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Hanappi, Hardy
Institut für Wirtschaftsmathematik - Ökonomie

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On the Nature of Knowledge

An Evolutionary Perspective

Hardy Hanappi
Economics, Technical University of Vienna (Austria)
www.tuwien.ac.at/hanappi/
Hanappi@econ.tuwien.ac.at

Abstract

Knowledge comes in ***two opposed forms*** – as structural property and as a process. Their interaction - in the time dimension as well as along a logical dimension - characterizes the evolution of knowledge.
Knowledge only works, i.e. evolutes, via its presence in ***carrier media***; be it books, hard disks or human brains. Embedding specifications and development of carrier media in an understanding of knowledge evolution is a pivotal step towards an understanding of what could be considered as progress in human societies. Indeed the impact of the ICT revolution of the last decades is now just only surfacing; it will show how important scientific advance in this field is.
Knowledge comes in pieces, in units of something that could be called ***language*** (in a wider sense). As an over boarding science of linguistics points out these pieces are organized, they form an evolutionary network. The opposing network element types, nodes and (directed) links, reflect the above mentioned opposed forms. In a sense language still is a natural phenomenon, one that provides knowledge about nature. Nature as process as well as natural structure comes into perspective as knowledge.

The paper discusses these three aspects and will position them relative to major scientific contributions from various disciplines. In a final conclusion the consequences for the methodology of evolutionary economics will be drawn.

Introduction

There is no shortage of attention for the notion of the ***knowledge economy*** in the social sciences. Contributions to this topic range from rather philosophic considerations to down-to-earth empirical questions of how to measure knowledge. Moreover the concept ***knowledge*** itself is used in various forms, and is set in relation to the concept ***information*** in an even larger variety of suggested definitions[1]. This paper sets out to present another one, and in doing so it will cross disciplinary borders to anchor its proposal in received theory fragments spread over seemingly disparate sciences.

Any new element in the set of approaches aimed to produce an adequate concept of knowledge increases the variety of this set – given that it indeed is a *new* approach. If a larger variety is put to the test of adequate theory formation the usual evolutionary conclusions to be drawn would be that:

i. A satisfactory theory has not been presented yet,
ii. The chances that one might hit on something more satisfactory are increasing.

These statements are indeed plausible, new evolutionary approaches to knowledge modelling are flourishing. As a closer look on the historical track of mainstream economic theories about expectation formation shows that it moved from adaptive learning processes towards the abolishment of any knowledge accumulation in the Rational Expectations approach[2], and then onward to macroeconomic game theory of more or less rational agents, usually caught in infinitely many equilibriums. This clearly is not a very promising theoretical stream for the development of useful models of knowledge. In other words, the stage is set for evolutionary economics to leave its mark in this area of economic research.

1 - Knowledge as Structure and Process

With higher education institution increasingly under financial stress the need to quantify the knowledge they produce rises. Most attempts to quantify start with a proposal for measurement of the size of the ***knowledge structure***. In its most naive form such quantification would start by counting the numbers of typical knowledge carriers – books, computing power, human brains and the like – and add up the weighted sums at a certain point in time. The idea is that knowledge crystallizes in each moment in certain carriers, and the more carriers, the more knowledge is around.

It is important to realize that this view transforms knowledge into a spatial image, a certain size of its carrier media at a point in time. Comparing two different points in time then immediately provides quantitative information about the growth of knowledge in the included

[1] As an early example see [5].

[2] If every agent has the same correct model, and knows that everybody else know it, then this assumption explicitly rules out knowledge accumulation.

time interval. Structure, the weighted sum of elements, is growing or shrinking at a certain rate without any necessity to take a look at what actually happens during this time interval.

Of course, there are many problems with this perspective. The most essential one is that the content of what carriers carry remains more or less unspecified. If in the year 1200 one person convinces another one that the earth is a disk then knowledge could have doubled! As a remedy some ***standardized quality judgements*** of what constitutes adequate knowledge have been introduced. Consider the distinction made between persons knowing how to read and write and persons who only master spoken language, parole. The first type of knowledge is generally considered to be qualitatively superior to the second one, and as a consequence rates of literacy in a population are widely used as indicators of the stock of knowledge in this population. Though this example is evident, remember that with the finite storage capacities of carrier systems (in this case humans), it is in general not clear that adding a new knowledge structure (in this case written language) always increases total knowledge. It might well be the case that the new structure implies deleting an existing one[3], and in this case relative quality of the two changes becomes crucial for the net effect. The recent upsurge of religions in several parts of the world is a vivid example for the urgency of scrutinizing qualitative assessment.

