Digital Ecosystem for Knowledge, Learning and Exchange: Exploring Socio-technical Concepts and Adoption

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Abstract. Knowledge is an indispensable element that ensures healthy functioning of any socio-technical system. Despite a terminological ambiguity, it is discussed by many researchers. Learning is a process to seek and recreate knowledge within socio-technical systems. In this paper we attempt to explicate the terminological ambiguities of knowledge and explore knowledge processing and creation cycles as relevant for socio-technical systems. Further we present insights about theories of learning discussed by different scholars. We extend the paper towards new models of knowledge exchange inspired by and flow inspired by digital ecosystem concepts.

Keywords: Digital Ecosystems, Knowledge, Learning, Socio-Technical Systems, Agriculture Innovation in India.

1 Introduction

Digital ecosystem (DE) is described as a socio-technical infrastructure and processes bridging three different disciplines: Social Science, Computer Science, and Natural Science [1]. The social science here refers to the behavioral aspects and addresses the instances of communities, culture, practices. Computer Science refers to the technological aspects of information and communication and addresses the issues of infrastructure, application environment and services to support the behavioral dimension. Natural Science act as a metaphor to observe, learn and apply the self-sustainability features such as 'self generation', 'self catalysis' etc. to the behavioral dynamics. In context of knowledge transfer and learning, a DE can be viewed as a socio-technical system which supports knowledge creation, recreation, diffusion, absorption and exchanges that support the dynamics of social innovation.

The socio-technical theory is one of the approaches initially conceptualized in the domain of organizational design where the main focus was given to people, technology and work environment. One of the seminal articles [2] defines the socio-technical systems as:

a work system is made up of two jointly independent, but correlative interacting systems - the social and the technical. The technical system is concerned with the processes, tasks, and technology needed to transform inputs to outputs. The social system is concerned with the attributes of people (e.g., attitudes, skills and values), the relationships among people, reward systems, and authority structures.

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According to this conceptualization, both social and technical systems jointly interact to produce organizational output. Social system holds its own requirements during adoption of the technology, while technical system may have their own constraints. These two systems when considered separately can be contradictory or complementary to each other. Earlier authors [2],[3] argue for the principle of 'joint optimization' of both of these two systems for effective functioning of any organization. In socio-technical context, knowledge can be viewed as one of the organizational outputs and learning as the process to internalize knowledge. In this we will elaborate upon the social and technical elements necessary for knowledge exchange and learning.

Knowledge is the central element which interacts with the individual and organization, gets embedded into them and drives it in a progressive manner. The human mind observes and interprets the surrounding in terms of concepts, theories, values, and beliefs, which form knowledge embodied in the mind. Knowledge is also recognized as a mental construct which resides within every individual and acts as a framework to understand, evaluate and acquire new knowledge. In this respect, Knowledge is highly personal to the knower who gathers facts by his/her objective observation of nature. In the book 'Personal Knowledge-Towards a Post Critical Philosophy', [4] highlights the personal component 'Intellectual Passion' as an individual urge that drives the exploration of patterns existing around the nature. Knowledge is created in the mind through mental processes such as cognition, comprehension, and through exchange in a social interaction. Knowledge once acquired, is reflected through actions, words, behavior, habit and attitude of the individual. It is also expressed into written or symbolic forms for dissemination, storage, protection, sharing, and future usage. Knowledge creation is understood as organizational phenomena and elaborated by the SECI model [5]. Another model of knowledge creation is presented by Boisot [6] in his 'social learning cycle'. Both of these knowledge processing theories can be related to the socio-technical theory. Knowledge creation happens by the contribution of both social as well as technological factors. Social components include behavioral phenomena such as learning (e.g. social learning and organizational learning) and knowledge sharing (which also includes knowledge co-creation). Technological components deal with the information and communication tools that help in codification, storage, dissemination and transfer of knowledge. Moreover, advanced information, communication and media technologies are also helping social interaction and experience sharing among individuals and communities.

2 Knowing about Knowledge

It is widely accepted that a valued part of the knowledge remains in the tacit form in the minds of the individual. The iceberg model of knowledge is widely accepted to give a general distinction between tacit and explicit spaces of knowledge. It is commonly understood that we can write less than what we can speak, and we can speak far less than what we know. There is always a large repertoire of unexpressed knowledge present within every individual. It is well evident that knowledge requires language and words for elaboration and codification. Nonaka argues upon the proposition that tacit knowledge can be (difficult to) externalized and codified into documents and physical artifacts external to the mind. An alternative argument exists against the codification strategy of knowledge, which says that all the tacit knowledge can never be captured and converted into explicit form [7]. This idea against codification also complies primarily with the technical know-how dimension of tacit knowledge. For example, riding a bicycle, swimming, convincing the customers, interpersonal skills etc. are unique experiential knowledge with respect to the individual and can never be transformed completely into the hard form, but only learned through practice. Innovation in a large socio-technical system needs dynamic exchange of tacit knowledge often in ad hoc transient networks like farmer's fairs or through 'problem based learning'.

