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Acquired Knowledge, External Memory, Cognitive Stress, Group Knowledge, Knowledge Convolution, Personal Knowledge, Primitive Knowledge Core, Unconscious Knowledge

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Developing Knowledge: Spiraling Ways for Individuals and Society

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Abstract

The structure and development of humankind knowledge is investigated. The new type of knowledge named Acquired knowledge was described. The factors which affect the knowledge such as its convolution and slow disappearance and replacement of facts are discussed. The sketch of humankind knowledge is depicted. Repeated standard stages of knowledge development are studied. The spiraling way of several basic processes connected with development of humankind knowledge is studied. The main types of integration of new knowledge in its system are revealed and described. The steps of Creative Destruction of knowledge are also discussed.

1. Introduction

It is well known that Nature in its core is heterogeneous. All its parts are treated as Objects which are in constant interaction between each other. These interactions are very complex. Yet it is possible to detect some basic laws of interaction processes [1]. Unlike non-animated matter, animated matter has an active reaction to external impacts. This is due to the fact that a living body needs to anticipate the changes in its environment. One denotes the search for forecasting as *Expectation* [2, 3], *Foreseeable Future* [4], or Probabilistic Prognosis [5]. Some general ideas associated with the processes of the prognosis of the future were discussed in a series of works by Michael Polanyi - see for instance [6]. Unlike animals, people can store and use the experience of previous generations. Humans try not only to predict future situations, but they try to find reasonable explanations for the previously observed events. Due to the evolution of mankind, requirements for results of such studies increase. People need to give predictions and to explain events more distant in time and more complex in nature. In all cases the inaccuracy of forecasts and explanations still exists. To improve the quality of such results, people have to create models. A model cannot be created without unprovable hypotheses. It follows from the so called *Theorem of Incompleteness* by Gödel [7]. Of course our ancestors did not know this. However, when comparing the number of events, they had to deal with the need to give them interpretations. Interpretations depended on the level of knowledge of that time. This level was usually insufficient for a good explanation of observed events. The experience of previous generations is reflected in the memory of individuals and in the memory of society [8]. Individuals, their groups, and society use the memory of previous generations after putting facts stored in memory in order. This ordered system of facts is knowledge. The amount of knowledge of individuals or their groups is different. Group and social

knowledge is the result of the averaging and generalization of the experience of a huge number of individuals. The volume of human knowledge is so great that it is impossible to imagine any person or some mechanical system that would simultaneously develop and use it fully.

The knowledge of humanity is reflected in science, religion, customs, and rituals. Human ideas about it are constantly changing. Therefore, a number of questions arise. The most important of them are the questions about the structure of knowledge, its dependence on humankind hierarchy, and the ways of knowledge development. The answers to these questions are being searched from the ancient times. The list of works on these issues is huge. However, there is no final clarity in the answers. Some of these works indicated a very important matter - a cyclical process of knowledge development [6, 9]. Recent studies have shown that there are several types of cyclicity in the development of knowledge [10]. Unfortunately the hierarchy of human knowledge is virtually ignored in all these studies. The ways of transition from the structure of knowledge of an individual to the group structure, and social knowledge has not been discussed in detail yet. Preliminary analysis of these issues is the purpose of this study.

2. Knowledge of Individuals: Its Formation, Structure and Development

The human body is a complex multilevel system. Each level of this system is associated with the use of relevant information. The program using information on each of the levels only affects the phenomena occurring at the next hierarchical levels. Moreover, the management of these programs is not associated with a single center. The processes occurring in any single isolated cell do not affect the behavior of the human body. Moreover, even bowel function is not controlled by the brain. Yet the brain receives this information. The managing of the part of such complex system is based on the so called principle of *Distributed Control* [3, 4, 11]. Sometimes, this principle is also called *Distributed Control Systems*, or *DNS*.

The aim of this issue is the study of human behavior as biological and social individuals. For this reason, we will pay our attention only to the human brain. The information and main programs (reactions) stored in the brain are inherited and acquired origins. We will limit our attention only to the fact that the brain acquires the results of experience and learning. The ordered sum of all the observations and facts which are stored in the brain represents the knowledge of the individual. This knowledge is used for codification of new facts that go into the brain. These facts can never fully reflect the observed events and phenomena [2, 3]. Additionally some incompleteness of incoming information appears due to partial selection in filters of the receptors. As a consequence, when new data is processed, their additions to the previous data begin in the brain. This is a specified type of prognosis. For example, when the eyes see the face, the eyes are more often drawn to its characteristic points (Figure 1). So cheeks, where there are no abrupt changes in profile and color, are looked at less often and in smaller number of points than other parts of the face. This means that the brain receives less direct information about this part of the face. Therefore, the face, which the individual sees, is largely created by the completion of the image. This completion is produced by the brain based on forecasts or guesses. For the considered problem it is important that this Supplementary Information is at such a deep level that the person cannot feel this process, and almost cannot influence it. For the considered problem it is important that this Supplementary Information is at such a deep level that people may not feel this process or control it. That is why one can call the knowledge created as a result of such a process as *The Unconscious Knowledge*.



Figure 1. The trajectory of the pupil at the process of the consideration of objects [12]. It is clear that the brain get nformin not from all possible ponts of human face. The most part of information comes from the characteristic points of the face. At the other points the inormation is supplemented by the operation of human brain. Left part – an ancient bust; right part – real person.

