Knowledge Management Systems as an Interdisciplinary Communication and Personalized General-Purpose Technology

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ABSTRACT

As drivers of human civilization, Knowledge Management (KM) processes have co-evolved in line with General-Purpose-Technologies (GPT), such as writing, printing, and information and communication systems. As evidenced by the recent shift from information scarcity to abundance, GPTs are capable of drastically altering societies due to their game-changing impact on our spheres of work and personal development.

This paper looks at the prospect of whether a novel Personal Knowledge Management (PKM) concept supported by a prototype system has got what it takes to grow into a transformative General-Purpose-Technology. Following up on a series of papers, the KM scenario of a decentralizing revolution where individuals and self-organized groups yield more power and autonomy is examined according to a GPT's essential characteristics, including a wide scope for improvement and elaboration (in people's private, professional and societal life), applicability across a broad range of uses in a wide variety of products and processes (in multi-disciplinary educational and work contexts), and strong complementarities with existing or potential new technologies (like organizational KM Systems and a proposed World Heritage of Memes Repository).

The result portrays the PKM concept as a strong candidate due to its personal, autonomous, bottom-up, collaborative, interdisciplinary, and creativity-supporting approach destined to advance the availability, quantity, and quality of the world extelligence and to allow for a wider sharing and faster diffusion of ideas across current disciplinary and opportunity divides.

Keywords: General-Purpose-Technologies (GPT), Personal Knowledge Management (PKM), Organizational Knowledge Management (OKM), World Heritage of Memes Repository (WHOMER), Systems Thinking, Memes, Knowcations.

1. EVOLUTION THROUGH INNOVATION AND KNOWLEDGE MANAGEMENT

Economic evolution is "the result of coevolution across three design spaces." Firstly, *Physical Technologies* "are designs and processes for transforming matter, energy, and information in ways that are useful for human purposes, for example, turning sand into glass or into silicon chips." Secondly, *Social Technologies* "are the designs, processes, and rules that humans use to organize themselves. Villages, armies, matrix organizations, paper money, the rule of law, and just-in-time inventory management are all examples of social technologies." Thirdly, *Business Plans* "play the critical role of melding Physical and Social Technologies together under a strategy, and then operationally expressing the resulting designs in the economic world" [1].

Accordingly, Nakamori [2] classifies our tasks in a knowledge-based society as (1) "to use information technology and systems science, and the management of technology and knowledge, to support the creation of knowledge and technology (*to create technological innovation*)", (2) "to reform social systems and people's minds to make effective use of advances in knowledge and technology (*to create social innovation*)", and (3) "to nurture leaders [and/or strengthen drivers] who[/which] can accomplish the first and second tasks and construct a better knowledge-based society (*to nurture innovators*)."

Schmitt [3] argues that the notions of the triple co-evolving design spaces and tasks have also shaped the past progress of knowledge management. Consequently, human civilization can be interpreted as five successive co-evolutions (table 1). "At each stage, civilization run into constraints which could only be overcome with the emergence of a further powerful co-evolution" in order to enable the formation of new knowledge types based on innovations such as language, writing, printing, information and communication technologies. The question is: If these patterns have changed history, will they also be able to exert influence in and on the future?

Well, once again, humans are facing significant constraints. Due to recent organizational, commercial, social, and legal innovations, our way of working and living has been subjected to ongoing accelerating changes resulting in an intensifying assault on our attention[1] caused by today's over-abundance of information which has replaced the information scarcity of the past. A triple coevolving design space solution to overcome this constraint can be construed from Kameoka's and Wierzbicki's 'Vision for the New Era of Knowledge Civilization' [5] by prioritizing (1) digital integration and convergence (*technological*), (2) cyber-personal systems geared towards autonomy and collaboration and supported by educational reforms (*social*), and (3) shifting the perceptions of the world by particularizing its Ideosphere (*concepts & drivers*).

By using this scenario as the point of departure, the objective of this paper is to elaborate on the possible impact of these three envisioned design spaces, not only based on theoretical considerations but also on their practical manifestation as exemplified by a Personal Knowledge Management (PKM) concept and prototype system[2]. With emphasis on the impact, only essential system functionalities are covered which can be deepened and broadened by using the cited URL and DOI references pointing to the freely available resources of the author's prior publications.

[1] Simon [4] noted already over forty years ago, that the "wealth of information is creating a poverty of attention and with it a need to allocate that attention efficiently among the overabundance of information sources that might consume it." "In a knowledge-rich world, progress does not lie in the direction of reading information faster, writing it faster, and storing more of it. Progress lies in the direction of extracting and exploiting the patterns of the world - its redundancy - so that far less information needs to be read, written, or stored".

