

Decentralizing Knowledge Management: Affordances and Impacts

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Abstract: Personal Knowledge Management (PKM) is envisaged as a decentralizing Knowledge Management (KM) revolution and as a vital educational concern. The objective of a current design science research (DSR) undertaking is, thus, the conceptualizing and prototyping of a PKM System (PKMS) aiming at departing from today's centralized institutional solutions and at strengthening individuals' sovereignty and collaborations, not at the expense of Organizational KM Systems, but rather as the means to foster a fruitful co-evolution. This article expands on a recent paper focussing on the PKMS's affordances in the context of the individual and collective, explicit and tacit knowledge of knowledge workers by integrating twelve renowned models of knowledge creation in a three-dimensional dynamic 'public-transport-like' map of holistically portrayed complementing work flows. In further detailing the impacts and benefits for a prospective PKMS user community, the article highlights the major radical changes of the PKM approach according to the decentralization, mobilization, accessibility, granularity, traceability, transdisciplinarity, transparency, diffusibility, negentropy, and synergies of knowledge. The results reaffirm the DSR concept of theory effectiveness aspired to in terms of the system's utility and communication as well as the PKMS as a sustainable intervention to confront opportunity divides independent of space (e.g., developed/developing countries), time (e.g., study or career phase), discipline (e.g., natural or social science), or role (e.g., student, professional, or leader).

Keywords: Personal Knowledge Management (PKM); Knowledge Management (KM); Knowledge Creation Theories; Knowledge Worker; Knowledge Society; Radical Innovation; Digital Platform Ecosystem (DPE).

1. Systems thinking and the Feedback Loops substantiating Knowledge Creation Theories

Crane's critical review of forty-two Organizational Knowledge Management (OKM) theories (dispersed over the nine inner cells of the 3x3 matrix in Table 1) reveals a sharply divided field "positioned on two bisecting continua: organizational versus personal knowledge, and objectification of knowledge versus knowledge as social action" which form "often the site of considerable debate and contradiction, characterised by accusations of misinterpretation and misrepresentation" (Crane, 2015).

Table 1: A 3x3 Taxonomy of 42 KM Theories (Source: Crane, 2015) plus further 9 Models to be applied

Focus: Knowledge as Object	Organizational Knowledge Focus			Focus: Knowledge as Social Action
	17 theories reviewed, including: Earl 2001; b.	2 theories reviewed	13 theories reviewed, including: Blackler 1995	
	0 theory reviewed, excluding: e.	1 theory reviewed, including: Snowden 2002; excluding: d. g.	4 theories reviewed, including: a.	
	0 theory reviewed, excluding: j. k. l.	1 theory reviewed, excluding: f. i.	4 theories reviewed, including: c.; excluding: h.	
	Personal Knowledge Focus			

The scope of the 42 KM Theories assessed by Crane (2015) ranges from static life-cycle categorizations to dynamic multi-dimensional frameworks. Most KM notions acknowledge the significance of knowledge types (tacit/implicit versus explicit) and knowledge carriers (individual/group/organization/society) although inevitably disagree on basic premises and related effects. These incompatibilities among KM notions have prevented the emergence of an "universally accepted framework or model" (Curado & Bontis, 2010).

By reconciling the selected twelve dynamic theories and models, this article contributes to a current design science research (DSR) undertaking. Its objective is to conceptualize and prototype a Personal Knowledge Management (PKM) System (PKMS). As a longitudinal stream of research (typical for a DSR project), the author published over forty multi-disciplinary papers (exceeding 400 external references) at appropriate times in

terms of the continually evolving prototype and design theories, including a publication justifying the DSR paradigm (design as an artefact as well as a search process) as evidence of its problem relevance, utility, research rigor, contribution, design evaluation, and publishability in IS research outlets (Schmitt, 2016b). Several prior findings and references are, hence, cited and summarized to avoid reiterating considerable detail.

Table 2: Twelve KM Theories/Models utilized in this paper (with references used in the further tables/figures)

Legend (copied also in figure 1):			Table & Figure		
[#]	Knowledge Creation Theories/Models:	Sources:	T1	F1	F2
*	Information-Space, SLC, Knowledge Assets	Boisot (2004)	a	a	a
*	SECI-Spiral, Ba, Knowledge Assets	Nonaka, Takeuchi (1995); Nonaka, Toyama, Konno (2000)	b	b, d6	
*	Three Worlds	Popper (1978); Gaines (1989)	c	c	c
+	'Seven Waterfalls', ARME, and OEAM Spirals	Wierzbicki, Nakamori (2007ab); Nakamori (2011)	d	d, d0-d9	
+	Foraging and Sensemaking Process	Pirolli, Card (2005)	e	e	e
+	Experiential Learning Model	Kolb (1984)	f	f	f
+	Holistic KM Framework	Yang, Zheng, Viere (2009)	g	g	g
+	Tacit and Explicit Knowledge	Collins (2010)	h	h	h
+	Self-Transcending Knowledge	Uotila, Melkas (2008)	i	i	i
+	Inferencing: Abduction, Induction, Deduction	Shank, Cunningham (1996); Chow, Jonas, Schaeffer (2009)	j	j	j
+	Cumulative Synthesis	Usher (1954, 2013)	k	k	k
+	Memetic Evolution	Dawkins (1976, 2006)	l	l	l
Legend: *: theories/models covered by Crane +: theories in this paper not covered by Crane, but added to her 3x3 taxonomy above [#] The letters in columns T1, F1, and F2 correspond to the notions and connectors discussed and visualized within the text, table 1, figure 1 & 2. The Connector's letters may be followed by a number to indicate sequence or sub-notions depicted (figure 1).					

Although the aim of PKMS departs from today's centralized institutional solutions and strengthens individuals' sovereignty and collaborations, it is not meant at the expense of Organizational KM Systems but rather as the means to foster a fruitful co-evolution between the systems. The envisaged PKM concept and system, hence, attempts to adopt an '*Emergent Innovation*' approach (Peschl & Fundneider, 2013, p.1,3-5) by trying to ease the challenging tension between a radically new (Personal) KM perspective and its fit with already existing structures. Hence, Blackler's notion of *Encultured Knowledge* (1995), Snowden's *Cynefin Model* (2002), and Earl's *Schools of Knowledge Management* (2001) have been touched on in prior publications in the context of knowledge types, ignorance, and PKM-OKM-synergies suggesting fruitful potentials for co-evolution (Schmitt, 2014a; Schmitt, 2018c; Schmitt, 2018a).

