KNOWLEDGE CLOUD AND TEXT-BASED DIFFUSION THROUGH LEXICAL PRODUCTIVITY

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Abstract: Management practices and information technologies to handle knowledge of satellite manufacturing organizations may prove to be complex. As such knowledge (with its explicit and tacit constituents) is assumed to be one of the main variables whilst a distinguishing factor of such organizations; amidst those specialist in nature, to survive within a marketplace. Their main asset is the knowledge of certain highly imaginative individuals that appear to share a common vision for the continuity of the organization. Satellites and their related services remain a good example of that. From early pioneers to modern day satellite manufacturing firms, one can see a large amount of risk at every stage in the development of a satellite or a related service, from inception to design phase, from design to delivery, from lessons learnt from failures to those learnt from successes, and from revisions to design and development of successful missions. In their groundbreaking book The Knowledge Creating Company (1995), Nonaka et al laid out a model of how organizational knowledge is created through four conversion processes, being from: tacit to explicit (externalization), explicit to tacit (internalization), tacit to tacit (socialization), and explicit to explicit (combination). Key to this model is the authors' assertion that none are individually sufficient. All must be present to fuel one another. However, such knowledge creation and diffusion was thought to have manifested and only applied within large organizations and conglomerates. Observational and systematic (corpus-based) studies – through analysis of specialist text, can support research in knowledge management. Since text could be assumed to portray a trace of knowledge. In this paper we are to show how knowledge diffuses in a specific environment (*a.k.a. Knowledge Cloud*), and thus could be modeled by specialist text. That is dealing with the satellite manufacturing domain, and having embedded within the knowledge about the business sector and knowledge domain.

1 KNOWLEDGE DIFFUSION IN SPECIALIST DOMAIN

In order to investigate the gap in knowledge diffusion within an organization we did carry an observational study, within an SME (Small to Medium Enterprise) in satellite manufacturing, a specialist domain. Inline with a study of the language used in satellite engineering in general, and that stemming from SSTL (Surrey Satellite Technology Limited) and Surrey Space Centre in particular. Both studies have an empirical basis. The observational study (mainly questionnaire-based) was designed to ask questions related to knowledge diffusion within the company during 2002-2005 period, as part of my doctoral research coverage. The questionnaire-based studies were not based on intuitions on how knowledge is managed, rather based on a set of empirical questions, partitioned under five sections namely:

1- Awareness and Commitment
2- External Environment
3- Information Technology
4- Knowledge Maintenance and Protection
5- Organizational Issues

We have investigated the diffusion of knowledge within SSTL, based on the practice within SSTL, as articulated through the questionnaire. There were two sets of questionnaire-based observations. The pilot study was conducted with managers and whereas the second run of the questionnaire was

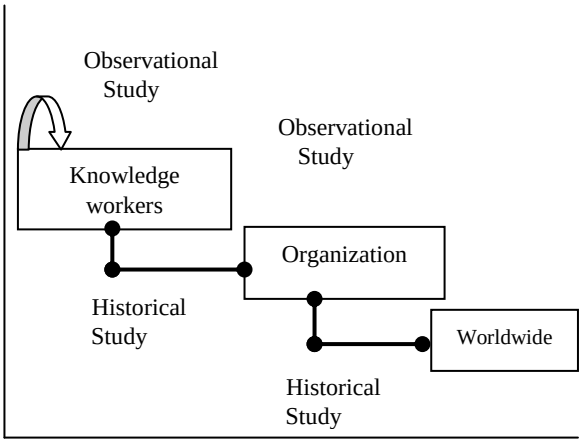
intranet-based, and more widespread. SSTL, is a small knowledge-based organization, for *minimalism*, a knowledge based organisation is one where knowledge is being the dependent input variable, as the need would exist for organisational resources to acquire such knowledge from physical entities (i.e. knowledge workers) and convert it as input for electronic storage medium (s), making it easier for retrieval and dissemination of information. Thus, knowledge (encompassing data and information) would be needed for creating and offering a product and service line mix, including that contained in individual employees and that in SSTL (as a collective entity, expertise accumulated over time). SSTL's principal assets are its engineers, its project managers and its researchers. Collectively, the engineers, managers and researchers are sometimes called *knowledge creating crew* (Nonaka *et al*, 1995). In a rapidly developing, high-technology field like satellite engineering, it is important to communicate, share and validate knowledge. We aim to describe in this paper our understanding of the nature of a specialist organization in a quantifiable manner, and the constructs of a knowledge management audit conducted through the observational study within a satellite manufacturing SME, based in the UK. We have examined how knowledge flows and is adapted between commercial and research types of corpora. One of the major results deduced from the observational study was that knowledge diffusion is paramount within the lifetime of an organization, and could be supported by information systems. Leading us to investigate on how knowledge diffusion takes place, in an empirical way. Our analysis shows that research papers (created within educational institution) and commercial documents (created within spin-offs of such higher education institution) can be distinguished rather on the basis of single word and compound terms. These two specialist lexis show the potential for identifying points of mutual interest in the diffusion of knowledge from the research institution to the commercialization process, thus to application(s) within a domain.

