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A complexity theory-based management framework for virtual organisations

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This article describes a complexity theory-based management framework for virtual organisations. Specific focus is on a South African virtual organisation as a complex adaptive system. A case study strategy was followed, and multiple data sources used to generate theory. The findings describe the management of an organisation where technology replaces conventional face- to-face contexts for integration and assimilation. The article showed how managers create a virtual context for sharing meaning and interaction through synergy, empowerment, participation and an accountable, committed workforce.

Key words: Complexity theory, management, post-modern organisation forms, virtual organisations.

INTRODUCTION

Global changes have impacted the organisational landscape. As a result, managers face a daunting task in reconciling a multitude of macro-environmental influences such as innovation, fierce competition, shifting market structures and empowered consumers. Within this context, an organisation's survival depends on the ability to adapt in a dynamic way and to evolve with changes in order to seize opportunities (Saabeel et al., 2002) amidst uncertainty and unpredictability. In addition, micro-environmental influences have necessitated new means of coordinating actors across traditional organisational boundaries. This is attributed to the opportunities created by information technology (McGreevy, 2003; Siggelkow and Rivkin, 2005). Information technology has extended the reach of organisations and individuals to the extent that access to an unlimited wealth of resources without intervention from any central authority is feasible. Thus, new forms of organisations that differ from the classic, bureaucratic organisation in "most aspects" (Parker, 1992) continue to emerge in the 21st century.

Contemporary organisations are information-driven hubs of communication activity wherein the collective abilities of a workforce separated by space and time not only complicate organisational actions, but also pose numerous challenges to managers. Senge et al. (1999) confirm that "continuing challenges will tax collective abilities to deal with them", and thus advise a "drastic redress of current organisation practices to cope with contemporary predicaments". This means that, as organisation design adapts to the post-modern environment, management must adapt as well. In the classical (modern) organisations of the past, managerial efforts focused on overseeing the activities of people in fixed units. However, in post-modern organisations (such as the adhocracy, networked organisation and virtual organisation) managers are required to link people, opportunities and resources across organisational boundaries. Despite this, most organisations continue to take the same types of institutional actions they have always taken. By the year 2000, most management literature was still predominantly based on an "implicit assumption of stability" (Lissack, 1999). A decade later, this assumption remains largely unchanged.

An implicit assumption of stability is problematic as the rapidly evolving global society is no longer characterised by the apparent stability of past decades. Instead, it reflects extensive, rapid, and complex change. This extends to organisations as they function within the context of a specific society, and are therefore influenced by the societal context (Van Tonder, 2004). Likewise, because managerial activities reflect the context of organisation structure and the broader environment (Chapman, 2001), management approaches are also influenced. Managerial approaches that were effective in

Weber's classical bureaucracy are no longer viable in the flexible organisation forms emerging today. Weber's (1978) bureaucracy, characterised by specialisation, formalisation, centralisation, hierarchy and standardisation of organisation action, cannot facilitate the adaptive responses needed to survive in contemporary environments (Clegg, 1992) . Specifically, the collapse of space and time highlights the need for management approaches that enable more flexibility, coordinated communication and adaptability to address emerging issues as they arise.

The literature thus reveals a need for new management approaches. In post-modern organisations managers face an unremitting challenge to their capabilities in both the volume and complexity of factors to be reconciled (Fowler, 2003). Furthermore, rigid hierarchies in classical organisations have been replaced with more adaptable designs (Schultz, 2003), thus, shifting management's focus from control to coordination and integration. While the implications of classical management are strongly contested in the literature, recommendations for post-modern management are usually limited to postulations that correspond with the opposite of mechanistic management approaches.

To address these shortcomings, this article focuses on the virtual organisation as one manifestation of the post-modern organisation. In Byrne's (1993) seminal work, the virtual organisation is described as a network of dispersed individuals and organisations linked by technology to rapidly respond to turbulent environments and to exploit market opportunities in a continuously shifting environment. The virtual organisation is an information-intensive organisation form (Child and McGrath, 2001) that centres round the knowledge of workers (Walters, 2004). The nature of the virtual organisation exacerbates the need for revised management practices, because managers have to coordinate multiple transactions and tasks on the one hand, and a geographic and temporally dispersed workforce connected by virtual networks on the other. However, the outcomes of environmental influences, interactions within and between organisations, and constant technological innovation are unpredictable. Therefore, the meta-theory for the article had to provide for continuous change and consider the interdependent nature of a diverse web of interrelationships, interdependencies and interactions.

Complexity theory is therefore adopted to understand the virtual organisation and management thereof as a dynamic, non-linear, complex adaptive system. While the literature is clear on the implications and challenges for management, empirical research on how these are addressed in virtual organisations is mostly limited. Furthermore, research focussing on the management of South African virtual organisations is almost absent, as is research that approaches the virtual organisation as a complex adaptive system. While complexity theory is mostly used as a meta-theory to understand or study

organisations, this article further premises that organisations also need to function as complex adaptive systems to survive in turbulent times.

The purpose of this article is to propose a complexity theory-based management framework for virtual organisations. This is relevant as, while virtual organisations provide the flexibility and adaptive capabilities needed to sustain a competitive advantage, technology amplifies the range of influences that needs to be reconciled. Complex adaptive systems are sustained by the continuous exchange of resources between them and the environment. Likewise, organisations are sustained by the continuous flow of information. However, in virtual organisations the traditional context of coordination and assimilation, namely face-to-face communication, is replaced by technology. The article is therefore valuable in that it provides validated recommendations on how to overcome potential barriers by translating complex adaptive system behaviour into organisational and management terms, both theoretical and practical. As such, the objectives of this article are to first extend complexity science principles to organisation theory. Second, the article aims to describe the virtual organisation as a complex adaptive system, within a complexity theory framework. The third objective of the article is to describe management practices at SchoolNet South Africa, a South African virtual organisation, from a complexity theory perspective.

The final objective is to propose a complexity theory-based management framework for virtual organisations. To achieve these objectives evidence collected during case study research is reported. In line with these objectives, the article is divided into four sections. In the first section, background to the study is provided and conceptual development described to extend complexity theory principles to organisation theory. Secondly, an overview of the research design, methodology and procedures is given. This is followed by a summary of key results wherein the virtual organisation is described as a complex adaptive system, management practices are described and the theoretical management framework proposed. Finally, conclusions of the article are drawn, and areas of further research highlighted.

THEORETICAL AND CONCEPTUAL FRAMEWORK

In this section, an overview of the virtual organisation is provided and conceptualisation problems in extant literature highlighted. The meta-theoretical framework and multi- disciplinary conceptual development is then described. Finally, the virtual organisation and management are re-conceptualised for the purposes of this article.