[2] The PKM System (PKMS) and concept has been used personally for career support as a management consultant, scholar, professor, and academic manager. Recent advances in development and hosting platforms have now provided a viable opportunity for innovation and its conversion into an application serving a wider audience and multiple platforms.

Table 1: Triple Co-Evolving Design Spaces with emerging Knowledge Types

(1) Physical Technologies (PT): Storage Devices	**(2) Social Technologies (ST):** Processing & Understanding	**(3) Catalysts of melding PT/ST:** Drivers of Co-evolutions
Co-evolving Design Spaces of the Past		**(Legend: K = Knowledge)**
Genes, DNA, Human Brain (embodied knowledge, instinctive)	Neo-Cortex, Memory, Thinking (embrained knowledge, tacit, personal)	Memes (as units of cultural transmission)
+ Constructing Tools & Habitats (encapsulated knowledge, embedded)	+ Learning & Imitation (encultured knowledge, shared)	+ Memeplexes, Plans (∑ accumulated meme pools)
+ Analogue External Storage (encoded knowledge, shared in time/space)	+ Collective Intelligence (organizational knowledge, collaborative)	+ Extelligence, analogue (∑ accumulated analogue record)
+ Digital External Storage (digitized knowledge, combinable)	+ Connected Communities (networked knowledge, socializable)	+ Extelligence, digital (∑ accumulated digital record)
+ Cloud-based Memory/Apps (enclouded knowledge, virtually hosted)	+ Cyber-Physical Systems (value-chained knowledge, self-optimizable)	+ Self-organizing Value Chains (∑ collective internet of things)
Potential Co-Evolving Design Spaces for the Immediate Future		
+ Digital Integration/Convergence (integrated knowledge, to be individually traceable, expandable, relatable)	+ Cyber-Personal Systems ('*knowcationed*'[11] knowledge, to be self-determined but universally shareable)	+ '*Knowcations*'[11] of the Ideosphere (∑ world heritage of memes repository [WHOMER] to be commonly accessible)

2. MARKET FOCUS: A GLOBAL VILLAGE IN NEED OF BRAVE NEW IDEAS

The era of print and geographical discoveries lasted from 1440 to 1760, the era of industrial civilization from 1760 to 1980, and the new era of knowledge civilization has commenced in 1980 marked by the starting integration of "two parallel developments - of computer networks and of personal computers - which brought digital information technology potentially to every home in the world" [5].

If we equate today's 2015 world population to a global village of 1000 people[3], then there were only 613 inhabitants thirty-five years ago, rising to 840 by 2000. While at the beginning of the new millennium only 50 inhabitants were online, the number is now reported to have risen to 418. 152 villagers visit Google per month, 138 YouTube, 124 Facebook, 103 Yahoo, 69 Amazon, and 65 Wikipedia. The total of the next ranked Twitter, Ebay, MSN, Microsoft, LinkedIn, Pinterest, Ask, and WordPress just matches the combined visitors of top-ranked Google and YouTube[4]. The providers' advance and attraction are built on the evolution from an analog to a digital media infrastructure and the rapid expansion of technologically stored and communicated information content.

Interestingly, Hilbert's [6] stock taking of the multimedia revolution (from 1986 to 2007)[5] reveals that the shares of still images (14% to 15%) and video (58% to 59 %) have hardly been affected due to the effect of optimized compression techniques on expanding content. The digitization of Audio, on the other hand, resulted in a decline of the audio share (28% to 5%) which has been primarily absorbed by a growing alphanumeric text share (0.25% to 20% for stored information). Hilbert points to the role of successful text-based SMS (short message service), digital text on Websites, blogs and eBooks, and the vast and ever increasing databases of financial and alpha-numeric scientific data.

But, in today's digital age, "our information technologies are [also] precisely the same as our communication technologies, so learning a fact can be precisely the same as publishing a fact to the world" [7]. Accordingly, any contents (or fractions of it) allow for an unlimited number of redundant, fragmented, distorted, incorrect, or outdated copies adding to the trivial chatter populating the web and search engines. Besides wastefully consuming our attention, a fact or idea - once stated - does not necessarily stay unchanged any more (as previously ensured by the physics of paper).

The services providers, unfortunately, force us to contribute to this digital mess. At the expense of our attention and productivity, their business models trap us as captives within their gated communities and captured audiences. As a consequence, "our identities are scattered across the web", "our reputations are isolated into single-site containers", and we are left with no choice other than cross-site-replicating-and-maintaining our content [8] and efforts.