The rest of a person's knowledge can be divided into two groups. The first of them is the set of standard reactions to the environment which is passed down by each individual from previous generations. Various instincts are a few of them. One denotes them as Inherited Knowledge. The second group of personal activities is created on the basis of individual experiences. The most simple of them are reflexes. Their sum one can denotes as Acquired or Obtained Knowledge. In higher organisms their acquisition is based on personal behavior as the basis of imitation. In this case, during the process of repeatedly obtaining such knowledge for many generations, any part of it can be fixed at the genetic level. It means that over a long time some part of Acquired Knowledge can be converted into Inherited Knowledge. It is important to note that even higher animals are unable to pass on their Acquired Knowledge to each other. This suggests that every animal has to get such knowledge for itself again. Opposite to other animals, people at the end of the Pleistocene era learned to convey the accumulated individual information to each other. It began approximately 10 000 years ago [13]. The development of these communication processes took quite a long time. Its result was the emergence of language and writing. In the end, individual human knowledge began to accumulate the experience of several people as well as the cumulative experience of previous generations. After this period, even personal knowledge of the individual becomes the result of the experiences and achievements of previous generations. The knowledge obtained this way can be called Learned Knowledge.

Since that time, humanity began to actively use the tools and create a new specialized technology. This, in turn, dramatically accelerated the evolution of mankind. The reasons for this leap in human development have been discussed repeatedly [13, 14]. In scientific literature it is possible to find the hypothesis that the cause of corresponding changes in the heritable properties of an individual was the changeability of climatic conditions on the Earth during the specified period of time. Rapid climate variations required rapid changes in the properties of the human properties. The emergence of Learned Knowledge produced an additional source which affected human behaviors. Therefore, this new type of knowledge was an additional factor of human variability. It provides a more rapid change of the properties of living beings in a rapidly changing external environment. In other words, the process of storing the accumulated knowledge was an important factor which ensured the rapid and successful evolution of humanity. However, the authors cannot go into this problem. Our goal is to study the process of knowledge development in society. We will come to this problem in the following section.

3. Knowledge Creating Process in Society

Evolution has developed various methods of communication between higher members of the animal world. The use of gestures and pheromones are a few among them. Historical paths of development life on Earth gave evolutionary advantages to animals which used transmission of signals in the audio frequency range. A limited number of phonemes and the ability to easily create the base of their numerous combinations turned out to be one of the major advantages of sound communications. The advent of human speech was one of the last stages of long time evolution of the brain. This process and its relationship with culture, arts and genetics is described in detail [13-15]. As a result of a long evolutionary process, humans could not only store in their memory their personal experience, but also additional information which the individual got by communication channels from their neighbors. This process started from nonverbal information exchange such as mimetic actions. This next stage of human evolution was connected with creating a high speed vocal communication system. The humans need to use this system to get a relatively large lexicon which contained several thousands of items. The third transition in human cognitive behavior was the emergence of external memory records such as drafts, primitive pictures and so on. It is supposed, these forms of human communication system appeared finally approximately 45 000 years ago [16]. As a result, humans have developed the ability to store large amounts of information in independent external media. This has dramatically expanded the abilities for transfer referral from person to person. It was then that along with Personal Knowledge of the individual, socialized collective Group Knowledge appeared.

The full reflection of one object on another is impossible [10]. Due to this, the transmission of information from one person to another comes with some loss and distortions. Therefore, despite the intensive communication interaction of people in society, their Personal Knowledge is different. One can say, the Group Knowledge may be treated as averaged sum of all Personal Knowledge of participants which take part in the information exchange. Information exchange between pairs of individuals can be realized in several ways. The first one is more simple. In this case one of the participants sends necessary information to the other. He (she) has the ability to choose the desired recipient. The second way has a longer history. In this case, the information signal is sent without any concrete address. It can also be sent to any group of recipients too. The recipient has the possibility to decide to accept the signal or not. Sending of determined recipient was information without any historically the first method of communication. The other ways of signal transmission were used for this purpose, for example, with the help of pheromones.

The principal innovation of the modes of transmission of signals was the use of intermediate saving of the signal. This can be done in two ways. The first one is simple. In this case, information from person A is transmitted to person B through one or more intermediates: C, D, F and so on. Each reseller has the ability to delay or change original signals. He can also add to them other signals, or withdraw any part of them. The second way was the most important novelty of ancient time. In this case the intermediate reseller is a non-animated tool. It is called *External Memory*. Non-animated system of memory

allows one to store information for a long time. Moreover, it permits the coping of information in parallel using memory devices and to process it into storage. The ability of long-term storage, processing and addition of new portions of information into the memory of society creates new type of knowledge: i.e. *Social System of Knowledge*. Its main useful property is processing of the cumulation of information created by the long set of human generations and various societies which existed independently from each other.

The emergence of intermediaries in the transmission and storage of information is not only limited to the increase in the volume of knowledge available to individuals. The emergence of collective knowledge changed the basic principles of its preparation and use. First of all, the differences in the abilities of various people make their contributions in obtaining new knowledge different. In addition the storage of the ordering and systematization of knowledge requires special skills. As a consequence, even in small communities, there appeared initial division of labor. In the further course of evolution this led to a release in the community of special groups of people who were involved in various aspects of work with knowledge. After the prehistoric period these groups were gradually evolved into social and class layers. This was a result of rapid growth in the accumulated knowledge of society. In parallel, there began an exchange of knowledge between various groups of people, different communities and countries. There is no doubt that the amount of knowledge stored by humankind is closely tied with the population of the Earth. In addition, this amount is dependent upon the duration of human existence. At the same time the population is largely dependent on knowledge, which is available to it. Also, one knows a number of additional significant factors that determine the volume and structure of total knowledge of humanity.

Before the authors refer to this material it is necessary to pay attention to the important fact, that Group Knowledge is closely tied with two problems. The first one is linked with the usage and storage of knowledge. We have just briefly discussed it. The second problem is the question how the fact of intergroup interactions impact the creation of new knowledge. One has to understand that collective actions must improve efficiency of production and processing new information. This effect is denoted as *Collective Learning* [17-19].

4. Amount of Human Knowledge and Population: Enumeration of Basic Factors

So far there is no reliable way to estimate the total amount of knowledge accumulated by mankind or just a certain group of people. Even a simple definition of the number of scientific journals produced in the world is not an easy task. It is no less difficult to determine the total amount of information stored in electronic form. It is known that it is impossible to reduce any knowledge to quantitative assessments of stored information. It is due to the fact that the amount of information is not directly connected with its semantic meaning. At the same time, to assess the knowledge, there is importance in evaluating their semantic meaning and certain intuitive values that can be defined as significance and utility.