2 METHOD

Nonaka et al's (1995) knowledge conversion model is intuitive. It is based on long experience and judgement. Such model emphasizes the importance of practice, knowledge amongst knowledge workers. The case studies produced were between researchers, practitioners, and managers. There was transfer of knowledge from researchers to knowledge workers. Such has yielded a contingency table for the transfer of knowledge, so-called *knowledge conversion model* that generates four knowledge conversion modes. Such model is plausible but remains largely intuitive. Our interest is tacit to explicit knowledge conversion (externalization) and explicit to explicit knowledge conversion (combination). The reason we have studied an SME (Small to Medium Enterprise) because it would appear that knowledge would be shared because smaller groups would get together easily, i.e. no logistics involved. As well as it appears that in a SME knowledge bottlenecks which are characteristic of large organizations would not exist. Being in relation to the size of SMEs, managers are expected to interact with and understand needs and requirements of knowledge workers. Consider an organization like SSTL, Surrey Satellite Technology Limited, we focused on the interaction between knowledge engineers and knowledge practitioners, and were aiming to see how knowledge is shared. In order to investigate the gap in knowledge diffusion within SSTL, we did an observational study, and a study of language used in satellite engineering in general. Both studies have an empirical basis. A bimodal research method was followed within the specialist domain of satellite manufacturing applied within SMEs [Small to Medium Enterprise]. Inclusive of:

- Observational study: questionnaire and interview based
- Corpus-based study: analysis of text repositories. Involving extraction and modelling of specialist terminology collated from: public domain publications (i.e. NASA, British Standards Institute – Terminology Specification, and BMP - Best Manufacturing Consortium database), and specialist domain publications (i.e. Surrey Space Centre and SSTL).

Knowledge Adaptation



Knowledge Flow

Figure 1: Knowledge diffusion through flow and adaptation processes

Figure 1 represents a relational view of the methodology, integrated within the possible set of agents for knowledge diffusion, being composed of a 2-tier process. Whereby knowledge is assumed to flow among or across from knowledge workers, to the organization, then to worldwide (horizontally), but the adaptation phase comes into place once knowledge is personalised and applied (vertically). However, such methodology was implemented in the specialist nature of the domain of investigation. Yin (1994) identified five components of research design that are important for case studies: the study's questions, its propositions, its unit (s) of analysis, the logic linking the data to the propositions, the criteria for interpreting the findings. The above components were integrated within the observational study, as guidelines to the formulation of the different stages involved within the conduct of this research, from the pilot run of the survey study, to the intranet-based survey and historical studies. In which the intranet-based survey seemed to generate interest, impact and a set of internal actions. Supported as well by over 30% participation rate for the intranet-survey, and being composed mostly by middle to senior managers. Evidence of knowledge diffusion and support for it was manifested as outlined in the table below.

Table 1 shows how knowledge bottlenecks have been looked upon during the flow and adaptation of knowledge amid agents involved in its diffusion. Through the observational study and the historical study, behaviour between agents was modelled using the techniques prescribed below.