Structure in human brains can aptly be described as the existence of models. In general these models in human brains are representing certain, closed parts of the environment of the individual including an image of the individual itself. The latter, this relation between the actual individual and its image in an environmental context, i.e. in a model, usually is summarized in the concept of consciousness. As there is no general internal model, but only a propensity towards the building of meta-models, there also is no strict consistency between the different internal models maintained for different environmental aspects, there only is a propensity towards consistency. The quantitative amount of these propensities again can be interpreted as the momentary outcome of an evolutionary process.

It is tempting – and proves to be useful – to describe these internal models present in human brains rather like small computer programs and not like analytically oriented, mathematical difference-differential equation systems. Nevertheless they are in principle time-less structures with a spatial extension, and as such represent one of the two extreme states in which knowledge appears: a structure at a point in time, i.e. during an infinitely short time span. But infinitely short time periods, even from the point of view of physics, do not exist; they are an analytical abstraction formulated to better be able to describe processes characterized by extreme differences in the speed of change of sub-processes[4]. As an analytical device timeless concepts are bound to refer to another abstraction which provides

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[3] This might happen not only due to short storage but also due to direct competition between the content of the new piece of knowledge and existing knowledge. E.g., if one accepts that a baby cannot be borne by a virgin (a medical fact) then part of the existing, religious knowledge will tend to be to deleted – even if there would be enough space for both to co-exist. This indeed is one of the evolutionary roots of the human propensity to consistency: it saves memory.

[4] In principle this idea can be traced back to Isaac Newton.

the background in front of which they can be identified. As easily can be guessed this background is the concept of (pure) time. Indeed models, they may be formulated in any language (see part 3 of this paper), try to ban time by introducing their own timeless notion of time that should refer to time outside the analytical language[5]. In short, all internal models are dynamic[6].

A typical canonical form of a knowledge structure as an internal model in a human brain is the extensive form of a strategic game. Time is represented as the (spatial) advancement through the game-tree from the root to the leaves. The nodes structure the imagined sequence in referring to points of action, points in time where an action has to be chosen out of repertoire of possible actions. This makes evident that the image in the brain relates to a tree-like sequence of actions in reality, with the crucial difference that reality always consists only of one path through this tree. There does exist a set of possible futures in the internal model, but there exists only one past in reality. The points of contact between the two worlds, the nodes, are characterized by the fact that actions in reality are chosen by the use of internal models and internal models are modified during the walk through reality that is sequentially chosen[7].

Turning around the perspective, this singular processing reality of living systems has produced the capacity of biological entities to maintain internal models. Consider model-building as using just another tool to further biological growth – of the individual entity as well as of the species. Let's start with the view that living systems are just episodes of neg-entropy in a sea of decay of order[8], in other words they try to spread and further modify their existing structure. To do so transmission of structure (genes) along generations of individuals evolved, structures of cooperating entities species organized into species, and a large variety of species, a rich biological structure, covered the globe[9].

It would be a possible choice to date the appearance of knowledge at the point where a species develops a diverse repertoire of possible behaviours, a mixed strategy in the sense of game theory. Each entity of the species, of course, follows a hard-wired pure strategy, which is not changed during its lifetime. But at the level of the species some kind of prudent randomness appears, evolutionary game theorists in biology[10] in the meantime have amassed lots of evidence to back-up this argument. Note that it is not the individual member of the species

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[5] The methodological, original sin of post modern thought is its failure to recognize this double image; as a consequence post-modern thinkers are forced to dismiss the concept of knowledge in favor of a vague notion of ever-changing images, their 'small stories'.

[66] It would therefore be most interesting how the highly artificial notion of statics became so important for the sciences at all. A good starting point would be comparative statics, which collapses the dynamics into its two extreme points at the start and at the end.

[7] The latter argument calls for an amendment of the extensive form of games, which we called 'algorithmic form' of a game [6].

[8] In an earlier paper I made reference to the famous metaphor of Maxwell's Demon to highlight this point [7].

[9] In a tour de force John Maynard-Smith and Eörs Szathmáry give an impressive account of the 'major transitions of evolution' in the animal kingdom [10].