As it was written, the process of sharp acceleration of production of new knowledge is tied with the advent of the Social System of Knowledge and the creation of the first funds of the external memory. The process of the merging of Social System of Knowledge, and hence Collective Learning, took a long time. It was not a uniform process. Currently, there are three surges or jumps of development. They cause the acceleration of the process of reflection of the surrounding world in the brain of our ancestors. These jumps were associated with changes in the characteristics of the brain. Ultimately, this led to the emergence of the human mind [13, 14, 21].

As was written above, Group Knowledge arises in the Collective Learning. In this process, the cross fertilization of information and innovation occurs between all stakeholders. Creativity, age, and experience of all participants of this process are different. However, in the simplest model of Collective Learning, one supposes that the contribution of all participants is the same. Such a model raises the question about the connection of the production of new knowledge with the number of people involved in Collective Learning. Information interaction in any group can be realized in various ways. First, all interactions in a group may be between pairs. For instance, person n_1 can be in communicative contact with person n_2 . Then n_1 will be in contact with person n_3 and person n_2 will be in contact with n_4 . In a new group of people this interconnections are accidental. One can say it is the pre-group interconnection system. One can meet the connections of this type in the groups of passengers at the beginning of any cruise. Another example is the situation with emerging group contacts in a new children group at the beginning of academic year. In these situations, all possible pairs can consistently ensure the interaction of all group members with each other (Figure 2a). After a short period in small groups each member of the group interacts simultaneously with all other participants. This can be considered as interaction "each to each" (Figure 2b). It is natural to assume that the process of Collective Learning starts with such a situation.

Let us agree with the idea that in fact each member produces the same amount of new information products. Let he (she) transform the constant part of this product during a pair interaction. These two assumptions lead to the conclusion that the quantity of new information, which is produced in this case, is proportional to the number of pairs, i.e to N/2. Here N is the full number of the group members. In the case of "each to each" interactions the full amount of new informational products are proportional to the full number of possible connections. This number is equal to N(N-1)/2. If the value of N is not too small one can say the amount of informational product is proportional to $N^2/2$. These two values are the extreme cases. In reality, the connection between the number of group members and the

value of this group population lies between these two dependencies.



Figure 2. The sketch of main types of interactions in people communities. a. Describes pre-group stage, other letters are different possible group interactions.

New knowledge, which population creates, affects humankind environment. It produces changes in conditions of population's existence. This affects the size of population. For the first time such reliable data was collected and processed by Heinz von Förster [22]. This article was the seed of the modern theoretical demography. In [22] authors collected and processed primary data on the demographic changes on our planet over the years. They also considered several basic models of the effect of population density on the character of the curve of its growth. Förster and his coauthors were probably the first who took into account the fact that average personal productivity of members of society is directly connected with mutual communications between them. They studied the equation which describes how the number of people in population N with the so called productivity of person α changes with the time t:

$$dN/dt = \alpha N.$$
(1)

It is evident that the strength of informational exchanges during communications is tied to the production of new personal and group knowledge. So, each attempt to estimate the nature of the relationship between types of communications and production of new knowledge is the first problem for the study of group knowledge development.

After article [22] a set of investigations devoted to studying if dependence between the type of personal group interconnection and the curve describing the growth of human population was fulfilled. In these works various types of connections were studied. A big part of them is tied to the book of Sergei Kapitza [23-26]. These studies are based on the idea of mutual influence of the knowledge of humanity and population. However, these works did not seriously study the mechanism of group knowledge.

In demographic studies the researcher takes into account an average life span of a person in the group. Each member of a group has similar interconnections with other members of the group across his life. He (she) has approximately the same number of children. All of them have similar possibilities to receiving any amount of new information. Because of this all demographic indicators are tied to the full number of group members. Yet, the information exchange between the group members is a more complex process. At each moment of one's lifespan, the individual communicates with people of various ages, life experience, and mental abilities. Such people make different contributions to the production of new group knowledge. Beside this, there are always fluctuations in their affectation on the other members of group. Therefore, even in small groups situations can emerge where it is possible to call Teacher (Experienced *person*) \leftrightarrow *Followers* (Figure 2c).

There is a more serious source of deviation of simple models which describe how connection between N determines production of group knowledge. Communication models based on the interaction between all members of the group in reality have serious limitations. One easily understands that in a small group of 10 - 20 people all its members can be in direct contact with each other. In the group with the number of about 100 members this type of interaction is almost impossible. These groups are split into several subgroups. Interconnections within each other in such groups are strong and all its members equally share information with each other. Information links between pairs of members of different groups became sporadic and weaker (Figure 2d). The growth of the total population creates more subgroups. Moreover, the subgroups, in turn, begin to fragment further. So, the communication net between

different groups became more complex. However, the information exchange within the elementary subgroups continues to be very strong. At the same time, the growth of the total population changes the types of information exchange between groups. This changes its force, and the relationships themselves become more various. This process is related to the fact that the progressive increase in the population of accumulated knowledge significantly affects the nature of information exchange. Analyzing historical facts one can suggest that the power of intergroup communications continuously increased. As a consequence, the interaction between subgroups and various groups is enhanced. Moreover, due to the evolution of mankind, isolated groups and communities begin to unite in a huge structure of Nations, States, and Civilizations.

In modern time, information exchange between different participants of Society: persons, subgroups etc. became stronger as it never was in the history. Nevertheless, a common cultural community of the people still does not exist. Moreover, it is known that any large, homogeneous system has a tendency to stratification [27, 28]. This idea is in accordance with the works by Ilya Prigogine [29]. Many examples of these process elements are described in the areas of economics and social sciences [30, 31]. Jürgen Klüver studied the problems of socio-cultural evolutions of humankind in a set of works [32, 33] He wrote: The long period of time between the biological emergence of Homo Sapiens and the Neolithic revolution was necessary to allow.... to generate a sufficiently heterogeneous society that could move to the next step in the evolutionary process. In other words, the Neolithic revolution could only take place when some societies were sufficiently differentiated... [33].