Table 1: Knowledge diffusion in the environment of a small organization

Agent A	**Agent B**	**Artefact**	**Technique**
Person	Person	Opinion, practice, know-how, organizational structures	Questionnaire-based study
Person	Organization	PhD Dissertation, Research Publications, technical reports	Text Analysis
Organization	Organization	Specialist documents (i.e. technical documents, technology-specific documents, missions documents)	Text Analysis
Organization	Worldwide	Specialist documents (i.e. technical documents, technology-specific documents, missions documents)	Text Analysis

The intranet-based survey study had 5 sections, stretching to cover possible areas of applications and implications for knowledge diffusion within an organization, namely - Knowledge Management Awareness and Commitment, External Environment, Information Technology, Knowledge Maintenance and Protection, and Organizational Issues. On the other hand, for our historical and special corpus, we followed where applicable and pertinent, Atkins et al's (1992:2), five principal stages for corpus building. Outlined in table 2:

Table 2: Stages for building a corpus (Atkins et al, 1992:2)

Stage	**Description**
Specification and design	Corpus type is identified taking into account sample size, language varieties and the time period to be sampled.
Computer Hardware and software	Hardware and software needs for the corpus project are estimated.
Data capture and mark-up	The data/texts are captured and transformed/transferred to electronic form, keyboarding, or audio transcription. The captured files are

	then marked-up with embedded codes containing text features.
Corpus processing	Includes basic tools, i.e. word frequency lists, concordance, and interactive standard query tools and tools for lemmatization, tagging, collocation etc.
Corpus growth and feedback	New materials may be added to the corpus or some of the old materials may be deleted according to feedback from previous analysis to reach a balanced and enhanced corpus.

Specification and design of a corpus and its processing are the most important steps in building the corpus and for any kind of subsequent study. Second and fourth stages are not so important due to the technological advances in computer hardware and software. The importance of the last stage depends on the nature of the study. Studying the state of the specialist terminology is considered important for the study of the language discourse. Corpus-based studies are empirical and depend on both quantitative and qualitative analytical techniques (Biber et al, 2002). Therefore to get results have an important effect, the corpus must be sampled and created carefully: "the decisions that are taken about what is to be in the corpus, and how the selection is to be organized, control almost everything that happens subsequently. The results are only as good as the corpus" (Sinclair, 1991:13).

3 OBSERVATIONAL STUDY

The term knowledge management is used to articulate the concept that knowledge is an asset on a par with the tangible assets of any organisation - land, capital, plant and machinery. Management involves the management of assets; ergo knowledge should be managed from its inception through its nurturing to maturity to exploitation and to ultimate obsolescence. The term was also coined to indicate that knowledge within organisations is communicated not only through the typical organisational hierarchies but also through interaction between members of the organisations across the hierarchies and the different structures (divisions/departments and their functions, management style, communication culture, computer-mediated processes, practices and so forth) contained with an organization. The questionnaire portrays through its five sections, some of the concepts raised within the Knowledge Management field, outlined in Section 1. Two runs for the questionnaire-based study were conducted, a pilot study, and an intranet-based study. The majority of the respondents were knowledge practitioners (i.e. team members). Over 80% from the intranet-based questionnaire were as such, like reported from the respective representative of the study onsite, head of Research and Development at SSTL. The key point was that the managers were more optimistic and confident about extent of knowledge sharing. Our analysis has been supported by the feedback received from one of the key managers cited previously. Our method is no more then holding a mirror to an organization and what is reflected is the management of knowledge within the organization when looked upon from the five different facets of the questionnaire sections (i.e. awareness and commitment, external environment, information technology, knowledge maintenance and protection, and organizational issues). The questionnaire study raises the need for a knowledge map through both the pilot and intranet-based observational studies, one that is specialist in nature. That can represent the domain language providing an environment for querying and validation for the knowledge worker, and thus containment of both elements of such knowledge (explicit and tacit). Allowing as well for the knowledge conversion modes (Nonaka, 1995) to take place, and hence knowledge to be created and utilized. This may act as basis for the research conducted on whether SMEs do create the dynamics of innovation, as such dynamics may need to encapsulate the sharing of the domain knowledge (touted and supported by knowledge workers), and thus embedded within the domain's *ontology* – referring to the explicit formal specifications of the terms in the domain and relations among them (Gruber, 1993).

This part of the research (observational/introspective) has focused on the organizational structures (management hierarchies, attribution and validation of knowledge, and so forth) in place, enabling or facilitating the diffusion of knowledge. Our conclusions from this survey; based on the feedback and responses received, affirm that knowledge sharing is encouraged. As well as innovation being encouraged either through collective or individual effort(s), and facilitating knowledge sharing is possible through availability of knowledge maps and communication channels between multi disciplinary teams for specialist areas.

