Application of Boundary Objects in Knowledge Management Research: A Review

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Abstract: Knowledge is considered to be a corporate asset, but in practice it is grounded in different organisational functions and is stored in repositories and in individuals' memories. Boundary objects have an important role in promoting knowledge sharing and transfer within and across social boundaries. These objects help individuals to learn from each other and to share their knowledge between and within groups. This study explores the nature of boundary objects as socio-technical constructs that relate to the practice of knowledge management. The researchers used a critical literature review of boundary objects use in the context of the knowledge management landscape. Relevant articles published in English between 2008 and 2018 were retrieved from Web of Science. Analysis of the selected studies indicated that boundary objects contribute significantly to the development of shared understanding, knowledge creation and innovative thinking. These objects play different types of role in supporting knowledge practices within and across organisations. The findings also show that, while performing similar enabling roles in different contexts, the impact and use of different types of boundary objects (i.e., semantic, syntactic, pragmatic and metaphoric) varied significantly. Boundary objects may also help to coordinate interaction in the absence of intended coordination by the actors. It is recommended that, in order to get maximum benefit from the power of boundary objects and to strengthen their role, it is important for an organisation to identify, create and facilitate its use in knowledge management.

Keywords: Boundary Object; Knowledge Management; Critical Review; Knowledge Management Practice

1. Introduction and Background

In recent years, organisations have been actively mobilizing their knowledge-based resources to create value in their business functions in a sustainable manner. This transformation changes the way people connect, collaborate, learn, and decide within and among organisations (North and Kumta, 2018). Therefore, knowledge has become an important resource of the contemporary organisations resulting both in the growth of knowledge workers and knowledge intensive organisations (Hislop, Bosua and Helms, 2018). Knowledge is explained as "a fluid mix of framed experience, values, contextual information, and expert insights that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the mind of knowers. In organisations, it often becomes embedded not only in documents or repositories but also in organisational routines, processes, practices and norms" (Davenport and Prusak, 1998 p. 5). Knowledge management is defined as "effective learning processes associated with exploration, exploitation, and sharing of human knowledge (tacit and explicit) that use appropriate technology, and cultural environments to enhance an organisation's intellectual capital and performance" (Jashapara, 2004 p. 12). In sum, managing an individual's knowledge and making it available as an organisational resource is at the core of knowledge management (Newell, et al., 2009).

In practice, since individuals within organisations do not hold every type of knowledge relevant to their organisation, they must interact and collaborate with other actors within and across organisations (Chen, Chen and Wang, 2014). To share, exchange, integrate and create new knowledge, individuals use artefacts known as boundary objects. These enable people to learn from each other, and to act as agents in co-generating, bridging and disrupting understandings, thus playing a role in making organisations more sustainable (Hawkins and Correia, 2017).

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The concept of boundary object arose from a study of information practices at Berkeley's Museum of Vertebrate Zoology (Star and Griesemer, 1989). The authors described boundary objects as translation devices capable of spanning intersecting social worlds, thereby helping to pave the way for effective communication, collaboration and cooperation. Star and Griesemer grouped boundary objects into four categories: namely, (1) repositories (e.g., ordered piles of objects), (2) ideal types (e.g., diagrams), (3) coincident boundaries (e.g., objects with the same boundaries but different contents), and (4) standardized forms (e.g., common communication methods).

Later, Carlile (2002) assigned three types of knowledge boundary to these categories of boundary object: (1) syntactic, (2) semantic, and (3) pragmatic. According to the taxonomy, boundary objects help to create particular contexts that help to translate, transfer and transform knowledge within a community of practice. Knowledge transfer is simply the processing of information, whereas knowledge translation is referred to as developing a common meaning to overcome interpretive differences between contexts (Tippmann, Scott and Parker, 2017). The knowledge transformation process refers to the conversion of knowledge into action and its application to organisational routines (Welo and Ringen, 2018).

Boundary objects, whether concrete or abstract, have different implications in different social worlds; however, the objects retain a common identity across the boundaries of these worlds. Boundary objects are characterised according to three dimensions: (1) interpretive flexibility, (2) the material/organisational structure, and (3) scale. In practice, researchers have focused mostly on interpretive flexibility; the other two dimensions have been less frequently discussed. More importantly, not every object is a boundary object. So, scale and scope should be considered in determining whether an entity functions as a boundary object in a given situation or not (Star, 2010). Furthermore, it may be possible that a boundary object works effectively in one context, but less well in a similar capacity in another context; and may even act as a hindrance to the sharing or transfer of knowledge (Kirby, 2006). Therefore, it is critically important to differentiate between 'designated' and 'in use' boundary objects for a specific context, and to select objects with reference to usability and adaptability to local needs (Levina and Vaast, 2005).