People who are familiar with the practice of social networking know that their users form different groups and subgroups in accordance with their interests, education, etc. Moreover, this effect as applied to the scientific community was described in by V. V. Nalimov in his books in which he at first proclaimed a new area of investigation quantitative studies, which was named Scientometrics [34]. On page 40 of this book there was introduced a concept of: A new form of the organization of the scientific work as a self-organizing by interests of groups of scientists. This term was called Invisible Collectives. Almost simultaneously in several papers in the field of Library and Information Science there was used an analogous term Invisible College [35]. This term reflected a historical term Invisible College which described a group of persons, who were in close connection with Robert Boyle [36]. John Milkins, John Wallis, Robert Hook were a few of them. As a result, it is evident that in all big social systems one can always detect a fragmentation in acquired knowledge and practical expertise. It means that the real knowledge of humankind is strongly heterogeneous [37]. The growth of knowledge also affects the size of the population. However, the growth of population is much slower than the growth of knowledge. Moreover, the change of information interaction in big human communities creates the new synergistic effects in reciprocity interference

between human communities and environment. For all these reasons, the use of demographic models for the study of the growth of knowledge should be used with great restrictions.

After emergence of Group Knowledge, the development of our species mind was completed. It was approximately 10,000 years ago. After this the socio-cultural evolution of humankind began. Up to this point, the information about the affectation of the external environment on the people was stored in their genome. After that such information was preserved and accumulated mainly in the collective memory of human communities. The stored information consisted of knowledge and moral laws. This process was really a new factor which influenced average human behaviors.

One knows that to find and investigate the objective laws of history it is necessary to average all data about real events over large periods of time. This period is known as Long Term (from the French Longue durée). First it was used in [38]. One way of explaining why the accumulation of new knowledge takes less time than the demographic processes is to study it using the values of Long term. Unfortunately, currently there is no reliable data that would enable us to implement this idea.

5. Development of Humankind Knowledge

Each object both inanimate, and animate is in constant interaction with its environment [1]. In the case of animated matter this interaction transforms its environment. Moreover, transformation of the environment affects living species. From time to time such reciprocal transformations lead to dramatic changes in the situation on the planet. The Great Oxidation Event is an excellent example of such Revolutionary transformation [39]. However, our species after the emerging of Collective Learning, significantly altered the nature of these mutual transformations. The results of this process are so stunning that there are grounds to speak about the beginning of a new era on our planet. The first ideas about these transformations of our planet were written in the 1920's by V. Vernadsky. Modern translations of his work in English can be found in [40]. This new era was proposed to be called Anthropocene. The history of this problem is narrated in [41]. It is very difficult to describe such complex nonlinear interactions between humankind and its environment. Nevertheless, it is clear that these interactions are not heterogeneous. They vary depending on the geographic areas on the planet and time period. As a consequence, human knowledge is also a complex heterogeneous system. One should understand that due to the continuous accumulation of humankind knowledge for long periods of time there is no person who could know the entire amount of accumulated knowledge.

Given the above, one can describe the humankind knowledge as a sectoral system. Each sector has the hierarchical structure. However all sectors of knowledge interact with each other. In many cases this interaction is weak. For instance, the intellectual communication between the primitive tribes of Amazon jungle, citizens of USA or European cities is almost imperceptible. Nonetheless this is the core of primitive human knowledge which all people possess. All people indeed know about seasons, difference between day and night and many other simple facts. Such facts provide a set of information which forms The Primitive Core of Humankind Knowledge (Figure 3). The average modern individual never takes into account this knowledge because he (she) develops them at an early age. At higher levels of system knowledge there is always a continuous informational exchange between different civilizational areas and professional sectors. This diffusion of knowledge averages knowledge of the underlying cultural base of different civilizations. The speed of this process is slow. However, it increases with time. In such processes there is a large amount of information which forms the basis of modern civilization. Information about different states and nations, various languages, climatic zones are few of them. This information and several special facts form The Basic Core of Humankind Knowledge.



I - IV Sectors of specific content knowledge

Figure 3. The principal sketch of the system of humankind knowledge.

Contrary to the primitive core this core is constantly developed across the time.

To study development of humankind knowledge it is necessary to supplement general considerations with some specific moments. They originate from the analysis of knowledge accumulation. The process of accumulation of humankind knowledge does not require a detailed study of the nature of accumulation. One can consider the demographic studies as an example of such an area. A closer look at the process of accumulation of knowledge shows that this process is not limited only by summing the detected facts, observations, and hypotheses. Let us discuss this.

First of all, one must pay attention to the fact that over time some data is not needed anymore and forgotten. Let someone try to remember all the breeds of horses or the methods for calculating square roots without a calculator, or special tables. This knowledge is not lost. Due to its practical usefulness, it disappeared from the common areas. One can say that from *The Basic Core of Humankind Knowledge* it moved into a specific area of history of Knowledge of Science. In some cases the old knowledge is replaced by new. So, the information about breeds of horses was successfully replaced with modern knowledge about car brands.

The second source of developing accumulated knowledge is the process which in mathematics is called *Convolution*. It is known that with time new information frequently permits the gathering and compression of many facts with the help of newly discovered laws. For instance, the data about the position of moved objects may be described with so called *Equations of Motion*. As in previous cases one can find many examples of such processes in various fields of knowledge. Evolution of human knowledge continuously generates new opportunities to use previously known information. One can say that *Process of Knowledge Convolution* is one of the General laws of developing of humankind in the fields of Science and Culture.

The system of humankind knowledge begins from gathering random facts, observations, laws, regulations, and hypothesis. This process creates a set of unorganized information. Stage by stage all these items turn into an organized and structured system. This process creates new information [42-44]. In each period of time the real condition of knowledge forms so called *Scientific Thesaurus*. It is continuously adjusted and, sometimes, seriously reconstructed [45].