As mentioned, Weber's (1978) bureaucratised, mechanistic, centralised structure of control is no longer a

viable option for organisations that must harness a multitude of factors amplified by technology and the subsequent interdependence of firms (Clegg, 1992). When internationalisation and de-industrialisation became increasingly evident in the 1980s, so too did organisational responses to these influences. Most notably, a new and distinct kind of organisation that differs from the classic organisation in most aspects began to emerge (Parker, 1992).

The result is a post-modern organisation structure that is functionally flexible with no clear centre of power or spatial location, such as the virtual organisation. Here, decentralisation and geographic dispersion affects the nature of work and ultimately management. It is emphasised, however, that despite marked differences from traditional bureaucracies, virtual organisations do not necessarily preclude traditional business methods, but the dominant method of doing business is heavily dependent on advanced information technology (Black and Edwards, 2000). However, previous research (Papastefanou, 2008) indicates that the virtual organi- sation does differ on all organisation design dimensions (the sub-concepts for this article discussed later) namely technology (including communication and information), structure, culture and strategy. Whereas Weber's classic (modern) organisation is mechanistic, hierarchical and centralised, new forms of organisation (post-modern organisations) are more organic and decentralised with flatter hierarchies. The virtual organisation, the focus of this article, is one manifestation of the post-modern organisation forms emerging in contemporary times.

The virtual organisation

The virtual organisation exists in cyberspace. It is a new organisation form that facilitates technological demands (Black and Edwards, 2000) . The virtual organisation is information-intensive (Child and McGrath, 2001), and centres round the knowledge of workers linked by technology across space and time. While a clear definition remains forthcoming (Kasper-Fuehrer and Ashkanasy, 2003 - 2004), there is general consensus that the virtual organisation is not a hierarchical structure but rather a type of network organisation. As such, it facilitates open access to and exchange of information throughout the network and across organisation boundaries.

The collapse of space and time in virtual organisations highlights the need for a management approach that enables flexibility, coordinated communication and adaptability to address emerging issues regarding a dispersed workforce. Therefore, virtual operations require organising efforts that move beyond efficiency and control to those that emphasise the ability to identify or create opportunities, and gather the needed players to

harness these opportunities. Definitions of the virtual organisation are ambivalent and lack clarity (Kasper-Fuehrer and Ashkanasy, 2003 - 2004) due to conflicting characterisations in the literature (Shekhar, 2006; Warner and Witzel, 2004). A primary problem in the literature is that virtual organisations are approached as technology-enabled extensions of traditional, structurally bounded organisations. Four additional reasons for conflicting views were identified based on a systematic review of the literature:

1. First, conceptualisation is based on the understanding of the term virtual, or degree of virtuality, where definitions imply that the virtual organisation is merely a binary concept which is either virtual or not (traditional/real-virtual continuum). This is evident in Bosch-Sijtsema (2002) who cites numerous definitions ranging from descriptions of the virtual organisation as a team within a single organisation, to a web company where different organisation partners combine resources and work through information technology. Divergent definitions result from research focused on different units of analysis when studying virtuality, such as the individual unit, the group unit and the organisational unit (Shekhar, 2006). However, accurate conceptualisation relies on this distinction because the degree of virtuality differs for each organisation type that displays different characteristics. This implies that the organisation processes of each need to be managed differently. For example, Katzy (1998) makes recommendations for the virtual organisation in general. The type of virtual organisation for which his recommendations are valid is unclear making them difficult to interpret and implement in practice.

2. Second, studies tend to be reductionist, with focus on one sphere of organisational activity generalised across the organisation. In this case, non-linear emergent properties are not apparent. It is for this reason that complexity theory was adopted to guide the study on which this article is based.

3. Third, definitions differ depending on whether a structural or process perspective is adopted, culminating in either an institutional (structural) or functional (process) view (Keinänen and Oinas-Kukkonen, 2001). The structural perspective (institutional view) focuses on constituent elements and features that differentiate the virtual organisation from other types (Keinänen and Oinas-Kukkonen, 2001; Saabeel et al., 2002). The functional perspective defines the functions and roles needed for the reconfiguration and renewal of the virtual organisation in response to changing customer demands or market conditions (Saabeel et al., 2002). Here, virtualness is a strategic characteristic used to enhance structures. For example, while Keinanen and Oinas-Kukkonen (2001) state that virtual "organising" focuses on the importance of knowledge and intellect in creating value, they are referring to the functional processes of knowledge leverage, not to how knowledge structures the

organisation (the post-modern processes discussed in the next section).

4. Fourth, there are two approaches commonly followed when defining the virtual organisation. These culminate in either intra-organisational or inter-organisational definitions (Kasper-Fuehrer and Ashkanasy, 2003-4; Scholz, 2000). Focus is then on either the intra-organisational challenge or on the inter-organisational question of how to define imaginary corporations as borderless systems (Scholz, 2000). As an intra-organisational form the virtual organisation is a collaboration of business units, such as cross-functional teams, in an existing organisation charged with completing a common task. These intra-organisational designs do not substitute traditional structures; rather, they are integrated into the extant design. As a result, intra-organisational boundaries are blurred and the degree of virtuality is low. In contrast, from the inter-organisational perspective business units of different organisations collaborate to establish a cooperative form, namely a virtual organisation (Kasper-Fuehrer and Ashkanasy, 2003-2004).

This article is based on an inter-organisational perspective to enable the identification of concepts for the "ideal-type" virtual organisation. To address these four sources of difficulty, the virtual organisation was re-conceptualised. First, the degree of virtualisation was considered to develop an in-depth typology for case selection. Secondly, analysis spanned the organisation dimensions discussed next. Lastly, structural and process descriptions of virtual organising were reconciled. Based on this, a multi-level conceptual framework grounded in organisation theory with additional concepts from complexity theory, such as flexibility and co-evolution, was developed to accomplish the aims of the article.

Complexity theory and multi-disciplinary conceptual development

In this article, the organisation is viewed as a complex adaptive system in accordance with the principles of complexity theory. Complexity theory "embodies a non-linear systems-oriented perspective that attempts to conceptualise and understand organisation systems at multiple levels in full recognition of the dynamic linkages and influences that operate within and between aspects of those systems levels through time and space" (Cooksey, 2001). This has numerous implications for both research and management.

Implications stem from the non-linearity of interdependent components. This means that the organisation cannot be studied or understood in terms of its constituent parts alone, or by focussing on what each unit does in isolation (Anderson, 1999). Complex adaptive system behaviour is induced not by a single entity but rather by the simultaneous and parallel actions

of agents by the system itself (Dooley, 2002). Behaviour of the system is therefore emergent, where emergence refers to the arising of new, unexpected structures, patterns, properties, or processes in a self-organising system.