Boundary objects enhance communication among groups (Fong, Valerdi and Srinivasan, 2007; Huang and Huang, 2009) and help them to access knowledge that would otherwise be inaccessible. They are considered connectors between different groups and within communities, and allow them to improve their practices (Impedovo and Manuti, 2016) by sharing knowledge (Huvila, et al., 2017). Moreover, boundary objects contribute to learning in communities where people have diverse viewpoints and ways of working. Because of the effective role they play in communication and collaboration of information and knowledge sharing, these objects have got the attention of researchers from the field of organisational learning (Hawkins and Correia, 2017). In sum, boundary objects successfully contribute to the development of shared understandings, knowledge creation, and innovative thinking among diverse groups (Kanwal, et al., 2018). More specifically, their application is quite visible in various functions within organisations, such as computer-assisted tools (Forgues, Koskela and Lejeune, 2009), drawings, sets of rules, research projects (Kimble, et al., 2010), and organisational blogs (Daniel, Hartnett and Meadows, 2017).

The notion of boundary objects has become increasingly important in exploring the interaction between individuals and organisations. Researchers, e.g., Huvila, et al. (2017), have indicated that the study of Star and Griesemer (1989) received considerable attention from information and knowledge practices researchers.

According to Google Scholar, the study has been cited more than 6300 times by 2016. Recently, the citation of the paper has reached over 9600. This citation trend shows that research on the application of boundary objects in the information and knowledge landscape is increasing.

Scholars, especially from information sciences, management and engineering, and specifically in information technology and in computer supported cooperative work, have focused on the application of boundary objects in knowledge management practices (Trompette and Vinck, 2009). This critical review considers this growing trend and explores the extant literature, addressing two distinct but interdependent concepts; boundary objects and knowledge management practices. It contributes to discussions on the importance of boundary objects in knowledge management research, and suggests future research directions to expand the field.

The study aimed to explore the application of boundary objects in knowledge management research. To achieve this aim, the following four research questions were formulated:

RQ1. What types of artefact were theorized as boundary objects in knowledge management research?
RQ2. Which research strategies have been employed to investigate the role of boundary objects in knowledge management research?
RQ3. What is the role of boundary objects use in knowledge management practices?
RQ4. Which factors affect boundary objects in knowledge management practices?

The remainder of this paper is structured as follows: section two explains the research methodology chosen for this study; section three presents research findings; section four reports on findings; and section five provides the study's conclusions, followed by implications, limitations and directions for future research.

2. Research Methodology and Design

To achieve the study's aim, this research used a systematic selection of relevant studies, followed by a critical analysis of the selected studies. To retrieve relevant studies, we adopted a three-step strategy: (1) selection of keywords and formulation of search queries; (2) study inclusion and exclusion criteria; and (3) selection of relevant documents and data extraction. This strategy provided a systematic and transparent means of assessing and synthesizing the findings of relevant studies (Nunes, et al., 2009). Previous studies (e.g., Nunes, Kanwal and Arif, 2017; Sarka and Ipsen, 2017) also used the strategy to investigate similar phenomena in the knowledge management domain.

2.1 Search String

The first step in the extraction process was to produce a suitable query. For this purpose, the following string was developed: (("boundary object" OR "boundary objects") AND ("knowledge management")).

2.2 Inclusion and Exclusion Criteria

When conducting a critical literature review, researchers should explore all relevant journals, regardless of impact status. It may happen that a useful paper is published in a low-ranked journal because it did not fulfil the review standard of an impact factor journal (Jesson, Matheson and Lacey, 2011). So, this study considered all journals and conference proceeding indexed in the Web of Science database. The selection of single comprehensive database helps to avoid duplication issues (Dwivedi, et al., 2011).

For this study, journal articles and conference papers written in English and published between 2008 and 2018 were included. To ensure that all the selected studies were relevant, and that they addressed the research questions of this study, a set of inclusion and exclusion criteria was adopted (see Table 1).