From epistemological perspective, any knowledge is valid only within the context and settings in which it is acquired and learnt. Before applying the previously acquired knowledge (as available in books and standard procedures), it is essential to critically compare both the contexts, i.e., context of knowledge acquisition and context of knowledge application. Therefore, knowledge of context is itself is a separate kind of knowledge which is critical during the process of learning and practicing. According to Nonaka, tacit knowledge resides in the humans as justified beliefs. Justified beliefs are the knowledge which are tested and evaluated by the current state of reasoning ability by the knowledge holder and liable to continuous modifications through learning. This notion can be related with another perspective to categorize knowledge, which is put forth by Firestone & McElroy [8] under 'unifying theory'. The unifying theory assumes that knowledge is produced by complex adaptive systems[1]. Authors propose three types of knowledge which are assumed to be tested and evaluated.

i. Tested, evaluated, and surviving structures of information in physical systems that may allow them to adapt to their environment (e.g. genetic and synaptic knowledge).
ii. Tested, evaluated, and surviving beliefs (in minds such as mental models) about the world that is subjective and non-sharable?
iii. Tested, evaluated, and surviving, sharable (objective), linguistic formulations about the world (i.e. speech- or artifact-based or cultural knowledge).

These three types of knowledge are called 'Biological Knowledge', 'Mental Knowledge', and 'Cultural Knowledge' respectively. Biological knowledge is highly personal in nature and is about becoming conscious of internal mechanisms of the body and mind which influences day to day activities. Mental knowledge can be understood as a latent knowledge that complies with the tacit dimension discussed earlier. Cultural knowledge reflects in the oral and behavioral expressions of individuals during work and social interactions. The brings out the latent knowledge of the mind to an observable form, which can be further investigated, analyzed, learned and adopted by the others.

[1] Examples of a complex adaptive system can be the ecosystem, where organisms interact with other species in the ecosystem and learn to survive and grow [9]; or it may be human brain whose neurons are connected by synapses to a complex network [10].

3 Knowledge Processing and Creation

3.1 Information Perspective: DIKW Model

Theories of information management attempted to situate ‘knowledge’ at a relative position in a pyramidal structure known as ‘Wisdom Hierarchy’ or ‘DIKW Hierarchy’ which has four successive states: data, information, knowledge, and wisdom [11]. Data is placed at the bottom of the pyramid followed by information, knowledge and wisdom staying at the top. Data are symbols representing observations and raw facts (A state of Know Nothing) which is external to our mind and can be interpreted in many ways. Information is processed and inferred data (Know what) with respect to some specific context of the recipient or interpreter. Knowledge is information combined with understanding, context, interpretations and reflections (Know-How which becomes richer than the information. Wisdom is the evaluated understanding (Know-Why) that helps to make strategic decisions, such as why, where, and when to apply the knowledge. The level of complexity, context dependency, and integrity gradually increases from bottom to top of the pyramid.

3.2 Cognitive Perspective: E2E Model

The four hierarchical constructs of DIKW pyramidal model is further extended by the arguments of cognitive system of knowledge, which presents a complexity based view. This view restructures the earlier conception of DIKW hierarchy with two additional constructs: ‘existence’ and ‘enlightenment’ and opens up the closed boundaries of the pyramidal knowledge system. This chain of six successive constructs (Existence-Data-Information-Knowledge-Wisdom-Enlightenment) is known as existence to enlightenment (E2E) model [12]. This proposition further says that data, information, knowledge and wisdom, all are constructs coming out as a result of abstraction of the existence at different levels. Such abstractions exist in a continuum and the highest level of abstraction is the state of enlightenment, which is hypothesized to be the most intelligent form of understanding. The relationship between these constructs is considered to be non-pyramidal and non-linear in nature.

3.3 Knowledge Processing Cycle

The cognitive perspective (E2E model) of knowledge is basically related with the process of learning through observation and abstraction of the different parts of reality existing in the world. In E2E model, Knowledge is processed by the mind by combining the context and conditions. Knowledge flow is directed towards the mind which usually happens during the process of learning or understanding. The nature of knowledge processing in DIKW model has alomost similar direction of flow. In this case, knowledge is created by interpreting the data and information with their respective contexts. Tuomi [22] challenges this pyramidal structure and proposed a reverse hierarchy of Knowledge, Information and Data. He contends that knowledge must exist to formulate information, and data emerge only after availability of information.

The abstract of these arguments relates to the top-down and bottom-up processing of knowledge and creates a cycle of 'learning' and 'elaboration' which leads to the creation of implicit and explicit knowledge respectively (Figure 1). Any knowledge artifact can be created by some agent (by his previously acquired knowledge) and represented as data of information. This data or information is observed, interpreted (through analysis and synthesis) and internalized by another agent and form a part of his knowledge repertoire. Elaboration leads to externalization of knowledge into knowledge artifacts, and learning leads to internalization of knowledge artifacts in the mind of the recipient. The nature of learning and elaboration are highly dependent upon the ability of the agent and his/her environment or interface.