The principles of self-organisation generate a new approach to management because emphasis is on adapting to rapid and constant change (Lichtenstein, 2000). The implication is that key managerial issues shift from maintaining control to supporting the emergence of a new order. This is because in complex adaptive systems organising is a mutually interdependent process between agents (actors). For this reason, seemingly disparate research perspectives and approaches, namely the post-modern research approach and structural and functional perspectives were integrated. The post-modern process approach emphasises "intricate patternings of relationships" (Chia, 1995), which are micro-organising processes, or micro-logics, that enact organisations. Micro-logics are "discrete behavioural process events" that bring about self-organisation and manifest an emergent reality. This can culminate in adaptations to organisation structure, culture and strategy (McKelvey, 1999).

Based on the above, the first stage in conceptual development involved the identification of organisation concepts or dimensions. In the second stage, these concepts were delineated into sub-concepts (indicators). The conceptual framework comprises the dimensions of organisation design, namely technology, structure, culture and strategy, each of which is mutually dependent. These concepts are "sets of forces in dynamic equilibrium among themselves" (Introna, 2001), which determine the forming of structure (Afuah and Tucci, 2003; Rybakov, 2001) and provide options for strategic and organisation adaptation (Lewin et al., 1999). Technology, organisation size and strategic choice are additional contingency variables that make the environment more complex than that implied by contingency theories. Contingency theories only address macro-level change without considering the co-evolutionary influence of the organisation on the environment, which is the micro-level influence (Dijksterhuis et al., 1999). By including both macro- and micro-level influences, the joint development of business environments and organisations, where both the internal and external organisational environment "canalises the forming of structure" (Rybakov, 2001), were addressed. This is aligned to the view of the organisation as a complex adaptive system.

Complex adaptive system behaviour depends on the organisation's openness to the environment as reflected in organisation design, technology, culture and strategy, as well as flexibility. Flexibility is related to strategic orientation and management capability (Volberda, 1996). Management capability relies on organisation design, which comprises technology (equipment and knowledge),

structure (formalisation, centralisation and specialisation) and culture, and is rooted in strategy. Strategy, structure and culture influence the technology deployed to produce goods and services and therefore the way an organisation attains goals. An organisation must thus design structure and culture to allow the efficient operation of technology (Schultz, 2003). Sub-concepts from each organisation dimension were then extrapolated for instrument development in the empirical phase of the study.

The macro-environmental context

Following Lewin and Volberda (1999), a distinction was made between the external context (economic, political and social forces) and the internal context (resources, capabilities, culture and internal politics). The relation between micro- and macro-environments results in additional environmental complexities. These relate to both the quantity of influences from surroundings (macro-level) and their meaning as interpreted on the micro-level (Rybakov, 2001). Despite this interrelationship the literature is mostly confined to relationships between environment and form characteristics at macro-level. The organisation's general environmental context with specific focus on operational contexts was thus, added to enable the inclusion of co-evolution, complexity and flexibility (complexity science concepts).

The micro-environment

The micro-environment comprises firm-level characteristics (Beugelsdijk et al., 2006), namely organisation culture, technology and structure (Daft and Marcic, 2004; Grant, 2005). However, the micro-composition of the micro-environment was also identified for this concept, namely actors, resources, and functions or activities.

Technology

Technology is an operational tool, the design of which is dictated by the demands of efficiency within given market conditions (Loveridge, 2002). At the organisational level, technology is the combination of human resources, raw materials and equipment that workers use to convert raw materials into finished goods and services (Bassett and Carr, 1996; Schultz, 2003). Technology therefore, includes physical properties and the procedures, methods and processes (functional) that constitute organisational action (Dooley, 2002). In addition, there is a positive relationship between technology and the four structural categories of complexity, formalisation, centralisation and configuration. Technology overlaps with facets of the micro-environment and the process environment. Technology and resources are deployed in

the input- transformation-output-feedback process, where feedback refers to the sub-concept communication. Following Volberda (1996), knowledge was added as a crucial aspect in the transformation of inputs to output. In this article, technology is referred to as the combination of resources, equipment and knowledge coordinated by communication to produce output.

Organisation design

Design is viewed as a micro-environment concept in this article, following Grant (2005). Organisation design refers to how labour is divided into distinct tasks (specialisation or division of labour) and how these tasks are coordinated (Andersen, 2002; Grant, 2005; Siggelkow and Rivkin, 2005). While there is some confusion on terminology, the structural sub-concepts organisation form and organisation type are viewed as different aspects of the umbrella term "design". In this article, organisation form thus, refers to the overall structure on a continuum ranging from mechanistic to organic (the organisation "ideal type" typology). Organisation type then refers to specific functional types of organisation such as the bureaucracy, networked, virtual, boundary less or horizontal.

Flexibility was added to organisation design, as organisation design influences flexibility, although, some (Oxman and Smith, 2003) see the influence in reverse. In Volberda's (1996) flexibility typology, operational and structural flexibility apply to organisation design. While dependent on organisation structure, operational and structural flexibility both relate to strategy as well. However, as both aspects impact structure and are in turn impacted by structure, they are identified as elements of structure that comprise important aspects of strategy. It is maintained for the purposes of this article that while operational flexibility is determined by technology and impacted by structure, operational flexibility is essentially a strategic use of structure embodied in management capability.

Organisation culture

Organisation culture is the set of unique internal characteristics embodied in commonly held beliefs and assumptions throughout the organisation, which are taken for granted by its members (Beugelsdijk et al., 2006; Volberda, 1996). Organisation culture distinguishes members of one organisation from the next (Hofstede, 2002), manifests in symbols, processes, and group behaviour (Werner, 2003), and refers to practices and values (Beugelsdijk et al., 2006) related to identity, community, support, trust, vision and communication (Fulk and Desanctis, 1995; Oxman and Smith, 2003).

An intangible resource, organization culture drives

behaviour and influences intra- and inter-organisational relations that are embodied in organisation identity (Hsu and Hannan, 2005; Santos and Eisenhardt, 2005). Values clarify organisation identity, purpose and the fundamental elements of strategy (Grant, 2005) by influencing choice of goals, strategic intent and the gaining of consensus and commitment (Bechtold, 1997). Organisation culture also plays a central role in the interpretation of environmental stimuli and the configuration of relevant strategic responses (Volberda, 1996).

The sub-concepts for organisation culture were based on Hofstede (2002) and Beugelsdijk et al. (2006) who have empirically substantiated these sub-concepts. These are process versus results orientation, job versus employee orientation, professional versus parochial cultures, open versus closed systems, tightly versus loosely controlled cultures, and pragmatic versus normative cultures.