Table 1: Inclusion and exclusion criteria

Included articles	Excluded articles
Available as full-text	Full-text unavailable
Published between 2008 and 2018	Outside the search timeframe
Written in English	Non-English research paper
Related to the research questions	Not related to the research questions
Articles in information and knowledge domain	Duplicate studies
Published in journals indexed in Web of Science	Review papers, editorial reviews, and book chapters

2.3 Search Strategy and Selection of Relevant Studies

After finalizing the inclusion and exclusion criteria, we used the search string shown in section 2.1 to search Web of Science. In total, the systematic search produced 513 records. After performing specific checks, and applying the inclusion and exclusion criteria, e.g., scrutinizing titles and abstracts, and checking duplication, redundancy, and unavailability of 14 full-text papers, finally 33 studies were selected for this critical review. A list of these studies are presented in Appendix A. Only those empirical studies were selected which addressed

the application and/or usage of boundary objects in information and knowledge domain. The entire process of the systematic extraction of the studies is sketched in Figure 1.

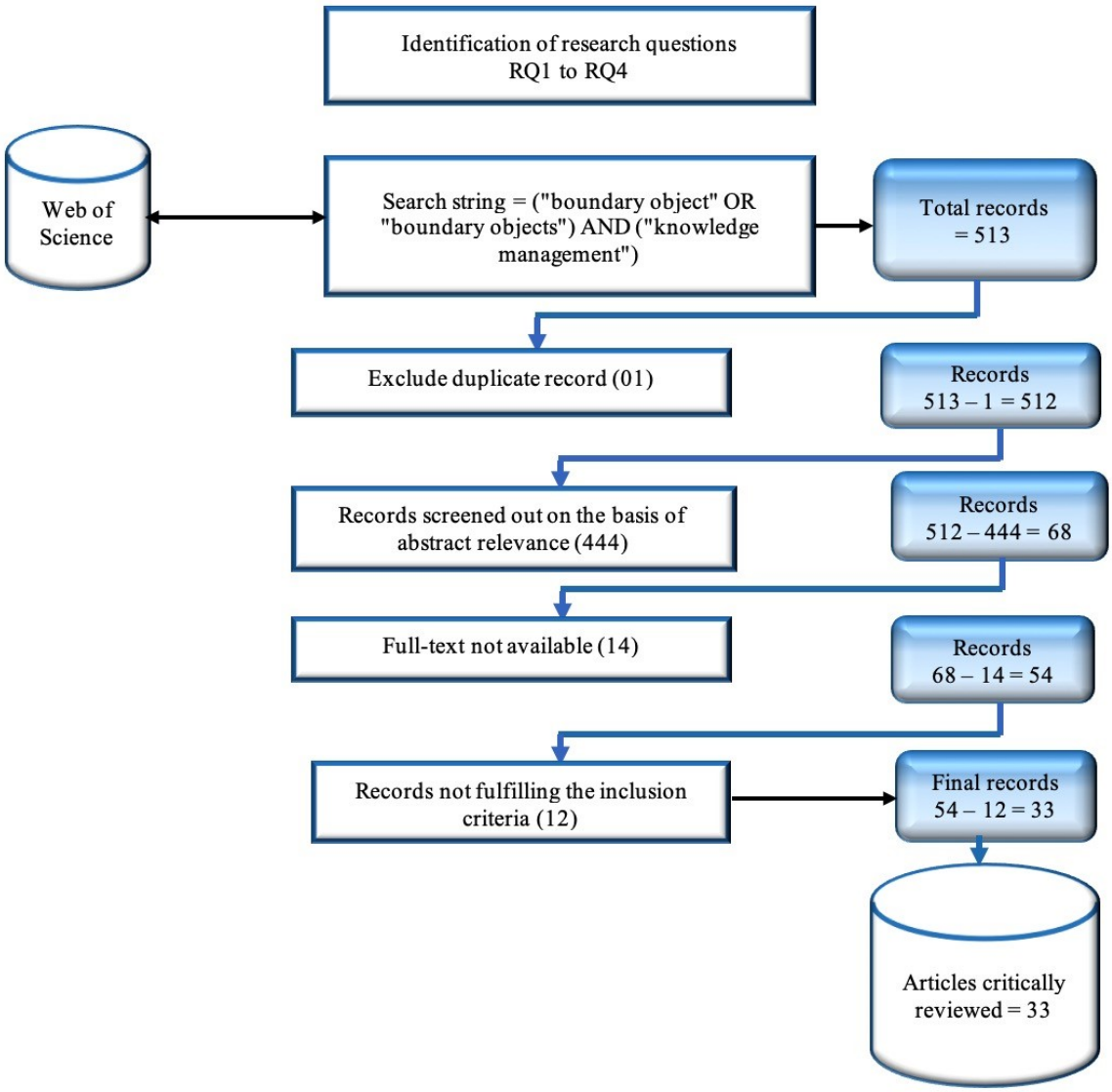

Figure 1: Study selection process

2.4 Analysis of Relevant Studies

A critical review should be original, insightful and analytical rather than a systematic attempt to gather and elaborate literature. For this, Jesson and Lacey (2011) outline three-step specific criteria; (1) fair selection of sources, (2) critically compare and contrast ideas and evidence, and (3) research gaps identification. Moreover, a priori coding process during the initial literature review helps to develop a conceptual framework for the phenomenon being studied (Nunes and Al-Mamari, 2008). Thus, for this study, a review and thematic analysis were carried out following the guidelines of Jesson and Lacey (2011) and Nunes and Al-Mamari (2008).

Specifically, the research reported in this paper critically analyzed 33 selected studies (Figure 1 explains study selection process) for methodological approaches, significant findings related to artefacts theorized as boundary objects, their role in knowledge management practices, and factors affecting the use of boundary objects in knowledge management practices. Furthermore, this research also identified research gaps and limitations in the selected studies and provided recommendations and future directions for research. The data extraction and analysis were completed using Microsoft Excel.

3. Research Findings

3.1 Artefacts Theorized as Boundary Objects