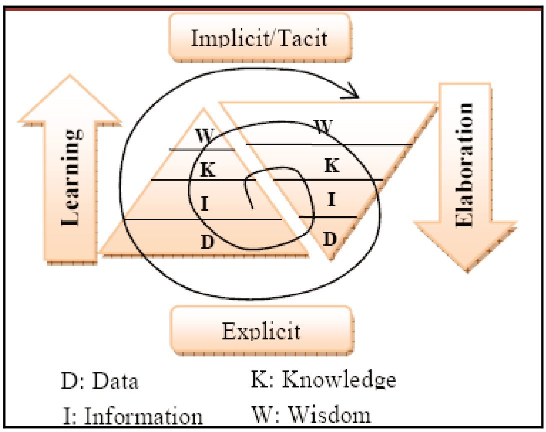

Fig. 1. Knowledge Processing Spiral

From above discussions it can be inferred that knowledge is a dynamic object which can be created in the mind in implicit (and tacit) form and can be explicated by expressing into different forms. The explicated knowledge when detached from the source and context, then it becomes an information (and/or data). When information is observed by the recipient and combined to his prepossessed context, then as a process of learning it becomes a new form of knowledge and stays within the recipients mind. Knowledge keeps on combining and updating with experience over the time. But this process is individualistic and cannot be easily controlled by centralized 'top down' system. In a goal oriented socio-technical innovation system we are however concerned with time bound (at least progressive) results. The preceding discussion elaborates the problems that can arise when one want to 'manage' and control a process which is inherently 'uncontrolled'. Our experimental Knowledge Exchange Network (KEN) system therefore draws upon the duality of figure 1, and conceptualizes an interactive network.

3.4 Knowledge Creation and Transformation

Knowledge can be processed with the help of mind and computing devises. But according to the earlier discussions in this paper, processed knowledge unless situated inside mind can't be termed as useful 'knowledge'. Every time any knowledge is processed, it changes its form and learning state of the knowledge processing entity. Here in this case, knowledge processing entities are essentially individuals. The theories of knowledge creation explain the phenomena of learning and elaboration happening among individuals, groups and organizations. Knowledge creation can be regarded as creation of both implicit and explicit knowledge as a result of cognition, social interaction, comprehension, and elaboration.

4 Theories of Learning

Learning can be understood as an integral part of the knowledge creation phenomena. As an organizational phenomenon, learning can be described from two different angles: Adaptive Learning and Generative learning [13]. The two types of learning are the part of macro level strategic debate between organizational learning [23] and learning organization [14]. These two learning concepts are elaborated in the following subsection.

4.1 Learning at Institutional and Individual Levels

Generally both adaptive and generative learning practices are followed by the organization in different proportions. Learning strategy is partially pushed by the top level management (e.g., radical technological changes) to match the organizational vision, and partially it is pulled by the individual and groups towards operations involving organizational innovations and incremental improvements.

Literature on Organizational Learning also discusses learning as a problem solving activity which involves error detection and corrections and to make decisions. Problems can occur either during the people trying to math their ability with the fundamental elements of the organization such as its structure, goals and objectives. In this context, learning is classified into two types: single loop learning, and double loop learning [15]. These two types of learning happen in two separate problem space: one is the space where organizational tasks are performed, and other is the fundamental principles, goals and objectives at which organizational tasks are defined. When people are working on a well defined job under formally set organizational policies and principles, then this gives rise to the phenomena of single loop learning. On the other hand, when people questions upon the job definition, organizational policies and principles, then it is the case of double loop learning. Single loop and double loop learning practically correlates with generative and adaptive learning respectively. Learning during problem solving is directly influenced by the way problem is understood and disseminated. In one of the popular works on Organizational Learning, [16] referes to 'bounded rationality' and discusses about the limited human ability to adap to the new and complex environments in finit time. The author discusses about the organizational learning in the domain of adopting organizational culture and transfer of innovation among the employees.

Apart from the strategic perspective, learning can also be seen from a process perspective at individual level. Learning takes place by social interaction, individual cognition and comprehension depending upon the nature and forms of knowledge. Jenson and others [17] propose two different modes of learning: STI (science, technology and innovation) mode and DUI (doing, using and interacting) mode respectively - which assist in knowledge creation and innovation.

i. STI Mode: This mode can be assumed close to theoretical learning (i.e. learning with codified documents/literatures etc.), which is associated with the ‘Know what’ and ‘Know why’ kind of 'explicit knowledge’, and primarily deals with 'Science, Technology and Innovation'. The important aspects of know-what and know-why may be obtained through reading books, attending lectures and accessing data bases. This mode of learning-innovation refers to procedures where a firm develops a scientific and technological understanding in R&D laboratories (e.g. ‘just in case’ learning). The STI mode of learning start with a local problem make use of global knowledge and end up in creating ‘potentially global knowledge’ in abstract forms which can be applied in many different situations.
ii. DUI Mode: This mode of is associated with tacit and experiential knowledge (‘know how’ and ‘know who’), which is embodied in the organizational structure and relationships. It is rooted in practical field experiences of the individual and group. This kind of learning is generally and often localized. Communities of Practice (CoPs) [26] are one of the examples of this mode of situated or localized learning. This kind of learning happens in real time (or ‘just in time’) on the job employees who keep confronting new work challenges. This results into enhanced skill of employees and extends their repertoires.