[10] As initiator of this research John Maynard-Smith has had a tremendous impact on scientific developments [11].

that has this type of knowledge; it only appears for the species as a whole. Via mechanisms of differential success at the individual level (extinction or rich offspring) the species also gains some flexibility in the long-run by adapting shares of pure strategies to changing environments. But though the species in this sense exhibits knowledge, in the animal kingdom there is no consciousness of the species. One could argue that the ***defining characteristic of the human species*** is to be found precisely in this ***step towards consciousness***: Options now appear as different paths through an internally built model, a model built in the brain of each member of the species. This model contains an image of the entity itself as well as other entities – it can recognize other model builders. So while the overall outcome of species behaviour might at first glance look alike the one with members being carriers of pure strategies[11], a change in the carrier of flexibility is apparent. Learning does now work within a lifetime of an individual by adjustment of the model set and not by number of offspring of members of the species in the next generation.

From this evolutionary perspective a snapshot of the existing sets of models in the brains of human individuals incorporates the whole history of the evolution – in reality - of this species. Since enhanced individual randomness through internal model-building needs as a complement for successful cooperation on the species level external devices for coordinating individual behaviour an ever increasing part of internal knowledge has been externalized and fixed on non-human carrier systems. Languages are just the software specifications that more or less are used by the members of the human species. As a consequence a given knowledge structure not only consists of the model sets of human carrier systems, but also of a huge amount of knowledge stored in external devices.

Seen as a tool, which in principle[12] is available to each member of the human species, this knowledge structure shapes perception, shapes model revisions, and in doing that forms each individual consciousness. ***Knowledge as a process*** thus takes place by the use of a template, a template called knowledge structure. Again a pure process perspective without reference to this template is an empty analytical abstraction. The symmetry also holds with respect to the social character knowledge development[13] assumes in human societies. Despite these symmetries at the extreme points of analytical abstraction – pure (spatial) structure, pure process (in time) – what actually is going on in reality is characterized by asymmetry: An ever growing mass of knowledge structure is getting more and more opposed to the abilities of the human species – still far away from being a conscious agent – to convert it into useful knowledge development.

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[11] Standard textbooks in game theory often hint at the formal equivalence, but possible 'double interpretation' of mixed strategies.

[12] Two major restrictions have to be mentioned: (i) Language versatility on the side of the entity and (ii) access to the knowledge structure. The latter has experienced an incredible boost through the introduction of the internet.

[13] 'Knowledge as a process' and ‚knowledge development' (analogue to Schumpeter's use of his ‚theory of development') are used synonymously, while the terms 'learning' and 'knowledge accumulation' are avoided to prevent the mistaken connotation that there is always an increase in knowledge involved.

What seems to be ***missing on the structural*** side is the ***development of synthetic links*** between overspecialized knowledge areas. Though there certainly exist synergetic reserves of cross-disciplinary research (observe econophysics to get an eye-opening impression), the established academic career profiles and fears of sudden human capital loss if new areas devaluate old ones hinder researchers to bridge gaps between disciplines. Further pointless specialisation in many sub-disciplines is carried on despite the much more prosperous expected gains from synthetic efforts[14].

On the other hand ***knowledge development*** suffers from a ***lack of structural knowledge about the generation of novelty***. The most difficult part of structural description of the development process concerns emergence of 'new combinations' – the concept used by Schumpeter, see also [8]. As expounded in the just mentioned paper this concept includes the view that there already exist 'old' elements waiting to be combined in a new way. Moreover combination first takes place in internal models – the plural indicating the lack of a conscious social agent. Schumpeter's construction of a pro-social substitute called 'entrepreneur' was already historically obsolete when he formulated its appraisal[15].

Interestingly enough most formal approaches trying to come to grips with novelty nowadays work on the level of observations most far apart from what actually produces novelty in contemporary industrial societies: the level of genetic re-combination and mutation. Indeed the mutation probability of genes in human reproduction is so low[16] and works so slowly (on a generational time scale) that it is absurd to link genetic algorithms directly to the emergence of novelty in 21st century societies. In a sense this is the absurd side of universal Darwinism.

What is badly needed thus are approaches which help to understand how new models are built out of the remainders of outdated or even never really fully elaborated fragments of older theories. And since it is knowledge itself, which is addressed, it is ***not*** new business models and the study of innovative activity of business men that is on this agenda. The latter type of investigations might be justified, but on a completely different level of arguments.

Some help in this enormous task might come from neurobiology. The eminent neuroscientist and Nobel Prize winner Gerald Edelman in a recent book summarizes the situation as follows:

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[14] This argument should also be seen as an advice to research organization.