To answer RQ1, the selected studies were analysed to identify the artefacts theorized as boundary objects in knowledge management research. The artefacts that were interpreted analytically as boundary objects consisted of physical and virtual objects, and of activities. Table 2 lists the artefacts identified and the corresponding studies, presented in chronological order.

Table 2: Artefacts theorized as Boundary Objects

Artefacts: Boundary Objects	Reference
Diagrams, visual metaphors, charts, sketches	Bresciani, Blackwell and Eppler (2008)
Referrals, laboratory reports, instructions for specimen taking and specimen handling, routines and rules prototypes or practical tests, standards and documentation	Maaninen-Olsson, Wismen and Carlsson (2008)
Excel workbooks	Cacciatori (2008)
Process management model	Hayes and Fitzgerald (2009)
Repositories, standardized forms and methods objects, models, and maps, figurative language and symbolism, non-verbal expressions, and visionary objects	Huang and Huang (2009)
Computer-assisted collaborative tools	Forgues, Koskela and Lejeune (2009)
Coding, seminars and forums, and patient files	Kimble, Grenier and Goglio-Primard (2010)
Software specification and project management tools	Barrett and Oborn (2010)
Tasks for students on work placement	Garraway, et al. (2011)
Physical repositories, reports, databases, standardized forms, objects, models and maps, diagram, Gantt charts, milestone charts, Program Evaluation Review Technique (PERT) charts, project timelines drawings, sketches, figurative language and symbolism, conceptual objects, visionary objects, and nonverbal expressions	Huang and Huang (2011)
Decision support systems	Eastwood, Chapman and Paine (2012)
Virtual objects	Miller, et al. (2012)
Email and instant messaging	Peng and Sutanto (2012)
Operation research models	Franco (2013)
Physical repositories, reports, databases, standardized forms, objects, models and maps, diagram, Gantt charts, milestone charts, PERT charts, project timelines drawings, sketches, figurative language and symbolism, conceptual objects, visionary objects, and non-verbal expressions	Huang and Huang (2013)
Sketches, drawings, resumes, descriptions of customer wishes, spreadsheets, and economic calculations	Koch and Thuesen (2013)
Animated stories, images, documents, symbols, digital archives, storyboards, and records	Chen, Chen and Wang (2014)
Digital and physical modes of visualizing	Eppler and Pfister (2014)
Standardized forms, a prototype, and a collaborative workspace	Rehm and Goel (2015)
Model representations and conceptual artefacts	Fragou and Kameas (2015)
Management plans, a template for a management plan, an interim plan	Stange, van Leeuwen and van Tatenhove (2016)
Presentation, metaphors, memos, pictures and blueprints, and factory tour	Maenpaa, Suominen and Breite (2016)
Building information modelling	Oh, et al. (2016)
Value models	Bertoni, Panarotto and Larsson (2016)