4.2 Boisot’s Social Learning Cycle

Boisot [6] described the knowledge transition in a three dimensional space which he named I-Space (or Information Space) where learning takes place through six different phases: Scanning, Problem Solving, Abstraction, Diffusion, Absorption, and Impacting.

i. Scanning: This phase involves gaining insights by searching potentially fruitful pattern of (diffused) data which is less codified and abstract. This data may be subjected to multiple interpretations. Scanning is quick when data is abstract and codified and slow otherwise.
ii. Problem Solving: This is a process of giving structure and coherence to the insights. This involves exploring and extracting novel patterns from the scanned data and giving it a defined structure by applying imagination and independent thought. The new insights are partially codified.
iii. Abstraction: The partially codified insights are generalized to diverse range of situations. This involves reduction of the abstract insights to specific features particular to different situations.

iv. Diffusion: Insights are shared with the target population. Higher degree of abstraction and codification of insights increase the diffusion of data at distributed locations by electronic medium.
v. Absorption: The codified insights are applied to different situations in a learning-by-doing or learning-by-using fashion which produce new learning experiences and behavioral changes during practice. New uncodified/tacit knowledge is created as a result of absorption.
vi. Impacting: The abstract knowledge is embedded into concrete practices e.g., artifacts, technical or organizational rules, or behavioral practices. Tacit knowledge is reflected in formal work practices through which standards are formulated.

5 Summarizing the Key Concepts

Following table enlists all the concepts of knowledge and learning explored in the previous sections.

Table 1. List of Concepts Explored

	Author	**Year**	**Key Concepts**
Knowledge	Polanyi	**1958**	Personal Knowledge, Tacit Knowledge
	Nonaka	1994	SECI Model
	Nonaka & Konno	1998	The Concept of 'Ba'
	Wilson	2002	Distinguishing Tacit and Implicit Knowledge
	Firestone & McElroy	2005	'Biological', 'Mental' and 'Cultural' Knowledge
	Rowley	2007	DIKW Hierarchy
	Faucher, Everett, & Lawson	2008	E2E Model of Knowledge
	Tuomi	1999	Reverse Hierarchy of Knowledge
Learning	Argyris	1982	Single Loop Learning and Double Loop Learning
	Senge	1990	Learning Organizations;
	Simon	1991	Bounded Rationality
	McGill, Slocum, & Lei	1992	Adaptive (Instrumental) Learning and Generative Learning
	Senge & Fulmer	1993	Anticipatory Learning and Systems Thinking
	Boisot	1998	Social Learning Cycle
	Jensen, Johnson, Lorenz, & Lundvall,	2007	STI and DUI modes of learning.

6 Socio-technical Approach

We attempt to look at the digital ecosystem from a socio-technical vantage point for observing the static and dynamic states of knowledge and learning. Firstly we try to elaborate upon the basic components of this system.

6.1 Socio-technical Elements

i. Actors: Since knowledge resides in the mind of the people, therefore they are the central actors of knowledge creation. Knowledge creation and learning can happen at individual level, group level, organizational level and social level at large. Mind and body are the two participating element with the actor. Apart from those, culture, ideals and skills are the inherent attributes of the people which influence the system. Organizational values, social norms, self esteem, incentives, peer to peer network etc. are the environment factors which influences the knowledge and learning of the social actors.

ii. Technology: In the context of knowledge creation, there can be three different segments of technology:

  a) Information Technology (codification/compression/ user interface design etc.)
  b) Communication Technology (telecommunication/ internet/ broadband wireless network, collaborative interaction etc.)
  c) Media technology (video, animation, audio, image/design, graph/chart, text/ number etc.)