Moreover, the diffusion of innovative supporting technologies that transmit, store, or compute information throughout our global village needs time and depends on individuals' circumstances and habitats as, for example, education, interests, age, purchasing power, conventions, status, or infrastructure. Given the huge socio-economic significance, the inevitable result is a digital divide [9] due to regress further into divides of access, content, learning, skills, knowledge, innovation, opportunity, wealth or poverty.

Since the overall performance and viability of societies and institutions are made up from innumerable small 'nano-actions' by individuals [10], the aggregated divides across our global village's households and neighborhoods translate into detrimental effects for an overall harmonious sustainable development. The pertinent question is how could we better incorporate the talents and motivations of those currently left behind in light of the sorry states alluded to earlier and to be explored further?

[3] World Population in millions, 1980: 4,451. 2000: 6,090. 2015: 7,253. US 2015: 321 (source: United States Census Bureau, http://www.census.gov/popclock). Internet Users in millions, 2000: 361. Latest Data: 3,036 (http://www.internetworldstats.com/stats.htm).

[4] The top 15 most popular websites ranking (April 2015) is a continually updated average of each website's Alexa Global Traffic Rank, and U.S. Traffic Rank from both Compete and Quantcast. (source: http://www.ebizmba.com/articles/most-popular-websites).

[5] The total analog and digital distribution rose from 2.6 Petabytes (2.6x1012 MBytes) with 1% digital content in 1986 to 0.3 Exabytes (3x1014 MBytes) with 94% digital content in 2007 [6].

3 PRODUCTIVITY FOCUS: THE PLIGHT OF KNOWLEDGE WORKERS[6,7]

The contribution of scientific data to the overabundance of (original, redundant, fragmented, distorted, incorrect, and outdated) information has been briefly mentioned. Academic publications have significantly increased due to the expanding footprint of higher education and 'publish-or-perish' qualifications and career standards; repetitions are thriving since many authors appear to be standing on the shoulders of the same giants. Peer-reviewed publications translate into individual and institutional reputations and rankings as well as monetary benefits from promotions, premium fees, and Higher Education funding formulas.

Funding and ranking methods are linked to citation and impact statistics and have reinforced the status of traditional publishing houses despite being criticized for their outdated models[8,9] and practices [15]. Online providers such as, for example, Google Books, Google Scholar, or ResearchGate, provide some kind of alternative, but non-transparent inclusion and indexing routines as well as the lack of rigor of adequately transforming textual references into digital citation links spoil authors' and researchers' experiences. Moreover, the traditional and emerging providers only host fragmented subsets of the world record with deficient overlaps, thus forcing the diligent researcher to forsake his/her attention for repetitive efforts.

Tertiary Education itself is under siege. Not only faced with expanding enrolments, costs, and administrative bloat [16, 17] and unable to reinvent itself after its adoption of industrial principles[10] (departmentalization, task division, and assembly-line-type practices), its role as major knowledge producer and disseminator is also challenged. One scenario foresees undergraduate education being taken up by the further education and private sector and to be "commodified to small, transferable modules that can be combined with work based learning to accumulate to degree awards". Its traditional full-time delivery experience is offered by a few elite institutions only to those who can afford it [19].

4 SOLUTION FOCUS: PERSONAL KNOWLEDGE MANAGEMENT DEVICES

A conundrum in these reflections is the neglect of addressing the problems technologically, although individuals' needs are well researched and articulated [10, 12, 20, 21, 22, 23, 24. 25] (occasionally even with outlining a system [13]), and their urgency is confirmed by recent studies expecting the loss of half the current US and EU workforce due to technological breakthroughs able to turn previously non-routine tasks into well-defined problems susceptible to computerization [26, 27].

Adequate solutions targeted at the individual level of knowledge workers, however, have not materialized [24, 28, 29, 30]. The Personal Knowledge Management Concept with its meme-based approach of 'Knowcations'[11] - as the digital counterpart of the Ideosphere (table 1, bottom row) - aims to fill this gap in a systemic manner and within an institutional and societal context.

Before its potential impact and success are further explored in the context of General-Purpose-Technologies (GPT), its four

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[6] In the context of this paper and the PKM concept introduced, the term 'Knowledge Worker' has been closely associated with the definition proposed by Gurteen [11]. Rather than an individual's type of work (as in Florida's Creative Class[12]), Gurteen places the virtue of responsibility at the center of his reflections: "Knowledge workers are those people who have taken responsibility for their work lives. They continually strive to understand the world about them and modify their work practices and behaviors to better meet their personal and organizational objectives. No one tells them what to do. They do not take 'no' for an answer. They are self-motivated". To his mind, they "cannot be coerced, bribed, manipulated or rewarded and no amount of money or fancy technology will 'incentivize' them to do a better job. Knowledge workers see the benefits of working differently for themselves. They are not 'wage slaves' - they take responsibility for their work and drive improvement".