Artefacts: Boundary Objects	Reference
	Panarotto, Bertoni and Bertoni (2016)
Digital online platform	Randhawa, et al. (2017)
Scorecard	Senyoni and Jorn (2017)
Organisational blogs	Daniel, Hartnett and Meadows (2017)
Agent based models	Reilly, Dillon and Guikema (2018)
Development planning	Dujardin, Hermesse and Dendoncker (2018)
Wadden Sea Barometer and the Waddenhouse Deliberation ranking.	van Enst, Driessen and Runhaar (2018)
Signature	Scoles (2018)
Ecosystem services framework	Steger, et al. (2018)

3.2 Research Strategies

To answer RQ 2, the selected studies were examined carefully to learn about the research strategies employed to investigate the application of boundary objects in knowledge management research. The findings disclosed that 19 studies (58%) applied a case study method and used several data collection tools, such as semi-structured interviews, observation, document analysis, and so on. A minority of the studies (27%) applied other research strategies, such as surveys, grounded theory, experiments, action research, and participatory design research. The remaining studies (15%) collected data through qualitative techniques and did not mention a particular research strategy. Overall, case studies seemed to be preferred to other methodologies, a finding which needs further investigation (Figure 2).

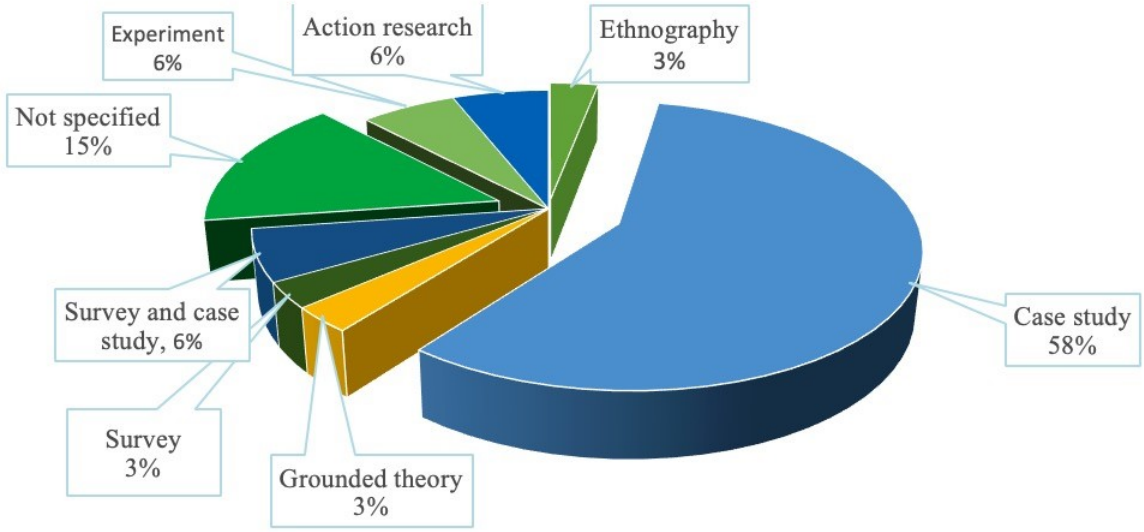

Figure 2: Research strategies adopted in the selected studies

3.3 Role of Boundary Object use in Knowledge Management Practices

The findings confirm the aforementioned argument that boundary objects support transfer, translation and transformation of knowledge between and among diverse social groups. The boundary objects are categorized under four knowledge boundaries; syntactic, semantic, pragmatic and metaphoric. The literature posited that under these knowledge boundaries, the boundary objects played various roles, such as mediator, facilitator, enabler, and platform during knowledge management practices in organisations and communities. The following sections address RQ 3 by discussing the role of boundary objects in knowledge management practices.

3.1.3 *Boundary object as mediator*

A key attribute of a boundary object reported in the literature is its role as a mediator. According to Senyoni and Jorn, 2017, boundary objects allow diverse actors to communicate and cooperate with each other. In a case study based on a health information system in East Africa, they found that a scorecard developed as a tool for managing maternal and child health, acts as mediator for communication and knowledge sharing amongst the collaborating organisations in different countries . The scorecard helped to overcome country differences and facilitated shared understanding between a variety of healthcare providers and recipients.

They also suggested that their findings could be useful in identifying unintended challenges to, or benefits of, the adoption of new knowledge according to specific country guidelines and practices.