Strategy

Grant's (2005) description of strategy as "a unifying theme that gives coherence and direction to the actions and decisions of an individual or organisation" were adopted for the purposes of this article.

The interplay between strategy and the other organisation concepts were alluded to earlier. More specifically:
1. Strategy impacts the organisation's intelligence on and response to the external and internal environment;
2. It affects the development, maintenance and deployment of technology including the flow of knowledge and communication;
3. It impacts organisation design by introducing and managing structures in alignment with the environment and technology; and
4. It reflects organisation culture.

This is substantiated by Grant (2005). These aspects are reflected in the sub-concepts of strategy identified, namely strategic orientation, corporate and business level strategy, and resources and capabilities. Additionally, they impact organisational complexity and flexibility.

Re-conceptualising key constructs

The key constructs of the study on which this article is based were re-conceptualised to develop working definitions of the virtual organisation and management in alignment with the research approach, perspectives and objectives of the article.

Re-conceptualising the virtual organisation

First, the virtual organisation was conceptualised as a

structural outcome of configuration, then as a process of organising, and finally as a complex adaptive system. Structural outcomes are the result of intricate patterns of relationships and interactions (process of organising) with configuration as influencer. The process of organising can be described according to the post-modern process approach adopted for this article.

Three operational (working) definitions of the virtual organisation were then formulated. Separate definitions are necessary because of ambiguity surrounding implicit structural or process views as mentioned earlier. The structural perspective definition reflects tangible end-states or outcomes of the organising process. The organisation process perspective definition highlights the functional processes that enable activities, and revolve around and alter structural outcomes.

The post-modern process perspective definition focuses on relationships and interactions in the creation of organisation. Based on these definitions, the concepts particular to the virtual organisation as construct emerged, each of which have implications for management.

Re-conceptualising management

In alignment with the purposes of this article, management was conceptualised as a trigger for complex adaptive system behaviour and therefore as an orchestrator of actors (agents), their functions and activities, and their capabilities and resources. Management roles were emphasised rather than position in the hierarchy. Complexity science highlights a holistic approach to management (Fowler, 2003; Tasaka, 1999). Fowler also suggests that managers cultivate the capacity to perceive and analyse relationships between their organisations and the business environment. These relationships constitute a complex, non-linear, adaptive, dynamic system containing networked feedback loops between organisation and environment. Emerging themes are relationship building, information and communication, and integration to coordinate the whole. The purpose of communicating and sharing information is to integrate the flow of ideas through the organisation to create output. Another important aspect of virtual management is the configuration and integration of partners to mobilise expanded resources (internal and external) (Walters, 2005).

RESEARCH DESIGN AND METHODOLOGY

Rationale and background

The purpose of this article is to propose a complexity theory-based management framework for virtual organisations based on case study research. No consensus has been reached, or proposed, for a management style that embodies the principles of post-modern process approaches based on a complexity theory meta-theoretical

Table 1. Research objectives and sources of data.

S/No.	Research objectives	Sources of data
O1	To extend complexity theory principles to organisation theory.	Systematic review of the
O2	To describe the virtual organisation as a complex adaptive system, within a complexity theory framework.	literature Documents
		E-mail interviews
		Self-type paragraphs
		"Real-time" Delphi
O3	To describe management practices at SchoolNet South Africa, a South African virtual organisation, from a complexity theory perspective.	E-mail interviews "Real-time" Delphi
O4	To propose a complexity theory-based management framework for virtual organisations.	E-mail interviews "Real-time" Delphi

framework. Even when researchers explicitly position results in a process framework, they still implicitly ascribe to modernist thought patterns. This is evident in the resulting "post-modern processes" that are static representations of organisation, not organising (hence structural). While this has been acknowledged in the literature, no solution has yet been offered. Furthermore, complexity theory has not been integrated into the broader post-modern process approach. Therefore no post-modern process benchmarks exist for management practices meant to reflect the ideals of the post-modern era.

While complexity theory is widely applied to management research and implications for managers conceptually highlighted, empirically based management practices to stimulate complex adaptive system behaviour within the parameters of post-modern process ideologies are absent. However, when the organisation is viewed as a complex adaptive system, the patternings of relationships and the way to explore them become apparent in the properties of self -organisation, non-linearity and emergence. In this article these are viewed as the processes underlying relationships that lead to co-evolution and structural changes.

Operationalisation thus, established how management facilitates self-organisation and non-linear structural emergence. This is the management of the "patternings of relationships" brought about by stimulating beyond equilibrium conditions.

Research design

A case study strategy was followed to generate theory. The case was theoretically sampled. Following Perry (1998), Riege (2003) and Yin (1994), a priori concepts (discussed earlier) were first derived from an extensive systematic review of the literature. The purpose was to create the domain for a multi-disciplinary, multi-level analysis, thus, providing a firmer grounding for emergent theory, and to identify the parameters for relevant case selection and analysis for enhanced validity.

From this the virtual organisation was re- conceptualised (as a structure, a process and a complex adaptive system) to formulate working definitions for the article. Types of virtual organisations were then classified according to a traditional/real-virtual continuum to select a case as close as possible to the "ideal" virtual type, or online virtual organisation. This decision was based on the premise that extant research predominantly focuses on more traditional organisations that merely make use of technology. Based on this, SchoolNet South Africa (SNSA) was selected as the case for analysis, positioned at the virtual end of the traditional/real-virtual continuum. SNSA displays a high degree of virtuality in strategy, structure (organisation design), links between actors, and culture.

The case study design

A single case study strategy was followed due to the pre-theoretical nature of the study. Daft and Lewin (1993) propose studying a limited number of case examples to understand and develop labels, variables and models to explain and define a phenomenon. Addressing Yin's (1994) concerns for single case designs, the case for analysis, namely SNSA, was systematically selected according to a set of criteria formulated during conceptualisation to minimise the chances for misrepresentation. SNSA comprises 12 permanent employees of which eight are managers or project coordinators. Of these, six agreed to participate in the study.

Sources of data

Multiple sources of qualitative data were used, namely documents, e-mail interviews, self-type paragraphs and the Delphi method to explore management approaches and the way in which the micro- and macro-environment impact on SNSA. This data is necessary to determine how sensitive the organisation is to its environment, and how SNSA adapts to its environment. Based on the evidence collected, complex adaptive system behaviour could be described, in line with the objectives of the article. The objectives of the article, as well as the data collection methods used to achieve each objective, are summarised in Table 1. The focus of each data collection method in terms of the organisation concepts described in the literature review is indicated in brackets where applicable.