[15] Almost a century earlier Karl Marx had a similar vision of an agent called proletariat, which was thought to rise to a conscious pro-social agent, from 'Klasse an sich' to 'Klasse für sich'. Despite Marx' and Schumpeter's frustrated short-run expectations the long-run historical record still seems to suggest that ever larger conscious agents producing novelty emerge. It might be the case that the current wave of globalization is just a prelude.

[16] From an evolutionary perspective mutation probabilities evidently developed into such low quantitative regions by the very process of Darwinian evolution. Knowledge structure development thus seems to have displaced blind randomness, substituting it by conscious - though risky - choice of entities using internal model-building ([9] discusses such a concept of choice in the context of John von Neumann's early game theory).

'In line with these reflections, I have previously suggested that there are two main modes of thought – logic and selectionism (or pattern recognition). Both are powerful, but it is pattern recognition that can lead to creation, for example, in the choice of axioms in mathematics. While logic can prove theorems when embedded in computers, it cannot choose axioms (Choice again, H.H.). Even if it cannot create axioms, it is useful in taming the excess of creative pattern making. Because the brain can function by pattern recognition even prior to language, brain activity can yield what might be called "pre-metaphorical" capabilities. The power of such analogical abilities, particularly when ultimately translated into language, rests in the associativity that results from the degeneracy of neural networks. The products of the ensuing metaphorical abilities, while necessarily ambiguous, can be richly creative. As I have stressed, logic can be used to tame the excess of those products, but cannot itself be creative to the same degree. If selectionism is the mistress of our thoughts, logic is their housekeeper. A balance between these two modes of thought and the endless riches of their underlying neural substrates can be sampled through conscious experience. Even if, someday, we are able to embed both these modes in the construction of a conscious artefact and thus further extend our comprehension, the particular forms of consciousness that we possess as humans will not be reproducible and will continue to be our greatest gift.' [4, pp.147-148]

Economists rarely make use of other disciplines results, evolutionary economists being perhaps a little bit more explorative. Even the empirical twist of some experimental economists often gets stuck in finding evidence for or against outdated hypothesis about innate 'economic properties' of human individuals. To understand knowledge structure evolution a creative turn in theory building itself – getting loose from sterile topics - seems to be mandatory. And this is not just important for the self esteem of economic science; understood as a tool, development of evolutionary economics is called for by dramatic changes in the real world of technological revolutions in the area of information and communication technologies[17].

2 – The Trajectories of Carrier Media

Two major technological devices have changed the life of almost every inhabitant of this globe: the mobile phone and the internet. The first refers to communication processes; the second refers to information processes; together they are at the core of the so-called ICT revolution.

[17] It is indeed remarkable that William Cooper anticipated the need to incorporate insight from biologists‘ knowledge on evolution already in 1961: ‚Conversly, given certain classes of of organization structures, what are the kinds of patterns (hence observations) that can be predicted? This kind of problem is clearly related tot he standard one in biology – e.g. in neurophysiology – of inferring structure from function and vice versa.‘ [2, p.139].

The ***communication process*** can easily be embedded in the discussion of knowledge structure evolution as developed in the previous part of this paper. Just consider the fact that via communication basically two tasks are envisaged[18]:

a) The coordination of short-run behaviour
b) Exchange of messages concerning emotional states

With respect to task (a) it is easy to see that internal model-building will be affected in a strong but indirect way by a radical innovation in the area of communication technologies. One route that this influence takes is the emergence and strengthening of industries and services related to communication processes. The employment shares of these economic branches will increase at the cost of other sectors and this will heighten public attention for communication support; the demand side will follow and larger shares of consumption will be devoted to communication support. On the one hand this takes away a lot of burden of the individual person: less remembering and scheduling of tasks since via omnipresent mobile phone connection re-coordination is permanently possible. But the free storage in internal information processing capacity is immediately occupied again with new communication links, which again are lean with respect to time. But more links usually means an amplification of scheduling problems that is increasing demand for communication support. In many cases scheduling tasks thus tend to occupy the time previously available for internal model building, model maintenance, and model use. In certain social strata, in growing parts of industrialized societies, this results in widespread use of badly maintained and rarely checked internal models, which nevertheless are almost religiously believed in since the high number of communication links seems to give them the reputation of being generally accepted[19].