The above results, from either the pilot study or the intranet-based studies; have encouraged us to explore how a collection of specialist documents will facilitate knowledge diffusion and perhaps to construct knowledge map.

4 TEXT ANALYSIS AND CORPUS-BASED STUDIES

Text analysis should be taken to mean the analysis of text by algorithmic processing, and that may involve the computation of specialist lexis within a given or emerging domain. An algorithm may be defined as a step-by-step procedure capable of being run on a computer, hence rendered automatic or semiautomatic. Before it can actually be run, however, the algorithm must be coded in some computer language as part of a software program. The tool currently used for the purposes of this research is *System Quirk*, a computational linguistic software system providing a computer-mediated environment for text analysis created by the Artificial Intelligence Group, University of Surrey. The compound terms generated through System QUIRK/Ferret (Artificial Intelligence Group, University of Surrey), illustrate to a certain extent the composition and acceptance of frequent specialist words within a text repository. As well within the language of the domain and the domain knowledge; since latent clusters of concepts, may be represented by each of the compound terms (a hierarchy of concepts through morphological productivity of terms). Whereas each term's relevance to a collection of documents is erratic, it may be validated (*combined* and/or *externalized knowledge*) by the knowledge worker as it composes toward a given terminology. That signifies being of use to the individual knowledge worker or group of them. Thus, achieving acceptance based on consensus within an organization, and growing to be part of it and its external environment *(ontological spectrum)*. We have used these and other sets of compound frequent terms extracted based on a statistical criterion (in relation to the BNC); for comparative purposes, sometimes referred to as "*Lexical Signatures*" to index collections of text to be contained within a text repository. Frequent compound terms extracted from the collection of documents (Source: Surrey Space Centre corpus) listed below, illustrate the specialist nature of the organization and the domain of the knowledge within aspects of satellite technology encompassed by the research and possibly of the commercial activities of the organization. The compound terms selected below, from the corpus of SSTL and Surrey Space Centre is from a listing of over 50.000 compound terms within the corpus. Such contains all collated research publications of the organization (s) aforementioned.

Table 3- Ranking of select compound terms in SSTL/Surrey Space Centre corpora

Rank	Compound Term	Rank	Compound Term
1	low cost	32	doppler shift
4	propulsion system	33	swath width
6	remote sensing	33	satellite platform
7	surrey satellite technology ltd	33	narrow angle image
8	surrey space centre	34	sstl microsatellites
9	board computer	34	control system
10	low earth orbit	34	satellite missions
15	spectral bands	34	data products
17	disaster monitoring constellation	34	disaster monitoring
18	attitude determination	35	multiple satellites
19	earth observation	35	satellite engineering
21	launch site	35	radiation environment
22	remote regions	35	space science
23	ground station	35	board processing
24	launch vehicle	35	satellite design
28	board computers	35	mission lifetime
29	satellite communications	35	system design
30	synchronous orbit	36	satellite programme
30	satellite technology	36	synthetic aperture radar
30	band downlink	36	board data handling
31	solar panels	37	data storage
31	global coverage	38	space technology

The above table is illustrative of the morphological productivity (Bauere, 2001) of single word terms, like: cost, satellite, system, launch, sensing, et cetera. Whereas, their compound word formations may be representative of a morphological process based on which knowledge of the domain flows and adapts to the organizational setting in which it is created. Sometimes similar terms that were ranked differently have appeared within the collection of documents collated from the Swedish Space Corp satellite technology news corpus, as shown below in table 4. Being possibly illustrative of wider *ontological spectrum* (knowledge sharing), of the knowledge of the satellite technology domain and corresponding research and commercial activities. That could as well happen to be dependent on the source of authorship; thus biased. Implying in turn a

wider *epistemological spectrum* (knowledge theory), as suggested by Nonaka et al (1995).