Information technology provides electronic spaces and facilitates representation, storage, and transfer of both semantic and episodic knowledge of the individual and organization. Additionally it helps in organizational knowledge processing and support semantic and episodic learning. Communication technology provides network and connectivity among the knowledge actors for their multilevel interactions and exchange of knowledge. Media technology provides richness or viscosity[2] to the knowledge flow and facilitates dynamic dissemination of knowledge objects. It provides highly interactive and dynamic interfaces which influence larger parts of human senses and helps not only in semantic learning, but also in episodic learning.

iii. Knowledge: Knowledge is not of any use unless it is processed, personalized and transferred to the application spaces (in our case towards social innovation).

iv. Learning: Learning happens through cognition which involves comprehension as well as apprehension. Problem representation (definition) and solving are the two fundamental aspects of learning. Due to cognitive limitations, problems are conceived by different individuals in different perspectives. Technology helps to integrate various aspects of a problem and overcome the phenomena of 'bounded rationality'. Apart from that, technology helps to create a better reflection of organizational image and overview by various dissemination methods. 'Scanning' and 'systems thinking' [24] are the fundamental aspects of problem representation and solving. Better representation of problems and

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[2] Viscosity refers to richness of knowledge and concerned with the gap between value of transmitted and absorbed knowledge. Long and continued mentoring exemplifies the phenomena of highly viscous knowledge transfer.

organizational processes facilitates not only single loop learning, but also in double loop learning. Technology can assist in both STI and DUI modes of learning which can build scanning ability and systems thinking approach within the individuals. Highly interactive design spaces encourage people to express their creativity and learn by DUI mode. Well design dissemination and communication spaces helps in STI mode of learning.

In the social context (for example in Indian agriculture), learning can also be understood seen as knowledge transfer between different social strata having varying accessibility to knowledge. One of the most valuable thought is given by Freire [25], who elucidated the phenomena of learning in a particular socio-political environment.

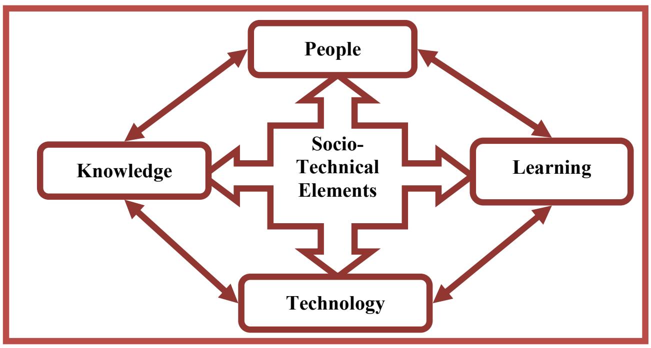

Fig. 2. Fundamental Socio-Technical Elements

6.2 Socio-technical Environment

Technology is a key determinant to create a characteristic environment where knowledge creation takes place. Environment has a major influence upon the behavioral patterns of the knowledge creating agents. In context of knowledge creation we limit our view on technology to information, communication, and media technology.

Extending the SECI model of knowledge creation Nonaka and Konno [18] highlights upon the four knowledge creation spaces: 'originating Ba', 'interacting Ba', 'cyber Ba' and 'exercising Ba' which corresponds to the four respective phases of SECI model. 'Ba' can be any physical space, mental space, or virtual space where knowledge is created in the organization. In the authors' conceptualization, Cyber Ba refers to the virtual spaces of interaction what is limited only to facilitate combination mode of knowledge creation. Cyber ba is highly influenced by drastic growth in information, communication and media technology. The technological trend has opened the conceptual boundary of 'Cyber Ba' to overlap and partially accommodate all other three modes of knowledge creation which includes socialization, externalization, and internalization (Figure 3). The extension of virtual world (or Cyber Ba) to other domains helps in the following ways:

i. Experience sharing through storytelling, empathizing and sympathizing (socialization) in voice based transactions. The virtual spaces that support socialization are: virtual chat rooms, audio blogs, video sharing virtual spaces etc.

ii. Interacting with the group and make a shared understanding over a subject (externalization). Examples of supporting spaces are Yahoo group, Google group, Online Forums etc.
iii. Analyzing and Synthesizing codified knowledge from different sources in order to innovate (combination). Examples include document sharing websites, social networks having personal and sharable spaces, collaborative web spaces (Wikipedia) etc.
iv. Learning from the interactive virtual spaces (personalization) such as online design environment, animations, and games.