To appreciate the influence of emotions (b), a brief characterization of the latter is necessary. As far as the set of internal models of a human individual is concerned emotions can be interpreted as an alphabet of short-cuts[20], which describe intuitive reactions on qualitative demands. Very much in sense of a reaction on 'pattern recognition', as described in Edelman's text cited above, emotions therefore are summarizing feelings about qualitative judgements on basic model ingredients: good or bad, beautiful or ugly, smart or circumstantial. They often concern basic modifications of internal models, changing or amending its structure, completely discard it and start a new one, or love it. Since a profound revision of the model set is as risky as a too inflexible attitude, these emotions are permanently cross-checked via communication: is my feeling shared by the community? As a

[18] Pretending more rigor than necessary for the argument one could consider this view as a *definition of the communication process*.
[19] The almost religious believe in highly inadequate small-scale models of the so-called 'neo-liberal' variety is an outstanding example. While the subtle merits of the professional neoclassical synthesis of Paul Samuelson in the 50-ties are unknown to most of the propagators of this pseudo-religion, their mutual support substitutes for adjustment to empirical facts.
[20] It is convenient to consider them isomorphic to the alphabet of emoticons used in email exchange.

short-run phenomenon communication is an ideal mode to exchange quick and dirty – but strong – assessments disguised as a personal relation to an internal model or the external system it refers to. As agent based simulations (with heterogeneous agents) of such processes show emotion exchange leads to clustering of likely minded individuals. Size and shaping of these clusters, of course, depends on the assumptions made about the heterogeneous agents[21]. But most experiments would support that if exchange becomes more frequent – mobile phones enter the scene – then clusters will emerge faster, will be larger and the borderlines between clusters will be characterized by deeper differences.

There undoubtedly is a significant interdependence between the development of knowledge structures and the technological development their carrier media. While the former push applied research towards certain technological pathways, the latter then enable particular forms of knowledge. As far as communication facilities are concerned it is hard to deny that the widespread adoption of mobile phones has changed life. Having restricted communication processes to those exchanges that do not touch the internal models' logic but only their average size and number as well as their distribution intensity and distribution speed allows for some conclusions: There will be a more volatile (speed) but also more streamlined spread of rather simpler (size) models. They will be shared by larger communities of people[22] but these larger groups will distinguish themselves by sharper contours (emotions). The influence on knowledge structures is straight forward: they will ***tend to look*** more and more ***like widely shared believe systems***.

The second, overwhelmingly important technological trajectory came with the introduction of the internet. It is introduced in the current context as a revolution in ***information processes*** with the main carrier medium being the computer. Contrary to communication processes what now is labelled information technology is directed towards changes in the model-building process itself and produces mid-run and long-run effects. Again it proves useful to distinguish between two different routes that this influence of carrier media takes:

c) Availability of a global information retrieval source
d) Availability of direct model building support

There is a profound change in behaviour with respect to the use of existing knowledge. Instead of being restricted to personal memory and physically close additional resources like books or more experienced colleagues, the internet now really brings an enormous amount of global knowledge to the fingertips of every single computer literate. This is what ***technological avenue (c)*** opens up. Building and modifying internal models is fundamentally influenced by the collection of items that are brought into the picture as existing – and not

[21] Early research in this field was stimulated by …

[22] Versatility in the use of communication devices is growing tremendously across all social strata and geographical areas - not the least due to the supply and demand side effects summarized in (a). This plays an important role for arguments concerning size.

further doubted – knowledge[23]. These knowledge elements come in different formats, ranging from empirically observed data via the opinions of famous scientists to mathematically oriented (assumed) axioms. Such findings are badly needed if a new model has to be constructed to make sense of a phenomenon never encountered before, but they also are pivotal in the process of calling into question generally accepted, received theory which more and more fails to be applicable[24].

In the spirit of part 1, and the Schumpeterian view on the emergence of novelty expounded there, it could be extrapolated that with the greater access to global knowledge the number of 'old elements' available for 'new combinations' has exploded. This not only opens up numerous possibilities, it also is a severe challenge for the selection capabilities of the model-builders. Some of them will be – and are already – dazzled and confused by the over boarding amount of possible candidates for essential model ingredients[25]. Others are still struggling for synthesis, forming new global alliances to master the dramatically increasing 'evidence'. There clear is a need for a new type of scientific activity, which combines some intuitively enhanced selection experience with an extreme form of scrutiny to make use of the available wealth of knowledge. Moreover, narrow borders between scientific disciplines are somewhat dissolving, but at the same time it cannot be expected that a single scientist can, at most, master more than two fields[26]. The synthetic task thus will be successfully approached only by a relatively small number of outstanding individuals. New combinations of science organization thus are mandatory too. If a global memory and perception apparatus of the human species emerges, then those who want to use it will have to face severe organizational changes[27].