Documents

Documents were used to gather data with which to describe the virtual organisation as a complex adaptive system (O2) . To achieve this objective, environmental influences first had to be determined. Documents were thus analysed to systematically construct the operational context of SNSA, to generate questions for the interview protocol by extracting information for further probing, and to corroborate and complement information from other data sources. Examples of the documents used included the latest minutes (2008) of SNSA's Annual General Meeting (AGM), e-mail corres-pondence between SNSA and clients (during 2007 and 2008), minutes of staff meetings and planning sessions, job descriptions, organisation process documents, and assessment strategies and reports.

Documents were content analysed in a three- stage process according to pre-determined sets of codes. Content was searched for passages that embodied coded themes. First, the data were

searched for themes related to organisation concepts, second for behaviour indicative of complex adaptive system behaviour, and third for management implications specific to virtual organisations. Coding was based on the theoretical and conceptual framework of the research to increase the transferability and reliability of the study.

E-mail interviews

These comprised of the primary source of data due to the geographic dispersion of participants. A total of 22 e-mail interviews with five participants were conducted to gather information on:

1. The macro- and micro-environment (O2).
2. Management approaches and practices at SNSA, while considering the structure of the organisation (O2, O3 and O4).
3. Relational processes (O2, O3 and O4).

Furthermore, the post-modern process approach of the study focused on patterns of relationships. In the literature no mention is made of how organising occurs in virtual organisations characterised by limited face-to-face interaction. E-mail provided the opportunity for a phenomenological experience of the case. It also facilitated and accelerated the probing of emergent themes during data analysis. The interviews focused on the a priori organisation concepts described earlier and clarified emerging issues from other data sources. First, environmental aspects (micro- and macro-environments) were addressed, then structural (organisation design) and individual aspects focused on, and finally relational processes (culture and technology) were analysed. This was achieved in consecutive "rounds" of questions, which followed a Delphi-type procedure. Feedback was provided to participants after each interview round based on the interpretation of initial responses to verify accuracy. This then generated further probes.

The first interview round focused on partner relationships, environment response and monitoring, strategy, communication, organisation processes and culture. The second round narrowed focus to the internal relational processes as these did not emerge in the first round of questions. After the second round, the e-mail interviews evolved into ongoing e-mail "chats" as questions and emerging issues were explored in more depth with each participant. Interviews were stopped when data saturation was reached, in other words, when new information or concepts no longer emerged. E-mails were tracked to avoid technology-related problems.

As for documents, the interviews were content analysed according to pre-determined codes. Accuracy was improved due to the e-mail nature of the interviews. Analysis took place in three consecutive rounds. Firstly, the interviews were analysed from a structural perspective, secondly from a process perspective, and thirdly for evidence of complex adaptive system behaviour. The interviews were analysed in an iterative process between data and theory (Brown and Eisenhardt, 1997; Kerssens-van Drongelen, 2001), which enabled joint collection, coding and analysis. This enabled the probing of emergent concepts, ideas and insights. Results from interviews were corroborated with those from other data collection methods.

Self-type paragraphs

The self-type paragraph approach was used to assess environment sensitivity and subsequently strategic orientation (O2). Self-type paragraphs were e-mailed to the executive director and strategic consultant. Instructions specified that the statements were related to intended strategy. Emergent strategy was explored in e-mail interviews. The completed exercise was mailed back, manually Analysed and results verified against data collected from other sources.

The self-type paragraph approach is based on the Miles and Snow (1978) typology of strategic orientations. It is a popular measurement instrument in research on strategic adaptation and has been effectively employed in general organisational research (Cueille, 2006; Slater and Olson, 2000). The multi-item adaptation by Conant et al. (1990) of the original Miles and Snow (1978) scale was used for the purposes of the study. This was because the former allows for more accurate and in-depth measurements of organisation concepts by considering the complexity inherent in each, which enhances validity. As an already-developed instrument, validity and reliability have been established.

"Real-time" Delphi

The Delphi was implemented to identify emerging patterns and to reach consensus on management (O2, O3 and O4) that could be followed up with other data collection methods. The Delphi panel comprised six managers of SNSA identified from the organogram in consultation with the executive director. Participants were geographically dispersed and therefore adhered to the theoretical requirements of the study. It was decided that although consensus should be obtained from at least three respondents (50%), the stability of responses through a series of rounds was also reliable. The Delphi consisted of two rounds when a set of management concepts was identified for further corroboration.

The Delphi technique is "a sequential, iterative, multi-stage process" (Hasson et al., 2000) for gathering information, opinions and ideas (Rushforth, 2007) by "structuring a group communication process to tap the wisdom of experts" (Duboff, 2007). The purpose is to establish consensus or negotiated reality to generate novel insights and broaden knowledge. This is relevant when very little prior information exists. Following previous applications of the technique, a "real-time" Delphi (Hasson et al., 2000) was implemented to determine emergent patterns of management in SNSA that could be probed in other data collection methods. The technique is well-suited to research in virtual organisations because participants do not need to be co-located or to meet face-to-face, therefore making it useful for conducting surveys with qualified people over a wide geographic area (Gould, 2003).

KEY FINDINGS AND DISCUSSION

In this section, findings are reported to first describe the virtual organisation as a complex adaptive system, highlighting management implications (O2). Second, management practices at SchoolNet South Africa are described (O3). Third, a complexity theory-based management framework for virtual organisations is proposed (O4) based on the evidence collected. Supporting evidence is in inverted commas (" ").

The virtual organisation as complex adaptive system

Findings showed that the virtual organisation comprises a large number of entities that display a high level of interactivity. It consists of a core organisation which coordinates and integrates core competencies and the resources of partners. Components of the system, namely the core and extended organisation (partners), comprise a loosely coupled network based on cultural

rather than structural relationships. The executive director says that "I think we function quite well without a very clearly defined structure, but we could not survive without relationships." During configuration, partners are identified and selected based on extant values and purposes that can be co-aligned. The selection process "reduces the types of individuals (actors) or agents that can inhabit the system (the virtual organisation) to those that can co-exist or have synergy with the other types present" (Allen, 2001). Says one participant: "The capacity to play our role is due to the strong network of teachers, trainers, mentors and consultants that exist in the SNSA community." Therefore, the co-alignment of goals and purposes is important.

Regular interaction and communication facilitate co-existence ("… we all move forward on a common path …") and "… maximise synergy". All complex adaptive systems are composed of and maintained by a flow of energy/resources from the environment. Emergent structural configurations or patterns of relationships enable goal attainment, while simultaneously the achievement of goals reproduces the configuration. Therefore, a high level of interactivity is vital for coordination, which takes place in extensive communication networks. Through interaction, knowledge is acquired, created or shared, and information disseminated to ensure productivity and efficiency. This is considered important at SNSA because "we do not want to make mistakes." Technology provides the context for interaction and relationship building, and amplifies interactions and influences across the traditional boundaries of time and space. At SNSA, preferred communication methods are technology-based: "We mostly rely on e-mail although we do supplement this with Skype messaging." The nature of interaction is non-linear, implying that the virtual organisation cannot be reduced to its individual components.