Moreover, Nonaka's *SECI and Ba Model* (Nonaka & Takeuchi, 1995; Nonaka, Toyama, & Konno, 2000), Boisot's *Information-Space* (2004), and Gaines' expansions (1989) on Popper's *Three Worlds* (1978) have informed a three-dimensional knowledge mapping (Schmitt, 2017) which further included the *Seven Waterfalls Model* (Wierzbicki & Nakamori, 2007a; Wierzbicki & Nakamori, 2007b), the *Foraging and Sensemaking Process Model* (Pirolli & Card, 2005), and the *Experiential Learning Model* (Kolb, 1984) (see rows a.-f. in table 2's legend and positionings). The map's aim is to "provide a visual meta-perspective of the novel PKM Concept and prototype application. In focusing on time, space, and causality, the bottom-up approach taken, pictures the relevant Personal and Organizational Knowledge Spaces as a substitute for the intangible KM territory and provides a guiding map for knowledge workers and KM education" (Schmitt, 2017). Its topography emphasizes how the

models represent the external environment in which the PKM devices are expected to operate in and which of the workflows suggested are suitable for supporting the internal PKMS processes.

As a common forte, the KM notions chosen (and to be complemented in this article) employ a system thinking approach by providing positive feedback loops (effects in support of causes in a self-referencing self-reinforcing manner) featuring as cycles, circles, and spirals and dynamic connectors of [knowledge] stocks and flows across distinctive levels of diffusion. This article provides a cumulative synthesis by integrating six further KM notions and by connecting their dots (see rows g.-l. in table 2's legend) to result in a narrated visualization comparable to a 'public-transport-like' map with an emphasis on the envisaged supporting features of the PKM System for individual knowledge workers, organizations, and society. Each of the twelve KM notions chosen is referenced in table 2 (which is also copied in figure 1) and is pictured individually in figure 1. Their particular differences and complementing features are visualized in the cumulatively synthesized map (figure 2) and discussed in the accompanying text (incorporating a recent conference paper (Schmitt, 2018d)).

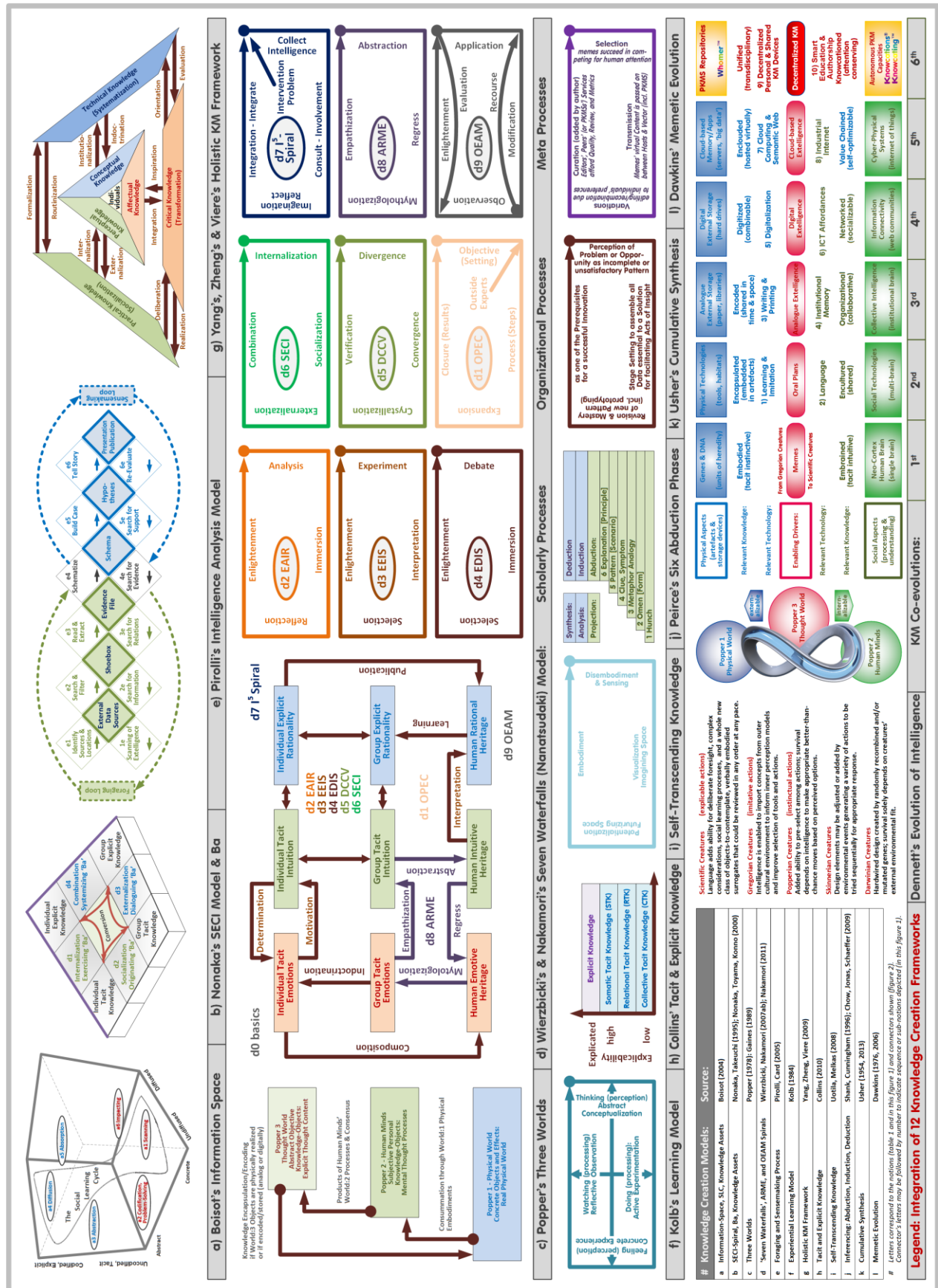


Figure 1: PKM Concept's Integrated Twelve Knowledge Creation Frameworks shown individually (Schmitt, 2018d)

2. Motivating the Map as a Means for Emergent Innovation and KM Education

Although put forward as a complementing (emergent although radical) concept and system, the novel PKM design represents wide-ranging changes compared to traditional KM System (KMS) configurations. However, a user-centred needs analysis (as part of a conventional ‘pull’ approach of incremental and sustaining product/service adjustments) has not been undertaken. This is common for radical innovation proposals since the socio-techno-cultural contexts in which clients are immersed tend to limit their interpretations to just those states and prospects within their actual perspectives (trapped in current paradigms). Instead, a product-engineering-based ‘push’ approach (pushing the envelope for breakthrough functional innovations) has been employed complemented by DSR-related (Schmitt, 2016b) and ‘design-driven’ philosophies (outside-the-box-thinking for breakthrough meaning innovations) aiming for ‘technology epiphanies’ (table 3). The latter implies radical changes in the underlying socio-techno-cultural regimes while their prospects and risks “might be understood only by looking at long-term phenomena with a broader perspective” (Verganti, 2008).