The three types of the developing of human knowledge discussed above are inevitable. They are the main driving forces which are responsible for constantly changing and evolution of Science and Culture. If one wants to analyze the development of knowledge he (she) has to take in account additional groups of specific circumstances. These circumstances are usually omitted in demographic investigations. Let us briefly enumerate the main questions in this area.

Human knowledge receives new items continuously. This process is never preplanned. All of them must be embedded in existing systems of knowledge. The criteria of their compliance with the current paradigm are one of the main factors of reasonableness of new information [47]. Frequently it may not be this simple. It means each new item often requires special adoption. It is clear that the continuous restructuring of knowledge systems is not real. Therefore, the system of knowledge accumulates a number of factors that are poorly matched, or even contradict the existing paradigm. As a result, in the system of knowledge there is a continuous struggle of different opinions, points of view, ideas, and hypothesis. In practice, this is manifested in the presence of people adhering to different and often diametrically opposed views. As a first approximation, one can say that all scientists may be divided into two groups according to their role. One group has a maintenance role. The second group has a creative role. It is possible for exactly the same group to allocate in other areas of human activity [33]. Both of these groups are not homogeneous. The authors study the composition of maintenance group in [47]. The same situation can be observed in creative group as well [48].

Various communities, professional groups, states and even

civilizations have different numbers of members of these main groups which determine the evolution processes of knowledge. The ratio of the average number of creative individuals to average amount of maintenance individuals is called the *Evolutionary Parameter* – S [33]. This value depends on the character of accumulation of new knowledge in different social groups. Detailed analysis of history suggests that the change of S in a particular Society is very difficult. One can suppose that stability of S enables us to explain why various societies have different amounts of their specific knowledge, culture, and moral regulations.

Professor Jürgen Klüver [32, 33] built mathematical models of social evolution. In his calculations he used various values of the *Evolutionary Parameter* – S [32, 33, 49]. From these results it follows that for effective production of new knowledge the part of creative individuals in the society must be large enough. Otherwise, no acceleration in the production of new knowledge through collective learning will occur. At the same time, one can assume that too big part of creative individuals in society violates the sustainability of its development. Therefore, the analysis of the distribution of different types of personalities in society is very important for studying the evolution of human knowledge.

From discussion of this section it follows that the study of the accumulation and development of humankind knowledge requires a more detailed account of its connection with characteristics of society than in case of problems studied the demography. This study requires consideration of a complex hierarchical structure of accumulated knowledge. This issue will be discussed in the next Section.

6. How the Structure of Humankind Knowledge Affects Its Development

Human knowledge has a very complex structure. Its very simplified form is given in Figure 3. All parts in this figure have a hierarchical structure. The hierarchical structure of knowledge is a consequence and reflection of the universal hierarchy of the Universe. First the idea of the universal structure of the World was expressed in 1961 by J. H. Lambert [48]. The main idea of this principle of the Universal Hierarchy can be expressed as *The structure of the World* is intrinsically complex, with variations of different objects at all detected scales. As a result the hierarchy theory considers that any complex system is at the same time a component of the other systems. The basic laws connected with these general problems of hierarchies can be found in [49-54].

It is known, that only the top levels of hierarchy are actually in development processes. It was first studied in detail by E. Sedov [55]. He called this law *The Law of Hierarchical Compensation*. (In many cases this expression is translated as *The Law of Requisite Variety*). Sedov's Theorem can be written as:

Sedov's Theorem: The growth of diversity at the top level of a hierarchical system is ensured by limiting diversity at the previous levels, and increased diversity at the lower levels destroys the top level of the system.

This theorem says that major changes of human knowledge only affect the upper levels of the information hierarchy. It does not mean that there is no development at lower levels. It only means that changes at lower levels have almost no influence on higher levels. So for example, new ideas about the solubility of some substances in the liquid have absolutely no effect on the physico-chemical laws which describe the phase equilibrium.

For study of this issue, it is important to pay attention to the nature of the interaction between elements of the hierarchical system. These interactions exist between all objects in the system. Let us call them *Internal Interactions*. If the interactions occur at the same level of a hierarchical system we call them *Horizontal Interactions*. The emergence of a substructure in the system is a consequence of the fact that at the same hierarchical level the power of internal horizontal interactions is much stronger than external. *Vertical Interactions* in many systems can occur between adjacent levels, and between levels spaced away from each other. Sedov's Law of hierarchical compensation in many cases in the first approximation enables one to neglect Vertical Interactions.

Human actions in the field of knowledge never stop. It develops unevenly over time, and in different areas. If one understands a new object or phenomenon he (she) immediately is faced with new ones. Therefore, in the system of humankind knowledge and in its various parts new levels and sublevels are constantly created. One can start to study the development of knowledge from discussion of this process at a new emerging level. One can assume that any new level was created as an action of any person or a small group of them. The process of creating new knowledge was described above with the help of equation (1). In this equation value α denotes the amount of new knowledge which is produced by a single member of a group or any small group at the unit of time. This hypothesis does not presuppose the interaction between various members of society. This assumption is simplified. Yet, it is quite acceptable as the first step of the description of new knowledge production.

The solution of equation (1) under this assumption is well known. Its exponent is:

$$I(t) = I_0 e^{\alpha A t}.$$
 (2)

Here I_0 is the full amount of knowledge which a creative person or group possessed before the act of creation. This is the starting moment of time in (2). A new level of knowledge occurs due to the emergence of a progressive idea. Its appearance is connected with the possibility of resolving some part of problems, which were accumulated in the previous time (t < 0). In most cases the first results tied with this idea are interesting. Basically, the form is the result of a new cognition level. This explains the active development of a new knowledge level at the beginning period. Stage by stage the novelty of a new idea is diminished. The new interesting results produced are not as extensive as earlier. Moreover, the number of problems amenable to solution using the proposed ideas is gradually depleted. This is due to the natural limitations of any resource. Let us add one condition (1) with the requirement of a limited amount of knowledge resources at each level of knowledge. It is well known that in this case the dependence of created new knowledge has a form, named *Logista*:

$$I(t) = \frac{I_0}{(I + Be^{\alpha At})}$$
(3)

The logistical curve has an *S*-shape (Figure 4). The growth of accumulated knowledge at any level after an active start is gradually diminished and after some time reaches saturation. On each level these processes are not strictly coordinated. It is useful to recall that in the first demographic work by von Förster [22] this dependence was proclaimed as the most likely law of growing total human population.