This means that environmental influences impact the functioning of the virtual organisation. For example, an environmental event (such as the entry of a new competitor) can propel the organisation beyond the limits of its capacity. When limits are reached, tension and threshold threaten to throw the organisation out of equilibrium. A beyond equilibrium state arises when influences, either through threat or opportunity, force the organisation to adapt and re-align resources. The re-alignment of resources could mean re- configuration and re-integration because the organisation is able to exhibit dynamic behaviour in this state. This was the case at SNSA in 2005, when the organisation was nearly shut down due to insufficient funding. Environmental influences arose from the social and education environments, most notably in the form of policies and regulations. Re-aligning strategy "saved" SNSA when, according to the executive director, "the motion was carried to continue running by tendering for contracts and training for donor and government funded projects." The uncertainty created by the non-linearity of interactions interactions is amplified due to the technological nature of the system. Technology amplifies feedback events because it increases the range of influence by providing a context connecting every aspect of the virtual organisation. Therefore, the virtual organisation is constantly subject to input from the environment. The key drivers behind SNSA's existence are the economic, technological, education and social environments, each of which presents numerous challenges in South Africa, such as financial constraints and a lack of infrastructure. To avoid being catapulted into a chaotic state the culture of the organisation (or dominant logic according to Lichtenstein, 2000), co-destiny, a common purpose, and shared commitment to common goals serve as the strange attractor around which the organisation revolves. Says one participant: "At our organisation, our culture is the glue that holds us together."

A dominant logic is reproduced (organisation culture) from the interactions of values, beliefs, structures and strategies, while at the same time the same logic determines the configuration of values, structures and strategies. This dynamic process can be described in terms of organisational learning because the system self-generates meaning and knowledge to maintain itself and to develop over time. This is influenced by structure, which determines the capacity for learning and for accomplishing goals through the mobilisation of resources. When the level of resources needed to self-generate the organising configuration or dominant logic is exceeded, the system begins a process of trans-formation. Transformation occurs through synergy and organising processes to reduce equivocality (uncertainty) while the organisation attempts to find a better way to organise, either through strategic re-direction or purposive organisation building processes. This leads to the emergence of a new dynamic order underscored by information and communication. In SNSA's case, this came through strategic re-direction as mentioned earlier.

However, evidence from the study indicated that a beyond equilibrium state is not a necessity for complex adaptive system behaviour. Rather, adaptive capability is increased by the non-enforcement of structures and hierarchies, free-flowing information, continuous communication, and the micro-logics of the organisation. Here, flexible, permeable, dynamic "non- structures" are emphasised. One manager explains, "We have tried not to be too hierarchical and obviously with me not being physically present in the office the onus is put on people to take responsibility for their own work." Another manager agrees, "We have tried not to have people being supervised as much as people being accountable for their own areas of work." This creates the conditions for self-organisation due to the freedom from constraints offered by decreased structural control, less reliance on traditional hierarchies (hierarchies exist in communication structures), empowerment, trust and an all-embracing cultural core that extends to all actors/agents.

Adaptive capability and the ability to self-organise also mean that the organisation can purposefully respond to environmental influences without the occurrence of major change. The self-type paragraphs classify SNSA in Miles and Snow's (1978) analyser/defender category, not the prospector category. A manager explains, "In most cases, new project opportunities find us, as opposed to us going out looking for them." This is closely related to SNSA's reputation, which has been established by "getting the job done, projecting trustworthiness, and building up contacts", according to the executive director.

Additionally, findings indicate that self-organisation does not create structures in the traditional sense (vertical or horizontal). Rather, it leads to the emergence of communication networks that increase interactions and may or may not be hierarchical. A manager explains that, "We rely on written communication, especially task descriptions and guidelines from our team leaders. We find these guides very important for project administration staff, especially if they are new to the job or new to a particular project". For the most part, "our meetings tend to consist of just sharing what we are each currently busy with". Furthermore, the micro-logics of organising mean that the virtual organisation is in a constant state of flux, this evident in organisation behaviour. Emergence is evident in the structures that form as a result of partnerships during configuration and integration. However, these structures revolve around the microscopic behaviours of the organisation; therefore, emergence is evident in the patterns of relationships that are formed. This is due to the self-organisation of actors as they arrange themselves to best achieve organisational goals.

The virtual organisation therefore structures itself around the patterns of actors' relationships and not the other way round. Here, the micro-logics of organising are united on a higher level in communication structures. This is evident at SNSA in terms of who communicates with whom, which is largely dependent on the specific project under completion. Patterns of relationships form as a result of synergy created between components (actors/agents) of the system. Synergy improves the flow of tacit knowledge, which culminates in an outcome that is greater than the sum of its parts: "We bounce ideas around and spark off one another's contributions when we need fresh approaches or sometimes just to finish a project." Synergy drives the virtual organisation through the creation of knowledge and the formulation of strategies based on the context for improvisation it provides. Therefore, strategy is formulated around culture, synergy, relationships and interactions.

In addition, the behaviour of complex adaptive systems is determined by the nature of interactions and not by what comprises components. Each element in a dynamic system is interdependent and depends on other elements for its identity and function (Lichtenstein; 2000). Mutual dependence implies that actions and structures mutually constitute and that they arise simultaneously over time. During organising action, reaction and learning arise mutually to create a collective mind (community nature of virtual organisations). Knowledge flows are also mutually constituting and mutually dependent. Therefore, structures have limited influence on resultant behaviours. Interactions are rich, dynamic and underscored by feed-back (communication). This highlights the importance of relationships in virtual organisations. Relationships are fundamental to all agents in the complex adaptive system. In the virtual organisation, these relationships are the cornerstone of culture and dependent on building and sustaining trust. Trust serves as the coordination mechanism in virtual organisations.

In summary, and of importance to managers, the structures of the virtual organisation are fluid and form around relationships which self-organise in the flexible technological context of the virtual organisation. This leads to the emergence of communication structures, rather than traditional hierarchical structures.

Managing the virtual organisation

Findings indicated that managers in virtual organisations follow a servant-leadership approach. Servant leadership is based on the assumption that work exists for the development of the worker as much as the worker exists to do the work (Daft and Marcic, 2004). Virtual organisation managers strive to fulfil workers' goals and needs and realise the larger purpose or mission of the organisation. They are people- and results-oriented, focussing on people to achieve results. For one manager (the executive director), the most important management trait is "to make colleagues feel supported". Says another participant: "A manager is someone who is prepared to lead by example. My manager is someone who works harder than all of us, someone who believes passionately in what we do and someone who always has the organisation's best interests at heart. This is the kind of manager I try to be too."