[7] In addition to the traditional division of the workforce into an agricultural, working, and service class, Florida introduced the concept of the Creative Class as a rising and driving force of economic development. Estimated to be one third of the workforce in the United States, their economic function is to create new ideas, new technology, or new creative contents as well as to engage in complex problem solving that involves a great deal of independent judgment and requires high levels of education or human capital [12].

[8] In 1945, Vannevar Bush [13] observed a steadily "growing mountain of research" and an "increased evidence that we are being bogged down" as specialization extends further in the name of progress. He regarded our methods of transmitting and reviewing the results of re-search "to be generations old" and "totally inadequate for their purpose".

[9] Nielsen [14] urges reforming our traditional academic citation systems by removing barriers that prevent potential contributors from engaging in a wider sharing and faster diffusion of their ideas, sources, data, and outputs for the benefit of more rapid iterative improvement.

[10] "We continue to prepare students as if their career path were linear, definite, specialized and predictable. We are making them experts in obsolescence" [18].

[11] 'Knowcations' are the results of knowledge being digitally converted or 'knowcationed' to be stored in PKMS repositories for retrieval and reuse ('Knowcations' also represents the name given to the PKMS, a registered trademark, web domain, and logo). The artificial term is made up of 'know' as a reference to knowledge and know-how and 'cation' as an intended association to ten metaphors embedded in the proposed PKM concept and system:
a. Dedi*cation*, where knowledge opposes ignorance & divides and promotes opportunities.
a. Vo*cations* or Abilities, where knowledge proves useful for one's talents and careers.
b. Suppli*cations* or Requests, where knowledge is incomplete and needs further elaboration.
c. Edu*cation* or Tutoring, where knowledge is acquired by learning and instruction),
d. Unifi*cation* or Integration (where knowledge is joint or linked to other knowledge),
e. Publi*cation* or Dissemination (where it knowledge made available to an audience),
f. Appli*cation* or Relevance (where knowledge is put to instructive or practical use),
g. Lo*cations* or Spaces (where knowledge indicates where knowledge or know-how resides),
h. Collo*cation* or Association (where knowledge is considered within contexts),
h. Revo*cations* or Invalidations (where knowledge designates other knowledge as no longer valid or relevant).
The letters correlate to Probst's eight building blocks of Knowledge Management: a. Knowledge Goals, b. Knowledge Identification, c. Knowledge Acquisition, d. Knowledge Development, e. Knowledge Distribution, f. Knowledge Use, g. Knowledge Preservation, and h. Knowledge Measurement [31].

key deviations from current Knowledge Management (KM) system philosophies are pointed out:

• *Personal Focus*: This attribute has best been laid out in a 12-level 'PKM for Development' (PKM4D) framework closely linked to Maslow's extended Hierarchy of Needs [32]. Its execution addresses several current market barriers identified [33] to ensure one's digitalized knowledge is always at one's disposal and can easily be retrieved, expanded, shared, and re-used independent of changing one's social, educational, professional, or technological environment.

• *Bottom-up Focus*: Strengthening individual sovereignty by employing grass-roots affordable PKMS devices entails a departure from today's centralized, top-down, institutional KM developments. However, common knowledge-related methods, resources, and objectives provide strong arguments to exploit synergies between Personal and Organizational KM (OKM) systems for mutual benefit [34].

• *Meme Focus*: As probably the most radical departure from the current document-centric KM systems, the PKMS concept focuses on the capturing, storing, and re-purposing of basic information structures (memes or ideas) and their relationships (to create knowledge assets and documents) [35, 36] rather than storing them the conventional way in their containers only (e.g. book, paper, report) [37, 38, 39].

• *Creative Conversation Focus*: The shared aggregated trajectories of the distinctive memes across multiple PKMS users provide a multitude of enhanced options to engage in one's topics of interest. Also, collaboratively interlinking knowledge bases to collectively trace, harvest and utilize accumulated knowledge subsets will overall reduce redundant content and improve the productivity of information seekers and suppliers alike Accordingly, the mission of a proposed 'World Heritage of Memes Repository (WHOMER)' is to guarantee continued access to the collective knowledge and ideas voluntarily shared among the PKMS user community as well as to overcome the redundancy, the perishability, and potential fallibility of current online information and services [39].