Stange, van Leeuwen and van Tatenhove (2016) also indicated that in collaborative activities where actors have diverse knowledge and interests, boundary objects mediate knowledge exchange through their support of boundary activities. However, for an artefact to mediate collaborative activities between actors from different social worlds, there is a need to consider individual differences, goals and motivations connected with those activities (Randhawa, et al., 2017).

3.1.2 Boundary object as platform

The role of boundary objects as facilitators of knowledge management practices was highlighted by Daniel, Hartnett and Meadows (2017). According to them, boundary objects are evolving in nature, and their use is increasing over time. They explored the use of social media platforms and suggested that the platforms functioned as intra-organisational boundary objects because they enabled staff posted at various geographical locations and operating at different grades to share knowledge and develop new insights. However, boundary objects can operate not only across geographic and social boundaries, but also across boundaries arising from different competencies and backgrounds. Panarotto, Bertoni and Bertoni (2016), within the context of product-service systems, found that the value models that formed part of the design process, helped to facilitate cross-boundary discussion in the early phases of the design process, and to provide a common platform for knowledge sharing within a cross functional team.

From another aspect, in cross boundary knowledge sharing, the researchers studied the role of boundary objects through the lens of translation, transformation, and transcendence in the use and production of innovative knowledge during the course of cooperation. In addition to Carlille's studies (Carlille 2002, 2004), this study discovered the way that boundary objects used in knowledge sharing involve the transformation of conflicts into creativity, which ultimately resulted in transcendence of the artefacts' symbolic meaning and attainment of their cultural meaning. Transcendence involves the use of boundary objects to establish trust, tolerate conflict, and achieve a creative state. In their study, boundary objects used for this purpose included animation technology, laws and regulations, and conference records (Chen, Cheng and Wang, p. 2224).

Other good examples of boundary objects contributing to the conversion of tacit knowledge into explicit knowledge can be found in areas as diverse as agriculture and policing. A decision support system for precision dairy farming in Australia facilitated knowledge sharing among farmers (Eastwood, Chapman and Paine, 2012).

Furthermore, boundary object role was highlighted as platform in knowledge visualization process. In this context, the findings suggested that organisations are required to pay special attention while selecting an artefact as boundary object and should also consider its compatibility with the visualization software (Eppler and Pfister, 2014).

3.1.3 Boundary object as facilitator

Miller, et al. (2012) suggest that technology has the potential to transform social interactions and collaborative work if it addresses the needs of its users. They support the use of visual models to facilitate knowledge sharing among different social actors, and argue that these models allow knowledge to be shared across and between disparate stakeholder communities. Forgues, Koskela and Lejeune (2009) also focused on the role of technology in facilitating transformational learning. They found that boundary objects facilitate knowledge sharing in collaborative work by breaking socio-cognitive barriers. According to Bertoni, Panarotto and Larsson (2016), boundary objects serve many purposes in an IT project design by encouraging cross-boundary discussions. These objects contribute to innovative content by helping to negotiate hardware versus service

trade-offs. They can also reduce the amount of re-working arising from misinterpretation of requirements. In the construction industry, Oh, et al. (2016) note that boundary objects promote the knowledge sharing needed for collaborative activities such as building information modelling.

Problems arising from cross-cultural difference can also be addressed, in part, with boundary objects. Barrett and Oborn (2010) examined the role of software specification and project management tools in a Jamaican-Indian software team. They reported that, in some situations, use of boundary objects can be become a focus for conflict, and so reduce knowledge sharing. For example, in software development, the requirements specification and flexible use of timelines contributed to the exchange of tacit knowledge in the early phases of development. Later, however, "these project management tools as temporal boundary objects decreased attention on the collaboration needed in expertise coordination around the spec and led to an adverse impact limiting team interactions among themselves and with users (p. 1214)".

In another study, Peng and Sutanto (2012) explored the role of wikis, email and instant messages, teleconference interactions, and face-to-face interactions as 'boundary spanners. In this capacity, such media facilitate knowledge sharing, but the nature of the influence varies depending on the medium being used. As a result, apart from identifying the role of boundary objects, it is also necessary to ensure that the right boundary object for a particular set of circumstances is selected (Kimble, Grenier and Goglio-Primard, 2010).