Table 3: Dimensions, Types, and Interdependencies of Innovations (Norman & Verganti, 2014)

	Features and Functionalities	Meanings
Radical Change & Innovation based on: Novelty, Uniqueness, Impact*	Technology Epiphanies	Design-Driven Research (Novel Meanings)
	Engineering-Research (Technology-Push)	
Incremental Change & Innovation	Human-Centred Research (Market-Pull)	
Without Considering Practicality	Tinkering (Bricolage)	Basic Design Research (Vision Driven)

For a newly framed solution to be technologically radical, it has to be novel and unique (condition assessible ex ante market introduction) and to be able to impact on future technology (ex post condition met after an invention served as an influential change agent) (Dahlin & Behrens, 2005). As the Change-Equilibrium Model (Leavitt, 1965) and the KM Framework Clusters (Heisig, 2009) show, change in any one of four clusters (technologies: artefacts including storage devices; human factors: people, culture, leadership; organizational aspects: structures & processes; tasks and management: operations and controlling) is likely to affect any of the other three. Any change process, hence, needs to consider the potential interdependencies to be effective; the introduction of PKMSs, however, directly impacts all four clusters (Schmitt, 2015a).

3. The Integration of Twelve Knowledge Creation Notions in a Single Knowledge Map

Trying to proactively ease the challenging tension between the PKM and OKM perspectives is vital for gaining system acceptance and includes providing transparency of existing approaches with their shortcomings and instructions and visualizations of how new features fit into the current KM landscape. After detailing the three-dimensional dynamic ‘public-transport-like’ knowledge map, the article, hence, highlights the major radical changes of the PKM approach impacting on the granularity, traceability, transdisciplinarity, decentralization, mobilization, accessibility, transparency, diffusibility, negentropy, and synergies of knowledge.

Boisot’s three-dimensional *Information-Space* [a] forms the base of Figure 2. With its codification axis tipped horizontally and divided in four sections (from left to right: *uncodified-tacit-emotional*, *uncodified-tacit-intuitive*, *codified-explicit-rational*, and *captured-explicit-PKMS*), its diffusion and abstraction axes provide the lattices for positioning the other eleven notions [b-l]. However, only Boisot’s *Social Learning Cycle* (SLC) [a] and Pirolli’s and Card’s *Foraging and Sensemaking Loops* [e] align to the latter axis (from concrete to abstract) and appear dispersed over the full sections, whereas the remaining models are all placed in the middle of the abstraction axis and spread only across the diffusion dimension (from top to bottom: *undiffused-individual*, *diffused-group*, *diffused-collective/organization/community/society*). Eight icons (octagons) symbolize the relevant knowledge types in each corner (in line with the *tacit/explicit*, *concrete-abstract*, and *diffused/undiffused* combinations) supported by the exemplification of knowledge assets (ellipses). The three segments along the diffusion axis of the left section (*uncodified-tacit-emotional*) also corresponds to Collins’ differentiation of *tacit knowledge* and its explicability [h]. Kolb’s *Experiential Learning Model* [f] is displayed at

the top between the two left sections to avoid illegible overlays, while Popper's *Three Worlds* [c] is placed at the mid bottom and linked to the notions of *Heritage Knowledge*.

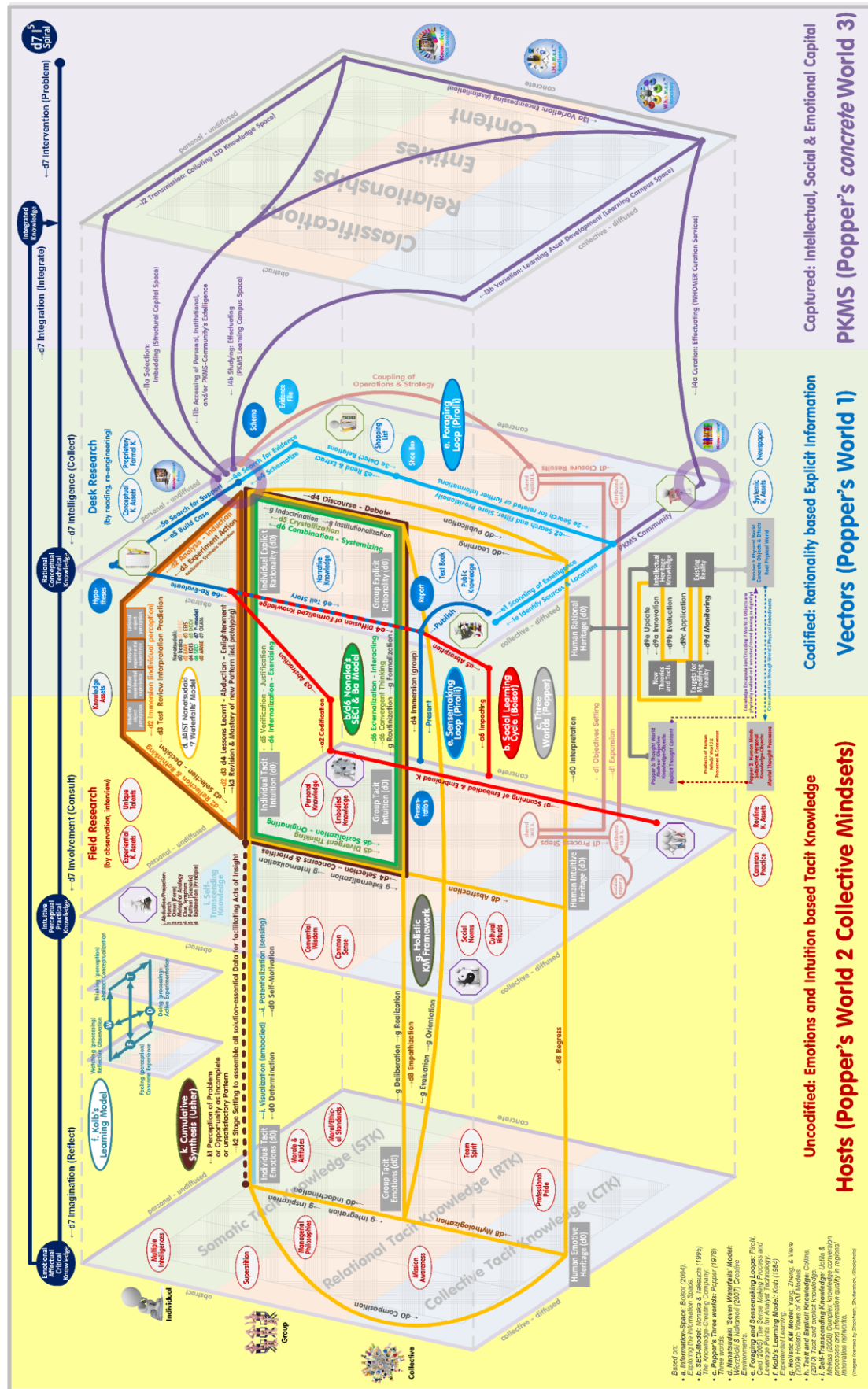
Wierzbicki's and Nakamori's *Spirals* [d] which integrate Nonaka's *SECI-Spiral* [b] are stretching from top to bottom across all the three left sections. Yang's *Holistic KM Framework* complements the map by adding terminology and further connections [g] although some terms (namely: *internalization*, *externalization*, and *indoctrination*) are used differently. Uotila and Melkas link *self-transcending knowledge* [i] to the *SECI Spiral* by incorporating processes of *disembodiment (sensing)* and *embodiment* (located between the two left individual tacit sections) for *visualizing (imagining 'ba')* and subsequent *potentializing (faturizing 'ba')* the presence of potentials which do not yet exist. This emphasis on *intuition* leads straight to Shank's and Chow's conception of *abduction* with its six levels of *inference* [j] complementing the *induction* and *deduction* approach.