Human actions in the field of knowledge never stop. It develops over time even at those levels, where it at any moment of time has reached saturation. At these levels the possibility to find new ideas is restricted. Therefore these areas of knowledge appear and accumulate various contradictions. After their magnitude exceeds a threshold the new progressive idea is usually born. If this idea is interesting and has sufficient novelty, the new knowledge level is achieved. Processing the creation of new levels is continuous. In various areas of knowledge and in different communities the new problems and their new solutions arise constantly. Therefore, the humankind system of knowledge is continuously improved. This process is called *Universal Modernization*. Sometimes several local crises arise simultaneously. In this case, the solution may need to rebuild some old top levels of the knowledge system. Yet, in such knowledge upgrade the old levels are not fully destroyed. One can say they are divided into some basic ideas. From these ideas the bricks of new knowledge creation are built. Using economic terms, this effect can be defined as The *Creative Destruction*. This term was at first coined by Joseph Schumpeter [56]. So we can say that:

Approval: Scientific revolution requires the Creative Destruction of Knowledge System.

As it was written above even the most radical destruction of the knowledge system does not affect its deep levels. This, however, does not mean that at these levels there is no development and restructuring. One reason for this is the absence of strong vertical interactions (See above). Along with this reason, there is another one. This second reason is often overlooked. The source in this case is tied to the different rates of developing processes at various system levels. Let us explain this with a simple example. It is well known that electrons in atoms continuously move at a high speed. However, this movement, similar to the behaviors of nucleons in the nucleus. has no effect on the motion of atoms and molecules in gases. One of the major reasons for this is the necessity to consider different rates of these movements. Similarly, scientists can find many new compounds and find and measure their properties. However, the knowledge about the properties of different constructions in which parts are used in these compounds changes more slowly. One can say these secondary properties are constant in comparison with the properties of their parts. Therefore, the simple models of our knowledge can be studied during their development at different system levels as fully independent.



Figure 4. The sketch of knowledge development.

a. S-curve (Logista) describes the development of knowledge at a single level;

b. Development of knowledge when after the period of saturation the new knowledge level is achieved after a part of the old system was destructed.

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Approval: Knowledge development is realized through a set of cycling and spiraling processes.

It should be noted that *Creative Destructions* of *Knowledge* take a noticeable period of time. Moreover, this process consists of several repeated stages. Each cycle starts from the accumulation of contradictions. After this the revolutionary part of partial decomposition of the system begins. This stage follows the stage of self-organization. It is realized from parts of the destroyed previous system. Competition starts between different new structures. The growth of the winning structure is restricted by stratification

and compromises. This is the end of the period of *Creative Destruction*. Only after that the relative balance and sustainability of the new structure comes.

7. Knowledge Development Through the Standard Triad Cycle of Questions

When moving to a new level in the hierarchy of knowledge, people face a new situation. In this situation one immediately creates questions. Their diversity can be reduced to three main questions [10]. The first question is asked by a human being when he or she meets a new object or phenomenon is: What is it? The primary response to this question enables us to generate a first perception of a new object or phenomenon. This perception makes it possible to differ the object (phenomenon) from others. One can say the answer to this question leads to separation or identification of the object or phenomenon. After one learns to identify the new object, his or her interest grows to find an answer to the next question: Where did this Object come from? Or: How does the sequence of actions enable its creation? If one is interested in understanding the new phenomenon he (she) asks: Where did this phenomenon come from? The answer to this question gives a general idea about the actions on how the new object comes up. Learning this, one finally asks Why was this Object created? Learning the phenomenon one asks: Why does it consist of a given set of actions? In brief, the way of human knowledge runs the sequence of three main questions [10, 57]:

$$WHAT \to HOW \to WHY \tag{4}$$

This sequence has a form of triad. After all the answers to the sequence of these questions are received one can say: A new step in creating new knowledge was completed. Human knowledge usually tried to find answers to these questions in a sequential order. There are two ways to run through this sequence: clockwise and counterclockwise. The first (Figure 5a) is from simple to complex (from left to right above). This way is traditionally denoted as synthesis. The second runs in the opposite direction. This way is denoted as analysis or reduction. Historically, the first way was closely connected with human practice. One can treat the second way as theoretical or philosophical. These ways of learning nature have always influenced each other. Moreover, it is known that in the long term development of knowledge the synthesis may be changed to analysis. This effect is known as The Arch of Knowledge [58, 59]. However, this change does not affect the sequence of the three basic questions mentioned above. Therefore, all three questions were frequently discussed simultaneously. However, the emphasis in their study has changed over the time and places.



Figure 5. Spiraling development of knowledge.

a. Simple sketch of sequence of questions (Knowledge cycle) – Counterclockwise case;
b. Spiraling way and the arch of knowledge

If one understands a new object or phenomenon he (she) immediately is faced with new ones. As a result, the triad of new sequences of questions runs again. This new set of questions acts at the next level of knowledge hierarchy. At each new sequence the human curiosity returns back from the last question to the starting one. This again is a cycling process. In the case of moving to new hierarchical level it is a spiraling process. So the development of the human study of nature is again built on the basis of spiraling. The way up a hierarchical ladder corresponds to the synthesis of knowledge. The way down corresponds to the analysis (Figure 5). As it was told earlier each new cycle replicates the same sequence of questions. So we can say this sequence of three questions is the *Simplest Step in the Cognition Process* or *SSC* [10]

8. The Ways of Knowledge Transfer During Learning

Personal knowledge of any human is the system of ordered and classified information. It should also include various control processing programs and the transmission of this information. In Section 3 the authors described the process of emerging of Group Knowledge. It was also narrated that Personal Knowledge of each person is in constant interaction with Group Knowledge. It can be implemented by direct information exchange with other people. Other effective ways of informational exchange are different instructional technologies and familiarization with the information which is stored in dedicated data bases. Museums, libraries, and archives are a few examples of such databases. One also knows several specific systems to teach people with the help of information accumulated and prepared by mankind. Various movies, TV programs, and advertisements are few of them.