Virtual boundary objects have been found to play a role in building development. The abstract representation of an idea in the form of drawings, spreadsheets, and economic calculations helps clients and construction companies to exchange ideas, leading to improved decisions (Koch and Thuesen, 2013). Other virtual boundary objects include documents of communications, negotiations and agreements at the beginning of the commercialization cycle. Hayes and Fitzgerald (2009) report that these may act as a structural intervention to decrease the likelihood of inter-occupational and inter-organisational miscommunication. Virtual boundary objects in the form of conceptual visualizations, for example, diagrams, visual metaphors, charts, and sketches, also support collaborative knowledge work and facilitate creation and the sharing of knowledge within teams (Bresciani, Blackwell and Eppler, 2008; Franco, 2013). Another example is an Excel workbook, which presents knowledge across occupations and provides memories that span projects (Cacciatori, 2008).

3.2 Factors Affecting the Role of Boundary Object

Many of the studies referred to above also mentioned factors which affect the role of boundary objects in knowledge management practices (RQ4). Several authors (e.g., Rehm and Goel, 2015) mentioned that these objects cannot always be used in isolation, but need to be linked with each other to mediate in the knowledge exchange or transfer process. For example, team members in an organisation regularly exchange knowledge about relevant and interesting aspects of their work. These exchanges may involve information generated from multiple processes that require formal and/or informal interactions with other units of organisations (Rehm and Goel, 2015). Moreover, multiple organisational factors can affect the formation and use of boundary objects. Randhawa, et al. (2017) discuss the importance of supportive leadership and motivations for transformation in objects, while factors that might adversely affect the use of boundary objects include cross-culture differences, negative image, lack of professional relationships among employees, and an atmosphere of mistrust (Barrett and Oborn, 2010).

Often, a relevant artefact is a standardized procedure made tangible in some way. However, an important consideration when using these standardized procedures is to create an appropriate link between organisational activities and knowledge management processes. Otherwise, knowledge management effort will result in waste of time and resources (Peng and Sutanto, 2012). The representational capacity of boundary objects is essential if they are to perform their functions. Boundary objects also need to have enough common structure to ensure consistency, but cannot be too structured, as they need to adapt to local needs (Cacciatori, 2008). Therefore, it is important to identify, create and facilitate the use of boundary objects specifically in relation to their environment, people and type of knowledge (Huang and Huang, 2009). Moreover, human brokers play an important part in using boundary objects to mediate in knowledge transfer (Maaninen-Olsson, et al., 2008). The role of brokers is also important in relation to the impact of boundary objects in knowledge sharing (Kimble, et al., 2010).

4. Discussion

This study critically reviewed the application of the emerging concept of boundary objects in knowledge management research and discussed some of the various types of object that have been identified as boundary objects. These objects can be categorized according to whether they operate at syntactic, semantic, pragmatic (Carlile, 2002, 2004) or metaphoric boundaries (Koskinen, 2005). Each category of boundary object performs differently, and the choice of artefact working as a boundary object depends upon on the context and nature of interactions (Huang and Huang, 2009, 2013). Various research strategies have been adopted to explore the use of boundary objects in knowledge management practices, with case studies proving to be the most popular.

Collaborative activities take place both inside organisations (among members), and with outside partners, customers and suppliers. During these activities, actors communicate and exchange ideas (Huang and Huang, 2013) and integrate professional knowledge, experience and skills into their business functions (Chen, et al., 2014). Some boundary objects have been found to facilitate this sharing process (Forgues, et al., 2009), not only across functional boundaries, but also across geographical ones (Peng and Sutanto, 2012). Where boundary objects enhance communication among actors, it is important to identify them and to encourage their use, taking into consideration their relation to their environment, to people and to type of knowledge (Maenpaa, Suominen and Breite, 2016). It is also suggested that consideration should also be given to circumstances which may lead to boundary objects limiting knowledge sharing (Barrett and Oborn, 2010).