Table 4- Ranking of select compound terms in Swedish Space Corp corpora

Rank	Compound Term	Rank	Compound Term
2	launch vehicle	40	resolution images
3	geostationary orbit	40	proton launch
8	launch pad	41	reusable launch vehicle
10	geostationary transfer orbit	43	satellite manufacturing
15	shuttle mission	44	remote sensing
17	surrey satellite	46	satellite constellation
19	rocket boosters	48	meteorological satellite
20	shuttle missions	49	spy satellite(s)
22	satellite launch	50	satellite launched
24	remote sensing satellite	52	mobile satellite
27	manned spaceflight	53	manned spacecraft
29	satellite launcher	54	satellites launched
30	geostationary satellite launch vehicle	54	geosynchronous orbit
31	satellite launches	55	satellite payloads
32	launch initiative	58	remote sensing satellites
36	synchronous orbit	60	disaster monitoring constellation
38	launch vehicles	60	launch mission
38	remote manipulator	60	launched satellites

Examining compound terms within collections of PhD Theses, from Surrey Space Centre. These compound terms have appeared to present some dominant terms within, thus knowledge created and utilized. As shown in Table 5 below, select compound terms are listed, relating their frequency behaviour to the number of total compound terms generated from the corpus in percentage value (frequency / total number of compound terms found). The data presented in the table below (composing 20.96% of the total compound terms found) is presented as such to see lexical composition of such collection of documents – the extent to which each compound term contributes to the total number of compound term. Nonetheless, terms like: mobile satellite, satellite communication, satellite network, leo satellite, satellite constellation, remote sensing, and last but not least geostationary satellite orbit. Though all exist in satellite technology corpora, which were collated from sources prescribed previously. Some common ground is possibly available for such concepts to be shared across such specialist domain, and organizations within. This is assumed to facilitate the diffusion of knowledge within such domain (s). However, level of adaptation and further flow of the knowledge involved, is related to technological implications for the knowledge worker or organization.

Table 5- Compound terms within a listing of PhD theses titles

Compound Term	Relative frequency ratio	Compound Term	Relative frequency ratio
mobile satellite	2.94%	selective fading	0.37%
satellite communications	1.47%	satellite constellation	0.37%
processing satellites	1.47%	IP multicast	0.37%
satellite networks	1.10%	geomobile satellite	0.37%
IP telephony	0.74%	multicast strategies	0.37%
satellite constellations	0.74%	adaptive multiuser detection	0.37%
leo satellite	0.74%	thrust orbit	0.37%
mobile satellite communications	0.74%	geostationary satellite	0.37%
satellite multimedia	0.74%	noise amplifier	0.37%
geostationary satellite orbit	0.74%	satellite inertia matrix	0.37%
mobile communications	0.74%	orbit calibration	0.37%
gravity gradient	0.74%	satellite diversity	0.37%
orbit satellites	0.74%	sstl satellites	0.37%
remote sensing	0.74%	frequency bands	0.37%
novel orbit propagation algorithm	0.37%	ozone content	0.37%
satellite imaging	0.37%	satellite measurement	0.37%

The observational and historical studies carried out, have provided better understanding into the field of investigation. Such studies provided the basis and validation for inferences made. Based on Nonaka et al's (1995) terminology used within the *knowledge conversion model*, portraying creation of knowledge and corresponding conversion processes. It is believed that knowledge undergoes a combination and socialization conversion process (for knowledge flow) within an organization or across a (sub) domain (s), and undergoes an internalization and externalization conversion process (for knowledge adaptation) within an organization or across a (sub) domain (s).

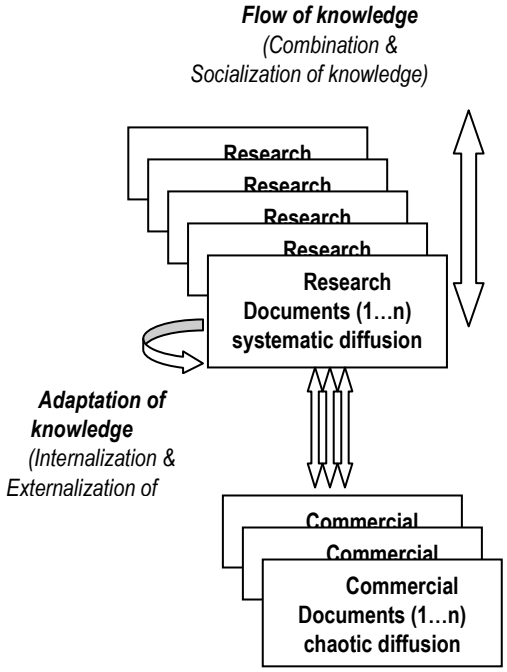


Figure 2 - Knowledge diffusion through the *knowledge conversion model (Nonaka et al, 1995)*

Figure above expands Nonaka et al's (1995) knowledge conversion model, to include consideration for how knowledge flows and is adapted within research and commercial documents. Within the case of an SME, Small to Medium Enterprise, such knowledge flow and adaptation through a *knowledge conversion model* may be a framework that could stimulate innovation through conversion of knowledge amongst the *Knowledge Creating Crew* (Nonaka et al, 1995) and stemming from an organization.