Usher's (1954, 2013) *Cumulative Synthesis* [k] and Dawkins' *Memetic Evolution* (1976, 2006) [l] accentuate – as the notions of the previous paragraph – the role of personalized and objectified knowledge. The former presents the emergence of novelty “as an accumulation of many individual items over a relatively long period of time. The magnitude of the individual item is small, but through [processes of] ‘*Cumulative Synthesis*’ the product becomes important” (Usher, 2013, p.61). Not every individual knowledge item, idea or meme captured might be of immediate utility, but, what might be considered to be irrelevant or misguided at a given time may turn out to be valuable later, and vice versa (Garud et al, 2016). Usher convincingly couples the activities of researchers and entrepreneurs by entailing a generic iterative sequence: (1) The perception of a problem or opportunity as an incomplete or unsatisfactory pattern, (2) which prompts the setting of an appropriate stage to assemble all the data essential to a solution, (3) in order to facilitate acts of insight, (4) followed by critical revision and full mastery of the new pattern (including prototyping), (5) as one of the prerequisites for a successful innovation (Usher, 2013, p.65). The approach (located between the three left individual sections) fits well with *memetic evolution* as well as with solving so-called ‘*wicked*’ problems, defined by Rylander (2009) as open-ended in the sense “that they are ill defined and characterized by incomplete, contradictory, and changing requirements and complex interdependencies and that the information needed to understand the problem depends upon one's idea for solving it.”

Dawkins (1976, 2006) originally introduced ‘*Memes*’ (e.g. idea, tune, catch-phrase, skill, technology) as basic units of cultural transmission or imitation that evolve over time through a Darwinian process of variation, selection, and transmission (in analogy to genes). This sequence [l] is located in the right (captured-explicit-PKMS) section (figure 2) since the PKMS departs from current document-centric storing traditions which are “unnecessarily replicating content via copy and paste operations” and instead opts for “digitally embedding and reusing parts of digital documents via structural references” (Signer, 2010). The right section, hence, represents the PKMS repository which is further segmented (from top to bottom) according to classifications (meta-memes), relationships (structural references), entities (meme labels), and content (memes' subject matter) residing in decentralized PKMS devices networked via *Heritage of Memes' Repositories* at individual/institutional (iHomer) or world (wHomer) level of aggregation (symbolized as icons on the right). The PKMS Knowledge Map from the Knowledge Worker's Perspective

The challenges facing today's knowledge workers have been addressed in the light of the shifting spheres of work, the lack of personalized tools, the growing world-wide opportunity divides, and the accelerating information abundance (Schmitt, 2013; Schmitt, 2014b). As a consequence, the PKMS aims “for (1) managing/growing the intellectual, social, and emotional capitals of individuals, (2) by supporting their creative authorship throughout their academic and professional careers anywhere as contributors and beneficiaries of organizational and societal performance, educational services, and the world's collective extelligence, (3) and by fostering creative conversations among teams, organizations, and communities for mutual benefit and competitive advantage via network and cloud technologies” (Schmitt, 2018c).

The *knowledge worker's* central position (marked by a transparent purple donut in the individual segment of the *codified-explicit-rational* section) affords him/her full access to the methodological processes described:



- Individually, his/her actual state of knowledge in this position might demand further analysis for full understanding and reflection which either lead to documenting the lessons learnt [d2] or to follow the path of *Cumulative Synthesis* [k123].

Alternatively, particular action (e.g. implementations, experiments) might be required where the subsequent outcomes need to be tested, reviewed, interpreted, or predicted, followed by a decision or selection [d3] which might trigger the need for or emergence of sensing [i] or abduction [j1-6] processes to add self-transcending creative insights [i, j] before results can be documented [d3]. The actual state of knowledge might not be deemed adequate necessitating a search for further evidence and information (4e, 2e) or the identification of relations, sources, and/or locations (3e, 1e) able to further inform the knowledge worker by following the *Foraging Loop* [e1234].

If satisfied, the material gathered can be utilized to build a case or devise a report to tell a story by either presenting it to an audience or publish it [e56] to be followed up by receiving feedback leading to a re-evaluation and a potential need for revisions and/or additional support (6e, 5e).

If the material is already sufficient, it can be directly published to what-is-labelled as the explicit *Human Heritage Knowledge* which, in turn, can also be accessed for learning [d0].

If other opinions or collaborations are called for, a debate or discourse might have to be initiated to fully inform the group in order to detect concerns, determine priorities, and/or select options to move closer to a suitable, feasible, and acceptable solution [d4].

To facilitate collective creativity, the existing state of knowledge has to be verified and justified to a group in order to initiate phases of divergent and convergent thinking after which the results of the brainstorming or brainwriting sessions need to be crystallized and recorded [d5].

In following the *SECI Spiral*, the material might need to be thoroughly internalized/routinized (*exercising 'ba'*) before it can be shared/socialized with the group to create new ideas (*originating 'ba'*) which have to be formalized/externalized (*interacting 'ba'*) and productively combined/in-doctrinated (*systemizing 'ba'*) [d6].

The *Holistic KM Framework* differs from the *SECI Spiral* by terms as indicated [g] and puts forward a reverse CES flow differentiated as *institutionalization* (from individual explicit to collective explicit), *routinization* (to collective tacit), and *internalization* (to individual tacit).

The status quo might also lead to a need to revise the overall goal or strategy of the endeavour, requiring the sharing of the knowledge and a (re-)setting of objectives, their breaking down into operative process steps to be supported by the implementing agents involved and the final documentation in form of strategies, policies, procedures, or guidelines [d1].

Boisot's *Social Learning Cycle (SLC)* focuses on field research by scanning concrete tacit (embodied and embrained) knowledge to be codified and abstracted [a123] and subsequently diffused in order to be absorbed by the relevant people to hopefully facilitate the impact intended [a456].