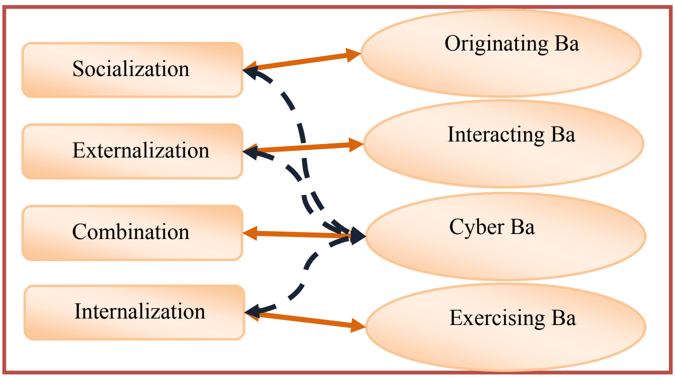

Fig. 3. Extension of Cyber Ba to all four modes of knowledge creation

6.3 Moving towards Social Innovation

We will now explore the role of knowledge exchange and learning among various constructs that lead to social innovation. In the article 'Knowing Life', Polanyi [4] discusses about the limits of observational capacities through which knowledge is acquired and how new knowledge further increases the same observational capacities through which knowledge was acquired. It is difficult to identify the initial point where there was no knowledge. Here we assume that some insights are always possessed by everyone at any point of time which comes from past experience, cognition and experimentations. Such insights help in the process of natural selection and creates urge to explore more knowledge of particular type of relevance to the respective agents. Personal insights are added with multiple modules of information coming from different domains. It is further enriched with collaborative interactions happening in social groups such as Communities of Practices, Knowledge Networks. Phenomena like 'produsage' [19], 'co-experience' [20] etc. illustrate the domain of the collaborative interactions in more detail and one can easily situate these concepts in the context of socio-technical innovation.

Knowledge construction is driven primarily by such collaborative interactions, while previously acquired insights act as a measure to believe and justify the trueness of the constructed knowledge. The trueness of knowledge however changes over time and space with change in social value propositions, purpose and utility. Therefore continuous learning and finding newer applications of knowledge becomes essential to keep the knowledge recent and useful. This stage of knowledge evolution unravels the possible roots of innovation that can occur in various social processes. The expansion of 'cyber ba' increases the possibilities of collaborative interactions and continuous learning, which paves the way for social innovation and strengthens the economic competency among the socio-economic actors. Figure 4 represents a framework to understand the relationships among different concepts that foster framework to understand the relationships among different innovation.

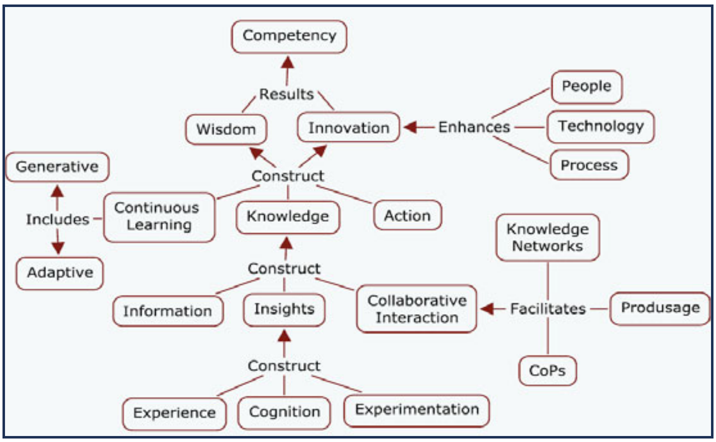

Fig. 4. From Cognition to Competency

7 Knowledge Driven Agriculture in India

Indian agriculture can be considered as one of the oldest socio-technical systems which engage directly or indirectly over 500 million people. The social part of this socio-technical system is composed of agriculture community which includes agriculture scientists, researchers, farmers, and service providers. Technology is embedded at every level in agriculture: right from the production of seeds, fertilizers, pesticides etc to tractors, tillers, and other farm equipments or in post harvest practices.

The Indian agriculture sector is expected to meet the growing need of food grains for a rapidly growing nation, new strategies are needed to enhance the agricultural growth rate to at least four percent from the current level of 1.8 to 2 percent. This level is essential to sustain a double digit growth rate for Indian GDP while retaining inflation at a manageable level. In order to pursue this target, knowledge and innovation are at the core of the strategy around which agricultural innovation can happen.

Several generalizations of the concepts of Knowledge are elaborated in earlier sections of this paper. For this particular domain of agriculture, we assume here that knowledge is socially constructed and adds to the personal insights. Online environment of collaborative interaction and community based learning or other ICT based learning opportunities enhances the potential of innovation and hence can introduce economic competency in this sector.

7.1 Review of Previous Experiences

Thus ICT implementation efforts across Indian villages attempt to connect agriculture community at all levels of practice and research. One of the efforts in this direction is DEAL (digital ecosystem for rural livelihood; website: www.dealindia.org) project which was deployed in 2006 at Indian Institute of Technology Kanpur. This project aimed to form a digital knowledge network among the Indian agriculture community to facilitate diffusion of knowledge and innovation. DEAL was structured around the concept of 'self-catalysis' (autopoiesis) [21] which proposes that if circularity in conversation can be created and maintained, then knowledge objects keep on reproducing and evolving. The structural design of DEAL has two different natures of knowledge spaces: 'Gana Gyan' and 'Gyan Dhara' focused to serve the knowledge needs of the organized, explicit and unorganized, emergent or transient agriculture communities respectively. 'Gana Gyan' implies folk knowledge existing in people's mind. This knowledge is primarily unstructured and embedded into work practices and insights. Gyan Dhara', on the other hand is formalized and validated knowledge which emerge from commonly accepted knowledge models of scientific community. This knowledge is highly structured in nature and can be disseminated, and circulated through internet. But paradoxically this digital distribution can result into ground level implementation only through social networks in the real world. These two streams of knowledge generation were targeted for different segments of agriculture communities. 'Gyan Dhara' was targeted for the people who constitute the knowledge storing and producing community. These include: agriculture scientists, researchers, field extension experts. 'Gana Gyan' on the other side is meant primarily for the communities who are knowledge users. They are lead farmers, small farmers, agriculture traders, student-researchers, Kisan (farmer) call-centers, agri-clinic etc. Scientific knowledge could thus be complimented and experimented with the field experiences, and the field experiences could be validated and generalized by the scientific knowledge. DEAL served for acquisition and visualization of knowledge and extended its services to the village level agriculture consultancy institutions known as KVKs (Village Knowledge Centers). The underlying assumption was, 'by infusing knowledge connectivity to human agencies and creating socio-technical feedback loops' critical success conditions can be created to energize rural economic infrastructure in India.