5 CONCLUSIVE REMARKS

The case study is a method of learning about a complex instance through extensive description and contextual analysis. The product is an articulation of why the instance occurred as it did, and what may be important to explore in similar situations, in our case the specialist knowledge and its diffusion is the product. As the observational study laid the framework for the conduct of our research, it was focused on examining knowledge flow, and corresponding practices and information technology support in place. Results from the observational study have indicated that knowledge bottlenecks may exist, in particular were technological support could be needed. The transmutation of science into technology is a complex process when one sees unique ideas highlighting the past scientific landscape and beneficial technological artefacts in the present. The notion of satellite technology or space technology, with variable scope and scale, was an ostentatious idea that has led to a range of remote sensing and earth observation instruments for instance. The *unique idea* is a key reference point for forecasting how the idea will metamorphose into an artefact. Knowledge is communicated through so-called semiotic systems: written text, images, mathematical and chemical symbols, and so on. The knowledge of emergent domains is yet to standardize its symbol systems which simply add to the (creative) chaos inherent in such emergent systems. The analysis of change in written text, amongst the most changeable semiotic system at the lexical level at least, may reveal a consensus or dissension in the use of terms. Terms denote concepts and textually help us to understand how knowledge evolves in an emergent domain. The emergent domain of small satellite technology was studied as an exemplar. This is our attempt to establish a method, which covers a broad range of texts, research articles, commercially-driven documents and state-of-the-art papers representative of research and development conduced within an organization, to observe the emergence of a new domain.

We have by design focused on an innovative organization to establish our method which is driven by knowledge workers, document-based and guided by terminology utilized. The method will facilitate the construction of knowledge maps in an objective and systematic fashion. This method will help in establishing knowledge visualization studies in the realm of decision making focused on how research is exploited and how such a process can be facilitated, at lexical and knowledge worker levels. Whilst aiming to model sustainability of an

organization through its continuous knowledge diffusion processes from persons composing such organization. It is an intuitive statement that research ideas and experimentation form the basis of new technologies, products, and practices. The research effort leads to the creation of new knowledge, and to the suspension of 'obsolete' knowledge, and this knowledge crosses over into technology. Perhaps a comparative analysis of the choice of terms (lexical signature) will indicate the extent of this cross-over. In this spirit of specialist knowledge still in the realms of research and not quite making it into the construction of artefacts and vice versa, we have compared the rank order of the most frequent words in the research corpus of SSTL/SSC papers with that of the Swedish Space Corp satellite technology news corpus, or between Surrey Space Centre PhD research theses and SSTL research publication, for instance.

Our analysis shows that research papers and commercial documents can be distinguished somewhat on the basis of single word and compound terms that were generated automatically. These two lexical signatures show the potential for identifying cross-over points in the diffusion of knowledge from the research arena to applications domain. The metamorphosis of science into technology is a complex process when one sees innovative ideas highlighting the past scientific landscape (i.e. in the form of PhD theses and state-of-the-art research papers) and beneficial technological artefacts in the present. The notion of satellite technology, with variable applications, was a unique idea that has led to a range of remote sensing devices for example. The innovative idea is a key reference point for forecasting how the idea will metamorphose into an artefact. Knowledge is communicated through so-called semiotic systems: written text, images, mathematical and chemical symbols, multimedia and so on. The knowledge of emergent domains is yet to standardize their symbol system which simply adds to the (creative) chaos inherent in such emergent systems. The analysis of change in written text, amongst the most changeable semiotic system at the lexical level at least, may reveal a consensus or dissension in the use of terms. Terms denote concepts and textually help us to understand how knowledge diffuses in a domain. The specialist domain of satellite technology or space technology, specifically an organization in such a domain was studied as an exemplar. This is our attempt to establish a method, which covers a broad range of texts, PhD theses, journal articles, technical reports, and state-of-the-art review papers, to observe the emergence of a domain and hence specialist diffusion of knowledge.

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