- At the meta-level, the *I5-Spiral* [d7] advises to collect intelligence (explicit), consult and involve people (tacit intuitive), and reflect and imagine together (explicit emotional) in order to integrate the findings for realizing an appropriate intervention for the problem or task at hand [d7]. In terms of an aggregated perspective of human civilization, the forms of knowledge (rectangles [d0]) accumulate as human experiences and culture and are "preserved as the Intellectual Heritage of Humanity (or the Third World according to Popper) with its emotive, intuitive, and rational parts". "Our Emotive Heritage consists of an explicit part, such as artistic products (music, paintings, literature, movies), as well as a tacit part: the collective unconscious, archetypes, myths, and instincts of humanity. Our Intuitive Heritage contains, e.g., the a priori synthetic judgments of Kant, not necessarily true but nonetheless very powerful in stimulating scientific creativity, determining our hermeneutical horizons. Our Rational Heritage contains all recorded experience and results of the rational thinking". This heritage exists "independently from the human mind in libraries and other depositories of knowledge" (Wierzbicki & Nakamori, 2007b).

The interrogation of this Intellectual Heritage of Humanity (IHH) might lead to the innovating of new theories and tools (like the PKMS) which – being evaluated – update the IHH and are applied in reality [d9abc]. Their real-world application may entail targets and their control to modify reality which - if met – change existing reality. In the process, conclusions are drawn regarding the performance of the applied new theories and tools which further inform the IHH stored about them [d9def].

Popper's Worlds (1978) differentiate reality into three distinct spheres [c]: "World:1 comprises the concrete objects and their relationships and effects in the real physical world. World:2 refers to the

results of the mental human thought processes in the form of subjective personal knowledge objects. World:3 represents the thought content made explicit in the form of abstract objective knowledge objects which express the products of World:2 mental processes" (Schmitt, 2016b). All three worlds are highly interactive: "World:2 acts as an intermediary between World:3 and World:1. But it is the grasp of the World:3 object which gives World:2 the power to change World:1" (Popper, 1978).

Successfully dealing with change, thus, constitutes an essential virtue and Yang et al (2009) position KM to be an appropriate tool for managing the dimensions and dynamic interactions of technical (TK: explicit), practical (PK: tacit intuitive), and critical (CK: tacit emotional) knowledge in an organization.

- Considering the particularities of the critical knowledge and its interdependencies [g, d0] with the other two forms (TK, PK) and within the relationships between individual (I), groups (G), and organizations (O) becomes increasingly important and involves *self-motivating* (PKI by CKI) and *determined/resolving* (CKI by PKI), *inspiring/indoctrinating* (CKI by CKG) and *integrating* (CKI into CKG), *realizing* (PKG by CKG) and *deliberating* (CKG via PKG), *orienting* (TKG by CKG) and *evaluating* (CKG via TKG), *composing/creating/performing* in artistic/publicizing/transforming contexts (CKI to CKO) and *interpreting* (PKO into TKO) (Yang et al, 2009), (Wierzbicki & Nakamori, 2007a).

By citing Motycka's theory of scientists' creative behavior in time of scientific crisis or revolutions, Wierzbicki & Nakamori (2006) stress that irrational factors can also become relevant. Accordingly, the *ARME Spiral* [d8] provides for the case of scientists who intuitively perceive a crisis of their discipline unable to be remedied by abstracting to intuitive heritage (PKG to PKO). As a way out, they revert to collective unconsciousness and regress to myths and instincts (PKO to CKO) which then requires influencing the emotional group feelings in order to obtain creative stimulation of novel disciplinary approaches (mythologization: CKO to CKG). However, the transition to and impact on group intuition necessitates specific discussions that have empathic understanding as its main goal (CKG to PKG).

The resulting map demonstrates that diverse and seemingly incompatible KM notions (table 2) are capable of mutually complementing and supporting each other by synthesizing their distinctive positive feedback loops to comprehensively cover the continua of tacit and explicit knowledge where – in the world view of process theory – "all that exists is indivisible, interrelated, and unbounded in time and space. Human beings are [likewise] interrelated in an extensive *continuum*, with their own past and future as well as that of others. The individual stands in the present moment holding past experiences within and unites with experiences of the self and others to transcend the self to a new unity" (Nonaka, Toyama, & Hirata, 2008, pp. 242-243). Integrating the structures and visualizations depicted together with the supported human interactions in the PKMS workflows as well as in the envisaged PKM e-learning content allows for adopting the '*Emergent Innovation*' approach alluded to.

4. The PKMS Concept and System as an Extension of Traditional Knowledge Management

Traditional Organizational Knowledge Management Systems (OKMS) are based on monolithic technologies requiring large investments and costly maintenance. Their institutional focus and top-down approach call for prohibitive restrictions and ring-fenced user communities. Although first-generation content-based OKMS have been broadened by collaborative community-oriented systems, shortcomings of insulated incompatible silos lacking integration and acceptance persist. While current KM technologies are capable of locating vast amounts of digital information, adequate tools for selecting, structuring, personalizing, and making sense of the ever-increasing digital resources available to us are missing (Kahle, 2009). Accordingly, the opportunity divides for connecting and empowering knowledge workers are widening.

KM's current status quo versus the envisaged PKM perspective has been further assessed utilizing the SVIDT methodology (Strengths, Vulnerability, and Intervention Assessment related to Digital Threats) (Schmitt, 2018b). By substantially breaking with current KM paradigms and practices, the PKMS rather qualifies as a disruptive General-Purpose-Technology (GPT) than a sustaining innovation (Schmitt, 2015b; Schmitt, 2019b).

It, hence, not only allows individuals and institutions to better focus their time and attention on exploiting their knowledge and on its further exploration, but also affords appealing opportunities for stakeholders

engaged in the contexts of education, curation, and research (Schmitt and Saade, 2017), professional practice (Schmitt, 2018c), development (Schmitt, 2016a), and entrepreneurship (Schmitt, 2018a). The following subsections summarize promising key features by focusing on ten knowledge-related qualities, each closely aligned to six digital ecosystems and their subsystems (Schmitt, 2016b) deemed relevant for the PKMS development.

4.1 Knowledge Granularity, Traceability, and Transdisciplinarity for Impacting Future Extelligence

“Economies don’t merely evolve over time, they *coevolve*. What people believe affects what happens to the economy and what happens to the economy affects what people believe. This *positive feedback loop* is the signature of *coevolutionary learning*” (Batten, 2000, pp.6) responsible for the exponential growth of knowledge further reinforced by advancing technologies propelled by humans in pursuit of affordances. Although *positive feedback* and *co-evolutions* share similar outcome properties, a key difference attributed to them is that the former is *predictive-causal*, whereas the latter is *reactive-unpredictable* (McKelvey, 2002).