In following a systems thinking approach, the overall PKMS concept has recently been validated against the Informing Science Framework. One aspect of this assessment has been the application of Gill's and Murphy's three dimensions of Design Task Complexity [40]. The paper aligned the dimensions with the needs addressed by the PKMS features offered and argued that a PKMS technology is able "to scale down each one of the complexities discussed in order to subsequently create 'productive' spaces for efficient storage, improved learning, assisted authorship, and innovative knowledge utilization which are able to better absorb and share prospective knowledge advances." Some of the complexity-reducing features mentioned have been exemplified and visualized in a PKMS Design Task Complexity Cube [41]. The dimensions and their measures are:

- *Objective Complexity* refers to the number and dynamics of elements and their interrelationships, measured by *Ruggedness* (see figure 1: R1, R2, and R3).
- *Problem Space Complexity* refers to the constraints, uncertainty, and irreversibility associated with the information processing and their solutions, measured by *Path Entropy* (see figure 1: P1, P2, P3, and P4).
- *Unfamiliarity* refers to the lack of structure, guidance, and/or task-specific knowledge as well as to inadequate tools, measured by *Perceived Difficulty* (see figure 1: U1 and U2).

A further dimension has been added (see figure 1: U3) to reflect the *Opportunity Divides* the PKMS concept aims to address to be determined and measured by Unsustainable Developments.

5 IMPACT FOCUS: POTENTIAL AS A GENERAL-PURPOSE TECHNOLOGY

The term 'general-purpose technology' "has seen extensive use in recent treatments of the role of technology in economic growth, and is usually reserved for changes that transform both household life and the ways in which firms conduct business" [42]. Wikipedia lists twenty-four examples which have profoundly changed the history of human civilization [43]. GPTs, in general, are characterized as exerting strong and lasting impacts in its own industry (*improvement*), on technical change and productivity growth across a large number of uses and/or industries (*pervasiveness*), and on product and process innovation in a broad range of uses and/or application sectors (*innovation spawning*). For swift acceptance and adoption of a GPT, it is essential to deal successfully with the inherent complexities involved.

By building on prior literature, Cantner and Vannuccini [44] enquire "more in deep the definitional problems related to the GPTs and the conditions for their emergence, together with the characteristic for their prevalence and pervasiveness." The terms and criteria used by them are representing the backbone of assessing the PKMS concept in terms of its GPT affinities; they also feature in the ten headers of the rectangles surrounding the large yellow ellipse (summarizing the main PKM concept features) as well as the ten ellipses in figure 1. The latter represent ten major GPT attributes (listed below together with their most important contributing PKMS features):

- Prevailing Technology accepted and adopted on broad Scale, difficult to be challenged (R3 & R2),
- Quasi-Irreversibility of Commitment due to dual Role as Contributor & Beneficiary (R2 & R1),
- Wide Scope for Improvement and Elaboration (R1 & U1),
- Applicability across a broad Range of Uses (U1 & U2),
- Potential for Use in wide Variety of Products/Processes (U2 & P1),
- Strong Complementarities with existing Technologies/Uses (P1 & P2),
- Applicability to wide Variety of Downstream Uses with technological Impact (P2 & P3),
- Discontinuity in the Sense of Representing a radical Break with existing Practice (P3 & P4),
- Strong Complementarities with potential new Technologies/Uses (P4 & U3),
- Sustainable Action for confronting detrimental Opportunity Divides (U3 & R3). This attribute has been added by the author to the complement the traditional GPT features in order to highlight the importance of the divides as a particular systemic case of unfamiliarity in need to be addressed.

The ten key features (R1-R3, P1-P4, U1-U3) of the PKMS concept are forming the center of figure 1, closely aligned to the complexity dimensions and in close proximity with the ten GPT attributes. These GPT attributes are met as follows:

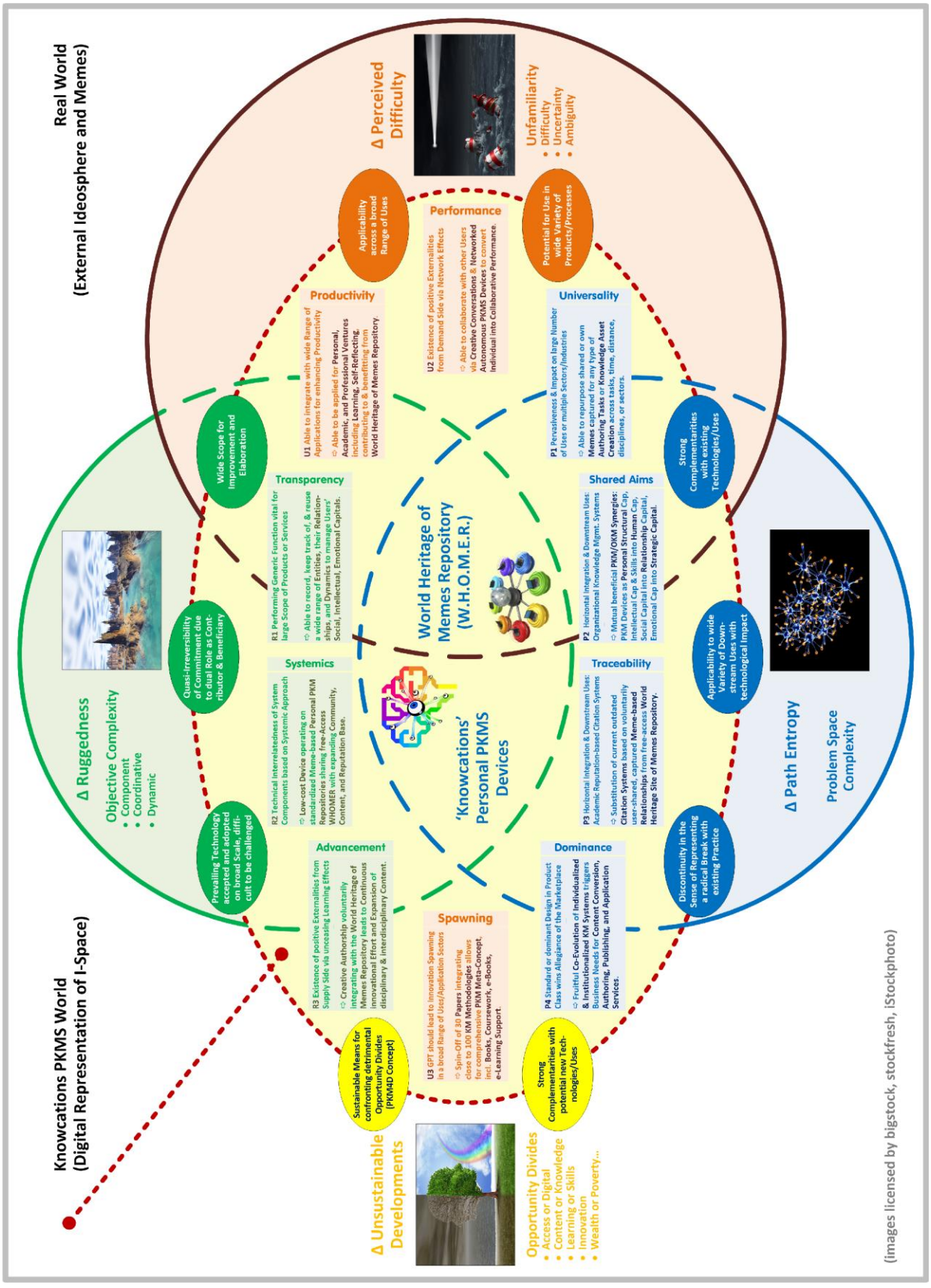

Figure 1: PKMS Design Task Complexity Cube versus General-Purpose-Technology Attributes.

Transparency facilitating Comprehensibility (R1)
As pointed out earlier, any viability and advancement of institutions and societies are made up from innumerable small 'nano-actions' by individuals (knowledge workers) [10] which govern, if effectively combined, the organizational (knowledge economy) and societal performances (knowledge society). The quality of any contributing 'nano-action' depends on the competences and skills of people which are based on their individual intellectual, social, and emotional capital. In turn, any knowledge possessed consists of either own ideas or has been acquired by learning or imitation from documented or undocumented sources. The progress and maintenance of this personal knowledge portfolio can be monitored with the assistance of the extended ignorance matrix [45, 32].

The PKMS ability to transparently record, keep track of, and re-use a wide range of knowledge entities, their interrelationships, and dynamics (*objective complexity*) to manage individuals' human capitals (*intellectual, social, emotional*) and learning (*competences and skills*) constitutes one of the hallmarks of a GPT: the performing of generic functions which are vital for a large scope of – if not all - products and/or services.

Systemic Approach supporting Personal Autonomy (R2)
By supporting the notion of portable and mobile knowledge and skills, professionals - moving from one project or responsibility to another - are able to carry their particular PKM version with them, thus, adding to the users' autonomy in the development of their expertise. Being able to determine how one's meme-based personal PKM repositories are used or exchanged via creative conversations with the user's associates, communities, or organizations further enhances the personal utility.

Based on a PKMS concept, functionalities, and interventions which are easily understandable and painlessly applied in practice, one single low-cost PKMS device is able to support one's dual role as contributor and beneficiary of organizational and societal performance over vibrant cycles of private, educational, professional and societal life [46, 47], complying to a further GPT attribute: the technical interrelatedness of system components based on systemic approaches.