7.2 Challenges Encountered

Indian agriculture has been facing many technological challenges such as: unavailability of proper harvest management information infrastructure. Indian agriculture extension system relied upon the model of vertical diffusion for knowledge transfer between KVK scientists and farmers (Figure 5).

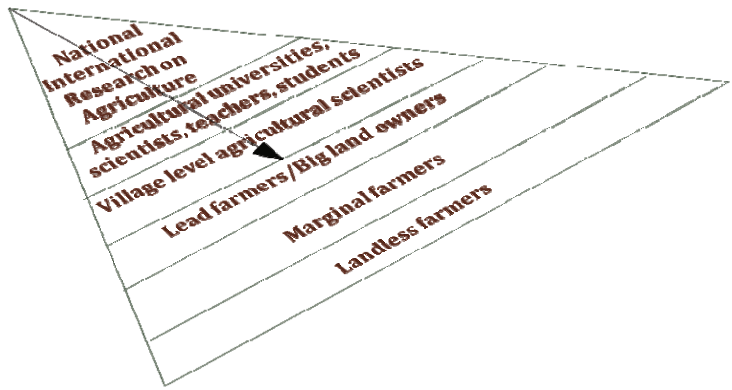

Fig. 5. Vertical Diffusion Model

Structure of communication was influenced by institutional hierarchy which impeded velocity and viscosity of knowledge transfer. Geographic distance was a critical barrier for the knowledge from one location to reach another in limited time. That gave birth to the phenomena of 'bounded rationality' among the field practitioners while taking critical decisions particularly during adoption of new techniques and methods. Same phenomena influenced the scientists whose research conclusions often lacked enough empirical instances.

In the beginning, the prime focus of DEAL was targeted to create digital knowledge repository and providing its accessibility to all the stakeholders of agriculture community in a networked environment. The network infrastructure established by DEAL to facilitate knowledge flow between lab and land possessed potential to overcome skepticism that farmers usually have while adopting new variety of seeds, fertilizers, pesticides, and farm machineries.

Despite having numerous promises to benefit Indian agriculture, DEAL has so far encountered many challenges which seek further attention. DEAL's knowledge based services are composed of two dimensions of knowledge: 1) tacit and experiential (Gana Gyan); and 2) validated and codified (Gyan Dhara). The level of knowledge diffusion to respective segments of agriculture community, and progress gaps are presented in the Figure 6. The upper quadrants of this figure represents the top end of the pyramid which include agriculture scientists and researchers from KVKs, State Agriculture Universities (SAUs), Indian Council of Agriculture Research (ICAR), and other similar Institutions. DEAL has been able to deliver in both of its knowledge dimensions to this section. For example, tacit and experiential component of knowledge flow is marked by participation in online spaces for Questions and Answers, Communities of Practices etc.

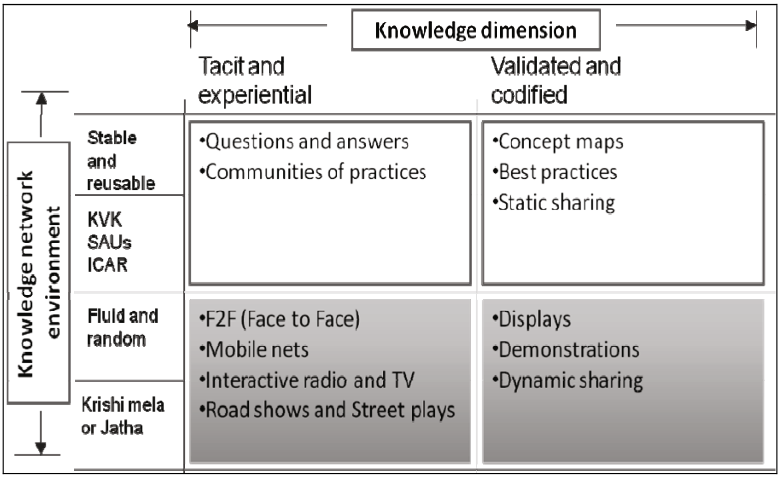

Fig. 6. Knowledge Dimension Vs Network Environment

Validated and structured dimension of knowledge flow is observed in the form of creation of concept maps, best practices etc. However this kind of knowledge contribution lacks direct p2p network based collaboration which is essential for social innovation.