Findings further indicate that managers in virtual organisations share power, ideas and information, and acknowledge the achievements of others. They value people, encourage and create opportunities for participation, share power, create the context for synergy and improvisation, and build and sustain trust through regular communication. Organisation building and behavioural processes are emphasised. Table 2 summarises the activities of managers in virtual organisations based on evidence from SchoolNet South Africa. In addition, Table 2 shows the corresponding behaviours to ensure the interactions and continuous information exchange needed for complex adaptive system behaviour.

Table 2. The activities of managers in virtual organisations for complex adaptive system behaviour.

Managerial activity	Purpose and description		To trigger complex adaptive system behaviour
Empower employees	Why?	Employees are empowered to make decisions.	Empowerment enhances decentralised decision-making. This creates a flexible structure for the emergence of autonomous informal groups. Decentralised authority also increases the adaptive capability of the organisation and its actors.
		Focus on developing skills and abilities of employees.	
	How?	Focus on regular communication and feedback (bottom-up and top-down empowerment).	
Delegate	Why?	To develop employee skills.	Managers are participative and democratic to enable collective learning across flatter hierarchies. This enables managers and employees to be adaptable and flexible to accommodate deviations from standard practices so as to respond to change. Strategic flexibility enables emergent strategy design.
		To maintain the "bigger picture", holistic focus of virtual organisation.	
	How?	Clearly articulate goals.	
		Encourage participative decision-making.	
		Provide regular feedback.	
Communicate	Why?	For effective coordination, information sharing and knowledge sharing so as to reduce equivocality.	Allows for the influx and import of energy into the system. Enables adaptive responses and the reduction of equivocality from environment through regular, transparent communication.
	How?	Communication must be transparent, frequent and consistent for both task and relational purposes. This can, however, result in information overload, especially if the nature of the organisation is participative. The executive director of SchoolNet South Africa explains that, "Despite this, we still consider keeping people informed more important than reducing e-mail overload, especially when there are particular synergies in projects".	
Build culture	Why?	To empower employees in a context with very limited face-to-face interaction.	A culture based on trust and a strong value system empowers employees. This creates a secure context that ensures that actors are more amenable to change.
	How?	Establish trust.	
		Instil organisation values by leading by example.	
		Align personal goals with the organisation's mission.	
		Establish a culture of virtuality to build and sustain a strong, innovative organisation culture.	
Focus on knowledge	Why?	To empower employees through information and knowledge.	Managers create the context for synergy and improvisation by disseminating and sharing knowledge. The manager must also establish open systems of communication for the regular sharing of information.

Table 2. Cont'd

	How?	Provide the context for synergy. This is best created in a face-to-face setting because non-verbal communication "contributes in a way that is difficult to replicate in electronic interaction…because you can spend more time going into depth". Share tacit knowledge, for example through brainstorming sessions or think tanks.	
Establish trust	Why?	To aid in synergy and culture-building and overall organisation effectiveness.	Building credibility and establishing trust involves the same activities as ensuring interactions and continuous information exchange needed for complex adaptive systems behaviour. Managers must continuously engage in environmental scanning to: Keep abreast of industry trends, developments and opportunities; build networks of beneficial contacts; acquire knowledge; and build credibility through expertise.
	How?	Trust is based on the credibility of the manager, where credibility refers to the ability to engender trust in others and is based on the expertise of the manager. Know your discipline, keep up to date with trends, and ensure a sound reputation. Lead by example.	

A complexity science-based theoretical management framework for virtual organisations

Findings showed that the virtual organisation manager cannot separate relationships and interactions (post-modern) from the core functions of the organisation (structural). The complexity science-based management framework is illustrated in Figure 1. The framework in Figure 1 depicts the virtual organisation as spinning around an axis comprising micro-logics and culture, which are represented as its core.

To accurately reflect the empirical results of the study and to accommodate post-modern processes an additional layer was added to the original framework. The innermost circle represents the interactions and relationships, which emanate from culture, around which the virtual organisation revolves. These can be envisioned as the "pulse of the organisation", and are therefore depicted as DNA strands. Technology is shown as the outermost layer because it creates

the context for virtual organising. Furthermore, technology is the link between partner organisations. Therefore, the framework represents technology as transcending organisational boundaries, where the core organisation is contained within the four concentric circles or layers. Additionally, technology offers the means by which to "realise potential" (Dibben and Panteli, 2000) . Surrounding the innermost post-modern circle (level 1) is strategy, as strategy follows culture. Structure (level 3) follows strategy (level 2) and comprises the third circle. As mentioned, technology (level 4) creates the context for virtual organising.

The framework summarises practical management actions derived from the empirical study making the model more accessible and relevant to organisations. The framework is specific to the virtual organisation; however, it can be applied in all typologies on the traditional/real-virtual continuum although further testing is needed. As a complex adaptive system, the virtual organisation is constructed from the core, meaning that it

emerges and revolves around its core value system and the people in it. Therefore, level 1 is related to culture building, trust and commitment and refers to (post-modern) patternings of relationships and interactions (the DNA strands that permeate all levels of the organisation). These relationships and interactions hold the organisation together. These extend to the extended organisation on level 3 (because the virtual organisation restructures around partners) and are therefore, related to influencers.