Our goal in this section is to focus only on the information

that can be specifically transmitted from person to person. Many animals can learn from each other through imitation. Obtaining such Mimetic Information is inherent to humans too. However, the establishment of group knowledge imitative processes is not enough. Here it is necessary to encode the required information in the form which is convenient for transmission, transformation, and reading. Speaking, creating drawings and diagrams, and writing are the main ways to implement such processes. One can say it is the creation and utilization of various symbolic languages. Over time, the amount of accumulated knowledge of humanity is growing rapidly, and its structure becomes more and more complex. As a result the problems of transmission and perception of human information become dramatically more complicated. Knowledge may be stored in several forms: recorded voice, various pictures, material objects and so on. Nevertheless the most important and best developed part of knowledge is stored and transmitted in writing. However, there is known to be a large part of very useful and practical knowledge which is impossible to transmit in writing. Each reader knows that without personal practice and training nobody can drive or shave. No one guide manual can explain what should be the movement of your finger across the screen to control an iPhone. All knowledge of this type one gets only after practical exercises and mimetic actions. First Polanyi [6] studied this problem, this part of human knowledge one would call as Tacit Knowledge. Explaining this type of knowledge Polanyi wrote: "We can know more than we can tell". The knowledge which one can explain in words was denoted as: Explicit Knowledge. Explaining the difference between them he wrote: "Rules of art can be useful, but they do not determine the practice of an art; they are maxims which can serve as a guide to the art only if they can be integrated into the practical knowledge of the art. They cannot replace this knowledge".

Many issues were devoted to this problem after the first books of Michael Polanyi were published. Many interesting and useful results were found in these issues. Their overview can be found in [60]. Some valid results are related to managing in industry, psychology and philosophy. The main resume of these studies is that there are two types of tacit knowledge. One of them is *Embedded* or *Tacit-Embodied Knowledge*. This type of knowledge precedes the transition from *Tacit Knowledge* to *Explicit*. In turn, *Tacit-Embodied Knowledge* is preceded by so called *Not-Yet-Embodied Knowledge* or *Self-Transcending Knowledge* [60]. The last type of knowledge has some other names that are not going to be discussed here.

It is well known that Tacit Knowledge is connected with skills which are better to teach as examples. Recently, several authors have investigated such processes in detail, which are a common part of instructional strategies. In this case the creation of Tacit Knowledge is realized in Hidden Processes [61]. It was also detected that all development of knowledge and introduction it in practice divided into a set of several standard stages which are repeated in spiral processes. Moreover, the sequence of these stages answers a chain of questions in (4). In some cases, tied with managing in companies and firms, this sequence is supplemented with additional questions of WHERE? or WHO? The answer to this question indicates positions (roles) of groups of persons which realized the final stage of this chain in a specific institution. The most important result of numerous issues devoted to study of knowledge may be expressed in the next

Approval: The development of knowledge is a repeating spiral sequence of three main stages: Creating of new knowledge, its integration, and its application in practice.

The experience says that the sets of creation of new knowledge and its application in practice are studied much better with integration of new knowledge in an already existing system. Therefore, the authors discuss this problem in detail. The system of knowledge makes it possible to draw a pattern of circles which depict various sectors of knowledge. They are partially tied with the lines that symbolize logical connections between them (Figure 6a). In this figure, for simplicity, we did not reflect the fact that lines of logical interactions may have different strengths. Let us depict newly created information with an additional circle. This circle integrates with the existing system of knowledge. This integration merges additional logical connections between the old system and a new information area. These connections transform new information into the part of the unified system of humankind knowledge.

Various ways of integration of new information are known. The most uncomplicated of them is a simple *Attachment* of a new circle to a logical surface of any knowledge sector (Figure 6b). This process expands this sector area. This does not cause any principal changes in the average humankind thesaurus. One can imagine situations in which new information is simultaneously attached to two or more knowledge sectors. It does not make any fundamental changes in the analysis. So, for simplicity, the authors omit this case.

The second type of integration is Incorporation of new information in the volume of any knowledge sector (Figure 6c). This causes the emergence of new logical interconnections. Moreover, it causes a partial restructuring of previously existing connections. Yet, this restructuring affects only a small part of the volume of the knowledge sector. This process does not cause any serious changes of the thesaurus. Both described types of integration are related to sustainable development of humankind knowledge. However, it is well known that occasionally radical restructuring of the entire system of knowledge happens, or Scientific Revolutions happen [45] (Sections 5 and 6). They are associated with serious restructuring of large areas of knowledge. On Figure 6d one can see the part (a building brick) of such reconstruction. This process interrupts old connections and creates new ones. As a result, a new interconnection logical net is created. These two types of closely tied pair of actions: Destruction/Creating is called Creative Destruction [56].



Figure 6. Various ways for integration of new knowledge into the system.

Creative destruction in the broadest sense of this term can involve restructuring not only surface sectors of the humankind system of knowledge (Figure 3). The Basic Core and even Primitive Core of humankind knowledge can be engaged in system restructuring too. Moreover, the structural changes can flow into deep parts of the system. Yet, at the same time, the external sectors can be affected very little. Let us explain this with an example. In modern times, the residents of many lesser developed countries utilize cell phones, cars, or modern weapons in their everyday life. They know their specific capabilities and have the necessary skills to manage. These skills are the well developed part of their Social Knowledge. Social Knowledge is included in their basic core of knowledge. Opposite to this are the citizens of some Western countries. Some of these people do not have enough information to understand the principles of modern tools they use. Diffusion of new technologies makes people change some skills in their basic core of knowledge and does not affect knowledge which is located at higher levels of their knowledge hierarchy. One has to take into account that diffusion of knowledge usually creates new content rich areas. Therefore, globalization produces active interactions between scientific, technical, and technological knowledge and social knowledge. These interactions may vary from one geographical place to another.