The advance of knowledge saw the successive emergence of the *tacit-emotional*, *tacit-intuitive*, and *explicit*-knowledge types in concert with their respective *positive feedback loops*, knowledge stocks and flows (as synthesized in figure 2). Initially based on the evolution of *intelligence* (table 1 bottom-left; Dennett, 1995, pp.373-380), the further progress can be aligned to a sequence of *co-evolutions* (table 1 bottom-right) each based on the interaction between physical (top row) and social (bottom row) aspects facilitated by an enabling catalyst or driver (middle row) (Schmitt, 2018b). At each transitional stage, human progress had been running into constraints which could only be overcome by adding an even more powerful *co-evolution* triggered by the emergence/invention of capacitating *general-purpose technologies* (#1-#10) (Schmitt, 2014a; Schmitt, 2015b; Schmitt, 2019b). Due to its own transformational muscle, the current 4th co-evolution (digital revolution) is again approaching a stage of severe constraints (e.g. information overload, fake-facts and post-truths, lack of personal tools and opportunity divides) which signify—in the author’s view—the presently emerging and most crucial barriers to the educational and work-related transformations essential for individual and collective development.

As a remedy, the conceptual scheme of ‘*Memes*’ (a driver from the very first co-evolution on) allows adopting the useful metaphor of ‘*Living Organisms*’ for knowledge and ideas whose survival depends on enduring in their medium of occupation and on the endurance of the medium itself. In terms of Popper’s *Three Worlds* [c] and the *SECI Spiral* phases [b] alluded to: “They, currently, either need to be encoded in inanimate durable *world:1* vectors (such as buildings, machines, products, software, storage devices, books, great art, or major myths) spreading at times unchanged for millennia, or to succeed in competing for a living host’s *world:2* limited attention span (such as people, teams, corporations, or economies) to be [*subjectively and tacitly*] memorized (*internalization*) until forgotten, codified (*externalization*) in further [*concrete*] *world:1* objects [(via *objective abstract world:3* objects)] or spread by the spoken word to other hosts’ *world:2* brains (*socialization*) with the potential to mutate into new variants or form symbiotic relationships (*combination*) with other memes (*memeplexes*) to mutually support each other’s fitness and to replicate together” (Schmitt, 2018b).

Granularity (extelligence ecosystem – codification): Since memes and their inbuilt ideas flourish in the virtual ‘*Ideosphere*’ (as maintained by Memetics) as well as in the visualized three-dimensional KM mapping (as exemplified by the *SECI Spiral*), the PKM repository is dwelling in the same space (figure 2 right) and is mimicking the memetic ideosphere with its rich resources and structural relationships (instead of storing redundant content in documents). Three of the repository’s four connecting workflows [I1ab, I4b] square straight with the knowledge worker’s central position (top transparent purple donut), while the forth [I4a] ties into the realm of the *Human Rational Heritage* (bottom transparent purple donut) and connects with the knowledge workers via the *Foraging Loop* and *Learning*. In consequence, a PKMS affords an alternative to the traditional document-centric storage paradigm which over-simplistically models digital documents “as monolithic blocks of linear content with a lack of structural semantics” (Signer, 2010). Instead, the PKMS repository offers a significantly finer *granularity* and easier *re-use* of the referenced ‘*atomic*’ and ‘*combined*’ *information units* (memes and memeplexes instead of documents).

Traceability (extelligence ecosystem – container): The cumulative synthesis of these unique memes within PKMSs forms bi-directional relationships between them with enhanced *traceability* and *metrics*. Traceability, already, acts as a back-bone of modern manufacturing by tracing the history, application or location of any entity and sub-entity by creating an as-built-genealogy across diverse value chains and sources. In PKMS terms,

memes correspond to entities, knowledge assets to as-built-genealogies, value chains to authorship and classifications, and sources to outputs across disciplines.

Transdisciplinarity (extelligence ecosystem – context): As a consequence, Popper’s abstract non-interrogatable World Three (*world:3*, figure 1c) is transformed into a concrete tangible interrogatable knowledge base named ‘World Heritage of Memes Repository’ (WHOMER) (right section in figure 2). Since anything (in a standardized memetic format) is expressible, combinable and curatable, linked distinctive memes of diverse disciplines are able to mature - with a growing user and shared meme base over time – into a single unified *transdisciplinary* digital knowledge repository of the world’s extelligence with distinctive benefits (to be further alluded to).

4.2 Knowledge Decentralization, Mobilization, and Accessibility for Impacting Human Development

Stewart and Cohen (1999, pp. 243-245, 288-289) termed this cumulative archive of human cultural experience and know-how ‘*Extelligence*’, the external counterpart to the intelligence of the human brain/mind which deals in information whereas intelligence deals in understanding; together they are also driving each other in a complicit process of accelerating interactive co-evolution. This accumulating knowledge heritage, however, can only be accessed, augmented, and further accrued by individuals with the know-how and means to utilize the KM topography depicted. Unfortunately, the current status quo of KM theories, practices, and tools does not meet this precondition, an assessment supported by a multiplicity of qualitative surveys and forecasts (which have guided the PKMS prototype design decisions), including:

- Rise of Information Loads (Simon, 1971; United Nations, 2005; Short, Bohn & Baru, 2011; Hilbert, 2011, 2014; Ekbja, 2015).
- KM Technologies and KM System Generations (Bush, 1945; Grant & Grant, 2008; Van Kleek & O’Hara, 2014; Sarka et al. 2014; Klie, 2015).
- Innovation, Management, and Design Issues (Romer, 2008; Stibel, 2009, 2013; Kurzweil, 2012; Johansson-Sköldberg et al., 2013; O’Reilly & Tushman, 2013; Sarooghi et al., 2015; Maier et al., 2016; Hult, 2016).
- Future of Work and Knowledge Workers (Gratton, 2011; Gorman & Pauleen, 2011; Reinhardt et al., 2011; Florida, 2012; Hamel, 2012; Frey & Osborne, 2013; Bowles, 2014; Heisig, 2014).
- Future of Education and Research (OAS, 2005; OECD, 2009a, 2009b, 2009c; Nielsen, 2011; Bedford, 2013; Blass, 2014; Adkins, 2016).

Decentralization (knowledge worker ecosystem): Levy’s call for a *decentralizing* KM revolution giving “more power and autonomy to individuals and self-organized groups” (Levy, 2011, 127) not only advances a solution to the shortcomings by aiming to educate more people better to narrow *opportunity divides* (Giebel, 2013) but also supports Wiig’s (2011) assertion that any (institutional as well as societal) viability and advancement is based on innumerable small ‘*nano-actions*’ by individuals (*knowledge workers*) which govern, if effectively combined, the organizational (*knowledge economy*) and societal performances (*knowledge society*). The scope of knowledge workers, in this context, is not confined to the socio-economic criteria of an individual’s type of work (e.g Florida’s Creative Class (2012)), but embraces the virtue of individual responsibility for one’s work life by continually striving to understand the world around, by modifying one’s work practices and behaviours to better meet personal and organizational objectives, by seeing the benefits of working differently for oneself, and by driving improvement (Gurteen, 2006). The quantity and quality of productive ‘*nano-actions*’, nevertheless, depend on the competences and skills of people and their individual intellectual, social, emotional, and structural capitals (Wiig, 2011) which together determine their personal *absorptive capacity* (ability to recognize, assimilate, and apply new valuable information).