Turning finally to ***trend (d)*** it seems that this route still is ***the least explored one***. The first university departments to be involved evidently were those immediately concerned with model-building, applied engineering, econometrics, and the like. But the list of model-building entities involved in such activities is rapidly growing. The difference to trend (c) is that in this case not only models are set up newly, or evaluated with the use of new incoming information – they are actively tested in simulation runs to see what their structure implies. ***Direct model-building support*** therefore includes software and didactics for tailored simulation environments[28], ***entities are indeed turned into entities with tremendously increased modelling abilities***. A first taste of what this means for communication between

[23] In economic theory these foundational blocks often are called ***stylized facts***.

[24] An excellent example is the evidence produced by ***experimental economists***, which erodes the basic assumptions of mainstream economics. The availability of this criticism contributes to modified and new theoretical formulations.

[25] This, in my view, is the background for trends in the philosophy of science that fundamentally deny the possibility of science at all – like ***postmodern philosophy***.

[26] As is rather evident in the meantime the so-called 'trend towards interdisciplinary research' is cheap talk. At best, one scientific personality can transport part of its only knowledge in one field into a second field of its expertise. The role model for this trans-disciplinary type of scientist, of course, still is John von Neumann.

[27] This comprises a change of the structure of all academic institutions.

[28] A typical example again has been provided by W. W. Cooper, compare [3].

scientific communities is already visible: While exchange of views between those working on neighbouring fields, or at least with similar models, is much more productive, exclusion of every other scientific community is almost hermetic.
Even more important, the links towards less academic (though not necessarily less scientific) entities are endangered too. This is not really avoidable since 'listening' to a fully fledged simulation model of another entity is a tedious and time-consuming matter; not to speak about 'answering'. The feedback of the wider social community to its knowledge producing subset thus is severely loosened; legitimacy of scientific work becomes harder to prove[29]. Semi-scientific intruders can occupy positions in between a public consisting of well educated laymen and full-scale researchers. The membrane between science and the general public becomes more permeable. This is not necessarily a bad thing, since it exposes academic research to some additional competition; but on the other hand it diverts the precious time of scientists to areas of promotion and defence of scientific findings. In any case it is again the organization of knowledge development institutions, which is heading for a fundamental re-design.

In that perspective the information technology revolution has not even started yet. Profit generated due to the introduction of hard- and software in firms is only a very weak indicator for what is happening with respect to internal model-building abilities of entities. As the sketched two routes of influences (c) and (d) make clear, this is only the tip of the iceberg.

What is for sure, is that there will be an enormous push in the average model-building capacity, compare (c) and (d). But taken the dangers of trend (d) and the increased volatility of large masses holding simplistic models, compare trends (a) and (b), it becomes evident that ***the fruits of this enhancement of knowledge structure developments will only be prospering if the organization of knowledge production keeps pace with its rapidly changing environment***. Unfortunately enough such a new organizational design cannot be expected to be developed by the scientific communities themselves; they rather oppose any organizational change.

Therefore one of the most interesting insights of such a perspective is the revival of Schumpeter's old vision of creative destruction, now manifesting itself in knowledge structure development. Apparently the scientific jargons, being rather successful in their respective domains, in general do not lend themselves to the scientific design of science organization. Indeed current needs are rather to be interpreted as the design of novelty, drawing on a combination of already observed elements – and the destruction of obsolete concepts and institutions. Even the language with which such a design can be successfully carried out is not

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[29] Imagine households running demand-oriented little simulation models, which include a tax system. Confront them with similar models maintained in other countries – what a change compared to the corresponding pseudo-scientific discourse available in today's newspapers.

yet completely clear. Certainly jargons of sociology and economics play an important role, some simulations and mathematical analysis might help too. But as history shows, choice of language alters the results of scientific research; the last part of this paper thus presents some ideas on language varieties.

3 – Language Varieties

In human societies knowledge appears in different formats. In this part of the paper I concentrate on knowledge that in principle can be transformed into information commodities, i.e. into bit strings. Though bit strings are an important constraint to designate what we are talking about, they clearly are only the lowest layer of the knowledge architecture that actually is used by human individuals; the previous parts of the paper should have highlighted this.