Conclusion

The purpose of this article was to describe a management framework for virtual organisations based on the principles of complexity science. To achieve this aim the article first extended complexity science principles to organisation theory through a systematic review of the literature. It secondly described the virtual organisation as a complex adaptive system, within accomplexity
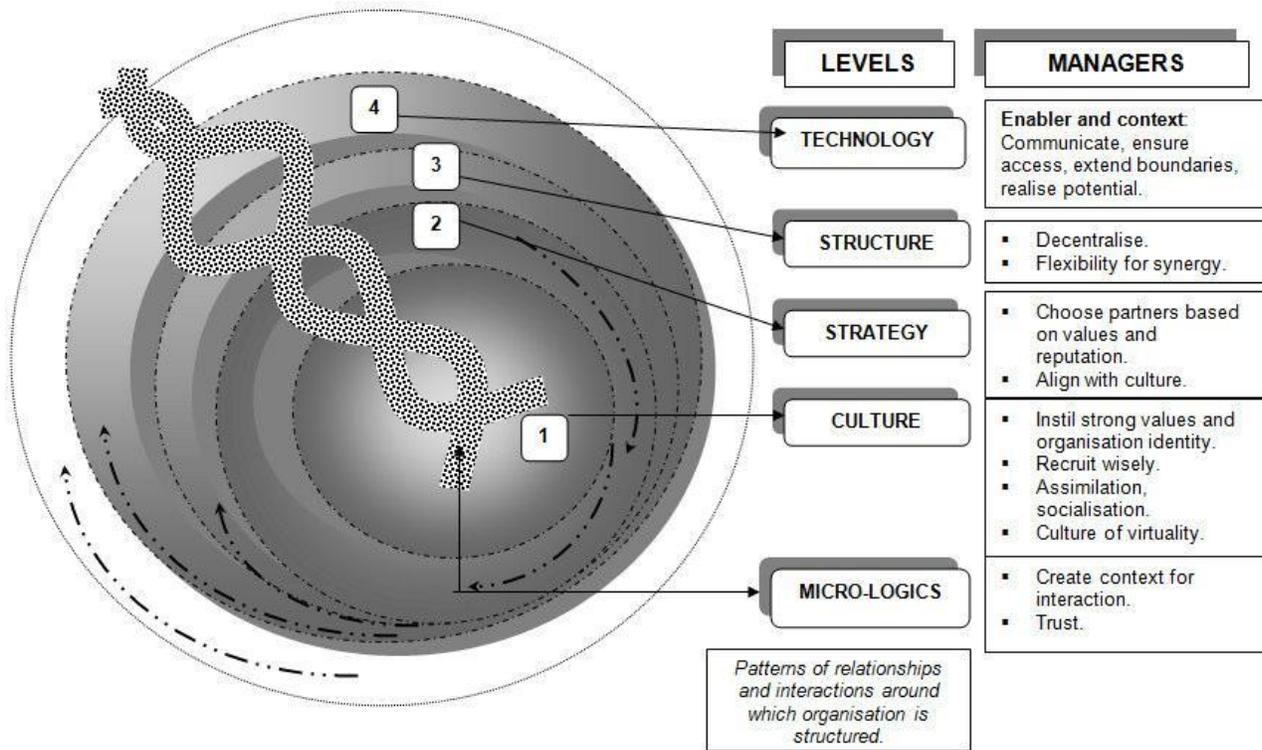
Figure 1. A complexity science-based management framework for virtual organisation.

acomplexity theory framework. Thirdly, management practices at SchoolNet South Africa were described from a complexity theory perspective. Finally, the article proposed a complexity theory-based management framework for virtual organisations.

The virtual organisation presents numerous challenges to managers because it is unrestricted by the traditional boundaries of space and time. Virtual organisations will radically change the way people work and the way communication and interaction are viewed, practiced and studied. Likewise, management practices will adapt and evolve to accommodate these changes.

The article started with the premise that organisations need to function as complex adaptive systems to survive in the 21st century. To function as complex adaptive systems, organisations need to be managed in a way that triggers complex adaptive system behaviour. Evidence was provided for a management framework that accommodates continuous change and that considers the interdependent nature of interrelationships, interdependencies and interactions. Complexity science serves as a basis for such a framework because it accommodates the dynamic linkages between aspects of the system.

The virtual organisation is based on patterns of relationships. Therefore, management emphasis was shifted from structures to people. As a complex adaptive

system, co-existence and synergy between components are vital. Communication and regular interaction form the foundation of the system, facilitating the knowledge and information exchange needed to self-organise into emergent structures. These are based on patterns of relationships that are underscored by synergy, information and communication. For managers, the implications are many. Managers should facilitate the emergence of new structures to achieve organisation objectives by empowering employees through delegation and knowledge sharing. The greatest attribute of the virtual manager is the ability to build an organisation culture where shared values, commitment, open communication systems and trust bind the organisation and its various components. Ultimately, managers of virtual organisations are not managers. They are leaders who encourage the development of others, as much as the development of self and the evolution of the organisation.

The outcome of this article is a complexity theory-based theoretical framework for management in virtual organisations. The framework is, however, based on a single case study. Therefore, considerable testing is still needed to refine concepts and to establish generalisability. In this case, transferability was aimed to obtain the depth required in pre-theoretical studies, over breadth of information. While a multitude of factors

were considered in the research on which this article is based, evidence was gathered for an overall description of the virtual organisation and management thereof. The focus was therefore, not on the effectiveness of management, but rather on the generation of concepts for further development. Numerous areas of further research therefore emerged.

RECOMMENDATIONS FOR FUTURE RESEARCH

Whether effectiveness is dependent on the manager's preferences for communication, emphasis on knowledge, values or virtual interaction with employees, requires investigation in organisations other than the one explored in this study. It is recommended that the influence of management on performance be approached from psychological, strategic, cultural and economic perspectives.

The influence of cultural factors on virtual interaction also deserves attention due to the importance of culture building. This is complicated by technology which has replaced traditional contexts for integration and assimilation. While the organisation in this study succeeded in building a strong organisation culture, further research is needed to determine whether this is linked to specific management traits or to careful recruitment, for example. The issue of gender was not addressed, although, gender influences management style. While not directly related to the outcomes of this article, and possibly specific to this study, the organisation researched comprised a staff component consisting almost entirely of women. This could be an important avenue of investigation. It is recommended that future research establish whether the feminisation of the virtual workforce is likely to increase as technology offers the potential to reduce stereotypes and overcome the barriers often associated with the traditional roles of women. Change management was not specifically addressed, although, it is a fundamental aspect of complex adaptive systems. Whether change management is actively needed in virtual organisations, which are by definition temporary and fluid, needs to be explored. For this, a longitudinal, preferably ethnographic investigation is recommended.

The final recommendation is not directly related to the purposes of this article, although, it is related to the meta-theoretical framework followed. While complexity science is strongly advocated for understanding the virtual organisation, it is recommended that quantum mechanics might be a potentially "stronger" meta-theory. Quantum mechanics explains how subatomic particles interact across space and time in unknown and unknowable ways (non-linearity). To explain, virtual organising is the process of coordinating virtual activities, or the motion or mechanics of organisation. In a complex adaptive system, a constant import of energy and matter are needed to sustain the system in a state of adaptation. In the virtual organisation, technology provides the context for constant information exchanges. Energy and matter (information exchange) result in motion, which is embodied in synergistic actions that transform input (often intangible and knowledge-based) into tangible output. This is an avenue for further research and development that could potentially change the way in which organisations and management are viewed. To date, the application of quantum mechanics to management and organisation science is limited.

The main contributions in this article have been to translate the principles of complexity science into tangible management concepts. As such, guidelines by which managers can effectively substitute technology for the traditional contexts of management have been provided. Ultimately, the virtual organisation offers boundary less opportunities for a new breed of managers in a relatively young information era.

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