Mobilization (knowledge-driven institutions ecosystem): Organizational leadership is eager to mobilize these potential absorptive capacities (as dispersed individually over the knowledge workers employed) to benefit their firm’s realized *absorptive capacity*, since “their success rests on converting tacit into explicit actionable knowledge, on aggregating individual into organizational performance, and on balancing between the exploiting of current capabilities versus exploring new ventures (to become an ambidextrous organization), all by dealing with unfamiliarity and perceived difficulties” (Schmitt, 2019a).

Accessibility (knowledge societies ecosystem): In addition to the widening opportunity divides alluded to, knowledge societies are challenged with disruptive trends driven by advancing digital communication

technologies (DCT). As a consequence, shifting demands for flexible amounts of labour (rather than discrete units) are transferring the control over when, where, how, and with whom to offer one's time and competencies to the individual supplier and alters the granularity of labour markets (Bhatt, 2017) accompanied by rising competitive pressures, evolving domain-specific knowledge and specializations as well as growing needs for flexible skill sets and self-development (Gratton, 2011). Guided by a PKM for Development (PKM4D) framework (Schmitt, 2016a), PKMSs address the ensuing concerns. They afford *access* to content and devices, further individual *proficiencies*, facilitate *collaborations*, empower to contribute to the *world's record*, and aid *self-transcendence* while ensuring individuals' attention preservation, knowledge retention, and privacy protection.

4.3 Knowledge Transparency, Diffusibility, Negentropy, Synergies for Impacting Technology and Innovation

Profound *innovations* are based on new ideas that forever alter existing *technologies and systems* (incl. products, processes, relations, and cultures) into which they are introduced. They eliminate incremental sustaining approaches to innovation and "radically restructure the relationship among manufacturers, distributors, consumers and any others in the supply chain" (Garon, 2012, 442-446). PKMSs, in this regard, are a response to the *currently failing KM promise* of "enabling people to obtain relevant, context-rich information, and connection with appropriate experts easily, when they need it, so that they can be more effective doing their unique jobs" (Pollard, 2008).

Transparency (technology ecosystem - autonomy): Today's network economy is generating a snowballing information granularity by differentiating between content creation, delivery, and distribution services, by unbundling the message from the medium, by re-bundling these components to configure output off-the-rack, on-demand, or tailor-made (Bhatt, 2017). Constantly fed by social media users and other causes (e.g. associated platform algorithms, popularity of personal blogs and web sites, self-publishing, academic publish-or-perish policies), the content and feedback created entail an ever-increasing share of distracting and attention-consuming *entropy* in form of duplications of original content (*redundancy*), partial (*fragmentations*) or erroneous (*inconsistencies*) replications or deletions of records, non-disclosure or subsequent erasure of sources (*untraceabilities*), unsuitable alterations of content (*corruptions*), lacking curation and maintenance (*decay*), as well as outdated (*obsolescence*) and falsified statements (*fake facts*) (Schmitt, 2018c). The resulting abundance is threatening the finite attention individuals' cognitive capabilities are able to master. As a remedy, the PKMS approach is closing in on the over seven decades old inspiring but still unfulfilled vision of the 'Memex' (Bush, 1945). Bush reminded us that the human mind operates by association (meme-based approach), not by indexing ('book-age' document-centric paradigm). Applying Bush's concept of 'Associative Indexing', hence, fosters *transparency* by affording the forward/backward tracking of relation/trails captured and by enabling knowledge-enriched and entropy-reduced *scholarship* as any "inheritance from the master becomes, not only his additions to the world's record, but for his disciples the entire scaffolding by which they were erected" (Bush, 1945).

Diffusibility (technology ecosystem - collaboration): Current DCTs are based on *networks* of instantly, continuously, and ubiquitously connected agents empowered to collaboratively create and directly share information without the need of market intermediaries (Bhatt, 2017) but constrained by humans' finite attention capabilities and further restricted by a multiplicity of concerns (e.g. confidentiality, copyrights, commercial interests, and market dominance strategies based on service barriers, captured audiences, walled garden approaches) and deficiencies (e.g. incompatibilities, lack of tools and functionalities). As an alternative, the PKMS's *bottom-up approach* is based on the *cumulative synthesis* of collectively shared human capital and creative acts. Its meme trajectories are closely aligned to the *SECI and Ba model*. It, hence, yields strong *synergies* with its traditional top-down-OKM-correspondent allowing for collaboratively interlinking knowledge bases and for collectively tracing, harvesting, and utilizing accumulated knowledge subsets more productively for personal as well as organizational benefit. The granular record structure and interdisciplinary classification system of the WHOMER repository, thus, allows not only for effectively combining the individual '*nano*' actions referred to but also support Nielsen's call (2011) to *reduce current barriers* preventing potential contributors from engaging in a *wider sharing* and *faster diffusion* of their ideas, sources, data, work-in-progress, preprints, and/or code for the benefit of *more rapid iterative improvement*.

Negentropy (ideosphere ecosystem - design): The *design* of the PKMS structures, workflows, and functionalities is aiming to *reverse entropy* (to strive for *negative entropy*) by affording *order and organization*. Once ideas

and content collected or received succeed in competing for a PKMS user's attention to be understood and made sense of as original or mutated memes, he/she can capture them using his/her PKMS device [figure 2: 11a]. These securely stored memes may be modified and/or related to each other to form symbiotic memplexes (e.g. classifications, draft documents, knowledge and learning assets) to replicate together [12]. By voluntarily sharing memes with the PKMS community, they are assimilated as extelligence in the WHOMER knowledge base [13a] where additional curation services focus on eliminating redundancies (by merging identical memes), consolidating traceabilities (by preserving all unique relationships of the memes merged), computing relevant metrics, and effectuating access and creative conversations benefitting the PKMS community [14a]. The trails captured in the unified transdisciplinary WHOMER repository can also be utilized to forward feed information about an ancestor-meme's obsolescence, authenticity, and validity to their subsequent uses and users.

Synergies (ideosphere ecosystem - implementation): A PKMS affords a central service structure (*Digital Platform Ecosystem* or DPE – figure 3) able to instantiate a digital version of the real-world *ideosphere* as alluded to. DPEs are meant to accommodate social actors with highly diverse ambitions and skills who expect to gainfully utilize the DPEs' resources and potential in their personal and local contexts (Eck and Uebernickel, 2016, p.13). The *PKMS-DPE blueprint* depicted (figure 3) follows Levy's (2011) envisaged decentralized KM Revolution alluded to by facilitating the emergence of distributed processes of collective intelligence, which in turn feed them via creative conversations. Its bird's-eye-view depicts the technological infrastructure "available to a social actor with the decentralized PKM devices (right) and the PKMS user community (left) depicted at the bottom, the cloud-based World Heritage of Memes Repository (WHOMER) where content is voluntarily shared and centrally curated (to reduce information entropy and assure associative integrity) on the middle-left, and the *Personal Learning Environments* (PLE) with their *e-learning functionalities* on the top-right" (Schmitt, 2019a). Synergetic interactions with external *Organizational Knowledge Management Systems* (OKMS) and *Learning Management Systems* (LMS) complete the broader technological ecosystems.