Advancement of the World Extelligence (R3)
Using information technology and systems science for a concept of decentralized autonomous but networked PKMS devices (*technological innovation*) and to reform social systems and people's minds to engage in creative conversations and collaborative authorship (*social innovation*) follows Nakamori's task set [2] which is complemented by the proposal for the 'World Heritage of Memes Repository (WHOMER)' for initiating a continuous innovational effort, advancement, and expansion of disciplinary and inter-disciplinary content including the associated metrics (*to nurture innovators/drivers*).

The latter's mission would be to strengthen the former two tasks by guaranteeing continued access to the collective knowledge and ideas voluntarily shared among the PKMS user community [39]. The co-evolving tasks not only provide the means for constructing a better knowledge-based society but also comply with a further GPT attribute: the existence of positive externalities from the supply side via unceasing learning effects.

Universality to enable wide sustainable Impact (P1)
Unlike discrete parts in an inventory, a meme captured in a private PKMS repository or the public WHOMER is not reduced when consumed and it is not lessened when transferred. As a virtual copy, it can be employed infinitely for the purpose of creating knowledge assets by eight different means, either unaltered (reposited, reclassified. redeployed, or reinvigorated) or in a modified format (revised, recontextualized, recycled, or repurposed) [41, based on 48].

Accordingly, PKMSs are able to provide crucial support by conserving memes with their relevant frames of references (e.g. origins, titles, formats, licenses), embedded in a more-dimensional classification system for subsequent easy retrieval, and as an either pure, pre-edited, re-purposed, or already re-combined version according to the user's individual preferences and objectives. Subsequently, a user is able to recall, sequence and combine stored memes with own new meme creations for integration in any type of authoring and sharing activity he/she would like to pursue independent of time, distance, and disciplines [36]. Thus, a further GPT-attribute is served which refers to the pervasiveness and impact on large number of uses or multiple sectors and/or industries.

Shared Aims fostering PKM-OKM-Collaboration (P2)
"Although the novel PKMS concept aims at departing from the centralized institutional developments and at strengthening individual sovereignty and personal applications, it is not meant to be at the expense of Organizational KM Systems, but rather as the means to foster a fruitful co-evolution" [32] based on a common ground of KM methodologies and mutually beneficial interests in collectively harvesting prior accumulated knowledge subsets via bottom-up approaches.

The GPT attribute of vertical integration with downstream uses is further supported by personal intellectual capital, competencies and skills feeding straight into organizational human capital as well as equivalences between personal social and organizational relationship capital, personal emotional and organizational strategic capital, and personal structural intellectual capital assets (like the PKMS devices) and organizational structural capital [34].

Traceability of Knowledge in Space and Time (P3)
The PKMS views knowledge assets and their containers as being made up of relationships between memes in the same manner supply chains connect materials and labor to their final products. Due to the captured relations, any meme can be tracked and traced by creating an as-built genealogy either back in history to locate prior usage or the original author or forward into the future to follow-up on subsequent uses and citations [39].

The functionality corresponds to the traceability of parts or ingredients which forms the backbone of modern manufacturing and incorporates a number of appealing opportunities in the educational [49, 50] and professional context of publishing, digital scholarship, curation, mentorship, and interdisciplinary discourse [35, 37, 38], including the potential for supporting or substituting current academic reputation-based citation systems by superior content tracing, citation and impact statistics to be derived from the proposed 'World Heritage of Memes Repository'. These potent features support a further GPT attribute: the horizontal integration with downstream uses.

Dominance of a new emerging Standard Application (P4)
The fruitful co-evolution of individualized novel and institutionalized traditional KM systems fit well with the anticipated focal points of the 'Next KM Generation' approaches which emphasize the 'Use of Existing and Creation of New Knowledge' and the 'Personal and Social Nature of Knowledge' [34]. The adoption of the novel concept with the many advantages alluded to by individuals as well as educational providers and professional organizations would trigger additional business needs for content conversion, authoring, publishing, and application services.

Such a scenario would likely affect the business models of existing publishers, search engine providers, and social and academic platforms with the potential of satisfying another GPT-attribute: the emergence of a new standard or dominant design in a product class which wins the allegiance of the marketplace.

Productivity benefitting Individuals and Institutions (U1)
The PKMS's features can be productively applied for personal, academic, and professional ventures, including learning, self-reflection, authorship, creative conversations and collaborations including the utilization of the proposed 'World Heritage of Memes Repository' (WHOMER) and its metrics or its subsets in form of 'Organizational Heritage of Memes Repositories' [51].