Knowledge is acquired primarily through the contribution of commissioned scientists and researchers whose work is to structure and validate expert knowledge. Voluntary sharing of knowledge among the scientists did not reflect much interest which is a major cause of concern. The acquired knowledge remained in the silos of the repository and no significant interdisciplinary flow is observed. 'Self-catalysis' as a phenomenon is yet not self evident.

The lower quadrants of figure 6 reflect agriculture community who are primarily farmers and field practitioners. In this section, the tacit dimension of knowledge flow relies on face to face communication, mobile networks, radio, televisions, road shows and street plays etc. Validated and structured knowledge flow happens through displays, demonstrations, and dynamic sharing among the community members. The DEAL portal has not been able to contribute enough to this section. Farmers having rich field experience are yet to take much interest in this present form of digital media.

7.3 The Ripple Model

The initial flow of knowledge in India agriculture extension system followed a pattern of vertical diffusion. DEAL attempted to flatten this vertical hierarchic structure to some extent and reduced the time to get validated knowledge. However, it is unable to encourage collaborative activities, voluntary knowledge sharing, learning and innovation among the members of agriculture community. So a new approach is framed upon the 'Ripple Model' (Figure 7) which promises to produce ripple effect of knowledge flow through collaboration and interactions happening at multiple levels between and within the closely formed communities. This model emphasizes community formation among the people who are at immediate position in the vertical knowledge flow hierarchy. For example, at the highest level, the people from national and international research (level 1) can more likely to associate with scientists, teachers and students at Agriculture Universities (level 2). This section has the highest potential to engage in collaborative knowledge creation when connected through a social network. The network can be considered as 'Collaborative Innovation Network' (COIN). This network can also extend partially to village level scientists (level 3) and diffuse innovation oriented community behavior towards this end. At next level network can be formed by close association among people at level 2 and village level scientists (level 3) which can further extend up to big farmers and landlords (level 4). At this level of collaboration, expert knowledge flows from advanced university scientists to village level scientists. The network formed at this level can be considered predominantly 'Collaborative Learning Network' (CLN). Both the networks COIN and CLN despite having different nature of collaboration, doesn't exist in isolation, rather remain connected and keeps influencing each other. This also allows transition of members from CLN to COIN and so on. At the farmers end (level 5 and level 6), network creation can happen by common interest groups. This network can be called 'Collaborative Interest Network' (CIN). To reach out to the small or landless farmers (economically the most deprived) a new pedagogy through new forms of knowledge mediators will have to be created. It is assumed that this new pedagogy will complement India's current ambitions NREGA (National Rural Employment Guarantee Act) and will be created by the users' with p2p collaboration with local knowledge producers.

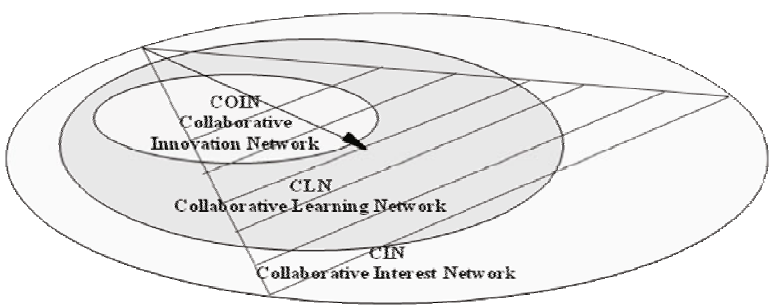

Fig. 7. Ripple Model

The 'produsage' and 'co-development' field experiment will provide new insights to understand the outermost ripples. 'Produsage' gives theoretical insights about knowledge co-creation by multiple agents who are collaborating and providing their individual inputs to create a common knowledge artifact. For example, many agriculture scientists having different domains of specialization can contribute their expert insights to create crop specific knowledge model. This kind of collaboration also results into co-experience mixed with social emotions. This co-experience can further create stronger ties among the collaborating entities and creates more potential for social interaction in future. This possibility has a strong affinity to visualize the phenomena of 'self catalysis' among the participating agents.

8 Conclusion

In this paper we have explored the socio-technical theories in relation to the DE framework to examine the phenomena of knowledge and learning in socio-technical systems. We extended the concept of Ba to the enlarged scope of 'Cyber Ba' and its possibility of transformation into social media. We have elaborated the case on Indian agriculture and presented a review upon previous experiences of DEAL implementation. The unmet gaps of the DEAL experience will be addressed through a new knowledge and innovation approach 'Ripple Model'. We propose a new design for transforming structural features of DEAL to shape it in the form of a new media for social innovation. This will need further research and investigation to track its performance over the next period.

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