Boundary objects have been found to work differently, according to context. Their different functions have been classified as (1) transference, (2) translation, (3) transformation, and (4) transcendence. Actors operating within an organisation whose exchange of knowledge leads to a mutual understanding in which interpretations are aligned, have overcome syntactic boundaries (Rehm and Goel, 2015). However, in activities where actors from different social worlds collaborate, the simple transfer of knowledge is not enough to achieve the collaborative goals of organisations and external communities (Randhawa, et al., 2017). In this type of situation, there is a need to recognize the difference in the agents' understanding and world views, and to select and employ boundary objects that can overcome semantic boundaries by acting as "translation devices" (Eppler and Pfister, 2014). However, to promote innovation, it is insufficient simply to span syntactic and semantic boundaries. To bridge different interests within and between organisations, and diverse perceptions of key issues, it is necessary to find means of overcoming pragmatic and metaphoric boundaries (Koskinen, 2005; Abraham, Aier and Winter, 2015). Often, various types of boundary objects come together to enable productive interactions and exchanges. Sometimes, an artefact on its own will be ineffective, but, in combination with others, it becomes part of a cluster that forms a boundary object. These clusters emerge from the interplay between artefacts, uses, practices, and knowledge (Rehm and Goel, 2015).

The research exposed the multiple factors affect the use and usability of boundary objects within and across organisations. Organisational factors that can have an impact on the formation and use of boundary objects include environmental factors, such as supportive leadership, level of motivation (Randhawa, et al., 2017), cross-culture differences, the quality of professional relationships, and the atmosphere and culture of organisations using the objects (Barrett and Oborn, 2010). In addition, the nature of boundary object itself is important. Cacciatori (2008) notes that it must have enough common structure to ensure consistency, but must be sufficiently flexible to adapt to local needs. Koskinen (2005) also discussed structure. According to him, when a boundary object is weakly structured, it can play a significant role in the sharing of tacit knowledge and understanding between the people involved. By contrast, when a boundary object is strongly structured, it can function as a coordinating mechanism in explicit knowledge communication. By implication, when a boundary object becomes more structured, it contributes less to creativity and to the communication of tacit knowledge.

The application of boundary objects is supported by brokers who help to ensure the objects' performance. The interplay between activities and boundary objects creates spaces within which actors share, transfer and translate their knowledge. In these spaces, actors learn from each other's interests and perspectives (Stange, van Leeuwen and van Tatenhove, 2016). Similarly, brokers play an important role in using boundary objects to mediate in the transfer of knowledge (Maaninen-Olsson, et al., 2008). The role of brokers is also important in relation to the impact of boundary objects on knowledge sharing. They have the power to make information

available to members of a particular community and can influence the direction of the community by controlling the flow of information (Kimble, et al., 2010).

5. Conclusions

The effective sharing of knowledge and information is vital. Since boundary objects contribute to that sharing, they too are important. A review of the extant literature reveals that there is lack of research exploring the current status of boundary objects in the knowledge management domain. This critical review sought to fill this gap by considering instances, based on 33 empirical studies, in which the highly theoretical concept of boundary objects was applied to knowledge management practices.

The findings confirmed that boundary objects enable different actors within and across organisational levels to share, transfer, exchange, and integrate knowledge into their work practices. Different types of boundary objects work across various knowledge contexts and boundaries. Each object has unique characteristics and is suitable for particular contexts and knowledge processes. The role of boundary objects can be extended with the support of organisational leadership, which can initiate activities at boundaries, and can enhancing the role of knowledge brokers. Boundary objects perform one or more of four roles: transference, translation, transformation, and transcendence and are subject to varying degrees of interpretative flexibility. The proposed classifications relating to boundary objects could help applied researchers and practitioners to make more informed decisions in their selection of socio-technical solutions for knowledge management.

5.1.1 Recommendations

This study also provides the following useful directions for future explorations of the role of boundary objects in knowledge management:

1. Researchers have tended to focus on the interpretive flexibility of boundary objects. Less attention has been paid to their structure and scope. These are aspects that would benefit from further investigation.
2. Additional research should be conducted to explicate how and why boundary objects operate, and to help identify and understand which factors enable or inhibit their capacity to perform their intended role.
3. Researchers should seek to identify the impact of different types of boundary objects in facilitating knowledge sharing in higher education, an area which has been neglected in the extant literature.
4. An in-depth analysis of knowledge sharing practices could help to improve understanding of the roles and characteristics of boundary objects from the perspectives of knowledge-based organisations perspectives.
5. There was a clear preference for case studies. Studies based on other research strategies, such as mixed-methods, might provide further details of the use of boundary objects in knowledge management.
6. In addition to looking at boundary objects, researchers should also examine the role of brokers in their selection and use.

5.1.2 Limitations

The main limitation of this critical literature review is the scope of the search. It reviewed only journal articles and conference papers written in English, and only those published between 2008 and 2018. In addition, the search was limited to just one database: i.e., Web of Science.

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