A first picture of the structural levels of a language - one built upon the other - is shown in table 1. Furthermore the table suggests that three typical types of knowledge languages – plain text, mathematics and algorithmic formulations – are similarly structured. Further ones, e.g. music, could easily be added.

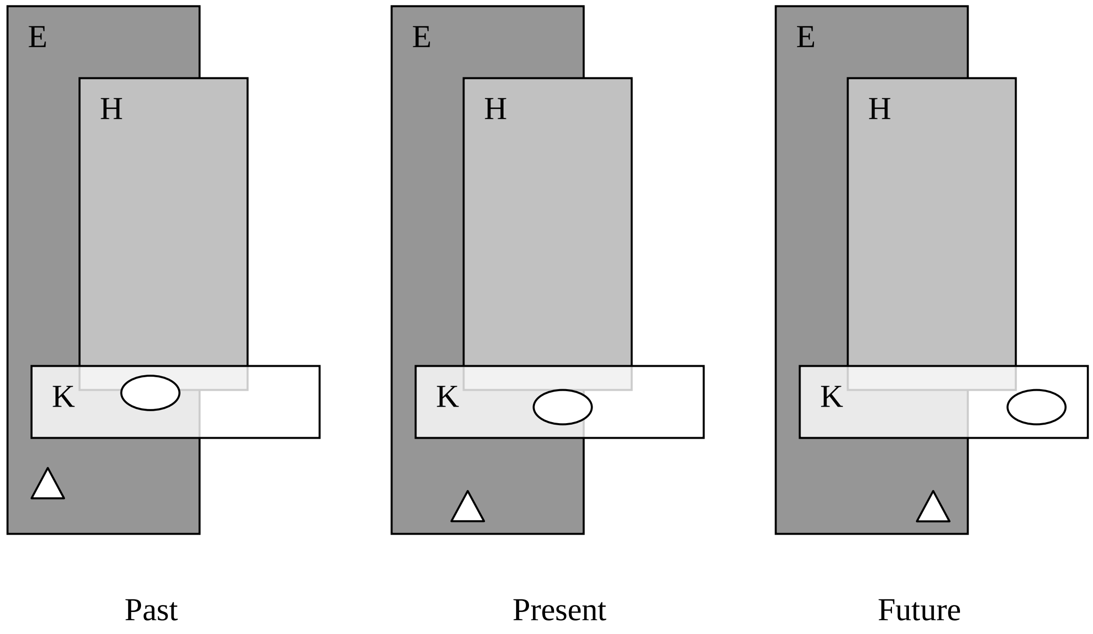
Table 1: Language Structures

Level	Prose	Mathematics	Algorithms
0	Bits	Bits	Bits
1	Words	Variables	Objects
2	Sentences	Equations	Statements
3	Texts	Equation systems	Programs
4	Sets of texts	Sets of systems	Sets of programs

As discussed at length in part 1, it is important to distinguish between the structure and development that exists in reality and the structure and development that describes this reality. Indeed the development of both – reality and its image – is only possible due to the interplay between these two levels. The evolution of structure that takes place in time and space thus could be characterized as being driven by the interaction of three types of elements: entities in human societies (H), elements of the stock of knowledge (K) and elements of the physical environment of both (E); see scheme 1.

Interactions between these entities characterize human evolution. A first circuit of interaction typically considers H as perceiving E (by using K), interpreting these perceptions as model realizations (again by using K) and finally changing K (again by using K) by updating existing models – hence the name circuit. Updating typically consists of adding, modifying and forgetting. All sets overlap to some extent. In scheme 1 three snapshots – past, present and future – are characterized by overlapping structures.

Scheme 1



By contrasting structure on the background of the passing away of time - using the graphical trick to display this movement as a movement of location from the left to the right – it becomes immediately visible that both elements, i.e. structure and process, condition each other. This was discussed at length in part 1.

