internal to the organisation, or a subjective or objective judgment. This hierarchical taxonomy, in which movement up the hierarchy provides broader conceptual classification and movement down the hierarchy provides conceptual refinement, is a useful basis for making decisions about measurement. These findings indicate at least two potential applications, the first regarding consistency between construct definition and measurement, and the second regarding differentiation between knowledge creation and other, related constructs.

The measurement taxonomy developed in this paper facilitates knowledge creation operationalisation by categorising measures in a way that allows assessment against existing comparable definitions. For example, using an output-oriented definition of knowledge creation provides a sound underpinning for an empirical investigation measuring enriched new ideas. Similarly, measurement of new products, for example, should be clearly identified as a measure of knowledge creation outcomes, defined appropriately. A number of research studies have aligned the definition and measurement of knowledge creation. For example, Styhre *et al.* (2002) describe knowledge creation as the utilisation of complex and discontinuous events and phenomena, and as a set of components emerging from communication across interpersonal relationships. This description focuses on the process of knowledge creation, depicted as complex and relational. Their empirical work investigates the notion of care, a relational component of the knowledge creation process, which encompasses open communication, cooperation, commitment, and an ability to value the qualities of others, in the process of clinical drug development. In this study, the outcome, successful new product development is not directly measured, but is used to justify the location of the study.

Similarly, Johnson (2002) describes knowledge creation as the difference between what is known and what must be known for project success, and measure this as a calculation of the extent to which the technical objectives were achieved, against the potential extent of technological innovation. However, a comparative assessment indicates that the majority of researchers employ no definition or do not align process, output- or outcome-based definitions and methods of assessment. Examples also exist of research studies in which knowledge creation is defined in terms of one aspect of the knowledge creation value chain but measures capture more than one component as independent and dependent variables (Nerkar, 2003). It is suggested that future research into knowledge creation should be anchored by clear construct definition, specifying whether the process, output or outcome of knowledge creation (or a combination) is the subject of empirical investigation. A clear

conceptualisation of the knowledge creation construct is a first step in accurate operationalisation and delineates the parameters that guide measurement decisions.

The second application of the taxonomy generated through this research addresses the current overlap in terminology and measurement between knowledge creation research, and studies into related constructs such as innovation, defined as the process by which knowledge is directed towards competitive ends (Dodgson and Hinze, 2000). Like knowledge creation, indicators that have been used to measure innovation include patent citations and new product development (Dodgson and Hinze, 2000; Organization for Economic Cooperation and Development, 1996; Tsai, 2001). An issue stemming from the use of this definition, and voiced in previous research into knowledge creation, is the differentiation of this construct from other related constructs such as learning and innovation (Dodgson and Hinze, 2000). Both innovation and learning have been defined in terms similar to knowledge creation, extending from the generation of ideas through to their implementation. As with knowledge creation, the term innovation has been identified as ambiguous and lacking an agreed definition (Adams *et al.*, 2006).

While the majority of recent innovation research focuses on successful exploitation of new ideas (Department of Trade and Industry, 1998; Schoonhoven *et al.*, 1990), significant early research exists into innovation that encompasses the generation, acceptance and implementation of new ideas, processes, products and services (Ravichandran, 2000; Thompson, 1965). Innovation has also been described as a form of organisational knowledge creation (Nonaka, 1994). A similar ambiguity exists in the organizational learning literature. Learning has been variously defined as the process through which knowledge is created, as the development and implementation of solutions to organisational problems, and as the realised value of know-how and experience (Argyris and Schön, 1996; Kamoche, 1997; Kolb, 1976). While there have been significant efforts to integrate innovation, learning and knowledge creation, which have reaffirmed their inter-connection these have yet to generate agreement on differentiation, delineation or unity (Akbar, 2003). A thorough investigation of concepts related to knowledge creation is outside the scope of this paper; however, the similarity present across reviewed definitions indicates that a taxonomy of knowledge creation measures may provide a useful tool to analyse measures used in innovation and learning research.

Utilising the same measures for both constructs is conceptually problematic. Whether knowledge creation is a component of the innovation process, separate to the process of commercialisation, or a broader construct that incorporates innovation, both the definition and measures need to be differentiated from this and other similar constructs such as creativity. By separating the outcome of knowledge creation from the immediate output, the taxonomy developed in this paper potentially provides a basis on which to differentiate concepts such as the generation of a new idea, from the notion of innovation as value-adding knowledge creation outcome. Future research should investigate the relationship between each component of knowledge creation and related constructs, including innovation and creativity.

This research also has significant practical implications. Measuring what is organisationally valued and strategically important has been often advocated in management literature (Stewart, 1997); however, it is also recognised that there are often challenges associated with easily and accurately measuring these valued elements (Kerr, 1975). The identification of indicators to measure different knowledge creation components, process, output or outcome, provides organisations with the ability to assess and evaluate the contribution of each element to performance. The use of different knowledge management measurement elements has been linked to organisational ability to evaluate resource allocation efficiency (Chua and Goh, 2008).

Finally, this research makes a significant contribution to understanding the potential antecedents and consequences of knowledge components. The exact nature of how knowledge creation processes contribute to value-added outcomes remains under-investigated. Future research should investigate the connection between different

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knowledge creation components, particularly the extent to which knowledge creation outputs are antecedent to knowledge creation outcomes, and processes are antecedent to outputs. Such investigation would assess whether, as a process, knowledge creation reflects the activities undertaken towards the generation of knowledge outputs, and whether, as an output, knowledge creation is the constructive change in subjective knowing that provides a conceptual basis for knowledge creation outcomes. Future research could also investigate the factors that moderate or mediate the relationship between each component. Investigating the utility of this model would be useful both to establish the linkages between each component, and between components and other constructs.

There are some limitations to the findings reported in this paper. With content analysis, as with other methods, issues of bias, including sampling, coding, and reliability represent possible limitations to the research. For example, the review undertaken in this study was not comprehensive and measures of knowledge creation may fall outside the taxonomy developed. In addition, some bias may have entered the coding, perhaps particularly with respect to placement of measures into process or output categories. Future research should attempt to reduce both biases by using diverse coders and additional techniques for identifying measures.

Despite these limitations, this paper and the taxonomy developed within, provide an integrative and comprehensive tool for further testing and theory development. Such a taxonomy makes it easier to clarify similarities and differences among knowledge creation measures, develop new propositions for future investigation, and identify neglected areas of study. Without a valid taxonomy, scholars have learned a great deal about knowledge creation, however, most studies have focused on specified outputs or processes. What more can be learnt by utilising different types and combinations of measures? For example, which knowledge creation processes most effectively contribute to progress toward achieving knowledge creation outcomes? Knowledge creation research can be revitalized by the more comprehensive study of the various measurement types and levels in the taxonomy and by the simultaneous utilisation of different measurement types.

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