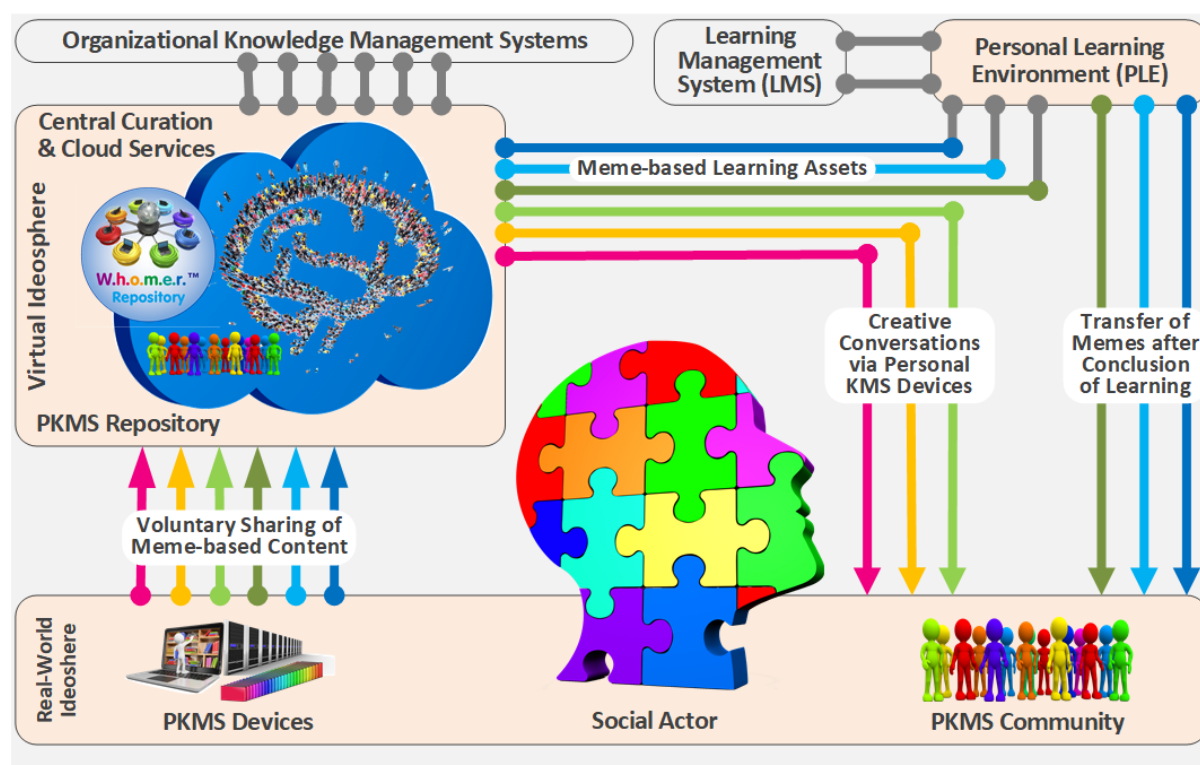


Figure 3: PKMS as a Digital Platform Ecosystem (DPE) (Schmitt, 2019a)

Further synergies may be realized by utilizing WHOMER's meme-based content to develop learning assets for the PKMS-aligned Learning Management System (LMS) [13b and figure 3] to foster an envisaged novel e-Learning approach [14b] (Schmitt, Saade, 2017; Schmitt, 2019c). The envisaged Personal Learning Environment (PLE) plans utilizing three-dimensional topologies as non-linear navigation/interaction spaces to offer learners suitable choices of where to start and how to proceed with their transdisciplinary learning experience

(Schmitt, 2018b). Also, once sets of memes repurposed in an e-learning asset have been studied, they also become 'active' in the learner's PKMS device for utilizing WHOMER's added connectivity, for learning retention, or for repurposing them in assignments or any other aspect of the learner's further career.

5. Conclusions and the Road ahead

In summary, PKM has been envisaged as a decentralizing KM revolution and as a vital educational concern aiming at strengthening individuals' sovereignty and collaborations - not at the expense of OKMSs but rather as the means to foster a fruitful co-evolution. Based on distributed networked personal devices, bottom-up, curation, and feedback approaches, and structurally-referenced meme-centric repositories (substituting document-based storage practices), the PKMS concept supports creativity and human capital formation throughout individuals' academic and professional careers independent of space (e.g., developed/developing countries), time (e.g., study or career phase), discipline (e.g., natural or social science), or role (e.g., student, professional, or leader).

The negentropic granularity and its associative integrity of the WHOMER repository is further enhanced by reducing the attention-consuming entropy referred to and by curation and context aggregation (memes inherit the relationships of their redundant identical copies). The connectivity between these unique, enduring, unalterable memes creates a virtual ideosphere (concretization of Popper's World Three); it dynamically evolves with further use and inputs, provides pathways for exploitation and exploration without requiring intermediaries (e.g. digital libraries, search engines), and allows focusing on non-redundant search results.

A follow-up on this paper (Schmitt, 2019d) confirmed these findings by applying the psycho-social notion of generativity - which recently stimulated contributions in technology and innovation - in its technical, informational, and social interpretations of generative fit and capacities and by cumulatively synthesizing a wide range of KM models with generativity-related concepts and perspectives.

While the document-centric 'book-age' paradigm compels us to experience our nonlinear holistic world via linear disciplinary-divided fragments, the information-and-trajectory-rich WHOMER base provides extensive associative multi-disciplinary pathways for exploration which can also be productively utilized in the context of personal learning environments and innovative e-Learning approaches. Besides, in taking on knowledge and skills as portable and mobile, professionals - while moving from one project or responsibility to the next - are afforded the autonomy to safeguard and develop their personal expertise systematically and sustainably and to voluntarily share it with associates and institutions close to them.

Figure 2 adds a further visualized map (labelled PKM for Action (PKM4A) framework) to the educational PKMS provisions which cover PKM for Empowerment (PKM4E) to address ignorance issues (Schmitt, 2018c), PKM for Development (PKM4D) to provide a heuristic for reflecting on the user's ambitions the PKMS serves and for assessing KM interventions (Schmitt, 2016a) as well as PKM for Impact (PKM4I) and for Sustainability (PKM4S) (both in-progress). After completing the test phase of the prototype, its transformation into a viable PKMS device application and a cloud-based WHOMER server based on a rapid development platform and a noSQL-database is estimated to take 12 months.

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