With respect to the levels of languages introduced in table 1 the scheme gives an idea of the respective role played by different levels.
Level 1 elements typically refer to elements in the sets H, E and K, which are characterized by a certain, constant existence: It is possible to choose past, present and future ***close enough*** to each other to have the same element in all three appearances of the set. This issue immediately implies its negation: There is always a choice of ***long enough*** time frames, which implies emergence and exit of elements.
The links between level 1 elements are typically provided by ***level 2 elements***[30]. Applying this characterization to econometric modelling scheme 1 could be redrawn as one of the early representations of dynamic models (compare [12]). Though in a the long-run level 2 elements are doomed by entry and exit in the same way as level 1 elements they nevertheless typically are kept constant with respect to changes in level 1 elements, more to the point they ***describe*** these changes. In a sense they are constants, which represent their opposite, namely the change of the content behind the name of a level 1 element[31].

[30] This is the fundamental idea of Noam Chomsky's generative grammar [1].
[31] Descartes' path-breaking methodological advance, the 'variable', is based on this dialectics.

If one considers the possibility that the nodes connected by the level 2 links have more than one connection, then a system of connected vertices emerges, and this is a ***level 3 element***. With the introduction of this level a great number of difficult questions emerge: What are useful borders of such an element[32]? Is there a critical mass of core links and nodes that characterizes a level 3 element[33]? If some links and nodes fade away and others emerge, what can be said about the level 3 element, has it fundamentally changed its character? The highly complicated and intrinsic nature of level 3 elements allows for their emergence only in rather developed human societies, first usually as a religious codex. Their lifetime is of astonishing length[34] and they are stretching out for generations of human carriers.

In their longevity ideological systems on a global develop in parallel. Even with the use of the same lower level elements in principle an incredible number of different level 3 elements can emerge. This will actually not happen since each such system needs as a carrier system a human society devoted to its maintenance and adaption – and large communities are scarce. Nevertheless a small number of such systems may co-exist – even in the brain of the same human carrier. In this widespread presence – in brains as well as on external media - these level 3 elements constitute the ***level 4 element***, which is structural knowledge.

Note also that with the introduction and nowadays omnipresent use of devices which support ***level 0 representations*** of languages a profound feedback on all other levels has been initiated - this was the topic of part 2 - a severe change in language structures will follow[35].

At this point of the argument a brief note on so-called ***tacit knowledge*** is appropriate. Early Ludwig Wittgenstein held a very decisive opinion on this issue: “Was immer gesagt werden kann, kann auch klar gesagt werden.” [13]. In other words, there is no principle obstacle for knowledge to be expressed clearly and explicitly. Even late Wittgenstein, preferring to discuss “Sprachspiele” (which happen to resemble level 4 elements) would insist to regard the development of these systems as a road towards more clarity. In this sense the concept of ‘tacit knowledge’ refers to state of transition that combines immediate actions with latent modifications of level 3 elements. It can be doubted that it provides additional insight to highlight the importance of this stage, in particular if it is set in opposition to its asymptote, explicit knowledge.

Language in the end still is a biological phenomenon. As the stepwise interpretation from one row of table 1 to the next showed, there is no general simple mechanism to be discovered, there rather is a sequence of ever more complicated procedures that produce novelty.

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[32] Translated into economics: How weak has the interaction with exogenous variables to be, to justify ignorance.

[33] A typical question of this kind in economics concerns the neo-classical approach. It is not yet clear what the core of neo-classical economics really is.

[34] Note for example that Christian ideology can look back on a historical record of more than two millennia.

[35] This not only concerns scientific language, everyday ‚parole’ is already rapidly changing due to email formulations.

Another interesting exercise would interpret a walk through the columns of table 1. The classical view, basically the Newtonian conception of science, would suggest an advance from simple utterances via everyday language towards mathematics. But is the end really reached, or even reachable with state of the art mathematics. From an evolutionary point of view the answer is evident: no! First of all mathematics itself is always in flux, it is hard to describe what the state of the art really is. Second, several other languages intervene, languages not clearly positioned relative to others: algorithmic languages, music (arts in general), and the like. Though corresponding elements along the rows of table 1 are rather evident, the sequence of columns is not so clear and remains a field of future (synthetic) research.

Conclusion

This paper is an attempt to cover some of the most intriguing questions related to the evolution of knowledge. It is necessarily eclectic, and it necessarily only touches upon the incredibly rich literature that can be found waiting behind every single point that is mentioned. The major goal was to link three seemingly distant discourses: (i) the dichotomy between knowledge structure and knowledge process, (ii) the influence of recent technological revolutions in the area of carrier media, and (iii) the evolution of language structures. Evidently the synthesis is far from being concise, or even on a standard where consistency could be checked. At best it can be seen as an evolutionary series of attempts to put some visions to a test, i.e. to keep knowledge evolution going.

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