Globalization also creates processes which are going in opposite directions. Many people move from lesser developed countries to the countries with higher level standards. These people frequently have high professional backgrounds and good practical experience. Some of them find good jobs easily. Yet, frequently their social experience, national and religious traditions are very different from their new social environment. For such people full adaptation to new conditions can take a long time. Occasionally their full adaptation is impossible. In these cases, heterogeneity in knowledge arises again in the deeper layers of the knowledge system.

It is not difficult to understand, that there exists other examples of deep seated heterogeneities in the *General System of Knowledge*. All are connected with the social sectors of this system. Our goal is not connected with the ideas of social problems. Therefore, we are not going to analyze this situation in detail. It is important for us, that all variants of the destruction integration of novelties are always associated with the same personal characteristics of the people, which will be discussed next. This allows us to restrict our consideration to the case illustrated in Figure 6d.

Let us again return to Figure 6. It illustrates how integration changes the system of logical connections and position of content rich sectors of the knowledge system. All parts of this Figure depict the projection of real mental space of the average human knowledge system. This system is also reflected in the brain of each person. Mapping of the human brain gives one a visual representation about its general structure. One can imagine that the logical connections have any similarity with synapse connections in the human brain.

Sufficient for our purposes of understanding is that the emergence of new information and new knowledge affects the processes of establishing connections in the brain. The degree of adjustment of connections in the brain depends on the restructuring of the logical connections in the system of human knowledge. With a significant restructuring of these relationships a person experiences psychological discomfort. Changing of the individual paradigm causes him (her) stress. We denote it as Cognitive Stress [61]. Such stresses periodically test them. It is known these stresses accompany the process of personal development and the learning process. Every child experiences stress when he (she) learns of the death of his (her) parents. Another typical stress of growing up can be the discovery that adults do not possess absolute knowledge. Yet, sudden and cardinal novelties, which adult people and experienced professionals can suddenly meet throughout their life can cause great discomfort. As a result, a person may experience internal resistance to a new idea. Additionally, many competent people who understand new idea very well do not use them in practice. So, Max Planck whose results were one of the basic ideas of Quantum theory, devoted his life to the theoretical work in this area.

Psychological resistance to new ideas depends on the power of new idea novelty. There is a certain average threshold, which at any moment of time the average person cannot accept and explain for himself. For this reason, many true ideas and technical solutions often cannot be undertaken because of the unpreparedness of society [46]. By analogy, in economics and pedagogy [61] one can talk about the Elasticity of the human thesaurus - E. This value can be introduced as the ratio of the maximum allowable extent of adjustment of understanding of the problem of the change of a logical structure in the area of an appropriate sector of knowledge. We are not aware of the development of reliable estimates of these quantities at this time. Therefore, we should not discuss this problem in detail. It is useful to draw attention to the fact that learning the ability to accept novelties is studied in particular in Sociology and other Political Sciences. In these Sciences, this effect is described using the so- called Overton Window [62]. Speaking about the system of knowledge, we can assume that any radical new idea may eventually be understood by humanity. These qualitative considerations allow one to estimate the possible speed of evolution of human knowledge. Currently, such assessments can only be done on the basis of the analysis of the history of ideas and concepts over long periods of time.

Speaking about the speed of evolution of knowledge should be considered, that time should be measured not in calendar time but in units of time of activity of human generations. This was intuitively felt by our ancestors. Not by chance according to the Bible, Moses led the Jews out of Egypt for 40 years. Let us translate this into the language of discussing problems. In this case, it turns out that a fundamental change of knowledge about the decree of the people took the lifetime of two generations. In the XX-th Century the lifetime of one generation of Germans was not enough that they have lost the generality of their behavioral knowledge. At the same time a longer period led to the separation of the Germans and Austrians.

9. Conclusions

The brief results of our analysis can be summarized in the following statements. First of all, the System of the Humankind Knowledge can be characterized as a complex structure. It has an inner core of *Primitive Knowledge*, and the surrounding spherical layer or the core of *Basic Knowledge*. This core is surrounded by a set of content specific sectors. All mentioned parts of humankind knowledge have a hierarchical structure. The interactions between various layers are not very strong. Therefore, the development of knowledge at each level in the first order can be studied independently.

The humankind knowledge is not a simple storage of different facts. All observations, ideas, and hypothesis are ordered. Its system is periodically rebuilt. Some facts became old-dated and forgotten, the others became convoluted. The development of knowledge at all levels of hierarchy complies with the same basic laws which have to give answers to the repeated sequence of questions. All development consists of several standard steps which answer the three main questions: WHAT HOW WHY. This sequence is the simplest step in the cognition process or SSC. The sequence moves from level to level in the hierarchy of knowledge. As a result, it is possible to say that the development of humankind knowledge consists of the set of independent spiraling ways. The General Development of Knowledge is also described with the set of three repeating stages: Creation of New Knowledge, Its Integration, and Its Application In Practice.

A new type of brain activity which creates so called *Acquired Knowledge* was detected. Several types of integration of new knowledge into its system were investigated. The results of this study permits detection of the *Logical Threshold*. Its origin is connected with the occurrence of *Cognition Stress* when any person gets a new idea. The study of interactions between the hierarchical system of knowledge confirmed the possibility of independent investigations of knowledge development at each level. It was detected that at different hierarchical levels of knowledge systems the rates of development change in wide ranges. The affect of *Cognitive Stress* was used for estimations of maximum rate of *Scientific Thesaurus Evolution*.

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Biography



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