The relevant GPT-attribute is the ability to integrate with a wide range of applications for enhancing productivity. While the potential range of applications are limitless due to the enhanced support offered by the PKMS in terms of authorship, creativity, and collaboration, the gains in productivity derive from better attention management and knowledge retention and superior retrieval based on captured trails and associations instead of indexing as well as by preventing redundant and fragmented knowledge which are typical for document-centric KM practices. The associated competences and learning cycles have been validated against renowned KM methodologies, taxonomies and qualification frameworks [52, 53, 54].

Performance Advantages based on Network Effects (U2)
The PKMS features to collaborate with other users via creative conversations, networked autonomous PKMS devices and the 'Organizational or World Heritage of Memes Repositories' in order to convert individual into collaborative performance refer.

Network effects are able to provide further advantages and apply to goods whose value increases at a geometric rate as more people possess and use them: "A new person added to a network adds value as a member and also adds some value for each other member in the network, so each new member in a large network is worth more than a new member in a small network." The effect defines the value of social networks and an increasing popularity of one network or social platform can have a devastating competitive impact on others [55]. The effect is also likely to be triggered by a growing PKMS user community negatively affecting the current providers of attention-consuming inferior services focusing on captured audiences. The barriers established by these actors have prevented novel Personal Knowledge Management approaches so far but are likely to be swept away if PKMSs are catching the attention of an expanding user base [33]. The respective GPT-attribute refers to the existence of positive externalities from the demand side via network effects.

Spawning triggering Product and Process Innovations (U3)
Lastly, a GPT should lead to product and process innovation in a broad range of uses and application sectors, referred to as 'Innovation Spawning'. In addition to the points already made in the context related to criteria U1, particular synergies have been identified and are already forming part of an extended PKMS meta-concept [56].

Following an overview of the challenges facing individuals' Personal Knowledge Management in September 2012 [57], a series of over 30 publications have explored these challenges and their resolutions further, including the integration of over 100 renowned KM notions and methodologies. These papers have been structured to further serve as a PKMS tutorial and help system and also form the basis for an envisaged book, two face-to-face study courses and an e-learning version.

The educational merit benefits from a comprehensive coverage of personal and organizational knowledge management and their respective issues, presented not as a disparate piece-meal collection, but as a coherent practice based on sound methodologies ready to be applied for one's utility, supported by the PKMS. The design thinking approach taken has been alluded to [58] and its educational perspectives have been continuously supported by a series of posters [59, 60, 61, 62]. Demonstrations of the prototype have taken place [63] and are planned together with tutorials and workshops.

These spin-offs of the PKMS development follow the 12-level 'PKM for Development' (PKM4D) framework and its close associations with Maslow's extended Hierarchy of Needs. Its relevance for personal development and for tackling opportunity divides has been portrayed in a prior paper [32] to be followed up by a differentiated breakdown of the PKM's and PKM4D's impact on social, cultural, economic, and environmental sustainability and ecosystems.

The PKM4D approach pays tribute to the multi/transdisciplinary complexities involved, especially in the educational context. While Levy, for example, calls for the encouragement of autonomous personal knowledge management capacities in students as "one of the most important functions of teaching, from elementary school to the different levels of university" [64], Bedford expects: "Just as business, engineering and science education were key contributors to the development of advanced industrial economies in the 20th century, KM education will provide key opportunities for growing a 21st century knowledge economy" [65].

6 CONCLUSIONS AND THE ROAD AHEAD

Meme-based PKMSs are destined to advance the availability, quantity, and quality of the world extelligence and its readily accessible interdisciplinarity, to allow for a wider sharing and faster diffusion of ideas across current opportunity divides, and to provide vital support for individuals' academic and professional growth and success.

The transformation into a viable PKM software application is estimated to take place within 12 months after prototype testing has been concluded. In the meantime, further supporting activities are in progress:

- A paper-in-progress is taking account of how the concept and system has evolved and its design thinking approach is validated against accepted general design science research guidelines.
- The consolidation of the numerous papers into a book and manual as well as the design of a PKM/OKM course description and training concept in support of the educational needs highlighted by Levy and Bedford.
- The organizing of further prototype demonstrations and conference tutorials as well as a comprehensive visualization of the PKMS concept and design on four A0-sized posters.
- A more technical paper-in-work will compare the meme-based PKMS prototype to the current semantic and ontology-based developments and will assess the potential of the PKMS to also publish the memes and relationships in its knowledge bases in the format of formal knowledge representation languages.
- A further paper follows up on this paper to assess the PKM System's potential as a Disruptive Innovation.

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